Rockshelter Excavations in the East Hamersley Range, Pilbara Region, Western Australia



edited by

Dawn Cropper and W. Boone Law

foreword by

Maitland Parker and Slim Parker,
Martidja Banyjima Elders



MARTIDJA
BANYJIMA



ACHM
AUSTRALIAN CULTURAL
HERITAGE MANAGEMENT

RioTinto

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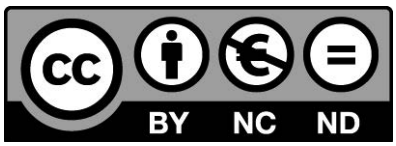

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Editor's Preface

Too often, the results of consulting archaeology projects disappear into the filing cabinets and bottom drawers of desks, never to be seen again. This reality is especially tragic when substantive field research is not disseminated to the general community. In this volume, we have endeavoured to make the results of the Hope Downs 1 excavations an exception to this fate, and we are fortunate to have the support of the Martidja Banyjima, Innawonga Bunjima, Rio Tinto Iron Ore Pty Ltd, and Australian Cultural Heritage Management to produce this document. Early on, we recognised that the findings of the Hope Downs 1 investigations are significant and important to the local Aboriginal community, and this research should be properly document and published for the Banyjima community and interested researchers alike. This document has taken years collate, and we have endeavoured to keep it up to date with recent literature, so we offer our apologies for any new regional findings that have been inadvertently overlooked or have been published in more recent times. We hope that this document will find a place in the Pilbara archaeological literature and serve the Banjima community in the years to come.

Acknowledgements

This monograph represents the work of many parties involved with the Aboriginal heritage salvage operations at the Hope Downs 1 mine. The editors wish to acknowledge and pay respect to the many Martidja Banyjima and Innawonga Banjima traditional owners that were involved with this extensive field project. The Federal Court recognises you together as the Banyjima People Native Title Group (WAD6096/1998), and we hope that this research volume will stand as a tribute to your long and enduring cultural legacy. The editors wish to express their gratitude to all of the excavators, field workers, and specialists that contributed to this project. We also thank Karijini Developments Pty Ltd and Rio Tinto Iron Ore for their assistance with project logistics and access to heritage documents. Furthermore, we sincerely thank Australian Cultural Heritage Management Pty Ltd for providing the opportunity to manage and participate in the direction of this large project. Completion of this project would not have been possible without the encouragement of heritage staff and management at Australian Cultural Heritage Management, Karijini Developments, and Rio Tinto Iron Ore. We thank all parties involved for your continuous support and your good faith efforts that have allowed us to produce this final publication. Funding for the Open Access publishing and the colour print hard copies of this monograph were generously provided by Rio Tinto Iron Ore.

Reporting of Dates

Dates are an important aspect of archaeological research, and the standards used for discussing dates must be clearly outlined. In this monograph, only radiocarbon dates are reported with the suffix 'BP' or 'cal BP', while dates obtained through means other than radiocarbon methods (*e.g.*, thermoluminescence or optically stimulated luminescence) are reported in calendar years rounded to the nearest century, and they are identified by the suffix 'ka' (thousand years before present) or 'mya' (million years ago before present). Uncalibrated radiocarbon dates are presented in years before present and are identified by the suffix 'BP'; calibrated dates represent calendar years before present and they are identified by the suffix 'cal BP'. Calendar ages were calibrated at 2-sigma (95.4%) accuracy using IntCal09 (Reimer *et al.* 2009) and OxCal v4.1 (Bronk-Ramsey 2010). Median values of the calibrated radiocarbon dates were calculated using OxCal v4.1. SHCal04 was not used to calibrate the dates as it is not recommended for calibration of dates beyond 11,000 cal BP without the use of an offset (McCormac *et al.* 2004: 1091), and this offset cannot be applied in programs such as OxCal v4.1. To provide consistency among the calibrated dates, IntCal09 was used to calibrate all dates in the document. IntCal09 is the first calibration dataset ratified by the 14C community to extend the calibrated timescale back to 50,000 cal BP; however, the 14C community recommend caution for the calibration of early dates (for a discussion see Reimer *et al.* 2009). When dates are discussed in the text as broad ranges or in general terms as 'years ago' (*e.g.*, 40,000 years ago) it should be understood that these dates are regarded as calendar years before present.

Abbreviations and Conventions

Term	Meaning
AAR	Acute angle retouch (<60°)
ACHM	Australian Cultural Heritage Management Pty Ltd
ACMC	Aboriginal Cultural Material Committee
AHA	*Aboriginal Heritage Act 1972 (WA)*
aka	Also known as
AMSL	Above mean sea level
Artefact Dimensions	Length-x-width-x-thickness
AU	Analytical unit
Avg	Average
BIF	Banded iron formation
BL	The largest of the four relevant categories of transverse fragments that are also broken longitudinally (excluding medial fragments) in the MNF calculation
BP	Conventional radiocarbon years before present (AD 1950)
C	The number of complete flakes in the MNF calculation
cal BP	Calibrated radiocarbon years before present
CHMP	Cultural Heritage Management Plan
CL	The greater of left or right longitudinal fragments without transverse breakage in the MNF calculation
cmbd	Centimetres below datum
cmbs	Centimetres below surface
DGPS	Differential global positioning system
DAA	Western Australian Department of Aboriginal Affairs
Frag	Fragment (*i.e.*, artefact fragment)
GDA	Geocentric Datum of Australia
GIS	Geographic information system
GIUR	Geometric index of unifacial reduction; ratio of the retouch scar thickness (t) to the flake thickness (T), where GIUR = t/T
GPS	Global positioning system
HDIO	Hope Downs Iron Ore Pty Ltd (a subsidiary of HPPL)
HDMS	Hope Downs Management Services (a subsidiary of HPPL)
HPPL	Hancock Prospecting Pty Ltd
IB	Innawonga Banjima
ka	Thousand years ago
Layer	Excavation layer; generally an arbitrary 5cm excavation layer (see Chapter 4 for further details)
LGM	Last Glacial Maximum
LCS	Longitudinal cone split
MHA	McDonald, Hales and Associates Pty Ltd
MIB	Martidja Banyjima Native Title Group
MIS	Marine Isotope Stage
MNF	Minimum number of flakes; where MNF = C + T + CL + BL
mya	Million years ago
n	Number of specimens
PAD	Potential archaeological deposit
PNTS	Pilbara Native Title Service (now Yamatji Marlpa Aboriginal Corporation)
PRI	Perimeter retouch index; ratio of the sum of the retouch length (RL) to the perimeter length (PL), where PRI = ΣRL/PL
Quad	Quadrant (0.5-x-0.5m)
Rockshelter Dimensions	Opening width-x-depth from dripline-x-height
ROM pad	Run-of-mine pad
RTIO	Rio Tinto Iron Ore (a subsidiary of Rio Tinto Ltd)
SAR	Steep angle retouch (>60°)
Section 16	Section 16 of the *Aboriginal Heritage Act 1972 (WA)*
Section 18	Section 18 of the *Aboriginal Heritage Act 1972 (WA)*
SD	Standard deviation
SL	Stratigraphic layer
T	The largest category of transverse fragments that are longitudinally complete (excluding medial fragments) in the MNF calculation
UTM	Universal Transverse Mercator
WA	Western Australia

Foreword

Go with a Clear, Open and Accepting Spirit, and the Country Will Not Treat You Badly

Maitland Parker and Slim Parker

Elders of the Martidja Banyjima Aboriginal Community

"Wirlankarra yanama. Yurlu nyinku mirda yurdarirda."

> - Go with a clear, open and accepting spirit, and the country will not treat you badly.

We, the Martidja Banyjima, (also known as the Fortescue Banyjima) are a strong and resilient people.

Our roots are embedded deep in the soil and rock of our lands. Our ancestors walk with us every day through the mountains, valleys and plains of our country. Those ancestors and our land give us our identity, strength and lore. Our culture is very alive, strong and vibrant as it was before the Europeans arrived.

The arrival of Europeans almost 150 years ago set in motion chains of events that changed our lands and our people forever. Many of us are old enough to remember the time before mining companies and archaeological excavations. Many things have changed in our land, but what has not changed is that we are still here, with our people, our lore ceremonies and our traditional cultural kinship and Language.

The Hope Downs project was significant for Banyjima people in several ways. But it is one of the examples that has been very devastating with regards to its impacts on our country and the very significant cultural Dreamtime sites of our Wardidba and Milgu song lines.

Firstly, Banyjima people were empowered to drive the research agenda and outcomes of this project far more directly than is now common. Secondly, the field work involved a large number of Banyjima people over three years, reconnecting many people with Djadjiling, Weeli Wolli Creek and the surrounding country.

Thirdly, the results of the archaeological excavations and analysis documented here demonstrate our people were using these places up to 47,000 years ago or more. That clear and ongoing connection to our old people spans more than 1,000 generations. This work is a repository of knowledge and culture reaching out to us across the ages.

We the Martidja Banyjima people have shouldered the responsibility of having to make the decisions to see this process through. We have fought as hard as possible to preserve our culture within the confines of legal processes and agreements, and we as a people will always continue the struggle to protaect the sacred and secret sites within our traditional country or Yurlu.

We are reliably informed that nothing like this has ever been produced for the Pilbara. It is a thorough description of the sites excavated at Hope Downs, including detailed site drawings, photographs, and specialist studies.

We commend this monograph for its protection of the memories and the historical and cultural significance of the heritage lost in the creation of this work.



Photo by Clive Taylor, A.C.S.

PART 1: INTRODUCTION AND BACKGROUND

Chapter 1

An Introduction to the Rockshelter Excavations at Hope Downs 1

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Between 2007 and 2010, Australian Cultural Heritage Management Pty Ltd (ACHM) carried out investigations of 31 rockshelters at the Hope Downs 1 Mine in the east Hamersley Range, Western Australia (Figure 1-1). The excavations were conducted as part of a larger archaeological salvage program prompted by the development of the Hope Downs 1 iron ore mine. This monograph is the culmination of the collaborative efforts of a large team of Traditional Owners, archaeologists, specialist researchers, and mining personnel. Six rockshelters are the focus of this monograph, including sites with both Pleistocene and Holocene archaeological sequences. The sites documented here were selected because they offer new data regarding the antiquity of Aboriginal occupation, past environmental conditions, Aboriginal subsistence and daily life, lithic technology, and site formation processes.

Four rockshelters with Pleistocene occupational sequences are detailed in this monograph, including Jundaru (HN-A9), HD07-3A-PAD13, HS-A1, and Djadjiling (HD07-1A-04). Together, these rockshelters demonstrate that there is a repeated pattern of early Aboriginal occupation of the east Hamersley Range from 41,000 years ago and possibly as early as 47,000 years ago. Prior to this series of excavations, the earliest rockshelter occupations in the inland Pilbara had been dated to between 28,000 and 31,000 cal BP, as reported for Newman Rockshelter (30,897±372 cal BP, SUA-1510; Brown 1987) and Mesa J24 Rockshelter (28,317±415 cal BP, Wk-2514; Hughes *et al.* 2011). The excavations at Djadjiling rockshelter provided the first indication that the Aboriginal occupation of the inland Pilbara was some 10,000 years earlier than previously reported (Law *et al.* 2010; Law and Cropper 2012; Law *et al.* 2008). Subsequent excavation at HD07-3A-PAD13 and HS-A1 confirmed the early occupation and even extended it slightly. While Jundaru was found to be occupied from a slightly later date (*ca.* 35,978±653 cal BP), it was found to have an incredible density of artefacts along with a rich faunal assemblage and series of well-preserved combustion features. These sites are not only important for establishing the antiquity of occupation,

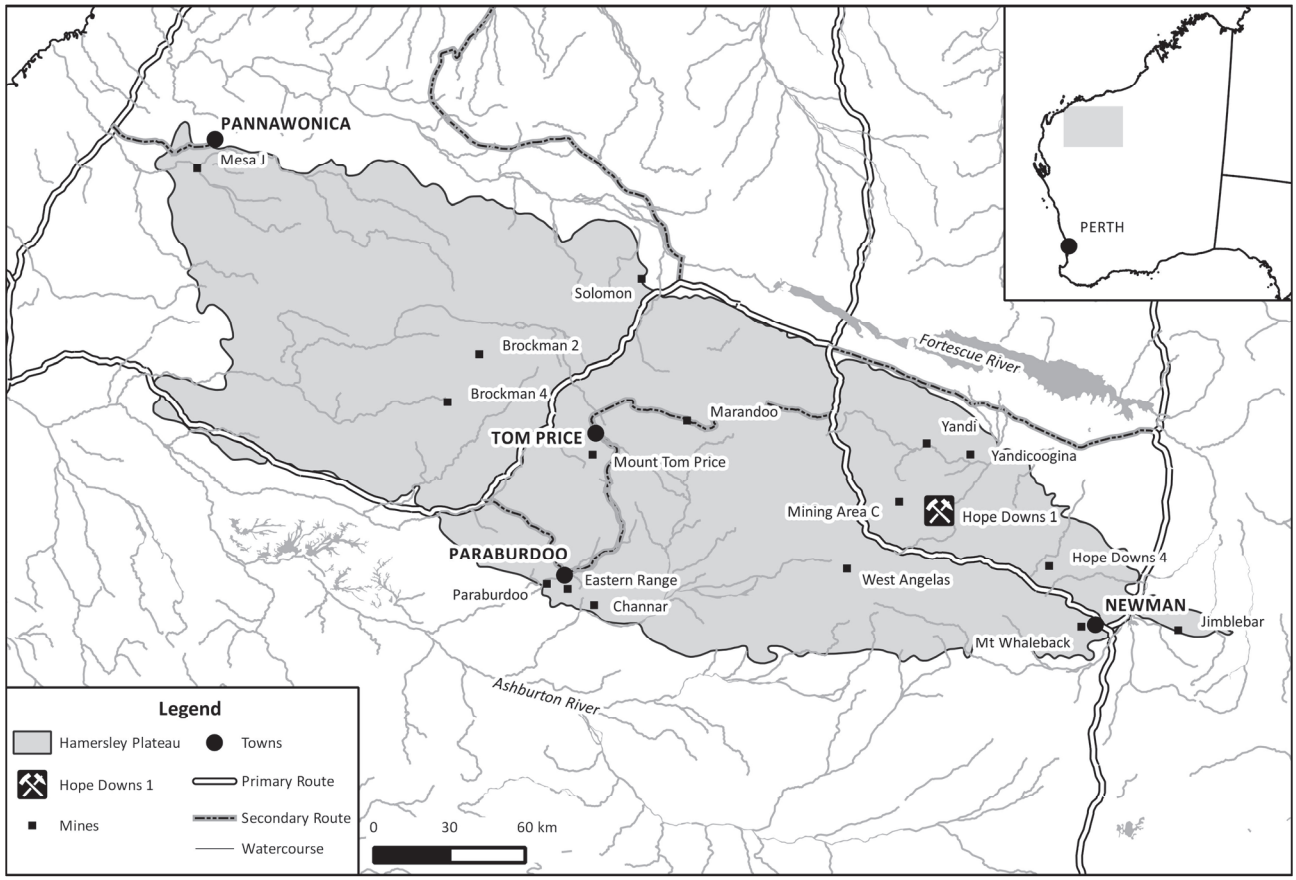

Figure 1-1 Map showing the regional location of the Hope Downs 1 mine

but they offer valuable insight into the intensity of occupation through time and provide data for evaluating the timing of the use of formalised retouched artefacts and grinding implements.

This monograph also includes the excavation and analytical results of two significant Holocene sites, PAD 3 and HD07-3A-03. PAD 3 was initially identified as a rockshelter having a potential archaeological deposit. Excavations at this site revealed an occupation spanning the Holocene. What is remarkable about PAD 3 is the series of exceptionally preserved combustion features in combination with the abundant faunal and macrobotanical remains. PAD 3 also provides the best chronological resolution for the initial appearance of backed artefacts at Hope Downs 1. Four backed artefacts recovered from a combustion feature dated to 4686±78 cal BP, and one additional backed artefact was found below this feature, suggesting that these artefacts were manufactured even earlier. HD07-3A-03 is included in this monograph because of its extremely high density of artefacts that is only paralleled at one other site investigated at Hope Downs 1, Jundaru. This site provides a rare large artefact assemblage through which it is possible to consider technological changes in artefact manufacture from the mid-Holocene through to the recent past. The site boasts one of the largest samples of tulas and backed artefacts from excavated contexts at Hope Downs 1. The context of the formalised retouched artefacts indicates that tulas and burrens appeared in the archaeological record much more recently than backed artefacts.

The well-preserved Holocene occupations at PAD 3 and HD07-3A-03 and the long occupational sequences at Djadjiling (HD07-1A-04), Jundaru (HN-A9), HS-A1, and HD07-3A-PAD13 provide the opportunity to explore local environmental changes and subsistence strategies through specialist studies. These studies include macrobotanical analysis, usewear analysis of stone artefacts, archaeomagnetic analysis of sediment samples, pollen and sediment analysis, phytolith analysis, faunal analysis, OSL analysis, geomorphology, and sediment analysis. These specialist studies offer invaluable contextual data for the archaeological sequences and make it possible to investigate correlations in settlement patterns and technological changes with palaeoenvironmental conditions.

The chapters in this monograph can be divided into four groups. The first four chapters provide background information that contextualises the excavation results. These chapters include an overview of the project and the environmental setting, reviews of the archaeological and ethnographic setting, and the research aims and methods. The second group of chapters documents the results of the excavations and analyses for the six rockshelters that are the focus of this monograph. The third group of chapters includes the results of the specialist analyses that have been carried out on materials from the six key rockshelters, including archaeomagnetic, pollen, phytolith, faunal, usewear, optically stimulated luminescence, and geomorphic analyses. Finally, the outcomes of this research are summarised in Chapter 18.

1.1 PROJECT BACKGROUND

The Hope Downs 1 mine (AM70/00282) is located approximately 75km northwest of Newman, in the east Pilbara region of Western Australia (Figure 1-1). The mine is an unincorporated joint venture between Rio Tinto Ltd (Rio Tinto) and Hancock Prospecting Pty Ltd (HPPL). The development and ongoing operation of the mine is managed by Rio Tinto Iron Ore (RTIO), a division of Rio Tinto responsible for iron ore operations. The Hope Downs 1 mine covers an area of approximately 42.5 square kilometres and includes the Hope North and Hope South project areas (Figure 1-2 and Figure 1-3). These project areas are roughly 5km apart and generally follow the large ranges that dominate the north and southeast areas of the lease. The mine is situated near several other iron ore mines, including Mining Area C (BHP Billiton Iron Ore [BHPBIO]; adjacent to Hope Downs 1), West Angeles (RTIO), Yandicoogina (RTIO), and Yandi (BHPBIO).

The Hope Downs 1 mine is in the traditional land of the Banyjima People native title holders (National Native Title Tribunal file no: WC11/6-1; Federal Court no.: WAD6096/1998). The excavations at Hope Downs 1 preceded the Banjima People Native Title Claim. During the fieldwork there were two overlapping native title claims areas over the mining lease: the Martidja Banyjima (MIB) Native Title Claimants and the Innawonga Bunjima (IB) Native Title Claimant areas. Representatives from each claimant group are identified as such throughout this monograph, reflecting the native title claims as they were when the fieldwork was undertaken.

In Western Australia, places of Aboriginal heritage are protected under the *Aboriginal Heritage Act* 1972 (AHA). Section 17 of the act states that it is an offence to damage any Aboriginal site whether it has been previously recorded or not, unless doing so under a Section 16 (excavation of Aboriginal sites) or Section 18 (consent to certain uses) authorisation. Since 1992, numerous heritage surveys were commissioned for the Hope Downs mine in order to identify heritage sites on the lease (Murphy *et al.* 1992; Edwards *et al.* 2001; Jackson *et al.* 2003; Jackson *et al.* 2007; Green 2001; Law *et al.* 2009; Mott *et al.* 2006; Mott and Liebelt 2006). As a result of this work, 164 heritage sites were identified on the mine lease, including both archaeological sites, sites with potential archaeological deposits, and ethnographic sites.

Development of a mine is classified by the DAA (2013) as an activity causing major disturbance, and in the case of Hope Downs 1, this occurred within a largely unaltered environment. As a requirement of the AHA, land users must apply for and be granted a Section 18 consent to impact an Aboriginal site, and excavation of Aboriginal sites requires a Section 16 consent. These authorisations are issued with specific conditions regarding the management of these sites, and these conditions must be adhered to by the proponent before any site impacts occur. In 2002, a Section 18 permit was granted to 'conduct open iron ore mining, and to construct associated infrastructure at the Hope Downs North and South Deposits' (Carpenter 2002). At the time the permit was granted, only 16 heritage sites were known to be on the mining lease, but numerous sites have since been identified on the Hope Downs 1 lease. These additional sites are also covered by the 2002 Section 18 permit, as 'blanket' permission had been granted to use the land on the mining lease. In accordance with the 2002 Section 18 permit, Pilbara Iron (on behalf of RTIO and HPPL) applied for Section 16 permits to undertake mitigative salvage and test-pitting at sites in the mining lease (Permits 416, 421, 423, 428, and 432).

ACHM was contracted to carry out the salvage investigations at Hope Downs 1 mine for sites scheduled to be impacted by the mining development (either directly or indirectly). ACHM was engaged by Karijini Development Pty Ltd, which represents the MIB Native Title claimants, who now form part of the Banjima People Native Title claim with IB. Over the course of 23 field trips between April 2007 and September 2010, ACHM investigated 31 rockshelters, salvaged 13 open artefact scatters, recorded three man-made structures, documented 11 culturally modified trees (including the salvage of five specimens), and

conducted extensive laboratory work in collaboration with Traditional Owners. Numerous additional field trips were conducted during this time for ethnographic consultation. The full results of this archaeological research are presented in three separate reports that are divided according to the stages of archaeological fieldwork (Cropper 2013; Cropper and Law 2012; Law and Cropper 2011).

The Hope Downs 1 Mitigative Salvage Project encompasses heritage fieldwork that was conducted in three stages, which are defined according to priority areas identified by RTIO.

1. **Hope North Stage 1** (MIB25): includes areas impacted by the development of the northeast pit number 2, the northwest pit, the southeast waste dump, the northwest waste dump, and the waste dump associated infrastructure.

2. **Hope South Stage 2** (MIB50): includes the development and mining of an initial mining area in the Hope South orebody. Contrary to the project name, it also includes mining and waste dump areas in the southern and eastern fringe of the Hope North orebody.

3. **Hope Downs 1 Mitigative Salvage Program** (MIB40): includes areas in Hope North and Hope South scheduled for the construction of infrastructure and mine development.

The Hope North Stage 1 Salvage Program (MIB25)

The Hope North Stage 1 salvage program was carried out over four field trips between March and July 2007. Thirteen archaeological sites were investigated, including two rockshelter sites (Hope 1-24 and Hope 1-43), five rockshelters with potential archaeological deposits (PADs 2B, 3, 4, 5, and 6), one man-made structure (Hope 1-47), and six stone artefact scatters (Hope 1-02, Hope 1-23, Hope 1-34, Hope 1-35, Hope 1-36, and HN-A4). All of the archaeological sites investigated during the Hope North Stage 1 salvage operations have been disturbed by the Hope 1 North mining development. The sites flagged for the Stage 1 salvage were impacted by the infrastructure construction, pit excavation, and/or waste dumps associated with the mine. The locations of the sites nominated for salvage were widespread across the Hope North orebody; although, a small concentration of rockshelters with potential archaeological deposits (PAD 2, PAD 3, PAD 4, PAD 5, and PAD 6) and a man-made structure (Hope 1-47) were concentrated in the run-of-mine (ROM) pad gully near the primary iron ore crusher, which was under construction during the investigation of these sites.

The excavations conducted as part of the Hope North Stage 1 program resulted in the documentation of several sites with Holocene occupational sequences. Excavations in one rockshelter identified as a potential archaeological site, PAD 3, revealed a series of well-preserved combustion features spanning from the early to late Holocene. The PAD 3 investigations demonstrated that rockshelters formed in banded iron formations can contain well-preserved cultural features with complex stratigraphic relationships, despite the fact that the deposit is comprised of a high proportion of exfoliated rock. Research at PAD 3 has also extended the antiquity of backed artefacts in the Hamersley ranges, with evidence for their use conservatively estimated between 4825 and 4569 cal BP.

PAD 3 is one of five rockshelters with potential archaeological deposits excavated during the Hope North Stage 1 salvage program. Work at these sites demonstrated that most rockshelters with potential archaeological deposits are likely to have buried cultural material. Admittedly, some rockshelters yielded few artefacts, but there is no way to predict the extent of the archaeological record in these places without proper test excavations. The most significant sites in the Hope North Stage 1 project were discovered in this manner, and they have yielded substantial information on Aboriginal subsistence, lithic technology, and past human-environment interactions.

The Hope South Stage 2 Salvage Program (MIB50)

The Hope South Stage 2 (MIB50) salvage program included the recording, collection and documentation of 14 archaeological sites between July 2007 and March 2008 (with a subsequent laboratory trip in April 2008). The sites investigated during the salvage program include five rockshelters (HD07-1A-02, HD07-1A-03, HD07-1A-04 (aka Djadjiling Rockshelter), HD07-1A-07, and HD07-1A-22), one rockshelter with a potential archaeological deposit (PAD 7), five open artefact scatters (HD07-1A-01, HD07-1A-08, HD2006-6, Hope 1-03, and Hope 1-33), two culturally modified trees (Hope 1-04 and Hope 1-05), and one man-made structure (Hope 1-14). With the exception of Djadjiling (HD07-1A-04), HD07-1A-07, and HD07-1A-22, all of the aforementioned sites were disturbed by the Hope North and Hope South mining development. The mine planners were able to re-design the impact footprint so that Djadjiling Rockshelter could be preserved. Sites HD07-1A-07 and HD07-1A-22 are located in an area that is not scheduled to be directly impacted by the mine development; however, the sites were included in the Stage 2 salvage program as nearby blasting may cause vibrations that destabilise the rockshelter and result in roof collapse. The remaining sites flagged for the Stage 2 salvage will be impacted by infrastructure construction, pit excavation and/or waste dumps associated with the mine.

Of the six rockshelters that were excavated as part of the Hope South Stage 2 program, one highly significant site was identified. Excavations at Djadjiling Rockshelter documented a Pleistocene occupational sequence, demonstrating Aboriginal occupation of the Hamersley Ranges 41,000 years ago. At the time of its discovery, this site pushed back the known initial settlement of the inland Pilbara by 10,000 years, as previous archaeological investigations suggested the region was first occupied by approximately 28,000 to 31,000 cal BP, as reported for Newman Rockshelter (30,897±372 cal BP, SUA-1510; Brown 1987) and Mesa J24 Rockshelter (28,317±415 cal BP, Wk-2514; Hughes *et al.* 2011). Djadjiling was most intensely occupied during this early occupational phase, and this has been demonstrated through artefact densities, archaeomagnetic analysis, and phytolith analysis. The long occupational sequence at Djadjiling allowed for the investigation of local environmental changes over time through specialist studies, including macrobotanical, archaeomagnetic, palynological, and phytolith analyses. These studies provide invaluable contextual data for the archaeological sequence that allow us to investigate correlations in settlement patterns and technological changes with palaeoenvironmental conditions, particularly when considered alongside the specialist studies undertaken for PAD 3. The usewear analysis of artefacts from Djadjiling has shown that many stone tools were utilised for woodworking, hinting at the possibility of a broad assemblage of wooden artefacts that has not been preserved. Moreover, several of the Pleistocene retouched artefacts show evidence of hafting, demonstrating the established use of this technology during the earliest phases of occupation.

Table 1-1 Sites investigated during the Hope Downs 1 Mitigative Salvage Project

Project Stage	Site Name	DAA ID	Site Type	Location	Salvage Start	Salvage End
Hope North Stage 1 (MIB25)	HOPE 1-02	24032	AS	Hope North	25-Jul-07	26-Jul-07
	HOPE 1-23	24033	AS	Hope North	01-Jul-08	01-Jul-08
	HOPE 1-24*	24034	RS	Hope North	30-Jun-07	30-Jun-07
	HOPE 1-34	24035	AS	Hope North	27-May-07	27-May-07
	HOPE 1-35	24036	AS	Hope North	27-May-07	27-May-07
	HOPE 1-36	24037	AS	Hope North	27-May-07	27-May-07
	HOPE 1-43	24038	RS	Hope North	01-Jul-07	04-Jul-07
	HOPE 1-47	25234	MMS	Hope North	16-Apr-07	16-Apr-07
	PAD 2B		PAD	Hope North	16-Apr-07	18-Apr-07
	PAD 3		PAD	Hope North	19-May-07	30-Jun-07
	PAD 4		PAD	Hope North	14-Apr-07	19-May-07
	PAD 5		PAD	Hope North	14-Apr-07	16-Apr-07
	PAD 6		PAD	Hope North	14-Apr-07	16-Apr-07
Hope South Stage 2 (MIB50)	HD07-1A-01		AS	Hope South	17-Oct-07	17-Oct-07
	HD07-1A-02		RS	Hope South	18-Oct-07	12-Dec-07
	HD07-1A-03		RS	Hope South	13-Dec-07	13-Dec-07
	HD07-1A-04 (Djadjiling)		RS	Hope South	18-Oct-07	07-Mar-08
	HD07-1A-07		RS	Hope South	13-Dec-07	17-Dec-07
	HD07-1A-08		AS	Hope South	18-Jul-07	19-Jul-07
	HD07-1A-22		RS	Hope South	18-Dec-07	18-Dec-07
	HD2006-6		AS	Hope South	19-Oct-07	19-Oct-07
	HOPE 1-03	25214	AS	Hope North	20-Oct-07	20-Oct-07
	HOPE 1-04	25052	CMT	Hope North	21-Oct-07	22-Oct-07
	HOPE 1-05	25053	CMT	Hope North	21-Oct-07	22-Oct-07
	HOPE 1-14	25059	MMS	Hope North	21-Oct-07	21-Oct-07
	HOPE 1-33	25230	AS	Hope North	20-Oct-07	20-Oct-07
	PAD 7	25195	PAD	Hope North	20-Oct-07	22-Oct-07
Hope Downs 1 Mitigative Salvage Program (MIB40)	HD07-3A-01		AS	Hope South	16-Sep-08	20-Oct-08
	HD07-3A-03		RS	Hope South	13-Jan-09	19-Jan-09
	HD07-3A-13		RS, MMS	Hope South	19-Oct-08	20-Oct-08
	HD07-3A-17		RS	Hope South	16-Nov-08	18-Nov-08
	HD07-3A-18		CMT	Hope South	14-Sep-08	14-Sep-08
	HD07-3A-PAD05		PAD	Hope South	15-Sep-08	15-Sep-08
	HD07-3A-PAD07		PAD	Hope South	20-Oct-08	21-Oct-08
	HD07-3A-PAD13		PAD	Hope South	08-Nov-08	13-Sep-10
	HD2006-5	26893	CMT	Hope North	15-Sep-08	15-Sep-08
	HN-A12	18715	MMS	Hope North	12 Aug- 08	12 Aug-08
	HN-A7	18712	RS	Hope North	06-Sep-08	11-Sep-08
	HN-A9 (Jundaru)	18195	RS	Hope North	20-May-08	20-Aug-08
	HOPE 1-09	25054	CMT	Hope North	13-Sep-08	19-Sep-08
	HOPE 1-10	25055	CMT	Hope North	12-Sep-08	12-Sep-08
	HOPE 1-11	25056	CMT	Hope North	12-Sep-08	12-Sep-08
	HOPE 1-12	25057	CMT	Hope North	12-Sep-08	12-Sep-08
	HOPE 1-13	25058	AS	Hope North	20-Oct-08	20-Oct-08
	HOPE 1-15	25060	CMT	Hope North	13-Sep-08	13-Sep-08
	HOPE 1-16	25061	RS	Hope North	12-Sep-08	13-Sep-08
	HOPE 1-17	25199	RS	Hope North	12-Sep-08	13-Sep-08
	HOPE 1-22	25200	RS	Hope North	03-May-08	03-May-08
	HOPE 1-39	25201	RS	Hope North	28-Apr-08	30-Apr-08
	HOPE 1-40	25202	RS	Hope North	25-Apr-08	26-Apr-08
	HOPE 1-41	25203	RS	Hope North	26-Apr-08	04-May-08
	HOPE 1-42	25205	CMT	Hope North	02-May-08	02-May-08
	HOPE 1-44	25206	CMT	Hope North	03-May-08	03-May-08
	HOPE 1-45	25233	AS, CMT	Hope North	02-May-08	03-May-08
	HOPE 1-46	25207	RS	Hope North	01-May-08	02-May-08
	HS-A1	18716	RS	Hope South	11-Oct-08	20-Oct-08
	HS-A2	18717	RS	Hope South	08-Nov-08	16-Nov-08
	PAD 1	25194	RS	Hope South	24-May-08	01-May-08

Key: AS - artefact scatter, RS - rockshelter, MMS - man-made structure, CMT - culturally modified tree, PAD - potential archaeological deposit.
*Hope 1-24 is a rockshelter with surface artefacts, but no deposit.

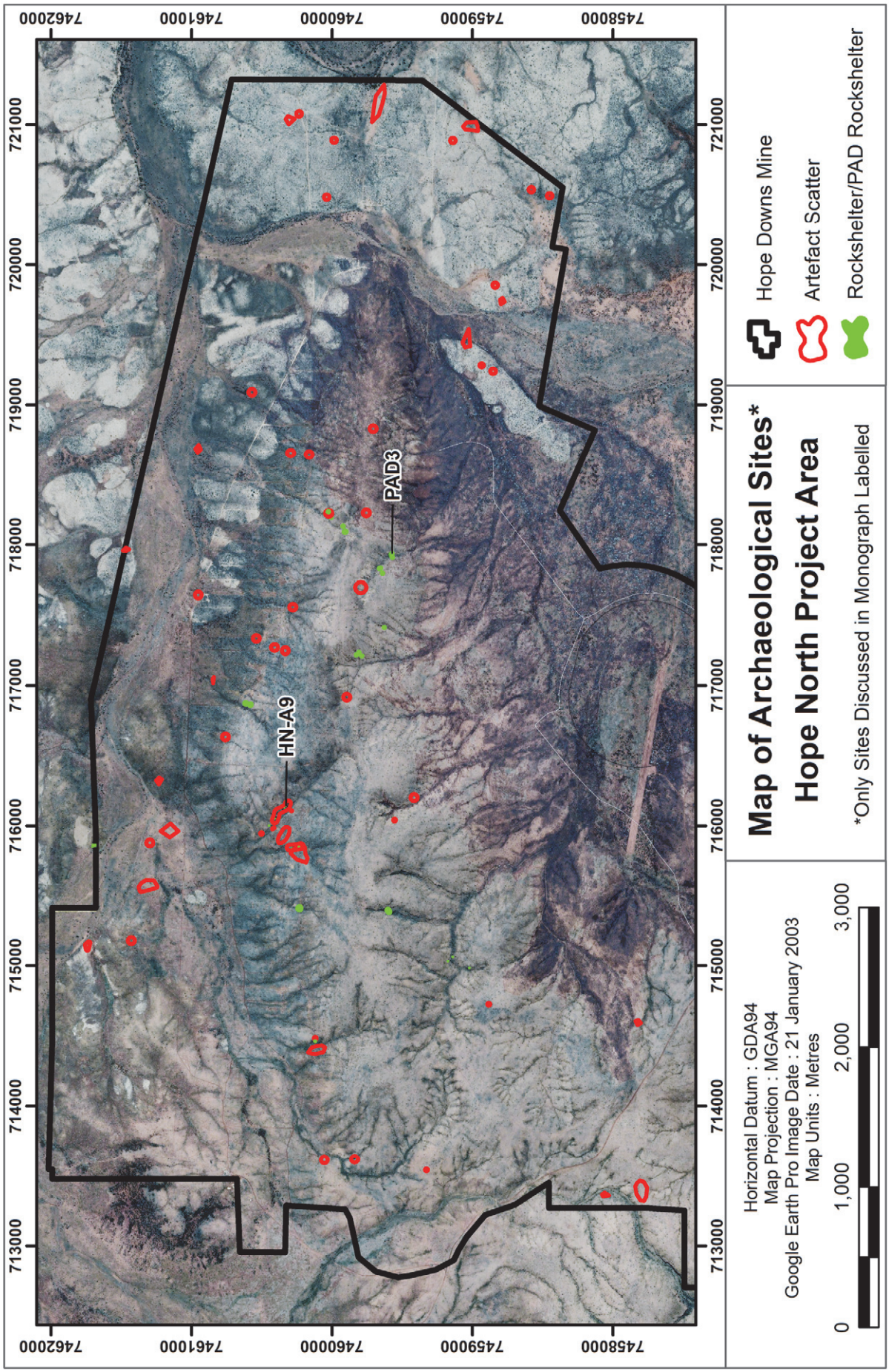

Figure 1-2 Archaeological sites in Hope North

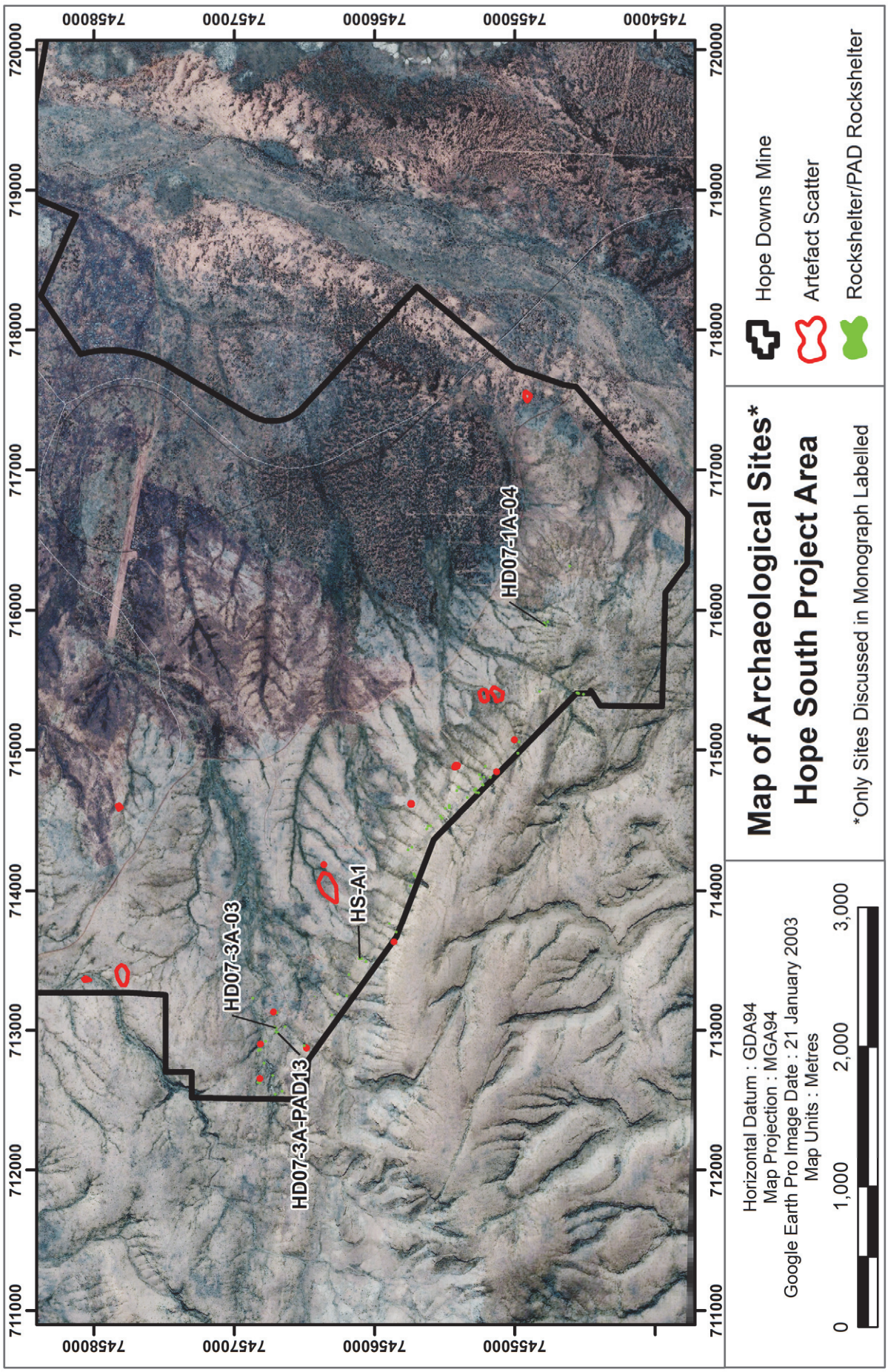

Figure 1-3 Archaeological sites in Hope South

The Hope Downs 1 Mitigative Salvage Program (MIB40)

The Hope Downs 1 Mitigative Salvage Program (MIB40) was carried out over 15 field trips between April 2008 and September 2010, and it included the recording, collection, and documentation of 31 sites prior to the impacts (direct or indirect) of mining activities. The sites investigated included 14 rockshelters (three with man-made structures), four rockshelters with potential archaeological deposits, three open artefact scatters (one with culturally modified trees), nine culturally modified tree sites, and one man-made structure site. All of the archaeological sites investigated during the MIB40 program were subject to mitigative salvage measures before they were disturbed by the Hope North and Hope South mining development. Two sites (Sites HS-A1 and HD07-3A-PAD13 are) are located on the edge of the Hope South mine pit, and they have not been impacted. It has been recommended that measures should be taken to avoid directly impacting these sites, as both are significant Pleistocene sites.

A key outcome of the MIB40 program was the identification of Pleistocene occupational sequences at four rockshelters: Jundaru (HN-A9), HS-A1, HD07-3A-PAD13, and Hope 1-41. These sites further confirm the early occupation of the local area as was first demonstrated at Djadjiling. Well-preserved combustion features were identified at Jundaru and HS-A1, and a rich assemblage of cultural material was recovered from Jundaru. The excavation at HD07-3A-PAD13 showed that its deposit formed under very different conditions to most other rockshelters at Hope Downs 1, and the OSL ages obtained from HD07-3A-PAD13 further substantiate the pre 41,000 cal BP radiocarbon dates for the initial occupation the region. Only a limited Pleistocene assemblage was identified at Hope 1-41, and the site has been affected by bioturbation. The long occupational sequences at Jundaru (HN-A9), HS-A1, and HD07-3A-PAD13 provide the opportunity to explore local environmental changes and subsistence strategies through specialist studies, including the macrobotanical analysis, usewear analysis of stone artefacts, archaeomagnetic analysis of sediment samples, pollen and sediment analysis, phytolith analysis, faunal analysis, OSL analysis, geomorphology, and sediment analysis.

In addition to the Pleistocene sites investigated as part of the MIB40 program, excavations also revealed HD07-3A-03 as an important Holocene site. HD07-3A-03 was found to have an extremely high density of flaked stone artefacts, dating from approximately 5716±64 cal BP and continuing until the recent past. The density of artefacts at this site is rivalled only by Jundaru.

1.2 ENVIRONMENTAL SETTING

The Hope Downs 1 mine lies within the rangelands of the Hamersley Plateau, in the eastern Pilbara region of Western Australia. The inland Pilbara is geographically remote and sparsely populated. The physiographic and ecological systems of the Pilbara are the consequence of a long geological and evolutionary history. Understanding the mechanisms that shaped these systems, and the natural resources contained within them, is vital to our understanding of the Aboriginal archaeological record. The following sections briefly describe the landforms, geology, and climatic history of the inland Pilbara. Also described is the native flora and fauna that occupy the land systems.

Landforms and Geology

Hope Downs 1 is located in a physiographic region known as the Hamersley Plateau, which stretches across large portions of the southern inland Pilbara and incorporates the Hamersley Range. The Hamersley Plateau covers an area of over 39,000 square kilometres, stretching from Newman in the east to Pannawonica in the west. The Fortescue valley and Chichester Range lay to the north, and the Augustus Ranges are to the south and west.

The land surfaces in the Hamersley Plateau are predominately erosional hills and ridges with low to very high (30-450m above mean sea level [AMSL]) topographic relief (Payne 2004: 72). Amongst these areas of relief are very low lying (9-30m AMSL) stony plains formed primarily by colluvial wash deposits and dissected by narrow drainages (Payne 2004: 73). Although uncommon, extremely low lying rivers (<9m AMSL) cut through this massive, weathered landscape (Payne 2004: 75).

There are seven land systems characteristic of the Hamersley Plateau that occur within the mining lease. These land systems are described by Payne (2004) as the Newman, Platform, Pindering, Boolgeeda, Calcrete, Oakover, and River land systems (Figure 1-4). The Newman land system is the most widespread and common land system at Hope Downs 1. It is an upland land system, easily identified by the rugged plateaux, ridges and mountains expanding across the lease. The Newman system is an erosional land surface, with vertical escarpments, steep scree slopes, and well-incised gullies and gorges (Payne 2004: 298). Soils are stony and shallow, with some residual, loamy red earths. The geological age of the land surface dates to the Lower Proterozoic, which formed approximately 2600 mya (Thorne and Tyler 1997). Rockshelters are a common feature throughout this upland system, offering protected locales for undisturbed soil aggradation and potentially, stratified archaeological deposits. Artefact scatters and similar open archaeological sites in this land system will be resting atop of the ground surface with little or no soil deposition.

At Hope Downs 1, the Newman land system is part of the Hamersley geological group, and the Marra Mamba Iron Formation is the most prominently featured unit (Thorne and Tyler 1997). The Marra Mamba Iron Formation is the oldest unit of the Hamersley Group, and it is the iron ore rich formation that is economically important to the mine. The Marra Mamba formation is divided into three members: the Nummuldi Member (lowest), the MacCleod Member (middle), and Mount Newman Member (upper) (Kneeshaw 1984; Blockley *et al.* 1993). The formation is siliceous, with alternating layers of yellow to yellow-brown chert, brown to black banded ironstone, interlayered thin shales, and pelite. Often, the contact between the Nammuldi Member and the MacLeod Member is marked by a distinctive elongated and lenticular-shaped chert layer know by geologists as the 'potato bed' (Thorne and Tyler 1997: 11). Chert outcrops from this formation were once a significant raw material resource for Aboriginal stone tool manufacture.



Figure 1-4 Land systems at the Hope Downs 1 mine

The Platform land system is a colluvial landform resting along the toeslope of the Newman system (Payne 2004: 320). The land system consists of partially consolidated Tertiary age (65-1.8 mya) colluvium, deriving from the upper Newman land surface. Most of the land system is dissected by gently inclined erosional slopes with closely spaced dendritic or sub-parallel drainage systems. Soils, if present, are red shallow loams and stony soils with no prominent stratigraphy. Archaeological sites located in this land system will be surficial and most likely degraded due to the gradually sloping and weathered nature of the land system.

The Boolgeeda and Pindering land systems occupy the stony lower slopes and plains beneath the Newman and Platform systems (Payne 2004: 196). The Boolgeeda and Pindering are depositional landforms, formed by Tertiary and Quaternary colluvial sheet wash (Thorne and Tyler 1997). The uppermost relief of these land surfaces is very gently inclined and becomes more level further downslope. The Boolgeeda drainage system is closely spaced, with dendritic and sub-parallel narrow drainages dissecting the land surface (Payne 2004: 196). Drainage lines of the Pindering land system are linear and arranged at right angles to the surface sheet flow (Payne 2004: 318). The stony ground surface is composed of unconsolidated soil, quartz, and ironstone fragments, locally derived from upland scree and talus slopes. The presence of spinifex grasses make these systems prone to bush fires. Open archaeological sites in this weathered and slowly aggrading land system are unlikely to be deeply buried, stratified, or *in situ*.

The Calcrete and Oakover land systems rest in the plains of the east and northeast lease area, between the Pindering and River systems (Payne 2004: 205-206, 306-307). The principal difference between the Calcrete and Oakover land systems is topography. The Oakover is a rangeland system comprised of mesas, plateaux, breakaways, and calcareous plains. It overlies the Calcrete land system, which is primarily low calcrete platforms and plains. Inside the lease, it is extremely difficult to differentiate between the two landforms; however, outside the lease, the differences are more topographically distinctive. The foundation of these land systems is Tertiary age calcrete, which occurs as a mosaic of low rises and platforms (up to 10m) above the surrounding plains. A loamy Quaternary alluvium has been deposited between prominent calcrete platforms via low energy water movement. Although soils are shallow, there is a possibility for buried cultural deposits to be present in lowland areas, and the low energy water movement increases the likelihood that these materials may be *in situ* or undisturbed.

An uncommon but important land system is the River land system (Payne 2004: 328), which abuts the north and east Hope Downs mining lease boundary. This system is a depositional landform clearly associated with Weeli Wolli Creek, which runs in a northeast direction from the lease to Weeli Wolli Spring. The soils of this system are Quaternary age alluvium, deposited by regular overbank flood events. Flood plains and river terraces are the most common land units of the River land system, with periodically washed sandy levees, stony plains, and water channels composing the remaining associated units (Payne 2004: 328-329). Red sandy soils are common along the upper terraces of the drainage, while loamy red soils and red/brown non-cracking clays occupy much of the flood plains and lower terraces.

It is possible that Aboriginal river terrace encampments were periodically inundated by flood waters in the archaeological past, and Aboriginal sites buried by low energy, sediment-rich waters have the potential to be stratified and well preserved. The terraces along Weeli Wolli Creek are therefore an important landform for archaeological investigation, as significant subsurface cultural deposits may be buried beneath alluvium.

Modern Climate and Palaeoclimatic History

The Hope Downs 1 Mine is in the Australian arid zone, a hot and dry climatic region where annual potential evaporation exceeds annual precipitation. Rainfall variability, often expressed by extensive droughts and occasional flooding rains, is the dominant climatic element for Australia's arid regions (Morton *et al.* 2010). The project area belongs to the desert-summer rain bioclimatic region of the inland Pilbara, a region characterised as regularly having up to 12 months of dry weather and high temperatures with occasional rainfall (Beard 1990). Rain usually occurs in the form of summer thunderstorms, and rainfall is heavily influenced by the Indo-Australian summer monsoon and associated cyclonic events. Pilbara summers are very hot, and winters are generally cool and mild. The local mean summer daytime temperature at the Newman weather station is recorded as 39.6°C (January data; Bureau of Meteorology 2009). In winter, mean daytime temperatures is 22.3°C (July data; Bureau of Meteorology 2009), and the night time winter temperatures at Newman rarely drop to 0°C.

Annual precipitation is extremely varied, and the region rarely receives an 'average' rainfall year unless it has high frequency of cyclone events (Leighton 2004: 21). The mean annual rainfall recorded at the Newman station is 310.2mm (Bureau of Meteorology 2009), and more than half of the annual rainfall comes during the summer months of December, January, and February. Historically, the wettest month in the Pilbara has been February, while September and October were the driest (Leighton 2004: 26).

The extreme climatic patterns of the inland Pilbara have not always been as they are at present. The regional climate has varied considerably over the past 50,000 years, and Aboriginal populations have continuously adapted to these climatic fluctuations. Unfortunately, there is very sparse palaeoclimatic data available on the Pilbara region itself; consequently, data from other areas of the Australian arid zone must be considered when modelling the palaeoclimatic record of the inland Pilbara.

Between 50,000 and 35,000 years ago, climatic conditions across the Australian arid zone were likely warmer, wetter, and more seasonally predictable than present, and there is evidence suggesting that summer monsoons penetrated the continental interior at regular intervals (Magee *et al.* 2004: 1151; Johnson *et al.* 1999). Inland freshwater playa lakes were more plentiful across the region at this time (Cohen *et al.* 2011), and in some areas of southern central Australia palaeoshorelines expanded and joined together to form mega-lakes (De Deckker *et al.* 2011). These favourable climatic conditions formed the backdrop for the original Aboriginal settlement of the inland Pilbara, which has recently been demonstrated as being prior to 41,000 cal BP (Law *et al.* 2010). Between 42,000 and 33,000 years ago, this lacustral climatic phase gradually transitioned towards the increasingly xeric conditions of the Last Glacial Maximum (LGM) (De Deckker *et al.* 2011: 49).

In comparison to the present day, the LGM was a climatic period characterised by decreased, unpredictable rainfall patterns and decreased terrestrial temperature across inland Australia. In some arid zone areas there is evidence for increased wind strength during the LGM, as demonstrated by aeolian dune-building activity; however, it is unclear if dune

aggradation was encouraged by an increase in wind strength or a decrease in dune-stabilising vegetation (Hesse and McTainsh 1999: 343). Palaeoclimatic research from northwest Australia indicates that the LGM covers the time interval between 35,000 and 14,000 years ago (Williams *et al.* 2009: 2410). Of course, there was climatic variability across Australia at this time, which makes the precise timing of the LGM period debatable, and it requires periodical revision as new data is collected. Recent research indicates that hyperaridity became markedly pronounced in the arid zone between 23,000 and 19,000 years ago, a period sometimes referred to as the 'LGM proper' (Mix *et al.* 2001: 636; Williams *et al.* 2009: 2400). Food and water resources during the LGM were diminished and more limited than today, and it is argued that the arid zone experienced colder winters than present (Harrison 1993: 223; Hesse and McTainsh 1999: 347; Williams *et al.* 2009: 2410).

Around 14,000 years ago, at the tail end of the Pleistocene, arid conditions ameliorated with the re-initiation of the northern summer monsoon cycle across northern Australia (Wyrwoll and Miller 2001: 127). Climatic conditions progressively warmed, and vegetation communities stabilised as surface water became more widely available. This more climatically predictable and wetter period most likely continued throughout the terminal Pleistocene and into the early Holocene (10,000-6000 years ago) (Wyrwoll and Miller 2001: 127; Quigley *et al.* 2010: 1099; De Deckker *et al.* 2011: 49). In central Australia, for example, increased effective precipitation has been measured at 11,500 cal BP and 8000 to 5000 cal BP, with peak moisture recorded between 7000 and 6000 years ago (Quigley *et al.* 2010: 1093).

In the mid-Holocene (6000-3500 years ago), many researchers contend that the arid zone experienced a comparatively dry climatic phase between 6000 and 4000 years ago (*e.g.*,Quigley *et al.* 2010; Dimitriadis and Cranston 2001; McCarthy and Head 2001). Of particular relevance to the Pilbara is recent climatic data from Shark Bay, located on the mid-north Western Australia coastline (Nott 2011). The Shark Bay study demonstrates that there is 1700 year gap in storm surge shell ridge building activity, leading Nott (2011: 722) to conclude monsoonal activity ceased between 5400 cal BP and 3700 cal BP, and the region became drier than present. During this time, Nott (2011: 722) hypothesises that the Shark Bay region experienced a mega drought that may have persisted for more than 1000 years. Similar research immediately to the east of the Pilbara, in the Lake Gregory Basin, indicates that a significant episode of sand dune building occurred around 5000 years ago, adding further evidence of a mid-Holocene hyperarid event (Fitzsimmons *et al.* 2012: 476). Although this recent research shows that rainfall became less frequent and more unpredictable during the mid-Holocene, it is evident that the dry climatic conditions were not as severe as those of the LGM.

For the last 2000 years, climatic conditions of the inland Pilbara have been much like the present climate. The late Holocene palaeoclimate has been considerably wetter than the drier mid-Holocene period, and it has been more climatically variable and less predictable than the early Holocene (McCarthy and Head 2001: 687). Seasonal rainfall has become more frequent than the mid-Holocene, but it is still not as regularly cycled as in the early Holocene.

Flora

The distribution of plant communities on the Hamersley Plateau is intrinsically connected to the geography and geology of the region. The Hamersley Plateau is considered to be one of the four subregions for the Pilbara biogeographical region (the Fortescue River Plains, Chichester Ranges, and Roebourne Coastal Plains comprise the remaining subregions). Thackway and Cresswell (1995) characterise the vegetation communities of the Hamersley Plateau as low mulga woodland over bunch grasses on fine textured soils and snappy gum over spinifex hummock grasses on skeletal sandy soils in upland ranges. The diversity and distribution of Pilbara plant communities is much more complex than this generalised description, and at Hope Downs 1, the distribution of plant communities is easily attributed to the surrounding landform and soils. The flora of the Hope Downs area was surveyed and mapped by Mattiske Consulting Pty Ltd (2009), which identified 18 vegetation communities within the mining lease (Table 1-2).

The vegetation communities identified at Hope Downs 1 can be divided broadly between those present in the creek lines and drainage areas and those characteristic of the ranges, hills, and hillslopes. Each vegetation community is linked with the geomorphology and land systems of each area. Table 1-2 provides a comparison of the dominant vegetation communities within the previously described land systems.

The uplands at Hope Downs 1 are dominated by hummock grasslands, which Mattiske Consulting Pty Ltd (2009) have defined as hummock grassland of *Triodia* species with an overstorey of isolated to scattered eucalypts, mulga, and shrubs. Within the two prominent upland land systems, the Newman and Platform land systems, there are a range of hummock grassland communities (Newman – S1, S2, S3, and S4; Platform S1, S2, and S3), which support slightly different ranges of species (Table 1-2). Dominant hummock grassland species include *Triodia epactia,* limestone spinifex (*Triodia wiseana*), echidna spinifex (*Triodia brizoides*), hard spinifex (*Triodia basedowii*), and occasionally soft spinifex (*Triodia pungens*) (Mattiske Consulting Pty Ltd 2009: Table 6). Woody species are dominated by eucalypts and acacia species, but there are also numerous species of scattered shrubs and flowering plants, such as *Senna*, *Ptilotus*, Wickham's grevillea *(Grevillea wickhamii)*, crimson turkey brush (*Eremophila latrobei*), native poplar (*Codonocarpus cotinifolius*), and *Indigofera monophylla* (Mattiske Consulting Pty Ltd 2009: Table 6).

Low woodlands are typically present within the lower-lying Boolgeeda (S1, S2, M2, and M4) and Pindering (M1 and M2) land systems; although, hummock grasslands continue to be a dominant vegetation community in the Boolgeeda land system (Mattiske Consulting Pty Ltd 2009: Table 6-7). The low woodland vegetation communities are dominated by *Acacia* species, with mulga (*Acacia aneura*) being predominant (Mattiske Consulting Pty Ltd 2009: Table 6). The stony slopes and lowland plains at Hope Downs 1 are dominated by plain hard and plain soft spinifex grasslands (Van Vreeswyk and Payne 2004). The dominant hummock grassland species of the lowlands vary, but *Triodia* epactia and soft spinifex are the dominant grasses (Mattiske Consulting Pty Ltd 2009: Table 6). The grass layer may potentially cover 60% of the ground surface, depending upon the timing of the last bushfire (Van Vreeswyk and Payne 2004). Trees and shrubs are infrequent, but when they do occur, they may form a prominent stratum.

Table 1-2 Vegetation communities present in the Hope Downs 1 lease (adapted from Mattiske Consulting Pty Ltd 2009: Tables 6-7)

	Code	Description	Dominant in Land System
Creek Lines and Drainage Areas	C1	Low Woodland of *Eucalyptus xerothermica* and *Eucalyptus victrix* over *Acacia citrinoviridis, Acacia maitlandii*, *Gossypium australe*, *Melaleuca lasiandra, Petalostylis labicheoides, Rulingia luteiflora* over *Triodia epactia, Chrysopogon fallax* and *Triodia pungens* on minor creeklines with sandy soils.	River
	C2	Low Woodland of *Eucalyptus xerothermica* and *Eucalyptus victrix* over *Acacia citrinoviridis, Acacia maitlandii*, *Gossypium australe*, *Melaleuca lasiandra, Petalostylis labicheoides, Rulingia luteiflora* over *Triodia epactia, Chrysopogon fallax* and *Triodia pungens* on minor creeklines with sandy soils.	River
	C3	Tall Shrubland of *Acacia arida*, *Acacia bivenosa*, *Acacia ancistrocarpa, Acacia maitlandii, Acacia monticola* with occasional emergent *Corymbia deserticola* subsp. *Deserticola, Eucalyptus gamophylla* and *Eucalyptus leucophloia* over *Gompholobium polyzygum, Indigofera monophylla, Rulingia luteiflora* over mixed *Triodia* species on sandy-loam soils in minor gullies.	None
	C4	Open Woodland of *Eucalyptus victrix, Eucalyptus camaldulensis* var. *obtusa, Melaleuca argentea* over *Acacia citrinoviridis, Acacia coriacea* subsp. *Sericophylla* and *Melaleuca lasiandra* over *Cyperus vaginatus* on major creeklines with pools with sandy soils.	River
	X3	Tall Shrubland of *Acacia bivenosa, Acacia monticola, Acacia marramamba, Petalostylis labicheoides* with occasional emergent *Eucalyptus leucophloia* over *Triodia pungens* and *Triodia basedowii* on calcrete soils in minor gullies.	Calcrete
	M1	Low Woodland to Low Open Forest of *Acacia aneura* var. *aneura, Acacia pruinocarpa, Acacia catenulata* subsp. *Occidentalis, Acacia rhodophloia, Grevillea berryana* with an occasional emergent *Eucalyptus leucophloia* and *Eucalyptus gamophylla* over *Psydrax latifolia, Keraudrenia nephrosperma*, *Acacia distans, Eremophila fraseri*, A*cacia tetragonophylla, Eremophila forrestii* subsp. *Forrestii, Solanum lasiophyllum* over *Chrysopogon fallax, Triodia pungens* and *Triodia epactia* and a range of annual species on sandy-loam flats and broad plains.	Pindering
	M2	Low Woodland of *Acacia aneura* var. *aneura* to a Tall Shrubland of *Acacia pyrifolia, Acacia bivenosa, Acacia ancistrocarpa* and *Acacia maitlandii* with occasional emergent *Eucalyptus xerothermica, Corymbia aspera, Psydrax latifolia* and *Acacia citrinoviridis* over *Gompholobium polyzygum, Rulingia luteiflora, Themeda triandra, Triodia epactia* and *Triodia pungens* on sandy soils on flats on edges of major creeklines.	River, Boolgeeda, Pindering
	M4	Low Open Woodland of *Acacia rhodophloia* and *Acacia tetragonophylla* with occasional *Eucalyptus gamophylla* and *Eucalyptus xerothermica* over *Acacia hilliana, Acacia maitlandii* over *Triodia pungens, Triodia basedowii, Aristida* species and a range of annual species on flats and broad valley floors.	Boolgeeda
	M5	Low Woodland of *Acacia aneura* var. *aneura* to a Tall Shrubland of *Acacia pyrifolia, Acacia bivenosa, Acacia ancistrocarpa* and *Acacia maitlandii* with occasional emergent *Eucalyptus xerothermica, Corymbia aspera, Psydrax latifolia* and *Acacia citrinoviridis* over *Gompholobium polyzygum, Rulingia luteiflora, Themeda triandra, Triodia epactia* and *Triodia pungens* on sandy soils on flats on edges of major creeklines.	None
	M7	Low Open Woodland of *Acacia aneura* var. *aneura, Acacia pruinocarpa* over *Acacia bivenosa* and *Triodia pungens* and a range of annual species on open sandy-loam flats and broad plains.	
Ranges, Hills, and Hill slopes	B1	Hummock Grassland of *Triodia basedowii, Triodia wiseana* and *Triodia pungens* with emergent patches of *Eucalyptus leucophloia, Acacia citrinoviridis, Acacia aneura* var. *aneura, Acacia pruinocarpa, Acacia synchronicia* over *Eremophila latrobei* subsp. *Glabra, Senna glutinosa* subsp*. Glutinosa, Solanum lasiophyllum, Eriachne mucronata* and species of *Maireana* and *Triodia* on narrow breakaways and rocky slopes on edges of hills and ranges.	None
	S1	Hummock Grassland of *Triodia epactia* with pockets of *Triodia basedowii* and *Triodia pungens* with emergent *Corymbia hamersleyana*, *Eucalyptus gamophylla*, *Eucalyptus leucophloia* over *Acacia aneura* var. *aneura, Acacia pruinocarpa, Acacia rhodophloia, Codonocarpus cotinifolius, Psydrax latifolia* and *Grevillea berryana* over *Acacia adoxa* var. *adoxa, Acacia arida, Acacia tenuissima, Acacia tetragonophylla, Acacia bivenosa, Acacia distans, Acacia hilliana, Eremophila latrobei* and *Eremophila forrestii* subsp. *Forrestii* over range of annual species on gravely soils on lower slopes.	Boolgeeda, Newman, Platform
	S2	Hummock Grassland of *Triodia basedowii, Triodia* aff. *Wiseana and Triodia epactia* with emergent *Acacia pruinocarpa, Acacia inaequilatera, Corymbia deserticola* subsp*. Deserticola, Corymbia hamersleyana, Eucalyptus leucophloia* and *Eucalyptus gamophylla* over *Eremophila latrobei, Acacia adoxa* var. *adoxa, Acacia arida, Acacia bivenosa, Eremophila exilifolia, Acacia spondylophylla, Acacia ancistrocarpa, Acacia bivenosa, Acacia inaequilatera, Acacia hilliana, Indigofera monophylla* and a range of annual species on gravelly soils on mid and upper slopes of small ranges.	Boolgeeda, Newman, Platform
	S3	Hummock Grassland of *Triodia wiseana* with emergent *Eucalyptus leucophloia, Corymbia hamersleyana* over *Acacia adoxa* var. *adoxa, Acacia hilliana, Acacia marramamba, Codonocarpus cotinifolius*, *Indigofera monophylla*, *Hakea lorea* subsp. *Lorea* over *Goodenia stobbsiana* and mixed *Senna* and *Ptilotus* species on gravelly soils on mid and upper slopes of ranges.	Newman, Platform
	S4	Hummock Grassland of *Triodia basedowii* and *Triodia pungens* with emergent *Eucalyptus leucophloia, Hakea lorea* subsp. *Lorea, Grevillea wickhamii, Acacia ancistrocarpa, Acacia bivenosa, Acacia inaequilatera* over a range of annual species on low hills and ranges.	Newman, Oakover
	X1	Hummock Grassland of *Triodia wiseana w*ith emergent *Eucalyptus socialis, Eucalyptus trivalva* and *Corymbia hamersleyana* over *Acacia tenuissima, Petalostylis labicheoides, Santalum lanceolatum, Senna artemisioides* subsp*. Oligophylla* x *helmsii*, *Rulingia luteiflora, Acacia bivenosa, Acacia inaequilatera, Acacia maitlandii* (narrow form) and a range of annual species on calcrete soils on mid to upper slopes.	None
	X2	Hummock Grassland of *Triodia wiseana w*ith emergent *Eucalyptus socialis* over *Melaleuca eleuterostachya*, *Senna artemisioides* subsp*. Oligophylla, Acacia maitlandii* (narrow form), *Calytrix carinata* and *Acacia bivenosa, Themeda triandra* and a range of annual species on calcrete soils on lower slopes.	Calcrete
	X4	Hummock Grassland of *Triodia basedowii, Triodia wiseana* and *Triodia pungens w*ith emergent *Eucalyptus leucophloia* and *Corymbia hamersleyana* over *Acacia adoxa* var. *adoxa, Acacia tetragonophylla, Mirbelia viminalis, Acacia victoriae, Eremophila cuneifolia, Acacia hamersleyensis, Petalostylis labicheoides, Senna glutinosa* subsp. *Glutinosa* and *Acacia bivenosa* and a range of annual species on calcrete soils on lower slopes.	Calcrete, Oakover

The calcrete soils present in the Calcrete and Oakover land systems give rise to hummock grasslands (X1, X2, and X4), as well as tall acacia shrublands (X3) within minor gullies (Mattiske Consulting Pty Ltd 2009: Table 6). Limestone spinifex is the most common *Triodia* species in the hummock grasslands, but soft and hard spinifex is also present (Mattiske Consulting Pty Ltd 2009: Table 6). There are occasional trees and shrubs (predominantly *Eucalyptus spp.* and *Acacia spp.*), as well as annual species (Mattiske Consulting Pty Ltd 2009: Table 6).

The narrow drainages, flood plains, and river channels of the River land system offer a comparatively diverse overstorey of trees and shrubs due to their proximity to water, particularly along channel banks. Low *Eucalyptus* woodlands (C1 and C2) occur along minor creek lines and have *Eucalyptus xerothermica* and smooth-barked coolabah (*Eucalyptus victrix*) over low shrubs, grasses, and flowering plants (Mattiske Consulting Pty Ltd 2009: Table 6-7). Open woodland (C4) occurs along Weeli Wolli Creek, the only major creek line in the project area, and this vegetation community is characterised by its large trees, including river red gum *(Eucalyptus camaldulensis), Eucalyptus victrix,* and silver-leaved paperbark (*Melaleuca argentea*) (Mattiske Consulting Pty Ltd 2009: Table 6-7). In addition, low mulga woodland to tall acacia shrubland (M2) is present along the edges of major creek lines (Mattiske Consulting Pty Ltd 2009: Table 6-7). While the C4 communities are restricted to Weeli Wolli Creek, M2 communities are more widely dispersed and occur alongside the larger tributaries of Weeli Wolli Creek (Mattiske Consulting Pty Ltd 2009).

Fauna

The native terrestrial fauna of the Hamersley Plateau include a wide variety of mammal, bird, and herpetofauna species that are important to the traditional diet of Aboriginal people. A faunal survey of vertebrate species within the Hope Downs 1 lease indicates that the species richness compares favourably with other areas of the inland Pilbara such as Karijini National Park, Yandicoogina, Woodstock-Abydos Reserve, and the Marandoo tenement (Ecologia 1997). It is important to note that the diversity of marsupial species has significantly decreased in the past century due to habitat loss and the introduction of non-native fauna.

Kangaroos and wallabies are important wild game to indigenous Australians, but smaller-sized marsupials were also targeted by Aboriginal peoples in the past. Several large macropod species subsist throughout the plateaux, including the red kangaroo (*Macropus rufus*), the euro or wallaroo (*Macropus robustus*), and the rock wallaby (*Petrogale rothschildii*) (Brown 1987: 10; Longbottom 2004: 54). Medium-sized marsupials occupying the ranges consist of the northern brushtail possum (*Trichosurus arnhemensis*), bilby (*Macotis lagotis*), mulgara (*Dasycercus cristicauda*), and the northern quoll (*Dasyurus hallucatus*). Smaller marsupial species documented on the lease include the western pebble mouse (*Pseudomys chapmani*), Pilbara ninguai (*Ningaui timealeyi*), delicate mouse (*Pseudomys delicatulus*), and common rock rat (*Zyzomys argurus*). The short-beaked Echidna (*Tachyglossus aculeatus*) is the only monotreme found in the region.

The dingo (*Canis familiaris dingo*), although not native to the Australian continent, has survived in the Pilbara since the mid-Holocene, approximately 4000 to 5000 years ago (Johnson and Wroe 2003). Through predation and competition, the dingo has been implicated in the demise of many native terrestrial fauna. Three prominent marsupial species that disappeared from mainland Australia are the Thylacine (*Thylacinus cynocephalus*), Tasmanian devil (*Sarcophilus harrisii*), and Tasmanian native hen (*Gallinula mortierii*) (Archer 1974; Baird 1991; Corbett 1995). Until recently, it is believed that these species only survived in Tasmania because the dingo was never introduced to the island; however, a recent argument suggests that humans may have hunted these animals to extinction on the mainland (Johnson and Wroe 2003).

The Hamersley Plateau is inhabited by hundreds of bird species, many of which were economically important to local Aboriginal people. Some economically important large bird species include the emu (*Dromaius novaehollandiae*) and bush turkey (*Ardeotis australis*). These birds were (and continue to be) an import component of the traditional Aboriginal diet, and many parts of the animal carcass were utilised as components of other material culture items (*e.g.*, bone awls, clothing, and headdresses). Other notable bird species include spinifex pigeon (*Geophaps plumifera*), galahs (*Cacatua roseicapilla assimilis*), and birds of prey such as the brown goshawk (*Accipiter fasciatus didimus*) and brown falcon (*Falco berigora berigora*) (Brown 1987).

Lizards and similar herpetofauna also inhabit the region and were frequently consumed by past Aboriginal populations. In particular, the large goanna (*Varanus giganteus*) and similar *Varanus* lizard species comprised an important part of the local diet.

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Chapter 2

An Archaeological Review of the Hamersley Plateau

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The archaeological record of the Hamersley Plateau is extensive and exceeds 40,000 years. This volume will demonstrate that the regional record is even older, with evidence from the Hope Downs 1 excavations indicating an early Aboriginal occupation of the eastern plateau by at least 45,000 years ago. As an archaeological area, it is important to recognise that the Hamersley Plateau does not represent a definitive cultural boundary, and the ancient archaeological record cannot be attributed to one specific cultural group. Archaeology is an important component of indigenous heritage, and it is valued by the wider Aboriginal community. Archaeological findings are seen as enhancing the cultural significance of traditional country, and archaeological sites often become entwined in the mythology of the cultural landscape.

Archaeological investigations of the Hamersley Plateau began in the late 1970s and early 1980s (*e.g.*, Bednarik 1977; Clarke *et al.* 1978; Maynard 1980; Bindon and Lofgren 1982; O'Connor and Veth 1984; Brown and Mulvaney 1983; Strawbridge and Tonkinson 1984; Veth 1984; Binford 1984), and most of the research has been driven by the mining industry's compliance with the AHA. Despite more than 30 years of research, much remains unknown about the regional archaeology. To some degree, the big questions of Australian Aboriginal archaeology remain unresolved. *How long have Aboriginal people resided in this region? How did they adapt and subsist in this seemingly harsh, arid environment? What kinds of technologies did they possess?* These are but a few questions investigators continue to ask, as new discoveries are made across the plateau.

Major studies have synthesised various facets of the regional record (Brown 1987; Veth 1995), but these studies require a significant update in consideration of the amount of research that has coincided with the recent mining boom. Research at Hope Downs 1 adds to this record and updates our understanding of the antiquity of Aboriginal occupation and land use in the inland Pilbara. The following review addresses two important aspects of the archaeological record of the Hamersley Range: Aboriginal site types and the long history of Aboriginal occupation within the range.

2.1 ABORIGINAL SITES TYPES

Aboriginal heritage sites of the Hamersley Plateau have been described and categorised in a number of ways. Site descriptions are not always consistent, so inter-site comparison is not a straightforward exercise. Individual site recording is not standardised in the archaeological community; therefore, site descriptions and reporting are subject to influence from independent research designs, investigator bias, recording methodologies, and limited field observations. This statement does not deny that DAA site data is an extremely useful tool, nor is it critical that site recording is not more uniform; but it is merely an acknowledgement that inconsistencies exist in the dataset that place limits on interpretation.

In most instances, Aboriginal archaeological sites can be discussed as habitation sites, special purpose sites, or combinations thereof. Habitation sites are localities where people resided and carried out day-to-day subsistence activities. In the context of hunter-gatherer archaeology, habitation sites are campsites or occupation sites where people lived temporarily, intermittently, or on a more regular basis. Habitation sites may have been used for a very short-term, perhaps overnight, or they have been revisited and utilised for generations.

Aboriginal groups are known to have utilised every part of the Pilbara landscape. Therefore, sites can occur anywhere: on plateaux and hilltops, ridgeslopes, stony washed plains, sand dunes, and along river drainages. It is unlikely that exposed, open occupation sites in upland areas and stony washed plains will have stratified layers of occupation because low-energy alluvial sedimentation does not occur on these landforms. Also, these exposed areas do not have much aeolian deposition, and because of heavy rainfall, the sites are subject to deflation. Consequently, the debris from an open artefact scatter can represent numerous occupation events that may be separated by hundreds or thousands of years. This poses a great problem for archaeologists trying to understand cultural and technological change through time because the occupation events cannot be temporally separated. Thus, these sites offer limited interpretive value to archaeologists.

Open artefact scatters are more informative when occupation events are clearly separated by a layer of sediment. Most often these sites form in deeply buried sediments along river terraces where low-energy flood events gently deposit fine sediment atop of an occupation event. The Pilbara is well-known for high-energy cyclonic flood events, which has undoubtedly disturbed or destroyed many open sites located on terraces. Presently, the authors are unaware of any terrace sites that have been formally investigated in this manner.

Rockshelters are the habitation site type that offer the best potential to demonstrate temporal changes in Aboriginal occupation. Unlike open sites, rockshelters act as natural sediment traps, as they accumulate sediment through roof fall exfoliation, aeolian, and colluvial processes. Pilbara rockshelters offer better preservation than open sites, and they generally contain a diverse range of occupational debris, including stone artefacts, stone tools, fire-cracked rock, fragmented bone, shell, and charcoal. In very rare instances where preservation is exceptional, wooden implements, such as spear-throwers, digging sticks, wooden dishes, or boomerangs, may also be recovered.

Habitation sites often have enduring, non-transportable cultural or natural features such as grinding patches, gnammas or rockholes, campfire hearths, and other man-made features (*e.g.*, stacked or arranged rocks). The stone tool assemblages of habitation sites are diverse in comparison to non-habitation sites. Artefacts manufactured from a range of raw materials such as chert, silcrete, quartzite, and quartz are indicative of mobility, planning, resource use, and transportation of resources. These sites are also expected to exhibit a diversity of stone tool forms, including cores, flakes, retouched flakes (often reported as scrapers), backed artefacts (symmetrical and asymmetrical forms), tulas, burrens, burins, and grindstones. In contrast, the stone artefact assemblage from a special purpose site will contain a narrow range of raw materials and stone artefact forms because site function was specific and activities were directed towards a single purpose.

Special purpose sites and features often occur in association with habitation sites, particularly at long-term/revisited encampments or localities with abundant natural resources. Often however, special purpose sites occur at isolated localities, with no evidence of associated habitation. Some commonly reported special purpose sites include rock art sites (*e.g.*, engravings and paintings), stone arrangements, stone artefact or ochre quarries, and culturally modified trees. Special purpose sites may represent a single, isolated event, or they may be a place in the landscape with a specific function or where specific activities occur. Culturally modified trees are often the result of a one-time food procurement activity (*e.g.*, native honey) or wooden implement manufacture. Aboriginal quarries function as a locus of raw material extraction, with no evidence of habitation. Stone arrangements (*e.g.*, standing stones, stacked rocks, and stone alignments) may have served a utilitarian function (*e.g.*, locational marker) or perhaps have a ceremonial/mythological purpose. Rock art sites may also serve as location markers, depict events, tell a story, or have another unknown cultural purpose. Burial sites are considered special purpose sites because of their specific function.

2.2 SITE DISTRIBUTION

The distribution and density of indigenous heritage sites across Pilbara land systems has been a recurring theme explored by academic and consulting archaeologists in the region (*e.g.*, Brown 1987: 20-21; Bradshaw *et al.* 1996: 15; Hook *et al.* 1998: 21-22; Jackson *et al.* 2007: 14-17). One reason this theme remains prominent in Pilbara archaeology is because site prediction is important to mine planners and developers in the region. Site prediction is often seen as a useful tool to assist developers with their compliance of the AHA.

The most prominent and oft-referenced model for predicting Pilbara archaeological site distribution is by Brown (1987). In his monograph, Brown makes a number of predictions on site types and their occurrence across prominent land forms, including the upper slopes and tops of hills or ranges, short rangeland gullies and valleys, plains and valley floors, as well as deeply incised valleys or gorges.

Based on the survey data available at the time, Brown (1987: 20) predicts that open sites, such as artefact scatters will be almost totally absent on the upper slopes and tops of hill ridges and rangelands. He points to a scarcity of resources, including adequate tool stone and water as being the major contributing factors for this pattern. He does recognise that rockshelters occur in these upper land forms and were visited in the past, and acknowledges that discarded artefacts or other cultural materials may occasionally be found in upland rockshelters.

Brown (1987: 20) suggests that the short, steep valleys and gullies incised into the rangelands or ridges are more likely to have archaeological sites because this landform is more resource rich with siliceous raw materials and ochre. He predicts that rockshelter sites will be common in these landforms but open sites will be seldom found (Brown 1987: 20). Brown believes that the proximity of low-elevation rockshelters to flat valley floors and plains arguably made them more accessible to people in the past. Therefore low elevation rockshelters are more likely to have secondary site components such as paintings, ground pigment, dry stone walls, wooden artefacts, engravings and secondary burials (Brown 1987: 20). Due to infrequent, yet intense high energy floods and erosion, Brown (1987: 20) argues that open scatters will be comparatively scarce.

Brown (1987: 20-21) predicts that large numbers of open archaeological sites will be found on the relatively flat plains and valley floors that lie between rangelands and drainage systems. However, this prediction is a broad characterisation of this landform, and as Brown (1987: 20-21) discusses further, there is much variability in the manner sites are distributed across the plains and valleys. To simplify his argument, Brown divides the plain and valley floor system into three areas: places close to major waterways, areas close to minor drainages, and areas away from drainages. Sites close to major waterways, he contends, will be large and complex, with high artefact densities and evidence of reuse. Areas along minor drainages will have an almost constant background scatter of stone artefacts, and associated habitation sites will be limited to low density artefact scatters (Brown 1987: 20). Away from minor and major drainages, archaeological sites are expected to occur less frequently and will be limited to open sites with low density artefact scatters with occasional platy ironstone grindstones. Brown (1987: 21) interprets these places as dinnertime camps, that is, places occupied briefly for task-specific foraging activities. Other sites that may be found away from drainages are stone arrangements and scarred trees, which tend to occur near the footslope of rangelands.

The final landforms Brown (1987) discusses are gorges and deeply incised valleys. These landforms tend to contain permanent water and are resource rich with raw materials and consumables. Brown (1987: 21) predicts that large open sites with dense artefact assemblages that are indicative of intensive reuse were once abundant within these landforms; however, floodwaters have removed or destroyed these sites. In gorge and deep valley systems, Brown (1987: 21) predicts that intact sites will be found in rockshelters located above the flood line or immediately outside the gully mouth. He predicts that rock art sites are more likely to occur in this landform unit than the others discussed above.

Brown's (1987) predictions are well-founded and logical, and they have been widely accepted amongst the consulting archaeological community for the past two decades (*e.g.*, Bradshaw *et al.* 1996; Hook *et al.* 1998; Jackson *et al.* 2007; Comtesse and Harris 2009). However, there is much more archaeological data available today than when Brown (1987) originally posited his site distribution model, and arguably it is time for the model to become more thoroughly tested and perhaps revised.

Geospatial mapping is an important tool for testing Brown's (1987) model. Two geospatial datasets that are crucial to scrutinising his predictions are the land system geomorphology data supplied by the WA Department of Agriculture (Payne 2004) and the Aboriginal Heritage Inquiry System managed by the DAA. Together, these datasets can provide highly accurate

spatial information and other attribute data for archaeological sites and their distribution in Pilbara land systems.

A good starting point to test this data is to query defined areas in the vicinity of the Hope Downs 1 mine. To provide an indication of the number and variety of site types in the surrounding Hope Downs 1 area, ACHM conducted a review of the number and variety of heritage site types located on the Munjina (Map No 2652), Weeli Wolli (Map No. 2752), Governor (Map No. 2651), and Ophthalmia (Map No. 2751) 1:100,000 Map Sheets. The Hope Downs 1 mine is centrally located at the junction of these map sheets; thus, a query of the areas should provide a good indication of sites and their distribution around the mine. The results of this investigation are listed in Table 2-1.

Table 2-1 DAA registered site types in the vicinity of Hope Downs (Munjina, Weeli Wolli, Governor, and Ophthalmia map sheets)

Principal Site Type and Secondary Components	n	%
Artefact Scatter	422	43.9
Artefact Scatter and Grinding Patches	27	2.8
Artefact Scatter and Midden	9	0.9
Burial	2	0.2
Burial and Artefact Scatter	1	0.1
Burial and Man-made Structure	1	0.1
Burial, Painting, Engraving, and Grinding Patches	1	0.1
Burial, Man-made Structure, Artefact Scatter, and Grinding Patches	2	0.2
Ceremonial	4	0.4
Ceremonial and Man-made Structure	1	0.1
Ceremonial and Mythological	4	0.4
Ceremonial, Mythological, and Modified Tree	1	0.1
Ceremonial, Quarry, and Artefact Scatter	1	0.1
Engraving	31	3.2
Engraving and Artefact Scatter	5	0.5
Engraving and Grinding Patches	2	0.2
Engraving, Artefact Scatter, and Grinding Patches	15	1.6
Engraving, Quarry, Artefact Scatter, and Grinding Patches	1	0.1
Grinding Patches	14	1.5
Mythological	9	0.9
Mythological and Artefact Scatter	1	0.1
Mythological and Man-made Structure	2	0.2
Mythological and Modified Tree	1	0.1
Mythological, Repository/Cache, Man-made Structure & Engraving	1	0.1
Quarry	7	0.7
Quarry & Artefact Scatter	9	0.9
Man-made Structure	98	10.2
Man-made Structure & Artefact Scatter	12	1.2
Man-made Structure, Artefact Scatter, and Grinding Patches	1	0.1
Man-made Structure, Artefact Scatter, and Midden	1	0.1
Man-made Structure and Engraving	1	0.1
Man-made Structure, Engraving, and Artefact Scatter	1	0.1
Man-made Structure, Engraving, Quarry, Artefact Scatter & Grinding Patches	1	0.1
Man-made Structure, Modified Tree, and Artefact Scatter	1	0.1
Man-made Structure, Painting and Engraving	1	0.1
Man-made Structure, Quarry, and Artefact Scatter	3	0.3
Modified Tree	39	4.1
Modified Tree & Artefact Scatter	11	1.1
Modified Tree, Engraving, Artefact Scatter, and Grinding Patches	2	0.2
Modified Tree, Quarry, and Artefact Scatter	1	0.1
Modified Tree, Painting, and Artefact Scatter	2	0.2
Painting	9	0.9
Painting and Engraving	1	0.1
Painting and Artefact Scatter	2	0.2
Painting, Engraving, and Artefact Scatter	1	0.1
Painting, Engraving, and Quarry	1	0.1
Repository/Cache	1	0.1
Repository/Cache, Man-Made Structure, and Artefact Scatter	1	0.1
Rockshelter with Artefacts	196	20.4
Total	**961**	**100.0**

At the time of writing, 961 Aboriginal heritage sites are recorded in the vicinity of the Hope Downs 1 mine. Open artefact scatters represent 43.9% of the registered sites, followed by rockshelters that comprise 20.4%. Together, these site types represent 64.3% of the heritage sites in the region surrounding the Hope Downs 1 mine. Open artefact scatters and rockshelters typically reflect past habitation, so for the sake of the following discussion, it is presumed that the distribution of open artefact scatters and rockshelters provides a broad indication of past Aboriginal land use and subsistence in the region.

Based on the principal archaeological site components, the DAA site types were geospatially correlated with the Pilbara land system types described by Payne (2004: 176), including rangelands and plateaux, stony and sheet wash plains, and alluvial plains and lowlands. The principal and secondary site components were used to infer if a location was most likely a habitation or special purpose site. A simplified version of this data is presented in Table 2-2.

The site data can be interpreted in a number of ways. One interpretation is that Aboriginal heritage sites are more commonly encountered in rangeland and plateau landforms (67.8%), followed by stony, sheet washed plains (28.6%), and alluvial plains or lowlands (3.5%). This information does not conform to Brown's (1987: 20-21) predictive model, which suggests site density would be greater along waterways and minor drainages, followed by plains and valley floors, and then rangelands. The disparity between these results is intriguing, and will be discussed further below.

The information displayed in Table 2-2 is useful for mine planners and workers who are at risk of unintentionally impacting an Aboriginal site, and it is also useful to archaeologists inspecting unsurveyed landforms because it shows the diversity of site types in the area. The table provides a rudimentary predictive model for determining where heritage sites are likely to be encountered. However, it can be asked if this information accurately depicts principal places of past Aboriginal occupation and land use.

At first glance, it would seem that Aboriginal people occupied upland areas more often than the plains and lowlands; however, such an interpretation would be a gross oversimplification of the archaeological record. It is likely that the land system site distribution data in Table 2-2 is skewed by sampling errors caused from environmental and geomorphological processes. It is also skewed by archaeological surveying methodologies, as well as mining development priorities.

For example, the rangeland and plateau areas surrounding the Hope Downs 1 mine are part of the Marra Mamba Iron Ore Formation, a major iron-ore target. These upland areas have been subject to intensive mining exploration for over 20 years. It is likely that the reported site numbers are skewed because rangeland areas have been more comprehensively surveyed for heritage sites than other land systems. Consequently, if only rangeland areas have been thoroughly surveyed, there is a significant gap in our understanding of site distribution in surrounding landforms.

Table 2-2 Archaeological site types as classified by Payne's (2004: 176) land system data

Site Type	Category	Rangelands and Plateaux[1]	Stony and Sheet Wash Plains[2]	Alluvial Plains and Lowlands[3]
Artefact Scatter	Habitation	233	169	20
Artefact Scatter*	Habitation	23	10	3
Rockshelter	Habitation	157	36	3
Grinding Patch	Habitation	11	2	1
Burial Site	Special Purpose	1	1	0
Burial Site*	Special Purpose	1	4	0
Ceremonial	Special Purpose	4	0	0
Ceremonial*	Special Purpose	3	1	3
Engraving	Special Purpose	25	5	1
Engraving*	Special Purpose	20	2	1
Man-made Structure	Special Purpose	84	13	1
Man-made Structure*	Special Purpose	17	5	0
Modified Tree	Special Purpose	22	17	0
Modified Tree	Special Purpose	13	3	0
Mythological	Special Purpose	9	0	0
Mythological*	Special Purpose	3	1	1
Painting	Special Purpose	8	1	0
Painting*	Special Purpose	4	1	0
Quarry	Special Purpose	7	0	0
Quarry*	Special Purpose	6	3	0
Repository/Cache	Special Purpose	0	1	0
Repository/Cache*	Special Purpose	1	0	0
Total		**652**	**275**	**34**

*Secondary archaeological components also occur at the site.
[1]Rangeland and Plateaux include Payne's (2004) Land System Types 1, 2, 3, and 4
[2]Stony and Sheet Wash Plains include Payne's (2004) Land System Types 5, 6, 7, 8, 9, 10, 11, and 12
[3]Alluvial lowlands include Payne's (2004) Land System Types 13, 14, 15, 16, 17, and 18

Additional factors that may skew the Table 2-2 results arise from environmental and geomorphic processes that affect archaeological site identification and recording. For example, ground surface visibility in upland areas is typically higher than on stony plains and alluvial areas. This is because upland areas lack the sediments to host dense communities of spinifex-hummock grasslands. Stony plains and alluvial lowlands are often densely vegetated with grasses that obscure observations of the ground surface. Unless a bush fire has recently cleared these landforms of vegetation, archaeological sites are easily obscured by the undergrowth and overlooked. Archaeological sites can also be missed in alluvial areas, where fine fluvial sediments bury archaeological sites and no evidence of occupation exists on the modern ground surface. Another possibility is that high energy floods have removed or reworked terraces that once hosted encampments; therefore, much of the evidence for past occupation has been destroyed by natural processes.

Further sampling bias may be attributed to archaeological surveying methodologies. Rockshelters are much more likely to contain significant, deeply stratified cultural deposits than other landscape features. Consequently most survey methods aim to identify rockshelters with sediment, regardless if archaeological materials are present on the surface. Rockshelters that have the potential to contain buried cultural materials are frequently subject to test excavation, often resulting in the verification of further rockshelter archaeological sites. Thus, this in-built methodological bias may be responsible for creating an illusion of site concentration in rangelands.

Brown's (1987: 20-21) model, is arguably a victim of the same biases discussed above, and it is equally subject to the limitations of the data it was originally based upon. Geomorphic processes and environmental processes have potentially biased his information, and the mining developments of the 1980s influenced his prediction. To conclude, neither Brown's (1987: 20-21) model or our Table 2-2 results clearly indicate past Aboriginal land use practices or settlement systems. Instead, they demonstrate the bias and limitations of such models. The only element that either model predicts is where surface archaeological sites are likely to occur, and there is considerable disagreement between the two studies. This disagreement serves to highlight that archaeological materials and site components provide better evidence to model past patterns of land use and settlement than landform alone.

There is clear value in predicting Aboriginal site location, particularly when heritage management issues arise for Aboriginal stakeholders and mining proponents. It is suggested here that one way to improve the predictive modelling of site distribution is to normalise the data by using information from comprehensively surveyed land systems. Presently, the Hope 1 North and Hope 1 South lease areas have been subject to a 100% pedestrian heritage survey. These areas encompass a land area of 42.47 square kilometres and include a number of rangeland/plateaux, stony plain, and alluvial land systems. The Hope Downs 1 site data should provide greater predictive accuracy on site distribution across these land systems and diminish errors caused by many of the sampling biases discussed above. The distribution and patterning of heritage sites at the Hope Downs 1 mine is a subject that will be explored further in the following chapter.

2.3 THE ARCHAEOLOGICAL RECORD OF THE HAMERSLEY PLATEAU

It is well documented that Aboriginal peoples arrived on the Australian mainland by 45,000 years ago (see Hiscock 2008), but the question remains as to when they settled major geographical areas of inland Australia, particularly the Hamersley Plateau and the Australian arid zone. Until recently, evidence from the Hamersley Plateau suggested that Aboriginal groups occupied the plateau between approximately 20,000 BP and 26,000 BP (Brown 1987; Maynard 1980; Edwards and Murphy 2003) or from roughly 24,000 to 32,000 cal BP. Emerging evidence demonstrates that Aboriginal people were in the central-west ranges by (Slack *et al.* 2009) and eastern plateau by 41,900 years ago (Law *et al.* 2010). Thus, until quite recently, the Aboriginal occupation of the Hamersley Plateau was underestimated by several thousand years (Law *et al.* 2010).

Over the past 45,000 years, climatic and environmental conditions experienced on the plateau have varied and changed considerably. Ancient Aboriginal peoples adapted to these changes through an effective reorganisation of land use, lithic technology, and resource use, presumably accompanied by significant social and cultural changes to their foraging systems. The following sections present the archaeological record of the Hamersley Plateau for the Pleistocene and Holocene periods. Major changes in the archaeological record are described for these periods and regional models of subsistence and settlement are discussed.

Pleistocene Archaeological Patterns

For discussion and analytical purposes, the Pleistocene archaeological record of the arid zone may be divided into three periods: the preglacial phase, the hyperarid LGM phase, and the terminal Pleistocene (*e.g.*, Smith 2006; Veth 1993). The preglacial phase refers to the period of initial settlement and disbursement of people across the arid zone prior to 35,000 years ago. It predates the onset of the cold and climatically harsh hyperarid phase of the LGM, which ensued from 35,000 to 18,000 years ago and peaked around 21,000 years ago (Williams *et al.* 2009). Between 14,000 and 6000 years ago, hyperarid conditions ameliorated and rainfall patterns became more regular. The time period between 14,000 and 10,000 years ago is referred to as the terminal Pleistocene.

It is hard to depict a clear picture of what Pleistocene Aboriginal life was like on the Hamersley Plateau. Wooden implements, bone, and other organics have largely disappeared from the archaeological record, leaving stone artefacts and charcoal as the only direct evidence of the Hamersley Plateau's ancient Aboriginal past. There are no distinctive, formal stone tool forms from this period, making it impractical to infer cultural and technological changes through well-defined stone tool forms or industries. A typical Pleistocene stone artefact assemblage consists of cores, flakes, and retouched flakes manufactured from a variety of raw materials. The absence of formal stone tools does not mean that these early groups were unskilled or placed no material value on the artefacts and objects they produced. Pre-LGM rock art from the Kimberley implies that early populations crafted ornate spears, boomerangs, headdresses, tassels, necklaces, and other items (Roberts *et al.* 1997; Walsh 2000; Walsh 1999). Unfortunately, these intriguing cultural items generally do not survive in the archaeological record. Poor organic preservation is a widespread problem across Australia, and it has led many archaeologists to depict Pleistocene Aboriginal life as being

culturally conservative and technologically uniform. In short, many researchers view Australia's Pleistocene foragers as a simplified version of the historic past (for a discussion see Hiscock 2008). This limited interpretation of the archaeological record does not acknowledge that early Aboriginal populations arrived in Australia with well-developed social, symbolic, and ideological systems. Ancient systems of socialisation do not preserve well archaeologically, but Hiscock (2008: 120-128) convincingly argues that social, symbolic, and ideological systems were in place amongst Pleistocene foragers prior to their arrival on mainland Australia. Understandably, the earliest Australians arrived with extant cultural and social norms that favourably assisted them with the rapid adaptation and exploitation of all Australian climes, including the harsh landscapes of the Australian arid zone.

Characterising Aboriginal Settlement and Subsistence during the Pleistocene

The Pleistocene settlement of the Hamersley Plateau occurred at a time when the climate and environment was much different than today. Preglacial palaeoclimatic data from 50,000 to 35,000 years ago suggests that the inland Pilbara was likely warmer and wetter than present, and the climatic pattern was more seasonally predictable (Harrison 1993; Cohen *et al.* 2011; Magee *et al.* 2004; Johnson *et al.* 1999). Regular rainfall patterns made surface water and food resources more abundant, enabling early populations to explore and disperse across the arid zone with low risk of resource restriction due to harsh climatic or territorial factors. The current published evidence suggests that early Aboriginal groups were established in the east Hamersley plateau by 41,901-39,548 cal BP (Law *et al.* 2010), and as the Hope Downs 1 research further indicates (see, this volume), it is likely people first entered the region by 45,000 years ago. This timeline is reinforced by recent rockshelter excavations on Abydos Plains, north of the Hamersley Ranges where Morse *et al.* (2014: 140) demonstrate occupation at Yurlu Kankala rockshelter between 45,704–42,682 cal BP.

Elsewhere, in the central Australian ranges, archaeological evidence suggests groups occupied the arid centre 30,000 to 35,000 years ago (Smith *et al.* 1997; Thorley 1998; Smith 2005). More recently, research from the margin of the Great Sandy Desert suggests that the occupation of the shoreline of Lake Gregory may have occurred 45,000 to 50,000 years ago (Veth *et al.* 2009).

Due to higher rainfall and more lacustral conditions, terrestrial plant and animal resources would have been more abundant in the preglacial phase. This was a period when many megafaunal species survived in the southern arid zone and possibly the Pilbara. Interestingly, there is no direct fossil evidence indicating that megafauna roamed the Western Desert or Northern Territory at this time (Webb 2008). Only four megafaunal species are known to have existed in northwest Australia, but the absolute age of these specimens is unknown. The four species are *Phascolonus gigas*, *Diprotodon optatum*, *Zygomaturus trilobus*, and *Procoptodon browneorum*, which are the most commonly occurring megafauna in Australia (Webb 2008: 332). The teeth from a *Zygomaturus trilobus* and a *Sthenurus brownei* are reported as to have been used in the manufacture of Aboriginal artefacts (Akerman 1973). It is unclear where, when, and how the items were acquired by Aboriginal people, but Akerman (1973: 141) hypothesises they were collected in the recent past from a limestone cave in the Kimberley region.

Historically, many settlement models have been have been posited for how Aboriginal groups settled and subsisted in the arid zone throughout the Pleistocene (*e.g.*, Birdsell 1977; Bowdler 1977; Rindos and Webb 1992). Birdsell (1977) believes that settlement was quick, and groups quickly occupied all geographical areas of the continent shortly after their arrival. Bowdler (1977) contends that the coastline was settled first, and Pleistocene foragers later moved into the inland via river basins and lake systems. Rindos and Webb (1992) suggest settlement around the coastline and through temperate belts, before arid settlement occurred. Archaeological discoveries from the past twenty years have tested and revised these early settlement models. The prevailing two models today are the 'islands in the interior model' proposed by Veth (1993) and the 'desert transformation model' offered by Hiscock and Wallis (2005).

An important question posed by these models is whether or not the Australian arid zone was continuously occupied throughout the preglacial, glacial, and terminal Pleistocene. Veth's (1993: 103-114) settlement model attempts to answer this question by characterising prominent biogeographical areas of the arid zone as refuges, corridors, and barriers. Summarising his work, Veth (1993: 102-113) describes refuges as rangeland environments, such as the Hamersley Plateau and the central Australian ranges, having high rainfall, plant, and animal resources. Refuge landscapes, Veth predicts, were continuously occupied throughout the Pleistocene. Barriers included the major sandy deserts (*i.e.*, Great and Little Sandy Desert, Great Victoria Desert, and Simpson Dune Fields), which he argues could not have been permanently occupied during the peak of hyperarid LGM phase due to a retraction of water and plant foods. Corridors are biogeographic zones (such as stony gibber plains) that acted as intermittent passageways across the arid zone during wetter periods and barriers during harsher climatic periods.

Hiscock and Wallis' (2005) desert transformation model compliments Veth's (1993) research, adding further insights into Pleistocene life. Hiscock and Wallis (2005: 41) contend that early populations initially settled and occupied inland Australia during the wetter preglacial period; however, they did not employ the same adaptive strategies and technologies that are observed in historic desert dwellers. They suggest that early Aboriginal populations utilised a foraging strategy that did not require specific stone tools or require a detailed knowledge of local resources (Hiscock 2008: 52). In fact, it is unlikely that the initial settlers required any desert adaptations during the preglacial period. Over time, their knowledge of desert resources became more refined, and with the onset of LGM hyperaridity, Aboriginal groups adjusted their foraging strategies or moved to less climatically harsh areas (Hiscock and Wallis 2005).

Current evidence from the Hamersley Plateau supports both the islands in the interior and the desert transformation models. Evidence from Milly's Cave, Malea (Jundaru), Juukan-1, Juukan-2, and Djadjiling rockshelters shows that the plateau was regularly occupied throughout the glacial period and Pleistocene to Holocene transition (Marwick 2002b; Edwards and Murphy 2003; Slack *et al.* 2009; Law *et al.* 2010). There is some debate as to whether the Newman Orebody XXIX and Newman rockshelters were occupied throughout the LGM (see Marwick 2002b: 23). A central argument to this debate is whether these sites are in or outside the Hamersley Range biogeographic area. In either case, these sites are clearly on the plateau margin, and the current archaeological evidence suggests that the region was intermittently occupied during the LGM.

It is suggested that following the LGM, when climatic conditions improved, groups were able to expand their foraging range and recolonise all areas of the arid interior (Hiscock and Wallis 2005: 46). By this time, Aboriginal peoples had become more familiar with the local resources and successfully modified their subsistence strategies to cope with the hyperarid LGM conditions. This knowledge remained in the cultural system and contributed toward the subsistence economies of the terminal Pleistocene and early Holocene. The transition from terminal Pleistocene to Holocene adaptations will be explored in the next section.

Holocene Archaeological Patterns

The Holocene period of the past 10,000 years was much more climatically stable than the preceding Pleistocene, but there were still pronounced climatic fluctuations. The warm and wet climatic amelioration that began in the terminal Pleistocene continued into the early Holocene, reaching a 'climatic optimum' of increased effective precipitation between 8000 and 5000 years ago (Quigley *et al.* 2010: 1101). These improved climatic conditions enabled groups to expand their foraging range into previously abandoned or unoccupied areas of the arid zone. Around 5000 years ago, there was mid-Holocene drying event, marked by a lengthy period of unpredictable rainfall (Nott 2011; Quigley *et al.* 2010; Fitzsimmons *et al.* 2012; McGowan *et al.* 2012), and this period of increased aridity may have affected some areas of the arid zone up to 2000 years ago, when modern climatic conditions were established (Cupper 2005; Cupper *et al.* 2000; Holdaway *et al.* 2002; McCarthy and Head 2001; Veth *et al.* 2011). This dry phase, with less surface water, would have posed considerable risks to arid-adapted populations. It has been argued that resident populations responded by adjusting their subsistence-settlement strategy and technological system (Hiscock 1994; Law 2009; Veth *et al.* 2011).

Evidence for this shift is most apparent in the significant increase in stone artefact discard in site layers dating from 5000 to 3000 years ago (Smith 1996; Veth 1993; Hiscock 2008). Across the arid zone, flake retouching and similar use-life extension methods become important technological strategies of the desert economy, and multi-functional stone tools such as backed artefacts expand across the region and specialised tula adzes, and burren adzes emerge at this time (Gould 1977; Veth 1993; Smith 1996; Law 2009; Veth *et al.* 2011). Accompanying these technologies are thermoplastic resins made from spinifex grasses, which furthered the development of composite hafted tools (Smith 1996; Pitman 2010). Two formal stone tools known to have been regularly hafted onto wooden implements are burrens and tulas, which typically functioned as woodworking adzes (Sheridan 1979; Moore 2004; Tindale 1965; Horne and Aiston 1924). Backed artefacts with resin residues suggest that these artefact forms were sometimes hafted and may have functioned as spear points or barbs (Hiscock and Attenbrow 2005; McDonald *et al.* 2007); however, their explicit use in this manner lacks conclusive evidence, and more recent research by Robertson *et al.* (2009: 298) suggests backed artefacts served as a multifunctional tool that may have been used for 'cutting, incising and scraping of plant and animal materials as well as stabbing/thrusting and/or projectile tools'.

Some informal stone tools were also hafted, as evidenced by resin residues at Kulpi Mara rockshelter (Thorley 1998). In the southern and central arid zone, unifacial points (often reported as pirri points) are a significant component of mid-Holocene technologies, but there is no known occurrence of these forms in the Pilbara (Mulvaney and Kamminga 1999; Hiscock 2008). To a lesser extent, it is argued that the pirri graver, a hafted engraving tool, also became technologically important, and it shares a similar spatial and temporal distribution with the tula (Kamminga 1985; Mulvaney and Kamminga 1999). Seed grinding technologies, such as mullers and millstones were incorporated into desert life around 3500BP, suggesting increased reliance on wild grass seeds (Smith 1986; Smith 1996).

Around 2000 years ago, modern climatic patterns and rainfall regimes become established across the arid zone. The stone artefact technologies that emerged in the mid-Holocene remain present throughout the late Holocene, with the exception of backed artefacts, which diminish from the archaeological record slightly before European contact period (Hiscock and Attenbrow 1998; Slack *et al.* 2004; Hiscock 2008). Grindstones are highly important component of late Holocene archaeological sequences, indicating an increased reliance on grass seeds as a food staple (Smith 1986; 1996). Smith (2006:372) proposes that there is a more intensive occupation and use of arid zone sites over the past 1500 years, but it is unclear if this pattern is due to increased sedentism, more frequent site visitation, increased population size, or combinations thereof.

An evaluation of the Holocene record of the Hamersley plateau shows that many of the archaeological patterns observed elsewhere in the arid zone occur in the Pilbara rangelands. Marwick's (2009: 16) research cites that the earliest known occurrence of backed artefact technology on the plateau is from Newman rockshelter. Charcoal associated with this specimen dates to 3749±100 BP (Troilett 1982). Five additional backed artefacts and one tula adze were deposited at Newman rockshelter after this time (Brown 1987: 27-29). Marwick (2009: 16) points out that backed artefacts were manufactured until quite recently, with two specimens dating to 310±50 BP at RR3-O rockshelter. Unifacial points have not been reported from any excavations in the Hamersley Plateau, but burrens and pirri gravers are infrequently recognised in assemblages (Slack and Fullagar 2008).

The earliest evidence of seed grinding technologies on the Hamersley Plateau comes from Cleft rockshelter, dating to approximately 1700 to 1100 years ago (Marwick 2009: 17). Compared to the central desert, it appears the proliferation of seed grinding technology developed fairly late in the Holocene; however, as Marwick (2009: 18) suggests, there are only a small number of sites with evidence of grinding technology. Moreover, bedrock grinding patches are a widespread archaeological site type in the Pilbara, and we suggest that seed grinding activities may have been focused at these specialised sites long before mobile grindstones were incorporated into the foraging economy.

Characterising Aboriginal Settlement and Subsistence during the Holocene

Ethnohistoric and ethnographic information has often been used to characterise the Holocene archaeological record and depict Aboriginal settlement and subsistence in the arid zone. One researcher who has championed the use of ethnography and has made a lasting impression on how archaeologists view Holocene desert populations is Gould (Marwick 2009; Gould 1978b; Gould 1977; Gould 1978a). Based both on his rockshelter excavations and ethnographic work in central Australia and the Western Desert, Gould proposed the Australian desert culture model. His model divides the Holocene archaeological record into two phases. Gould (1978b:

120-121; 1977: 90) sees the stone tools of the early Holocene as a continuation of the Pleistocene desert economies and cultural traditions. He contends that there are no significant changes in the Holocene archaeological record until approximately 4000 years ago, when a number of typologically regular and distinctive stone tool types appear. These new artefact forms include backed artefacts, unifacial points, and the tula, a stone tool the ethnographic record shows was often used for adzing hardwood. Gould (1969: 235) proposes that the appearance of these artefact forms marked the emergence of the Australian small tool tradition, a cultural tradition which survived into the recent contact period of Australian history. Gould (1969) also suggests that the small tool tradition is a temporally defined cultural sequence with continent-wide applicability; however, recent research has demonstrated that the small tool tradition is not as temporally well defined as Gould suggests (Hiscock and Attenbrow 1998). Many of these technologies emerge at different times in Australia. Hiscock and Attenbrow (1998) show that backed artefacts emerge in areas of New South Wales in the early Holocene, while Slack *et al.* (2004) clearly demonstrate their use in northwest Queensland during the terminal Pleistocene.

Expanding his Australian desert culture model, Gould (1977: 168) describes a contemporary risk minimising cultural system of subsistence and settlement employed by Western Desert Aboriginal peoples, and he infers that this system was in place throughout much of the Holocene. A central tenet of this system is that Aboriginal subsistence is inherently opportunistic and residential mobility is largely dictated by rainfall events. Gould (1977: 168-169) describes Western Desert Aborigines as 'rain chasers', where mobile populations planed and organised their foraging movements around ephemeral, semi-permanent, and permanent water catchments. After a rain, groups targeted areas in the landscape that were known to have staple foods adjacent to ephemeral waters. Once these short-lived resources were depleted, groups moved into and exploited areas within semi-permanent water catchments, before lastly foraging on resources surrounding permanent waters. This risk minimisation system conserved permanent water and food staples for times of climatic stress and resource depletion. It minimised the risk of Aboriginal groups becoming trapped and perishing in areas where there may be plenty of food, but no water (Gould 1977: 169). Gould (1977: 168) believes that this basic land use model was in place for much of the Holocene, and he suggests that it is testable archaeologically.

Building upon Gould's research is Thorley (2001; 1998; 1998), who also proposes that a risk minimisation subsistence-settlement model was in place for much of the Holocene. Based on his analysis of archaeological sites from the Palmer River catchment in central Australia, Thorley (2001) demonstrates that stone artefact assemblages next to ephemeral water sources have much higher artefact densities than those near more reliable, permanent water. Instead of establishing major base camps around permanent waterholes, Thorley (2001) proposes that late Holocene populations exercised a risk minimisation settlement system that utilised sites and resources located near ephemeral waters before utilising the resources around permanent waters. Thorley's (2001) model echoes much of Gould's (1969; 1977) ethnographic observations, while Thorley also presents archaeological data to support his model. A risk minimisation settlement system, according to Thorley (2001), conserved essential food and water resources and enhanced the probability of group survival.

Hiscock (1994) also explains Holocene subsistence and settlement in terms of a risk reduction model. His model emphasises the importance of the new stone tool technologies that emerge in the mid-Holocene. Hiscock (1994) argues that mid-Holocene populations adjusted their foraging strategies in response to the mid-Holocene dry period, which would have been harsher and more climatically stressful than the wetter early Holocene. Increased aridity, he contends, would have caused many resource restrictions, and populations responded to this situation by developing new, specialised stone tools that emphasised portability, maintenance, and multifunctionality. Backed artefacts and tulas are the most ubiquitous new tool forms, as are unifacial points in central and southern areas of the arid zone. Hiscock (1994) adds that the greatest advantage of these artefact forms is their performance as reliable composite tools that effectively reduced the risk of foraging failure during a climatically stressful period.

Like Thorley (2001), Gould (1977; 1978b), and Hiscock (1994), Veth (1989; 1993; 2000) agrees that Holocene subsistence and settlement systems were heavily influenced by rainfall and climatic sequences; however, Veth (1993) interprets the archaeological record in a slightly different manner. Veth (1993: 105) argues that all desert habitats were occupied during the early Holocene, with the notable exception of sand ridge deserts (*cf.*, Smith 1988). He believes that it is not until the mid-Holocene, approximately 5000 BP, when populations expanded into and reoccupied sand ridge deserts. Veth sees the mid-Holocene expansion as having connections to the development of extended social networks, territories, and several key stone artefact technologies, including seed grinding implements, backed artefacts, and tulas. These developments, he suggests, allowed mid-Holocene populations to settle previously unoccupied arid regions. He also suggests that the mid-Holocene subsistence and settlement pattern was heavily influenced by the availability of permanent water sources. Veth's (1993: 89) model predicts that core (and typically larger) habitation sites will be located near water, in the drainage landform unit. In support of this argument, he cites archaeological data that predicts sites near permanent and semi-permanent waters typically have artefact assemblages in advanced, late-stages of reduction (*e.g.*, micro flakes, broken flake fragments, and modified flakes) (Veth 1993: 93-96). These sites also have a greater proportion of formal stone tools (*e.g.*, backed artefacts and tulas) amongst the retouched flake assemblage. Conversely, he argues, that sites located at ephemeral water sources typically exhibit early stage reduction characteristics (*e.g.*, cortical flakes, and macro flakes) and have fewer formal stone tools (Veth 1993: 93-96).

Smith (1988; 1996) acknowledges a Holocene archaeological sequence similar to Gould (1977; 1978b), Veth (1993), and Hiscock (1994), but argues two significant areas of difference. First, Smith (1993) suggests that all biogeographical areas of the arid zone were inhabited during the early Holocene, including barrier sand ridge deserts (*cf.*, Veth 1993: 93-96). Smith (1993) refers to the Puritjarra and Puntuntjarpa archaeological records as evidence for early Holocene occupation of sand ridge deserts. He recognises the widespread appearance of formalised mid-Holocene stone tool technologies (*e.g.*, backed artefacts and tulas) approximately 3500 BP, but argues that the most significant transformations in the arid zone archaeological record occur around 1500 years ago when climatic conditions improve (Smith 1988; Smith 1996; Smith 2006; Smith and Ross 2008). Smith (1996: 68) suggests that there is a late Holocene intensification of site use across the arid zone, and it is reflected in the 'greatly increased artefact densities of chipped stone artefacts, grindstones, charcoal, bone, and other types of occupation debris after this date'. He believes that these patterns mark a late Holocene intensification of human occupation in the arid region (Smith 1996). In further support, he cites a steady increase in artefact densities, discard

rates, and core reduction throughout the Holocene sequence (Smith 1988: 131). He suggests that this trend peaked in the last 1400 to 900 years, and the pattern demonstrates 'the residue of a substantial and probably more sedentary population' (Smith 1996: 68).

All of the aforementioned subsistence-settlement models are based on a comparatively scant body of research that encompasses large geographical areas of the arid zone. Future research is likely to produce variants of these models, as refinements are made to suit the biogeographical regions of the arid zone. These previous models have been discussed because they are likely to have applicability to our interpretation of the Hamersley Plateau archaeology and the findings of the Hope Downs 1 salvage excavations.

2.4 REPRESENTATIVE SITES FROM THE HAMERSLEY PLATEAU

The site summaries presented below are from a selection of excavated sites across the Hamersley Plateau. As a representative sample, these sites make a significant contribution to our understanding of the regional archaeological record. Discussions of excavated sites within the Hope Downs 1 lease, such as Jundaru (Malea) and HS-A1, are reserved for the following chapter, which reviews all previously investigated sites on the lease. The purpose of including these individual site summaries is to illustrate variations in archaeological patterns. The pattern of Aboriginal occupation in Hamersley Plateau is patchy, and archaeological preservation is uneven. Not all sites from the Hamersley Plateau exhibit the same regional trends in site use, stone artefact technology, and subsistence. Therefore, it is important to look at the collective patterning of these sites to establish regional trends. The following site summaries are presented in geographical order, beginning in the western plateau and moving eastward (Figure 2-1). For comparative purposes, radiometric dates from these sites are presented in Table 2-3.

Newman Rockshelter

Newman Rockshelter, also referred to as Ethel Gorge Rockshelter (aka DAA ID 10142, Site Number P2055, and P2055.2), is located in Ethel Gorge, approximately 15km northeast of the township of Newman. The site is one of three rockshelters excavated in June 1979 by members of the Western Australian Museum (Troilett 1982). The purpose of the excavations and subsequent salvage of 16 additional artefact scatters was to assist the Mount Newman Mining Company Pty Ltd with their compliance of the AHA. Comtesse (2003: 48) revisited the artefact assemblage and has provided further chronological resolution with seven additional radiocarbon dates.

Since its original recording, the rockshelter has been renumbered several times, leading to confusion in the DAA site register and other publications. Troilett (1982: 27) originally describes the rockshelter as belonging to a group of rockshelters that he numbered together as Site P2055 (Western Australian Museum site number) as well as project code EG80/4 (Ethel Gorge 1980, Site 4). Using a decimal system, Troilett (1982: 27) individually numbered the rockshelters from west to east and selected rockshelter number P2055.2 for test excavations. In 1986, Brown expanded on Troilett's (1982) original description of the rockshelter, formally naming the site as Newman Rockshelter; however, Brown (1987: 24) describes Newman Rockshelter as Site P2055, without the decimal recognition.

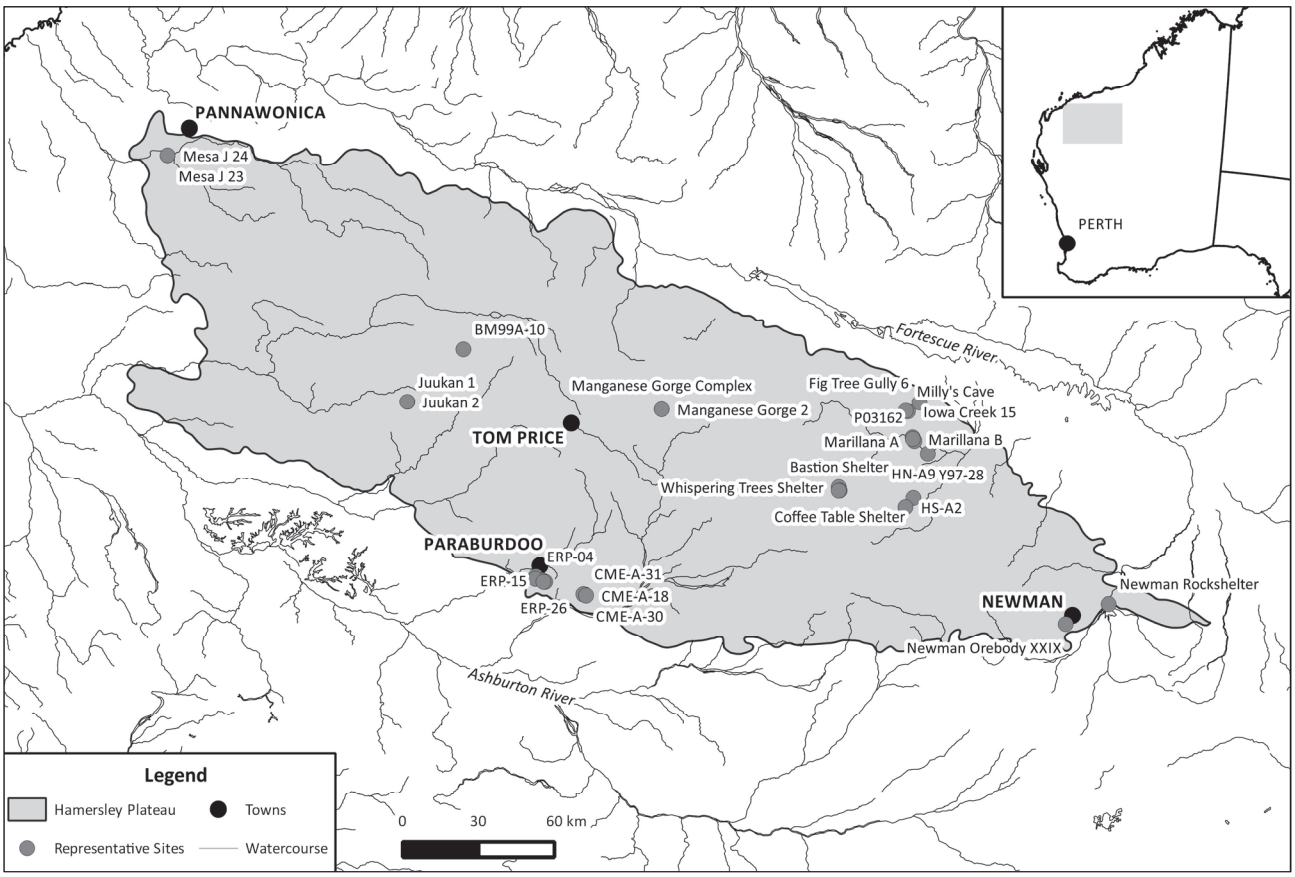

Figure 2-1 Map of previously investigated rockshelter sites of the Hamersley Plateau

Today, the DAA site register refers to Site P2055 (DAA ID 10142) as Ethel Gorge Rockshelter. Newman Rockshelter, according to the DAA site register, is Site P2056 (DAA ID 10143), and it is located approximately 70m west of Ethel Gorge Rockshelter. The DAA register appears to be erroneous in this situation, and Newman Rockshelter is actually DAA ID 10142, or as the register refers, Ethel Gorge Rockshelter. According to Troilett (1982: Map 2) P2056 is approximately 250m southeast of Newman Rockshelter, and only surface collections were undertaken at the former.

Newman Rockshelter is a north-facing rockshelter situated 160m south of the Fortescue River. The site is in a small gorge that opens onto the Fortescue River Basin. The primary, outer chamber of the rockshelter has a floor area of approximately 36m^2, and a smaller, enclosed chamber is located to the west. According to Troilett (1982: 27), a possible stone arrangement was constructed at the back of the west chamber. Two adjoining 1.0-x-1.0m excavation units (Pits A and B) were placed at the back of the primary chamber, and an additional 1.0-x-1.0m unit (Pit C) was excavated in the west chamber.

The Pit A and Pit B excavations produced some significant results on the function and antiquity of backed artefact technology in the Pilbara; however, the reporting of these results is inconsistent amongst the literature (Troilett 1982; Brown 1987). For example, Troilett (1982:41) reports that six backed artefacts (including 4 backed blades and 2 eloueras) were recovered from Newman rockshelter, but Brown's (1987: 29) reanalysis states that five backed artefacts and one tula adze slug were found in the uppermost levels of the site. Troilett (1982: 30) also reports that an elouera from Pit A-Spit 3 was recovered with resin adhering to the artefact; however, close inspection of Troilett's (1982: 40-41) artefact illustration suggests that this may be a typographical error, and the resin is actually adhering to a small, symmetrical backed artefact. Presumably, Brown (1987) noticed this discrepancy, and through closer inspection, Brown (1987: 49) reports that three backed pieces from Pit A have resin adhering to the backed margin (*cf.*, Troilett 1982).

During the investigations at Newman rockshelter, the excavators chose to halt excavations in Pit A so the deposit could be preserved for future work (Troilett 1982: 30). It is unclear at which depth the Pit A excavations were terminated, but it is inferred in various reports and section drawings that the excavations were halted in either Spit 3 at roughly 15cmbs (Troilett 1982: 31), Spit 4 at 20cmbs (Brown 1987: 27-28), or Spit 5 around 25cmbs (Troilett 1982: 56).

The Pit B excavations were removed in 19 spits, varying from 5 to 10cm depths (Troilett 1982; Brown 1987). The individual spit depths are not reported in either Troilett's (1982) or Brown's (1987) description of the rockshelter excavations, so it is difficult to determine the exact depths of much of the rockshelter stratigraphy and features. The Pit B excavations were terminated at a depth of 145cmbs, when a large rock slab obscured more than half of the unit floor and excavations became too constrained to continue. At this point, a steel probe was hammered into the floor, and at least 70cm of unexcavated sediment is estimated to remain at the site (Troilett 1982: 30).

The excavators identified 33 layers of sediment, contained within two stratigraphic units (Brown 1987: 27). The upper horizon extends to 52cmbs and is described as loose, dry, dusty cave earth with interleaving ashy lenses and preserved hearths (Brown 1987: 27). Troilett (1982) suggests that this upper unit is primarily aeolian sediment. Charcoal from a hearth identified in Spit 10 provides an age estimate of 6270±210 BP (WAIT-121) (Brown 1987: 27). Although the depth of the hearth is not provided by Troilett (1982) or Brown (1987), it is inferred that the hearth is near the contact of the lower sedimentary unit, which is described as a compact brown earth matrix with a high proportion of stone fragments (Brown 1987: 27). Troilett (1982: 33) believes that this lower sedimentary unit is of waterborne origin, possibly transported into the shelter from the hillslope above. He further argues that stone artefacts associated with this lower unit may have washed into the rockshelter (Troilett 1982: 33).

Due to a lack of charcoal, it was not possible to date the base of Newman Rockshelter; however, a combination of several charcoal fragments collected from Spit 16 (10cm deep), suggests an age of 26,300±500 BP (SUA-1510) (Brown 1987: 27). Thirteen chipped stone artefacts are reported from Spit 16, and 28 artefacts are reported as occurring beneath this date (Brown 1987: 31). A number of charcoal samples collected during the excavation were stored at the Western Australian Museum. Comtesse (2003: 48) submitted seven samples (from Spits 2, 3, 7, 9, 13, 14, and 15) for dating, and the results are in good chronological agreement with the existing data. There is a considerable gap between the dates from Spit 15 (13,852±72 BP, Wk-12576) and Spit 16 (26,300±500, SUA-1510); Comtesse (2003:48) notes this gap, but does not further explore its implications. Because the depth of each spit has not been reported by Troilett (1982), it is not practical to plot the dates on an age-depth curve as the spit depths varied; however, the disparity between the Spit 15 and Spit 16 dates suggests that either sediment deposition decreased significantly over this time or that the Spit 16 date is erroneous. Therefore, the antiquity of the occupation of Newman Rockshelter must be viewed cautiously, as is likely much older.

Chipped stone artefacts and charcoal comprise the principal archaeological materials recovered from Newman rockshelter. The small assemblage recovered from Pits A, B, and C has been the subject of at least four separate analyses (Troilett 1982; Brown 1987; Comtesse 2003; Williams 1986 cited in Comtesse 2003). While Williams' (1986) research was not reviewed, each of the other three researchers reported different assemblage sizes (*e.g.*, Troilett 1982: 56-57; Brown 1987: 30-32; Comtesse 2003). Moreover, there are discrepancies in the assemblage size throughout Comtesse' thesis (*e.g.*, Comtesse 2003: 24, 28, 50, 86, 86). It is not clear why there are differences amongst the analysts.

Regardless of the exact assemblage size, it is evident that artefact density is consistently low throughout the occupation. Brown (1987: 27) notes that the rate of artefact discard at the shelter is low, with one discarded every 100 years. Comtesse (2003: 86) reports that from the onset of occupation until 6270±210 BP, artefact discard rates are very low and less than one artefact per century. There appears to be a peak in site use between 6270±210 BP and 3740±100 BP, with an estimated five artefact discarded per 100 years (Comtesse 2003: 86). Site use appears to decrease after this time, with lower discard rates. Throughout the assemblage, retouched artefacts are rare.

Table 2-3 Radiometric dates from representative archaeological sites of the Hamersley Plateau

Region	Site	Years BP	Calibrated Years BP 2σ	Lab Code	Context (cmbs)	Comments	Reference
Newman	Newman Rockshelter (P2055.2, DAA ID 10142)	1388±37	1366-1264	Wk-12570		Spit 2	(Brown 1987; Comtesse 2003)
		3487±40	3865-3642	Wk-12571		Spit 3	
		3740±100	4413-3860	SUA-1509	~10-15	Hearth 10-15cmbs, Spit 4	
		6254±43	7268-7018	Wk-12572		Spit 7	
		5109±43	5932-5744	Wk-12573		Spit 9	
		6270±210	7569-6678	WAIT-121		Hearth, Spit 10	
		8862±51	10174-9743	Wk-12574		Spit 13	
		9004±51	10,248-9925	Wk-12575		Spit 14	
		13,852±72	17,151-16,758	Wk-12576		Spit 15	
		26,300±500	31,646-30,168	SUA-1510		bulk sample, spit 16	
	Newman Orebody XXIX Rockshelter (P0187, DAA ID 11963)	3010±85	3388-2957	SUA 1040	~ 10-20	Hearth, depth of sample not recorded	(Maynard 1980)
		5260±110	6286-5753	SUA 627	~ 30-40	pit-shaped hearth, depth of sample not recorded	
		9870±80	11,689-11,166	SUA-2553		Hearth 7, spit 6	
		20,740±345	25,753-23,912	SUA 1041	~60-100	Derived from a combined sample from 3 spits.	
Hope Downs	HS-A2 (DAA ID 18717)	500±50	644-475	Wk-5549		Spit 1	(Edwards *et al.* 2001: 149)
		6,260±60	7309-7004	Wk-5550		Spit 10	
	Jundaru (Malea, HN-A9, DAA ID 18195)	290±50	492--1	Wk-3209	6.3-9.9	'five samples of diffuse charcoal' (Edwards *et al.* 2001: 68)	(Edwards *et al.* 2001: 68)
		2820±80	3161-2764	Wk-3381	27-30.4		
		6570±60	7578-7333	Wk-5748	55-60		
		15,230±230	18,877-17,928	Wk-3382	72.5-79.6		
		20,360±320	25,075-23,505	Wk-3210	97.3-102.1		
Yandi	Marilana A (P03184, DAA ID 9133)	3630±70	4150-3724	Wk-2683	15	Square 11B	(Strawbridge 1992: 41; Marwick 2002a)
		9200±200	12072-9148	Wk-2582	46-51	Square 11B, Unit 8	
		13,167±89	16,591-15,264	Wk-10198	48-51	Square 9B, unit 22	
	Marilana B (DAA ID 21351)	1791±57	1865-1565	Wk-10350	32	Bulk sample collected from sieves; Spit 13	(Marwick 2002a)
	Iowa Creek 15 Rockshelter (Wallaby Cave, P6107, DAA ID 6855)	1730±110	1889-1399	not reported		hearth	(Strawbridge 1992: 39)
	P3162 (DAA ID 9165)	250±50	468--4	Wk-3867	5-10	Bulk sample from sieve	(Quartermaine 1997)
		240±50	461--4	Wk-3868	15-20	Bulk sample from sieve	
	Milly's Cave	modern		Wk-2187	20	Square 4A, *in situ*	(Marwick 2002a)
		719±57	759-555	Wk-10351	27-36	Square 4A, bulk sample from sieved fine fraction	
		14,150±320	18,408-16,667	Wk-2584+	48-50	Square 4A, Spit 8; *in situ*	
		19,750±460	24,727-22,428	Wk-2188	55-57	Square 4A, Spit 10; *in situ*	
	Fig Tree Gully 6 (Cleft Rockshelter, P06090, DAA ID 6838)	1120±70	1240-921	Wk-2583+	~10	Square 4A	(Marwick 2002a)
		1710±100	1865-1404	Wk-2582	~25	Square 4A	
		3610±70	4144-3717	Wk-2581	40	Square 4A, Spit 7; *in situ*	
		7900±90	9007-8541	Wk-2189	~50	Square 4A, Spit 8; *in situ*	
		701±69	743-541	Wk-10199	80	Square 4A; Bulk sample from fine fraction.	
		12,730±271	16,419-14,099	Wk-10845	80	Square 5B	
	Y97-28 (DAA ID 15180)	modern		Wk-5603	15.5	*In situ* sample	(Hook *et al.* 2000)
		modern		Wk-5604	24.4	*In situ* sample	
		810±80	54-46^	Wk-5605	Surface	Surface baler shell	
		380±80	541-286	Wk-5627	11.4-14.5	*In situ* sample	

Region	Site	Years BP	Calibrated Years BP 2σ	Lab Code	Context (cmbs)	Comments	Reference
Packsaddle Ridge	Coffee Table Rockshelter (P4623, DAA ID 8023)	130±50	451-...	Beta-7211	4	*In situ* sample, Feature 1	(Brown and Mulvaney 1983)
		770±50	790-653	Beta-7212	8	*In situ* sample, Feature 3	
	Phantoms Rockshelter (P4627, DAA ID 8027)	260±60	489--4	Beta-7213	2	*In situ* sample, Feature 2	(Brown and Mulvaney 1983)
		2640±130	3061-2356	Beta-7214	8	Bulk sample, Feature 4	
	Bastion Rockshelter (P5315, DAA ID 7606)	2440±60	2711-2352	Beta-7215	14	Bulk sample; Feature 8	(Brown and Mulvaney 1983)
		8090±80	9277-8717	Beta-7216	22	*In situ* sample, Feature 12	
	Whispering Trees Rockshelter (P5316, DAA ID 7607)	2330±50	2677-2158	Beta-7217	21	Bulk sample; Feature 1	(Brown and Mulvaney 1983)
Marandoo	Manganese Gorge 2 Cave (P07337, DAA ID 732)	4190±130	5270-4360	Wk-2478	10	Square Z17, Spit 5	(Quartermaine 1994: 10, 19)
		5370±60	6283-6000	Wk-3024	5-14	Square D10, Spit 1	
		6460±60	7474-7266	Wk-3022	22-23	Square C10, Spit 7	
		8990±100	10,386-9742	Wk-2477	44	Square T19, Spit 22	
		13,460±90	16,902-16,059	Wk-3023	44-60	Square C10, Spit 5	
		17,900±230	22,065-20,542	Wk-2476	60	Square T19, Spit 30	
	Manganese Gorge 8	430±90	639-298	Wk-2474		Charcoal	(Morse 2009)
		4070±110	4847-4259	NZ-2578		Bone apatite carbonate (AMS)	
		720±110	906-526	NZ-2577		Bone apatite carbonate (AMS)	
	Power Corridor 5 (DAA ID 17686)	930±50	930-739	Wk-2660	21	Charcoal	(Greenfield 1992; cited in Morse 2009)
		3200±90	3639-3214	Wk-2585	32	Charcoal	
		3950±90	4802-4100	Wk-2459	55	Charcoal	
Channar Ranges, near Paraburdoo	CME-A-18 (DAA ID 16147)	390±50	515-315	Wk-8002	Surface	Wood, spear point/burned wood	(Veitch *et al.* 2005; Dias *et al.* 2007)
		1000±60	1055-780	Wk-8001	Surface	Spinifex resin ball	(Veitch *et al.* 2005)
	CME-A-30 (DAA ID 17719)	440±70	623-310	Wk-8955	Surface	Wood, Tree ladder	(Veitch *et al.* 2005)
	Yirra Rockshelter (CME-A-31, DAA ID 17720)	1307±40	1303-1152	Wk-12534	4.5	*In situ* sample, Spit 1	(Veitch *et al.* 2005; Hook and Martin 2000; Dias *et al.* 2007)
		1610±50	1683-1385	Wk-9147	10.7	*In situ* sample, hearth, Spit 3	
		3230±50	3567-3364	Wk-8953	22.1	*In situ* sample, hearth, Spit 4	
		3702±56	4230-3889	Wk-12535	24-29	*In situ* sample, Spit 5	
		1057±45	1065-834	Wk-12536	29-34	Sample collected from 3mm sieve (*Corymbia* sp) interpreted as erroneous due to white ant bioturbation, Spit 6	
		10,628±74	12,699-12,408	Wk-13779	29-34	*In situ* sample, Spit 6	
		13,375±94	16,860-15,634	Wk-12537	34-35	*In situ* sample, hearth, Spit 7	
		16,950±94	20,391-19,616	Wk-9148	43.1	*In situ* sample, hearth, Spit 8	
		17,169±114	21,053-20,060	Wk-12538	40.5-44	*In situ* sample, hearth, Spit 9	
		18,950±235	23,373-22,124	Wk-12539	46-49	*In situ* sample, hearth, Spit 10	
		19,270±140	23,444-22,483	Wk-8954	55.1	*In situ* sample, hearth, Spit 11	
Eastern Ranges, near Paraburdoo	ERP-04 (DAA ID 16890)	2000±50	2110-1830	Wk-6325	3.9-7.5	*In situ* sample, hearth	(Veitch *et al.* 2005)
	ERP-11B(ii) (DAA ID 16895)	350±50	499-308	Wk-6322	4	*In situ* sample, hearth	(Veitch *et al.* 2005)
		370±50	505-314	Wk-6326	6	*In situ* sample	(Veitch *et al.* 2005)
	ERP-15 (DAA ID 16892)	950±50	953-742	Wk-6323	3.1	*In situ* sample, hearth	(Veitch *et al.* 2005)

Region	Site	Years BP	Calibrated Years BP 2σ	Lab Code	Context (cmbs)	Comments	Reference
Eastern Ranges	ERP-22 (DAA ID 16894)	560±50	653-514	Wk-6324	7.5	*In situ* sample, hearth	(Veitch *et al.* 2005)
	ERP-26 (DAA ID 16900)	1840±50	1888-1626	Wk-6327	10	*In situ* sample, hearth	(Veitch *et al.* 2005)
Brockman	BM99-10 (DAA ID 16916)	470±50	630-332	Wk-8000	3	Charcoal, *in situ* hearth	(Veitch and Di Lello 2000)
		540±50	651-505	Wk-7090	surface	Spinifex resin	
	Juukan-1	760±40	764-656	Beta 249757	near surface		(Slack *et al.* 2009)
		26,640±160	31,340-30,964	Beta 249758	35		
		32,950±70	38,374-36,931	Beta 249759	60		
	Juukan-2	470±40	621-342	Beta 247330	~10		(Slack *et al.* 2009)
		16,160±80	19,459-18,925	Beta 247331	~55		
		20,090±100	24,390-23,666	Beta 247332	85		
Pannawonica	Mesa J J23 Rockshelter (P06696, DAA ID 6276)	240±90	484--3	Wk-2504	8-15	Date reported as Spit 3 in 1992 report and Spit 2 in 2011 report	(Hughes and Quartermaine 1992; Hughes *et al.* 2011)
		650±190	972-294	Wk-2503	15-20	Date reported as Spit 4 in 1992 report and Spit 3 in 2011 report	(Hughes and Quartermaine 1992; Hughes *et al.* 2011)
		2230±160	2712-1892	Wk-2505	20-25	Date reported as Spit 5 in 1992 report and Spit 4 in 2011 report	(Hughes and Quartermaine 1992; Hughes *et al.* 2011)
	Mesa J J24 Rockshelter (P06697, DAA ID 6277)	1400±60	1411-1180	Wk-2635	12.5-17.5		(Hughes and Quartermaine 1992; Hughes *et al.* 2011)
		3950±110	4814-4089	Wk-2634	22.5-27.5		(Hughes and Quartermaine 1992; Hughes *et al.* 2011)
		23,500±350	29,301-27,657	Wk-2514	53-58		(Hughes and Quartermaine 1992; Hughes *et al.* 2011)

+ The lab code for Milly's Cave date 14,150±320 BP has been previously reported as Wk-2583 (a code also used for Fig Tree Gully 6); however, the Radiocarbon Laboratory at the University of Waikato has confirmed that the correct lab code for this date is Wk-2584 (F. Petchey 2011, pers. com., 3 Aug.).
^ This sample was calibrated using the Marine 09 calibration curve (Reimer *et al.* 2009) with a ΔR value of 76±68 (Reimer and Reimer 2011). The ΔR value was calculated from a weighted mean of all WA values in the Marine Reservoir Correction Database (Reimer and Reimer 2011).

While there are minor reporting inconsistencies, several observations can be made about backed artefact technology. The first observation is that backed artefact technology is present by the mid-Holocene. A radiocarbon age estimate associated with the deepest recovered backed artefact from Newman Rockshelter suggests that the technology was in use by 3740±100 BP (SUA 1509), which calibrates to 4413 to 3860 cal BP (Troilett 1982: 71; Brown 1987: 27). The Hope Downs salvage data supports this assessment with further (and slightly older) evidence of mid-Holocene ages for backed artefact technology (see Law and Cropper 2011).

A second technological observation is that backed artefacts were often hafted to make composite tools (Troilett 1982: 41). The resin adhering to the backed margin suggests that backed artefacts may have been hafted. McDonald *et al.* (2007) have demonstrated incontrovertible evidence that they often functioned as spear barbs; however, as Robertson *et al.* (2009) have shown, backed artefacts have additional multi-functional qualities and were not exclusively utilised as barbs.

Comtesse (2003: 90) found that raw material preferences varied throughout the occupation of the site, with peaks in chert use greatest during the initial occupation (26,300±500 BP and earlier) and after approximately 3740±100 BP. The use of ironstone was greatest between approximately 6270±210 BP and 9004±51 BP (Comtesse 2003: 90), and quartz was a dominant raw material type in the mid-Holocene (accounting for over 60% of the artefacts; Comtesse 2003: 118).

Small quantities of bone, organics and insect remains were recorded, but these are almost entirely confined to the upper spits (Clarke 1982). Wood shavings were also recovered from the late Holocene layers (Comtesse 2003: 104). Clarke (1982) noted that the density of organics (charcoal, plant remains) varied throughout spits, showing no gradual decrease with depth and with no correspondence with artefact numbers.

Marwick (2002b: 24) suggests that chronological resolution is low for this site (particularly in Pleistocene deposits). The paucity of artefacts between 26,300 and 6270 BP do offer support for a reduction of site use or periodic episodes of abandonment during the LGM.

Newman Orebody XXIX

The Newman Orebody XXIX (DAA ID 11963, Site Number P00187) is a rockshelter located around three kilometres southeast of Mount Whaleback, near Newman, WA. The site was first recorded in 1975 during an archaeological survey of geological Orebody XXIX for the Mount Newman Mining Company. In preparation for the development of Orebody XXIX, members of the West Australian Museum were engaged to test excavate the site in March 1976 (Maynard 1980).

The Newman Orebody XXIX site is located in a slight overhang that faces southeast across the floodplain of the Fortescue River. The rockshelter is medium sized, with a floor area of approximately 20m^2 (Maynard 1980: 3). Stone artefacts, including a grindstone and a number of quartz and chert flakes,

were observed on the ground surface during the time of recording. An area near the centre of the rockshelter floor was selected for a 1.0-x-1.0m test unit excavation. The team removed the sediment in 10cm spits, stopping at 100cmbs. Bedrock was not encountered, and presumably due to confined space issues, the excavation was halted at the completion of Spit 10 (Maynard 1980: 3). A steel rod was driven into the floor of the unit, penetrating a further 110cmbs (Maynard 1980: 5).

Maynard (1980) describes the deposit as consisting of fine reddish brown sediment with eroded iron stone fragments. She saw observed little stratigraphic change with depth, and the only variation in the sediment profile was the ratio of fine sediment to rock.

In total, Maynard (1980: 5) reports that the team recovered 400 stone artefacts and recorded eleven hearth features. Hearth 4 was interpreted as a 'fire pit' because in cross-section, the feature was bowl-shaped and 20cm deep. Presumably, this feature was used for baking animals, as it is similar to those observed being used by contemporary Aboriginal groups (Maynard 1980:5). Only one organic item was recovered from the excavation, a macropod tooth from Spit 1. Ochre was observed in the deposit, but Maynard (1980: 5) is doubtful that the ochre is of cultural origin.

Maynard (1980: 7) obtained four age-estimates from the rockshelter, including an early date of 20,740±345 BP (SUA 1041). This estimate comes from near the base of the excavation, and it represents a combination of charcoal fragments from the three lowest spits (70-100cmbs). Due to the mixture and potential contamination of charcoal samples, it is likely the date is even older than the age this estimate provides.

Further dates in the overlying unit contexts were obtained from a number of hearth features. Hearth 7, located 50 to 60cmbs, produced an age estimate of 9870±80 BP (SUA-2553) (Brown 1987: 23). Charcoal from the Hearth 4 fire pit cooking feature noted by Maynard (1980: 7) dated to 5260±110 BP (SUA-627). If Hearth 4 is indeed a pit, then the age estimate should be associated with the top of the hearth, which is approximately 18cmbs (Maynard 1980:7). Maynard (1980: 4) acquired an upper age estimate of 3010±100 BP (SUA-1509) for the sequence, which comes from Hearth 3 in Spit 2, 13cmbs.

The Newman Orebody XXIX has been subject to reinvestigation since Maynard's (1980) original reporting of the site. Brown (1987: 24-25) conducted a reanalysis of Maynard's artefact assemblage, concluding that only 250 of the collected specimens are artefacts. One reason for the discrepancy is that Brown considers many of the banded ironstone specimens to be natural. He states:

> Ironstone is the local material of which the overhand is composed (Marra Mamba formation, Hamersley groups) and it contains numerous thin bands of poor quality, fine-grained metamorphosed material that often fractures concoidally. I only classified those ironstone pieces with immediately recognisable bulbs of percussion as artefactual and dubious pieces were not included in the analysis. (Brown 1987: 24)

Comtesse (2003: 49) has also revisited the Newman Orebody XXIX assemblage, during which she analysed 609 flaked stone artefacts. She provides no explanation for the discrepancy in assemblage size from both Brown (1987) and Maynard (1980).

Brown's (1987: 24) reanalysis observed three trends in the artefact assemblage. First, he noted that artefacts manufactured of local ironstone material increase in number after 5000 years ago. In contrast, Comtesse (2003:66) found that there were only marginal increases in the use of ironstone between 9870±80 BP and 3010±100 BP. These disparate results are likely related to the different approaches to the classification of BIF or ironstone artefacts by the two researchers. Second, Brown (1987: 24) suggests that the low number of artefacts in Spits 1 and 2 are indicative of decreased site use in the last 3000 years. Brown (1987: 24) observes that this pattern is notably different from other sites in the area (*e.g.*, Newman Rockshelter and Packsaddle Ridge), which show an increase in site use and discard at this time. Brown's third overall trend is that artefact size decreases over time throughout the site history. This is most noticeable in the average length of flakes, which are greater than 2cm throughout the Pleistocene, but less than 2cm in the Holocene layers (Brown 1987: 24).

Although Brown's (1987) findings are slightly different from the assessments made by Maynard (1980) and Comtesse (2003), the pattern remains that the artefact assemblage size is relatively small. Artefact discard is estimated by Brown (1987: 24) to be one artefact every 80 years. This low pattern of artefact discard is similar to that observed at other Pilbara rockshelters such as Newman Rockshelter and Packsaddle Ridge.

Y97-28 Rockshelter

Rockshelter Y97-28 (DAA ID 15180) was excavated as a part of the salvage program for the Hamersley Iron Yandi railway and mine area, near Yandicoogina (Hook *et al.* 2000). The small rockshelter (6.6-x-5.0-x-1.9m) is oriented to the north, and it is situated approximately 10m above a small gully (Hook *et al.* 2000: 91). Numerous flaked stone artefacts (n=136) and grindstones (n=16) were recorded on the surface of the rockshelter (Hook *et al.* 2000: 92; Hammond 1997: 58), demonstrating use of the site during the recent past. Hook *et al.* (2000: 91-99) excavated two test units (Test Pit 1, 1.0-x-1.0m; Test Pit 2, 0.5-x-0.5m) using arbitrary 4cm spits or following stratigraphic changes where possible; their results are summarised here.

Fragments of exfoliated bedrock comprised the majority of the deposit, and while charcoal was scattered throughout, no cultural features were identified. White ant disturbance was noted in Test Pit 1. Excavation terminated at bedrock reaching maximum depths of 38.45cm in Test Pit 1 and 18.85cm in Test Pit 2. The artefact discard rates are relatively high at Rockshelter Y97-28, with 345 flaked stone artefact recovered from the excavation. Artefact density was highest in Spits 1 through 6 in Test Pit 1 (n=267 of 272) and in the first three spits of Test Pit 2 (n=64 of 73). Only the artefacts from Test Pit 1 appear to have been analysed, and there is no discussion of the range of artefact types recovered from the excavation. Among the artefacts from Test Unit 1, artefact size remains consistent throughout the deposit; however, the term 'size' is not defined in the report (*e.g.*, length, width, thickness, weight, or a ratio). It is possible this information is available in the report appendices, which were not available at the time of writing.

Four charcoal samples and one shell fragment were submitted for radiometric dating. In Test Unit 1, charcoal samples collected *in situ* from Spits 6 (Wk-5604, 24.4cmbs) and 4 (Wk-5603, 15.4cmbs) yielded modern ages. Hook *et al.* (2000: 94) reject these age estimates, suggesting they were a result of modern carbon contamination through macropod or termite bioturbation. In Test Pit 2, a charcoal sample from Spit 3 yielded a date of 380±80 BP (Wk-5627). In addition, a baler shell fragment recovered from the surface of the rockshelter was

submitted for dating, returning an age of 810±80 BP (Wk-5605). Hook *et al.* (2000: 94) interpret the dates as indicating the site 'was in use during the last 800 years'.

The use of the uncalibrated date of the surface baler shell fragment to provide chronological context for the archaeological deposit may be problematic (for a discussion of the 'old shell' problem see Rick *et al.* 2005). The marine reservoir effect on the radiocarbon age should be taken into account, as it can alter the date by several hundred years and this varies depending on local offsets (ΔR; Stuiver *et al.* 1998; Ulm 2006). There is very little data on the ΔR values for Western Australia, particularly around the Pilbara coast; however, data from elsewhere in Western Australia suggests that the marine reservoir age ranges between 261 to 497 years with an average ΔR value of 76±68 (Reimer and Reimer 2011). While acknowledging the limitations of the data, when sample Wk-5605 is calibrated, it suggests that the baler shell was left at the site between 54 and 46 cal BP (*i.e.*, between 1896 AD and 1904 AD). Once the date on the shell is calibrated, it demonstrates that this surface artefact was left at the site in the recent past; moreover, the calibrated date supports the modern age estimates from Test Unit 1 (contrary to Hook *et al.* 2000: 94) and the date of 380±80 BP from Spit 3.

Marillana A Rockshelter (P03184, DAA ID 9133)

Located in the southern extent of the main orebody for the Yandi Project Area, Marillana A Rockshelter is situated within a steeply-sided gully that runs off the Marillana Creek (Strawbridge 1992: 40; Marwick 2005: 1358). The broad south-facing rockshelter has maximum dimensions of 22.5m wide, 5.5m deep, and 6.5m high at the dripline (Strawbridge 1992: 40). The rockshelter was once much larger, as indicated by the large blocks of roof fall in front of the shelter and Strawbridge (1992: 40) suggests that these boulders may have protected the deposit from erosion. After rainy periods, a water pool is located near to the site and an intermittent waterfall is adjacent to the rockshelter.

In 1991, a 1.0-x-1.0m test unit (Unit 11B) was placed behind the dripline and was excavated in two to three centimetre spits, which increased to five and ten centimetres in deeper deposits where insect bioturbation and rocks made the small spits impractical (Strawbridge 1992: 41-42). Excavation ceased at 99cmbs when bedrock was exposed. A second 1.0-x-1.0m unit (Unit 9B) was excavated in 1993, which is located southwest of Unit 11B (Marwick 2002a). The excavation of Unit 9B terminated at a depth of 147cmbs (Marwick 2005: 1358), and it appears that bedrock was not exposed in this excavation unit.

Charcoal was present through the deposit, and a large hearth was identified in Unit 11B (7-8cmbs). There are three radiocarbon dates for the site (Table 2-3); while taken from different excavation units, the dates of Wk-2582 (9200±200 BP) and Wk-10198 (13,167±89 BP) are significantly different despite the similar depth below surface; this may suggest that disparate depositional processes occurred throughout the site.

In Marwick's (2005: 1358; Marwick 2002a) analysis of the bulk sediment samples, he identified four stratigraphic horizons and found no evidence of bioturbation. Stratigraphic Layer 1 (SL1) is approximately 12cm thick and encompasses the loose surface deposit. Comprised of light brown sediment and ash lenses, the upper limit of SL2 is dated to approximately 3630±70 BP, while SL3 has an increased proportion of roof fall. Marwick (2005: 1358) uses the 9200±200 BP date as the boundary between SL2 and SL3, but it is unclear why the 13,167±89 BP date is discounted, as the samples were obtained from similar depths (Table 2-3). Beneath the roof fall layer, SL4 was more coarse-grained due to increased erosion; this layer continued to bedrock.

The flaked stone artefacts were in highest concentration in Unit 9B (n=1227), while Unit 11B had only 407 artefacts (Marwick 2002a). A large proportion of the artefacts recovered from Unit 9B were classified as angular pieces (n=634 aka flaked piece or debris), and this group of artefacts comprised between 50% and 83% of the artefacts in each layer (Marwick 2002a). Marwick (2005: 1358) interprets the dates and distribution of flaked stone artefacts as indicative of a repeated period of site use between 9000 BP and 3000 BP. Flaked stone artefacts were recovered in SL4 up to a depth of approximately 120cmbs (Marwick 2005: 1359, Figure 2). The pattern of raw material use in Unit 9B indicates that chert, chalcedony, and quartz were common in SL1 and SL2, while silcrete, ironstone, and BIF were more commonly used in SL3 and SL4 (Marwick 2002a; Marwick 2005: 1361).

Marillana B Rockshelter (DAA ID 21351)

Marillana B Rockshelter (DAA ID 21351, no site number) is a shallow overhang that is located on the south side of the main orebody (Strawbridge 1992). The rockshelter is small, measuring 3.7m deep and 2.5m high at the dripline (Marwick 2002a). In 1993, Lynda Strawbridge directed the excavation of 1.0-x-1.0m test unit (4A), which was set inside the dripline (Marwick 2002a). Using arbitrary spits (2-3cm), 30 spits were excavated to a depth of 79cmbs (Marwick 2002a).

A single radiocarbon date of 1791±57 BP is reported for the site, and this was collected as a bulk sample from the sieved sediment of Spit 13, approximately 32cmbs (Marwick 2002a). A total of 226 flaked stone artefacts was recovered from the excavation, and there is a peak in artefact discard rates in Spit 12 and few artefacts were recovered below this peak (Marwick 2002a). The majority of the artefacts were classified as angular pieces (n=102; aka flaked piece or debris), flake fragments (n=60), and complete flakes (n=57), which were predominantly produced on chert and chalcedony (Marwick 2002a).

Site P03162 (DAA ID 9165)

Site P03162 (DAA ID 9165) was excavated in conjunction with a salvage program carried out in response to the expansion of exploration and mining at BHPIO's Yandi mine, which is approximately 100km northwest of Newman (Quartermaine 1997). The site is situated on the north bank of Marillana Creek, and it is comprised of both an artefact scatter and two rockshelters. The artefact scatter extends over an alluvial terrace, which is bounded by Marillana Creek to the southwest, a small tributary creek to the east, and the two rockshelters to the northwest (Quartermaine 1997: 45). Of the two rockshelters, Rockshelter A is the largest (17.5-x-8.5-x-2.5m) and is closest to Marillana Creek, while Rockshelter B was smaller (9.0-x-6.6-x-2.0m), had fewer surface artefacts, and appeared to have a shallower deposit (Quartermaine 1997: 42). One 0.5-x-0.5m test unit was opened in Rockshelter A, and the results of the excavation are summarised in the following paragraphs (Quartermaine 1997: 42-51).

Using arbitrary 5cm spits, the test unit was excavated to bedrock, which had a maximum depth of 22.5cmbs. The excavated material was dry-sieved (3 and 6mm). No stratigraphic changes were observed in the deposit, but there is no description of the composition, texture, or colour of the

deposit. Based on the report photographs and the rockshelter profile illustrations, the deposit appears to be a continuation of the alluvial terrace. Quartermaine notes that in early 1995 the area was flooded and was under water for a period of time, and considering the proximity of the rockshelter to the creek, it seems likely that the deposit is shallow due to scouring and reworking during high-energy flood events. Two bulk charcoal samples were collected as the excavated sediment was sieved, and they were submitted for radiometric dating, yielding results of 250±50 BP (Wk-3867, Spit 2) and 240±50 BP (Wk-3868, Spit 4). The dates from Spit 2 (5-10cmbs) and Spit 4 (15-20cmbs) are virtually the same, suggesting rapid deposition.

A small assemblage of faunal remains and flaked stone artefacts was recovered from the excavation. The faunal analysis identified both macropod and golden bandicoot remains. From the excavation, 43 flaked stone artefacts were recovered with chips accounting for 86% of the assemblage, as well as three flakes, two flaked pieces, and one core. Quartermaine does not define the category 'chips', although he notes that his classification followed Hiscock (1989). As Hiscock (1989) does not employ the term 'chip', it is unclear how chips and flaked pieces are differentiated in the assemblage from P3162. The artefacts were produced on a variety of raw material types (siliceous sediment, quartz, ironstone, and chalcedony), with no one type being overwhelmingly predominant. No diagnostic formal retouched artefacts were noted in the report.

Quartermaine (1997: 42) also conducted a collection of surface artefacts within the rockshelters and on the alluvial terrace. A total of 174 surface artefacts was collected from immediately in front of, and within Rockshelter A. In contrast to the excavated assemblage, the surface assemblage from Rockshelter A had a high proportion of flakes (34.3%) and broken flakes (24.4%), followed by flaked pieces (15.7%), chips (6.5%), cores (5.8%), and adze/scrapers (5.8%). The assemblage from Rockshelter B (n=74) was comprised of equal proportions of flakes, flaked pieces, and chips (totalling 85.2%). A sample of artefacts (n=1950) was also collected from the alluvial terrace to the east of the rockshelters, and two concentrations of artefacts were identified. Interestingly, chalcedony was the predominant raw material type for the open artefact scatter (49%). In contrast, the surface assemblage in the rockshelters and the excavated assemblage had much lower proportions of chalcedony (25.8% and 20.9% respectively).

Quartermaine (1997: 44) interprets Site P3162 as a large to medium-sized campsite and suggests that the distribution of surface artefacts reflects possible spatial patterning or differentiation of activities between the rockshelters and the alluvial terrace. He does note that some of the surface artefact clusters may be the result of post-depositional processes.

Fig Tree Gully 6 (Cleft Rockshelter, P06090, DAA ID 6838)

Fig Tree Gully 6 Rockshelter (P06090, DAA ID 6838), also known as Cleft Rockshelter, is located in the broad Fig Tree Gully (Marwick 2002a), which is approximately 10km north of Marillana and 12km north of Yandi. The site was identified in a survey along the proposed 32km-long rail route between Iron Ore BUMI mine site at Yandicoogina to the Newman to Port Hedland rail line (Strawbridge 1988: 1). The site is situated approximately 5m above the valley floor on a low ridge on the south side of Fig Tree Gully (Strawbridge 1988: 10). Moderate-sized blocks of roof fall were present beyond the dripline, and surface artefacts were observed throughout the shelter including several large grindstones, a muller and muller fragments, ochre (with evidence of grinding), and flaked stone artefacts (Strawbridge 1988: 10-11). The rockshelter was given its name after the distinctive horizontal cleft that appears along the rockshelter wall (Strawbridge 1988: 11). The rockshelter is large, measuring 12.1m wide, 15m deep, and 3m high at the dripline (Marwick 2002a).

Two 1.0-x-1.0m test units were opened at the site; Unit 4A was excavated to a maximum depth of 96cmbs using spits of approximately 6cm in depth, and Unit 5B was excavated to a depth of 90cmbs using spits of approximately 3cm in depth (Marwick 2002a).

Six radiocarbon determinations are published for the site (Table 2-3), and together with the distribution of artefacts through the deposit, the dates suggest that the initial occupation of Cleft Rockshelter occurred prior 12,730±271 BP. The date of 701±69 BP was determined on a bulk sample collected from the Unit 4A fine fraction below 80cmbs, and based on communication with Strawbridge, Marwick (2002a) reports that the date is anomalous suggesting that younger charcoal may have fallen into the trench during excavation.

A total of 1381 flaked stone artefacts were recovered from the excavation, and grindstones and numerous artefacts were also identified on the surface of the rockshelter (Marwick 2002a). Marwick (2002a) identified two peaks in the artefact discard rates: Spit 12 in Square 4A, which lies in SL4 (7900 BP-12,700 BP), and at approximately 1700 BP (Square 4A, Spit 3). Marwick (2002a) analysed the artefacts from Square 4A (n=577) including 166 complete flakes and conjoining artefacts; in each stratigraphic layer there are high proportions of flake fragments (28-36%; ventral surface but no point of applied force) and angular pieces (25-56%; aka flaked piece or debris). The patterns of raw material use show changes over time, where chert was predominate in SL1 and SL2, shifting to equal proportions of chert and siltstone in SL3, and siltstone became the dominant raw material in SL5 (Marwick 2002a).

Iowa Creek 15 Rockshelter (Wallaby Shelter, DAA ID 6855, Site Number P6107)

Iowa Creek Rockshelter 15, also known as Wallaby Shelter (P6107, DAA ID 6855), is situated within a small gully that drains into Iowa Creek (Strawbridge 1992: 38). Like Fig Tree Gully 6, the site was identified in a survey along the proposed 32km-long rail route between the Iron Ore BUMI mine site at Yandicoogina to the Newman to Port Hedland rail line (Strawbridge 1988: 1). The rockshelter is small and consists of two chambers; the front chamber is 2.8m wide (at the dripline), 1.95m deep, and 1.5m high (on average). The second chamber leads off the back of the front chamber, and it is approximately 3m deep and has a lower ceiling (Strawbridge 1992: 38).
A 1.0-x-1.0m test unit was opened behind the dripline, and after excavating several spits with little cultural material, the excavators decided to close two quadrants focusing the excavation on an 0.5-x-1m area (Strawbridge 1992: 38). In total, ten spits were excavated, reaching a maximum depth of 35cmbs at which point bedrock was exposed (Strawbridge 1992: 38). The deposit was initially silty, but became increasingly rocky with depth, and Strawbridge (1992: 38) notes that the lower deposit was cemented by insect activity.

While the excavation yielded little cultural material, of particular significance is the identification of a glass artefact in Spit 3 (Strawbridge 1992: 38); this artefact demonstrates post-contact use of the site. Three large grindstones and a small assemblage of other artefacts were identified on the surface of

the rockshelter (Strawbridge 1992: 39) A single radiocarbon date of 1730±110 BP is reported for this site (Strawbridge 1992: 39); however, the laboratory code is not reported and the only provenance for this sample is a brief mention that it was taken from a hearth (Strawbridge 1992: 48). The identification of a hearth is not mentioned in the excavation results, but Strawbridge (1992: 38) does note that the upper spits were charcoal rich. Morse (2009: 4) reports that the date was recovered from 35cmbs; however, this is not in agreement with Strawbridge's report.

Milly's Cave

Milly's Cave is located in a small gorge that is a tributary of Iowa Creek, and it is situated in close proximity to a small permanent freshwater spring (Marwick 2002a; Marwick 2002b: 25). The medium-sized rockshelter has a west-facing opening and measures 6.1m wide, 5.5m deep, and 6.1m high at the dripline (Marwick 2002b: 25). The site coordinates (713145mE/ 7495098mN; L. Strawbridge 2009, pers. com., 16 Nov.) place this site approximately seven kilometres northwest of Marillana and less than one kilometre west of Iowa Creek Sites 11 through 17.

In 1991, Lynda Strawbridge excavated a 1.0-x-1.0m test unit (Unit 4A), and in the following year an adjacent 1.0-x-1.0m unit (Unit 5A) was excavated; both units were placed approximately one metre behind the dripline (Marwick 2002b: 24). Excavation of Unit 4A continued until bedrock was exposed across the trench at a depth of 70cmbs, while excavation of Unit 5A ceased at 25cmbs (Marwick 2002b: 24). Three stratigraphic layers were identified: Layer 1 (0-27cmbs, homogeneous sediment with ash lenses and few rocks), Layer 2 (27-36cmbs, roof fall layer), and Layer 3 (36-70cmbs; homogenous sediment below roof fall layer; Marwick 2002a).

Four radiocarbon determinations are published for the site (Table 2-3). The chronology and distribution of artefacts in Unit 4B, suggests that the site was occupied as early as 19,750±460 BP. Marwick (2002a) rejects the date 719±57 BP for a roof fall event at the site, suggesting that the timing of this depositional event should be contemporaneous with a similar roof fall event at Marillana A Rockshelter that he believes occurred between 9000 BP and 13,000 BP. He also raises the possibility that the small charcoal sample may have migrated through the deposit. The charcoal sample for this radiocarbon determination was collected as a bulk sample from the sieved fine fraction (Marwick 2002a).

Marwick (2002a) analysed the assemblage from Unit 4B, from which there were a total of 1497 flaked stone artefacts. The overwhelming majority of the artefacts were classified as angular pieces (n=901; aka flaked piece or debris) and flake fragments (n=456), while only 120 complete flakes, four longitudinal flake fragments, and 16 transverse flake fragments were identified (Marwick 2002a). The artefact discard rates peak in Spits 8 and 9, which Marwick (2002b: 25) dates to approximately 14,150 BP and 18,750 BP. The patterns of raw material use shift over time, with coarser-grained materials (BIF and ironstone) more common in the upper two stratigraphic layers, transitioning to chert in SL3 (Marwick 2002a). The artefact discard rates drop dramatically between Spits 7 and 4, only increasing again in Spits 3 and 2 (Marwick 2002b: 25, Figure 5). Importantly, the cultural material from Milly's cave provides evidence of occupation in the inland Pilbara during the LGM (Marwick 2002b: 31); although, it should be noted that only 86 complete flakes were recovered in SL3 (Spits 8-13). The high proportion of angular pieces in the assemblage is of some concern, as there is the potential to misinterpret fragments of roof collapse as artefacts, particularly if the analyst was not involved in the original excavation and familiar with the deposit. Archae-aus Pty Ltd staff examined the assemblage from Milly's cave and have suggested that approximately 90% of the angular pieces are not artefacts but fragments of exfoliated bedrock, and they further questioned the identification of some of the flakes (Dias *et al.* 2007: 14).

Packsaddle Ridge - Coffee Table, Phantoms, Bastion, and Whispering Trees Rockshelters

Packsaddle Ridge is situated approximately 100km northwest of Newman. During an archaeological survey, conducted on behalf of the Main Roads Department for the alignment of the Perth to Darwin National Highway, four rockshelters were identified in the impact zone (Brown and Mulvaney 1983: 1). Two rockshelters, Coffee Table (DAA ID 8023, Site Number P04623) and Phantoms Rockshelter (DAA ID 8027, Site Number P04627), were recorded as archaeological sites, while rockshelters Bastion (DAA ID 7606, Site Number P05315) and Whispering Trees (DAA ID 7607, Site Number P05216) were identified as having PADs (Brown and Mulvaney 1983: 1). Whispering Trees, Coffee Table, and Bastion Rockshelters, are situated at the base of a large escarpment, with Phantoms Rockshelter located on the side of the gully to the southwest; these rockshelters formed within the Brockman Iron and Marra Mamba Iron Formations. Southwest of the rockshelters, the Packsaddle ridge transitions to an open plain where there is a permanent waterhole and the large intermittent Lake Gundawuna forms after heavy rains (Brown and Mulvaney 1983: 6).

A 1.0-x-1.0m test unit was opened at each rockshelter, with each unit situated behind the rockshelter dripline. Excavation was carried out in spits that varied in both size and depth, and features and stratigraphic units were excavated within the spits (Brown and Mulvaney 1983: 14). At each site, stratigraphic horizons were identified based on differences in colour and rock proportions. Excavation ceased at either bedrock or what was considered natural culturally sterile deposit (Brown and Mulvaney 1983: 14).

Phantoms Rockshelter is moderate-sized (11.6-x-4.7-x-2.6m), and its surface is covered by large and small fragments of exfoliated bedrock (Brown and Mulvaney 1983: 17). The results of the excavation and the analysis of the associated material are summarised from Brown and Mulvaney (1983: 17-34). Bedrock was exposed at depths ranging from approximately 20cmbs to 60cmbs, and four soil horizons were identified. Four features were identified during excavation, two of which were interpreted to be hearths. Dating to 260±60 BP (Beta 7213, *in situ* sample), Feature 2 was a small hearth located just below the surface. A small quartz flake and a burned material (possibly spinifex resin) were found in association with Feature 2. Feature 4 was a charcoal-rich lens identified at a depth of approximately 8cmbs and dated to 3061 to 2356 cal BP (2640±130 BP, Beta 7214, bulk sample). The remaining features include a cluster of stones, as well as a possible animal burrow. Artefacts were recovered up to a depth of 13cmbs, below Feature 4. Of the 63 flaked stone artefacts, the majority were produced on silicified rock (n=48), while quartz (n=12), ironstone (n=1), and other (n=2) raw material types were less common. Two backed artefacts were recovered from Spits 1 and 4. Because the backed artefact from Spit 4 is stratigraphically below Feature 4, it suggests that it was deposited over 3061 to 2356 years ago. Unburned bone fragments were recovered, but they could not be identified

because of their highly fragmented nature; however, macropod teeth were recovered.

Coffee Table Rockshelter is a moderate-sized (14.5-x-4.3-x-4m) rockshelter with a broad opening and a south aspect with no significant roof collapse (Brown and Mulvaney 1983: 35, 44). Two flakes, numerous fragments of wood, and six grindstones were noted on the rockshelter floor, including one specimen interpreted as being used as an anvil (Brown and Mulvaney 1983: 36). A 1.0-x-1.0m test unit was positioned near three surface grindstones; the results of the excavation are summarised here (Brown and Mulvaney 1983: 35-50). Like Phantoms Rockshelter, the deposit was predominantly comprised of exfoliated bedrock, with differences in colour and rock proportions leading to the definition of two stratigraphic horizons. Bedrock was not reached, but the excavation ceased at what the excavators considered to be a culturally sterile deposit, which had virtually no silt. Three features, charcoal lenses interpreted as hearths, were identified in the upper sediment horizon. Feature 1 dates to 130±50 BP (Beta 7211), and it overlies Feature 3 (770±50 BP, Beta 7217). Both dated charcoal samples were collected *in situ.* A total of 35 flaked stone artefacts was recovered from the deposit, and no artefacts were found below 17cmbs. A backed artefact was recovered from above Feature 3; hence, it was deposited subsequent to 770±50 BP. A blade adze was also reported; however, the illustration of this artefact suggests that it is a retouched flake fragment. Faunal remains include Golden Bandicoot (bone and teeth fragments), dingo (tooth fragment), macropod (teeth fragments), as well as several unidentifiable bone and tooth fragments. Brown and Mulvaney do not consider the faunal remains as being related to past human activity.

Bastion Rockshelter is located approximately 30m northeast of Coffee Table Rockshelter, and like the latter, Bastion is a relatively broad but shallow rockshelter (12.5-x-4.5-x-3.0m) with little significant roof collapse (Brown and Mulvaney 1983: 51). No cultural materials were identified on the surface of this rockshelter; however, the excavation demonstrates intermittent use of the site from 9277 to 8717 cal BP (Brown and Mulvaney 1983: 51-68). The results of the excavation are summarised below. Four stratigraphic layers were identified, and in Layer 1, disturbance relating to a white ant nest was noted. In contrast to the majority of the stratigraphic designations among the Packsaddle Ridge sites, SL3 was distinguished from overlying SL1 and SL2 on the basis of an increased proportion of charcoal, and numerous features were recorded in this layer. A new horizon, SL4, was identified once the excavators came upon the deposit they considered to be natural culturally sterile sediment, with a very high ratio of rock to silt. Excavation ceased within SL4 at a depth of 55cmbs; bedrock was not exposed.

Fourteen features were recorded at Bastion Rockshelter, including charcoal-rich features interpreted to be hearths (Features 1, 3, 4, 5, 6, 7, 8, 9, and 11), cooking pits (Features 12 and 14), and a post-hole (Feature 13). Interpretations were not offered for Features 2 or 10, which were described as charcoal-stained soil. Two charcoal samples were submitted for dating: a bulk sample from Feature 8 (2440±60 BP, Beta 7215) and a sample collected *in situ* from the top of Feature 12 (8090±80 BP, Beta 7216). The cooking pits are an intriguing find, and they appear to be differentiated from hearths on the basis of their depth. Feature 12 contained lenses of charcoal-rich sediment, underlain by patches of red and brown sediment with pale grey and white flecks, and found in association were twelve flakes and two macropod tooth fragments. Feature 14 is considered to be a smaller version of the cooking pit described as Feature 12. Brown and Mulvaney also identified a feature that they interpret as a post-hole (Feature 13), which was located within Feature 12 and therefore, it post-dates the use of the cooking pit. They suggest that the post-hole 'may have resulted from the construction of a 'lean-to' or brush wind break' (Brown and Mulvaney 1983: 56). An alternative explanation is that this circular reddish brown soil feature may be the result of bioturbation.

Despite the high amount of activity at Bastion Rockshelter that is suggested by the numerous features, only 31 flaked artefacts were recovered. Artefacts were recovered *in situ* between 12cmbs and 31cmbs, but the archaeological deposit is considered to continue down to 47cmbs, the depth of Feature 14. Brown and Mulvaney (1983: 57) note that most of these artefacts were recovered below Feature 8, including a backed artefact (trapezoid) immediately beneath Feature 8, suggesting that it was deposited some time before 2711 to 2352 cal BP.

Whispering Trees Rockshelter is the most westerly of the three rockshelters located on the escarpment above the gully head, and like Bastion, no artefacts were identified on the rockshelter floor (Brown and Mulvaney 1983: 69). The very broad but shallow rockshelter has low overhead clearance (34-x-6.5-x-2m), and there is no evidence of a significant roof fall event (Brown and Mulvaney 1983: 69). The results of the excavation are summarised from Brown and Mulvaney (1983: 69-74). Three stratigraphic horizons were distinguished based on textural and colour changes, and organics were found throughout the deposit. One feature, dating to 2330±50 BP (Beta 7217, bulk sample), was identified, and it consisted of a thick charcoal lens overlying reddened or burned sediment. Brown and Mulvaney suggest that this feature may have been used as a roasting or baking pit. Only one bone fragment and four stone artefacts were recovered from the excavation, and no archaeological materials were identified below 29cmbs. The reasoning for the cessation of the excavation is not discussed; however, it is assumed that the excavators felt that they had encountered culturally sterile deposits.

Brown and Mulvaney's (1983) research demonstrates intermittent use of the Packsaddle Ridge rockshelters, beginning 9300 to 8700 years ago. The excavation of Coffee Table, Bastion, and Whispering Trees did not terminate at bedrock, but in what was deemed culturally sterile sediment; therefore, it possible that older cultural material may have been present at these sites below the sterile layers, as has been demonstrated at nearby Djadjiling (Law *et al.* 2008). An important finding of the Packsaddle Ridge excavations is that deposition rates can differ significantly even within a very localised area, with charcoal samples dating to approximately 2500 BP recovered from depths ranging from 8cmbs to 21cmbs (Brown and Mulvaney 1983: 78). The analysis of the flaked stone assemblages demonstrates artefact sizes were small, with high incidences of facetted striking platforms; in addition, the research shows that backing technology was present in the region from 2440±80 BP to less than 260±50 BP (Brown and Mulvaney 1983: 79).

Brown and Mulvaney (1983: 81) note that prehistoric use of the Packsaddle Ridge area may have coincided with cyclonic events, which would have brought water to intermittent Lake Gundawuna, and they use ethnographic observations of land-use within the Packsaddle Ridge area to support this theory. Artefact discard rates vary among the sites, but they are generally low. Brown and Mulvaney (1983: 79-81) interpret the low proportions of artefacts as a reflection of intermittent use; furthermore, they suggest that low incidences of artefact edge damage and good hearth preservation indicates the sites were infrequently and irregularly used by small groups of people.

Manganese Gorge 2 (P07337, DAA ID 732)

In 1974, the Marandoo Mining Company contacted the Western Australian Museum for the purpose of identifying of Aboriginal sites on their mining lease (Palmer 1975: 1). A research officer from the Department of Aboriginal Sites at the museum conducted a survey of the lease in April 1975. The lease is approximately 40km east-northeast of Tom Price and five kilometres south of Mount Bruce (Palmer 1975: 1; Quartermaine 1994: 2). The mine is now operated by Hamersley Iron, a subsidiary of RTIO. Palmer (1975: 2) reports that artefacts were concentrated around the permanent water at Bandjima Pool, while both rockshelters and open artefact scatters were identified in Manganese Gorge. Fragments of baler and trumpet shell were found at both Bandjima Pool and Manganese Gorge, and sharpened sticks were found in rockshelters in Manganese Gorge (Palmer 1975: 2).

Surveys conducted in response to the application of a Section 18 permit for the project area identified Manganese Gorge 2 Rockshelter. Two 0.5-x-0.5m test pits were excavated at the site under the direction of P. Hughes (Quartermaine 1994). Quartermaine Consultants conducted further investigations of the site in the early 1990s.

The DAA register lists Manganese Gorge 2 Rockshelter as Site Number P07337 and DAA ID 732. The site is located on the west side of Manganese Gorge, approximately 2km southeast of the old Marandoo mining camp (Quartermaine 1994: 2, 15). Near the top of the ridge, the rockshelter opens towards the east and looks onto Mount Bruce and the surrounding plains (Quartermaine 1994: 2, 15). Unlike many rockshelters in the Pilbara, this site is very deep and relatively narrow with a moderate ceiling height (6.5-x-11.3-x-1.7m), and the entrance is obstructed by large blocks of roof collapse, which suggests that the rockshelter was larger in the past (Quartermaine 1994: 15, 2). Prior to excavation some of the roof collapse in front of the rockshelter was cleared by a backhoe to facilitate entry to the site (Quartermaine 1994: 17). Steel support pylons were also installed as an added safety measure due to the instability of the rockshelter (Quartermaine 1994: 15).

Quartermaine Consultants excavated a total of nine 1.0-x-1.0m units, which formed a T-shape through the site with five squares excavated along the east-west axis (B7-B11 with B7 at the near the front of the shelter), three squares excavated along the north-south axis (C10, D10, and E10), and one test unit (F7) was placed near the entrance of the shelter (Quartermaine 1994: 16). Square C10 incorporated one of the test pits excavated by Hughes, and the other Hughes test pit is located north of Square F7 (Quartermaine 1994: Figure 2). Bedrock was exposed across the trench, with depth being greatest in the centre of the rockshelter and reaching a maximum depth of 74cmbs (Square B8) (Quartermaine 1994: 16). The deposit was described as poorly-sorted and homogeneous consisting of rock (size ranging from gravel to cobble-sized), silt, sand, and clay, and Quartermaine (1994: 16) interprets the deposit as predominantly originating from weathering of the rockshelter; some termite bioturbation was noted and no cultural features were identified.

In addition to the three radiocarbon dates from the Hughes excavation, Quartermaine Consultants submitted a further three samples for dating (Quartermaine 1994: 17-19). Only four artefacts were recovered during the excavation including a grindstone on the surface of the rockshelter, a core in Spit 1 (Square D10), a flaked piece in Spit 2 (Square B8), and a flake in Spit 2 (Square C10) (Quartermaine 1994: 18). The artefacts recovered by Quartermaine Consultants are estimated to represent intermittent occupation of the site between 4190±130 BP and 6460±60 BP. There are no artefacts associated with the date of 13,460±90 BP, and likewise Quartermaine (1994: 2) notes that the Hughes report did not indicate if the samples submitted for radiocarbon dating were associated with cultural materials. Therefore, there is no evidence to suggest that there was a Pleistocene occupation of Manganese Gorge 2 Rockshelter, and it should not be considered in regional summaries of Pleistocene archaeology in the Pilbara (*e.g.*, Veth 1995; Morse 2009; Marwick 2002b).

There are reports that the rockshelter was disturbed subsequent to the initial test excavations. A newspaper article claimed 'The cave at Marandoo in Western Australia, where evidence has been found of occupation going back 18,000 years, has been vandalised by heavy equipment' (Anonymous 1992). It is reported that a drill rig drilled a hole through the rockshelter and into the deposit, a railway sleeper was wedged into a crack in the rockshelter roof, and the deposit in front of the rockshelter was disturbed (Anonymous 1992). This damage to the site is not mentioned in the Quartermaine report; however, the report includes site plans drawn by Hughes that include the position of the drill hole near the front of the rockshelter north of one of his test pits (Quartermaine 1994: Appendix 4).

It is important to point out that there is some confusion regarding the naming of the Manganese Gorge sites. Veth (1995: 736) refers to Manganese Gorge 2 Rockshelter as Manganese Gorge Rockshelter 8, and he cites four radiocarbon dates for the site including Wk-2474 (430±90 BP), which is from Site P0235. Veth's (1995: 736) confusion of the two site names has led to researchers to refer to the site as Manganese Gorge 8 (*e.g.*, Marwick 2002b; Slack *et al.* 2009) further compounding the problem. Quartermaine (1994) clearly identifies Site P07337 as Manganese Gorge Rockshelter 2 in his report on the continued investigations of the site.

Manganese Gorge 8

Palmer (1975) excavated a 1.0-x-1.0m test unit in one rockshelter; in the original report the site number is not listed, but Brown (1987: 22) lists the site as P0235 (DAA ID 11906, Manganese Gorge Complex). The excavation was conducted using arbitrary levels that ranged in depth between one and two centimetres; the excavation identified a hard-packed surface (9-10cmbs), and bedrock was exposed across the entire trench between 10 to 12cmbs (Palmer 1975: 3). A number of artefacts were found in association with the hard-packed surface including flakes, charcoal, and faunal remains (including a possible goanna mandible; Palmer 1975: 3).

As noted above, Manganese Gorge 8 should not be confused with Site P07337, which has been clearly identified as Manganese Gorge 2 Rockshelter by Quartermaine (1994).

Power Corridor 5 (DAA ID 17686)

Rockshelter site Power Corridor 5 (DAA ID 17686) is located approximately 1.5km east of Tom Price (Veitch 1992: 4). The medium-sized rockshelter (9-x-5m) has a sloping roof that is 1.6m high near the dripline that decreases to 0.5m for the majority of the rockshelter (Veitch 1992: 4). At the front of the shelter, there is a large block of roof collapse and a dry-stone wall, which appear to have protected the deposit (Veitch 1992: 4). A surface scatter of artefacts was observed both inside the rockshelter and immediately in front of the shelter (Veitch 1992: 4).

In February 1992, Veitch (1992: 5) supervised the excavation of a 0.5-x-0.5m test unit, which was placed behind the large block of roof collapse. A total of 19 arbitrary 2cm spits was excavated to an approximate depth of 50cmbs, but bedrock was not reached. Veitch (1992) recorded four stratigraphic layers, including a brown ashy matrix (*ca.* 0-5cmbs), grey ashy matrix with charcoal (*ca.* 5-12cmbs), orange sediment (*ca.* 12-33cmbs), and grey-brown dusty matrix (*ca.* 33-50cmbs). Numerous *in situ* charcoal samples were recovered from the excavation, and Veitch (1992) observed that artefact densities increased in the orange sediment layer, and burned bone was recovered in Spit 17. The recovered materials were later analysed by Greenfield (1992; cited in Morse 2009) resulting in the publication of three radiocarbon dates for the site (Table 2-3).

Channar Ranges Rockshelters - Yirra Rockshelter and Sites CME-A-18, CME-A-30, CME-A-31

The Channar Ranges are situated approximately 20km southeast of Paraburdoo. A series of rockshelters were excavated as part of a salvage program relating to the extension of the Channar mine, operated by Hamersley Iron. While numerous rockshelters have been identified in surveys in the project area, of particular interest are Sites CME-A-18, CME-A-30, and CME-A-31, which are described below.

CME-A-18 (DAA ID 16147) is a large rockshelter (24-x-27-x-5m) located on the east side of a steep hill, approximately 100m above the valley floor (Veitch *et al.* 2001: 17-18). At the time of recording, the site is situated near the boundary of the proposed pit extension, and the area above the site was disturbed by drill pads and access tracks (Veitch *et al.* 2001: 17). While the site was not excavated, it is notable because organic and flaked stone artefacts were recovered from the surface of the rockshelter. A 55cm-long probe was used to explore the extent of the sediment on the shelter floor, and the multiple tests suggested that the deposit was 12.5cm deep on average (Veitch *et al.* 2001: 18).

Numerous pieces of wood were scattered on the surface of the rockshelter including three wooden spear points and a straight shaft with a rounded end that appear to have been abandoned during an early stage of manufacture (Veitch *et al.* 2001: 18). Veitch *et al.* (2001: 18) also report that near the back of the rockshelter they found 'three large branches have been wedged upright between cracks in the large piece of roof fall' along with a several other smaller branches lying in the cracks next to the larger branches. A piece of modified resin was also identified, which had linear marks on the surface, which Veitch *et al.* (2005) suggest could be finger marks. A multi-platform core was also identified among the surface assemblage (Veitch *et al.* 2001: 17). A sample of the surface artefacts, including the spear points, a shaft fragment, and the multi-platform core, were collected at the request of the Traditional Owners so that the items could be curated and mounted in a display case (Veitch *et al.* 2001: 17).

Veitch *et al.* (2005) report that a spear point and spinifex resin ball were sent for radiometric dating; however, an earlier report indicates that the wood selected for dating was a burned piece of wood that was found at the back of the shelter (Veitch *et al.* 2001: 17). The age estimate for the spear point is 390±50 BP (515-315 cal BP, Wk-8002) overlaps with the date on the tree ladder from CME-A-30 (Veitch *et al.* 2005). A date of approximately 300 to 500 years for this surface artefact suggests that there was extremely slow sediment deposition in the site or some disturbance of the upper deposit; however, it is also possible that these artefacts were produced more recently. For example, wood inherently has an inbuilt age, and long-lived trees can add hundreds of years to a sample (for a discussion of the 'old wood' problem see Schiffer 1986). For example, mulga can live up to 250 years (Crisp 1978); in addition, mulga can stand dead for up to 75 years and the wood can persist for another 60 years after it has fallen (Sinclair 2004). While it is likely that the spear point was made on green wood, it is important to identify the type of wood so that the inbuilt age can be considered.

The age estimate of 1000±60 BP (1055-780 cal BP, Wk-8001) for the spinifex resin is intriguing. Considering that most rockshelters in the region show a few centimetres of deposition for each millennia (*e.g.*, Yirra Rockshelter and the Eastern Ranges rockshelters), it seems unusual that an object of this antiquity would not be buried under several centimetres of sediment. It is possible that the resin may have been found at another archaeological site, transported to CME-A-18, and then re-deposited, or there may have been some disturbance to the deposit that revealed this artefact. A third possibility is that the old spinifex resin was used.

Ethnographic observations suggest that spinifex resin was produced using two methods. Resin may be produced by manually processing the spinifex, which involves threshing the spinifex to produce a dust, cleaning it, heating the dust, and moulding it into a ball (Binford 1984). Dating resin produced by this method would provide an accurate date, as there would be virtually no in-built age within the resin. Pre-processed spinifex resin can also be collected from termite mounds, and this can lead to problems with radiocarbon dating; however, research suggests that this practice is a recent phenomenon that may be restricted to post-contact periods (Pitman 2010: 89-91). Because termite mounds can be used for long periods of time, there is a chance that old resin may be collected, and this would affect the age estimate. There is little research on the longevity of termite mounds in Australia. Observation of a termite mound in the Northern Territory indicates that it was active for at least 65 years; when first observed in 1872, the mound was over four metres high (Watson 1972). In South Africa, active termite mounds have been dated to 4000 years old, but it is unclear how long organic material persists in the mound, as it is eventually replaced by carbonates (Moore and Picker 1991). Dating of pre-processed spinifex resin is complicated further by the possibility that termite use and rebuilding contaminates old carbon with modern carbon. Radiometric dates on surface spinifex resin should be viewed cautiously unless it can be determined whether the resin was processed manually (typically high-quality resin with few impurities) or incorporated resin from termite mounds (lower-quality with numerous impurities).

CME-A-30 is a double-chambered rockshelter that is situated on a ridge overlooking a valley. The larger chamber measures 9.5m wide, 20m deep, and 2.2m high at the dripline, with the height increasing to 5m towards the back of the shelter; the second chamber is smaller (maximum dimensions: 6-x-16-x-4m). In November 2000, the site was subject to test excavation, where two 0.5-x-0.5m units were excavated to bedrock, but did not yield archaeological remains (Dias *et al.* 2007: 26, 36). Like Site CME-A-18, an organic artefact was also identified on the surface of Rockshelter CME-A-30 (DIA ID 17719; Veitch *et al.* 2005: 58). The artefact, interpreted to be a tree ladder, is a dead tree trunk that has had its branches removed, and it was found positioned close to two niches in the rockshelter, which are approximately 1.5m above the surface (Veitch *et al.* 2005: 58). Hook and Martin (2000: 27) note that the niches would have been inaccessible without the aid of the tree ladder; however, they were found to be empty upon inspection. A sample of

wood from the tree ladder was submitted for radiocarbon dating, yielding an age estimate of 440±70 BP (Wk-8955; Veitch *et al.* 2005: 58), and as noted above, this date overlaps with the age estimate for the wooden artefact found in Rockshelter CME-A-18. The age estimate of the tree ladder should be viewed cautiously in light of the 'old wood' problem, particularly as the wood was identified as being a type of *Acacia*. It is not clear if the researchers were able to determine if the branches were removed from the tree while it was still green, or whether the branches were removed from older, dried-out wood. As this artefact was not lying on the rockshelter floor, it is possible that it remained standing for a long period of time.

Site CME-A-31 or Yirra Rockshelter (DAA ID 17720) is situated on the north side of a narrow gully that opens into a large riverbed in the Channar Ranges (Veitch *et al.* 2005: 58). A multi-platform core was identified on the surface of moderate-sized rockshelter (12.5-x-6m), which has a southwest aspect and measures 2.8m high at the dripline (Dias *et al.* 2007: 40). In November 2000, a 1.0-x-1.0m test unit was excavated to bedrock (79cmbs), revealing a series of hearth features and burned plant remains (Veitch *et al.* 2005: 58; Dias *et al.* 2007: 40). Excavation was carried out using both the natural stratigraphy as well as arbitrary spits of approximately 4cm (Dias *et al.* 2007: 41), and the results are summarised below.

Two stratigraphic layers were identified in the deposit. SL1 extended from 48cmbs to 54cmbs and consisted largely of degrading exfoliated BIF fragments which transitioned in colour from yellowish red to brown (Dias *et al.* 2007: 41). SL2 consisted of a gravely deposit comprised of red silty sediment and degrading exfoliated BIF (Dias *et al.* 2007: 41). The quantity of fine silty sediment decreased with depth with a concomitant increase in the proportion of large rock and gravel (Dias *et al.* 2007: 42). Six hearths (charcoal concentrations) were identified in the upper 56cm of the deposit (Dias *et al.* 2007: 43); however, no clear description of each feature is provided.

Nine samples were submitted for radiometric dating, and they provide a sequence of occupation ranging from approximately 1300 BP to 19,000 BP. It is reported that all but one of the samples were collected *in situ*; however, several samples show depth ranges varying up to five centimetres (see Table 2-3), and the broad depth range for these samples suggests that they were collected as bulk samples. In addition, one sample (Wk-12536) was collected from the sieve, and it yielded an erroneous date. Veitch *et al.* (2005) attribute the erroneous age as the result of bioturbation, but it is possible that there was contamination of more recent charcoal within the sieves. Charcoal recovered from a depth of 43.1cmbs yielded a date of 16,950±94 BP, while another sample collected from 55.80cmbs dated to 19,270±140 BP (Veitch *et al.* 2005: 58). A concentration of artefacts and charcoal (43.13-51.50cmbs), is interpreted as demonstrating a period of intense occupation at Yirra Rockshelter during the LGM (Veitch *et al.* 2005: 58). The age-depth curve suggests that the rate of sediment deposition varied over time. There are moderate deposition rates from the onset of deposition until 16,950±94 BP, but the rate of deposition subsequently slows significantly until 3702±56 BP, after which there appears to have been rapid deposition. The close spatial relationship of the charcoal samples yielding the age estimates of 10,628±74 BP (Spit 6) and 3702±56 BP (Spit 5) led Dias *et al.* (2007: 53) to conclude that there was 'negligible sedimentation during this time'; however, it is possible that the nature of the depth curve may be skewed by the method of charcoal collection (collecting from large depth ranges).

In total, 176 flaked stone artefacts were recovered from CME-A-31, including 72 flakes and 60 flake fragments. Dias *et al.* note that (2007: 45) for analytical purposes, SL1 was divided into two analytical units, AU1 (excavation Spits 1-5, 1307±40 BP to 3702±56 BP) and AU2 (excavation Spits 6-9, 10,628±74 BP to 17,169±114 BP), while SL2 comprised AU3 (excavation Spits 10-16, 18,950±235 BP and older).

The number of complete flakes in the three analytical units indicates that discard rate is slightly higher in AU2 (n=33), while it is slightly lower in AU3 (n=20) and AU1 (n=16), and this pattern is even more clear among the broken flakes (AU1, n=9; AU2, n=36, AU3, n=15) (Dias *et al.* 2007: 46-48). The raw materials used throughout the occupation remain relatively constant and demonstrate the knappers' preference for locally available ironstone; although, finer-grained raw materials were also used (chalcedony, chert, quartz, and mudstone) in much lesser quantities (Dias *et al.* 2007: 48). Retouched artefacts were rare in the assemblage, and no formal tool technologies were present in the assemblage apart from a backed artefact fragment identified in Spit 2 (Dias *et al.* 2007: 47, 50). While only a limited assemblage of cultural material was recovered from CME-A-31, it is an important site in that it demonstrates the pattern of repeated intermittent Aboriginal occupation in the inland Pilbara during the Pleistocene and through the LGM.

Eastern Ranges Rockshelters ERP-04, ERP-11B(ii), ERP-15, ERP-22, ERP-26

The Hamersley Iron Eastern Range mine is located approximately ten kilometres southeast of Paraburdoo and is situated between the Channar mine and Paraburdoo. Eleven archaeological sites were salvaged for the development of the mine during two field trips in 1998 (18 March to 1 April and 13 May to 24 May), and while two of the sites did not contain archaeological material, buried cultural remains were identified at the remaining nine sites (Hook *et al.* 1998: 1). Two of the sites, ERP11B(ii) and ERP-26, were assessed as having high levels of archaeological significance due to their large assemblages of flaked stone artefacts. Radiocarbon determinations are available for five of the Eastern Ranges rockshelters, including ERP-04, ERP-11B(ii), ERP-15, ERP-22, and ERP-26; the results of the excavations from these five sites are summarised in the following paragraphs.

ERP-04 (DAA ID 16890) is a small rockshelter (5-x-2-x-2.5m) with a northeast aspect; the site is situated on the southwest side of a gully approximately 5m above the gully floor (Hook *et al.* 1998: 32). A 0.5-x-0.5m test unit was opened and excavation terminated at bedrock at 18.6cmbs and the results of the excavation will be summarised briefly (Hook *et al.* 1998: 32-35). Four flaked stone artefacts were recovered from the excavation, and all artefacts were found at the same level or above a charcoal lens interpreted to be a hearth. A charcoal sample from the hearth yielded an age estimate of 2000±50 BP, indicating a late Holocene occupation of the site. A small surface assemblage of artefacts was also recovered, including nine artefacts and a grindstone.

Site ERP-11B(ii) (DAA ID 16895) is a large rockshelter that is located within close proximity to two other rockshelters, ERP-11A and ERP-11B(i), all of which are situated near the base of a small gully (Hook *et al.* 1998: 39). Test pits were excavated at all three sites; however, no cultural material was found at ERP-11B(i) and only one small flake was recovered from ERP-11A.

ERP-11B(ii) is located on the north side of the gully, 12m east of ERP-11B(i); this large rockshelter (14-x-5-x-3.5m) has a south aspect (Hook *et al.* 1998: 40-41). Just east of the rockshelter, a surface scatter of 61 artefacts was recovered,

including flakes (n=28), debitage (n=19), flake fragments (n=6), broken flakes (n=3), a backed artefact, a core fragment, a multi-platform core, a retouched piece, and a manuport (Hook *et al.* 1998: 41). Two adjacent 0.5-x-0.5m test units (Test Pits 2 and 3) were opened at ERP-11B(ii) and excavation ceased when bedrock was exposed, which was on average 20.1cmbs in Test Pit 2 and 16.6cmbs in Test Pit 3 (Hook *et al.* 1998: 44). A total of 102 flaked stone artefacts were recovered from the shallow deposit, including artefacts from both the coarse and fine sieve fraction (Hook *et al.* 1998: 4). While no archaeological features were identified, two charcoal samples yielded dates of 350±50 BP (Wk-6322, 4cmbs) and 370±50 BP (Wk-6326, 6cmbs), indicating a recent occupation. It is possible that the location of the rockshelter, low in the gully, has meant that it has been subject to scouring during periods of intense rain events, removing traces of earlier occupation. Hook *et al.* (1998: 48) recommended further excavation of the site due to the high density of artefacts; however, this report is currently unavailable to the authors.

ERP-15 (DAA ID 16892) is a medium-sized rockshelter (8.5-x-5-x-3m) that is located on the west side of a steeply sided gully (Hook *et al.* 1998: 61). Two manuports and four flakes were observed on the surface of the rockshelter. Two 0.5-x-0.5m test units were excavated, reaching bedrock at 15.8cmbs and 19.3cmbs (Hook *et al.* 1998: 62). A white chalky layer was identified in Test Pit 1, and Hook *et al.* (1998: 64) tentatively suggest that it could be a cultural feature or mineral salts. Scattered charcoal was present throughout the deposit, but no concentrations were identified (Hook *et al.* 1998: 62). A charcoal sample recovered *in situ* from Spit 1 yielded an age estimate of 950±50 BP (Wk-6323). A total of 15 artefacts were recovered from the excavation, and while the majority of the artefacts were recovered from the upper three spits, all three of the flakes found in the 3mm sieve fraction were from the lower three spits in Test Pit 2, suggesting some disturbance to the deposit (Hook *et al.* 1998: 62). Hook *et al.* (1998: 63) note that macropod scat was present throughout the entire deposit and makes the important point that macropods can significantly affect site preservation.

Site ERP-22 (DAA ID 16894) is a small rockshelter (4.6-x-4.3-x-2m) with a west aspect and is located near the base of a valley. When the site was initially recorded, no artefacts were identified on the surface of this rockshelter; although, a hearth was recorded in the northwest side of the shelter (Hook *et al.* 1998: 72). Three 0.5-x-0.5m test units were opened to determine if cultural materials were present in the deposit, but no artefacts were identified. One hearth feature was noted in the upper layers of Unit 1, from which an *in situ* charcoal sample was collected at a depth of 7.5cmbs (Hook *et al.* 1998: 72). The sample yielded an age estimate of 560±50 BP (Wk-6324), suggesting a very brief late Holocene visit to the rockshelter.

ERP-26 (DAA ID 16900) is a medium-sized rockshelter (13-x-4-x-2.4m) that lies low within a small gully (Veitch *et al.* 2005) (Hook *et al.* 1998: 104). On the surface of the rockshelter deposit, a quartzite muller and two possible anvils were identified (Hook *et al.* 1998: 104). While the site was approximately 70m outside the impact area of the mine, the Traditional Owners requested further investigation of the site and test excavations were carried out in in March 1998 to determine if sub-surface archaeological remains were present at ERP-26 (Hook *et al.* 1998: 104).

A 0.5-x-0.5m test unit was opened, and excavation ceased at 24cmbs when numerous flaked stone artefacts and a hearth were revealed (Hook *et al.* 1998: 104). The team did not continue excavating until bedrock was exposed because the identification of artefacts and a feature were deemed sufficient to 'evaluate the archaeological potential of the site' as per the Section 16 permit (Hook *et al.* 1998: 104). In total, 28 flaked stone artefacts were recovered throughout the extent of the deposit. A charcoal sample was collected *in situ* from the hearth at a depth of 10cmbs, and it yielded an age estimate of 1840±50 BP (Hook *et al.* 1998: 105). On advice from the archaeological consultants, Hamersley Iron has 'undertaken to avoid this site'; however, further excavations at the site were undertaken in October 2002 upon request from the Traditional Owners (Veitch *et al.* 2005). The excavation area was expanded, revealing a hearth and flaked stone artefacts; excavation terminated at 65cmbs when bedrock was exposed (Veitch *et al.* 2005).

BM99-10 Rockshelter

In 1999, Archae-aus Pty Ltd conducted excavations at five rockshelters in the Pit 4 and Pit 6 extension areas of Rio Tinto's Brockman mine (Veitch and Di Lello 2000), which is located approximately 60km northwest of Tom Price. Out of the five rockshelters tested, only Rockshelter MB99-10 yielded any significant amount of cultural material; together, only 13 artefacts were recovered from the coarse and fine fraction from Rockshelters BM99-01 (3 artefacts), BM99-03 (no artefacts), BM99-04 (4 artefacts), and BM99-95 (6 artefacts; Veitch and Di Lello 2000: 48).

Site BM99-10 (DAA ID 16916) is a small southwest facing rockshelter located in a steep-sided valley on the east side of the extension area of Pit 4 and Pit 6 (Veitch and Di Lello 2000: 39; Veitch *et al.* 2005). The rockshelter measures approximately 4m long and 7m wide, and it is 2.9m high at the dripline. The site is in close proximity to artefact scatter BM99-11, which is below the site.

A 1.0-x-0.5m test unit was placed near the centre of the rockshelter over what was initially recorded as a hearth feature, but later determined to be a natural calcium carbonate deposit (Veitch and Di Lello 2000: 40). While the maximum depth below surface was not reported, two spits were excavated yielding significant quantities of charcoal (interpreted to be a hearth feature) and 138 flaked stone artefacts including 87 artefacts from the fine sieve fraction (Veitch and Di Lello 2000: 41). The flaked stone artefact assemblage includes complete flakes, flake fragments, and debris (flaked pieces), which were produced primarily on ironstone (Veitch and Di Lello 2000: 41). One geometric microlith was recovered from Spit 1, and spinifex resin was recovered from the rockshelter ground surface (Veitch and Di Lello 2000: 40-41).

A sample of charcoal recovered from the hearth feature in Spit 1 was sent for radiometric dating, and it was determined to be 470±50 BP (Veitch and Di Lello 2000: 41). A sample of spinifex resin was sent for radiometric dating, resulting in an age estimate of 540±50 BP (Veitch and Di Lello 2000: 41). As discussed in relation to CME-A-18, dating spinifex resin may be problematic due to the potential use of old resin. While the radiocarbon date for the spinifex is older than that of the charcoal, the dates overlap and there is no statistical difference between them.

Veitch and Di Lello (2000: 43) cautiously suggest that the recent occupation of this site may support the theory of population growth during the late Holocene. No further excavation was recommended for the site prior to the extension of Pit 4 and Pit 6 of the Brockman mine.

Brockman 4 Mine - Juukan-1 and Juukan 2 Rockshelters

In 2008, Scarp Archaeology Pty Ltd test excavated Juukan-1 and Juukan-2 rockshelters, located in the central Hamersley Plateau, approximately 75km north of the Ashburton River. The excavations were conducted on behalf of RTIO in preparation for their proposed developments on the Brockman 4 mining tenement. The field results indicate that Juukan-1 and Juukan-2 rockshelters contain significant Pleistocene-age archaeological deposits that predate the LGM. These sites also provide evidence that a resident Aboriginal population occupied the Hamersley Plateau throughout the LGM.

Juukan-1 is a large, south-facing rockshelter that measures 25m wide, 8m deep, and 10m high (Slack *et al.* 2009: 34). Based on these measurements, the floor area of the rockshelter is estimated to be around 200m^2. At the time of recording, artefacts were observed in front of the site, particularly on the west end of the rockshelter (Slack *et al.* 2009: 34). The floor of the rockshelter slopes gradually from the rear of the rockshelter to the entrance. A single, 1.0-x-1.0m test pit was excavated at the east end of the rockshelter, reaching bedrock at a depth of 75cmbs. Three prominent soil horizons were observed during excavation. The upper horizon consists of loose topsoil less than 10cm thick. Beneath this upper layer is brown/grey horizon of compacted sediment with many organic finds (Slack *et al.* 2009). Based on the section drawing, this horizon terminates around 60 to 65cmbs. The lower horizon overlies bedrock, and it is an orange-brown colour.

Radiocarbon determinations from Juukan-1 indicate that the site has an archaeological sequence spanning the past 37,000 to 38,000 years. An age estimate of 32,950±270 BP (Beta-249759; 38,374-36,931 cal BP) was derived from a piece of charcoal buried 60cmbs (Slack *et al.* 2009: 34). A mid-sequence date of 26,640±160 BP (Beta-249758) was obtained above a hearth buried 35cmbs (Slack *et al.* 2009: 34). In the upper deposit, a hearth buried approximately 5 to 10cm below the surface was dated to 760±40 BP (Beta-249757) (Slack *et al.* 2009: 34).

The Juukan 1 excavations recovered 32 flaked stone artefacts, with the majority of the artefacts recovered from the upper 10cm of deposit (analysis is underway, so artefact numbers by spit are not reported in, Slack *et al.* 2009: 34). One artefact was recovered beneath the date of 32,950 BP (Slack *et al.* 2009: 34). Only isolated occurrences of artefacts are reported to occur in the lower layers of the site.

Bone is moderately well-preserved in the Juukan-1 sequence. Sixty-seven bone fragments were recovered from the sequence, and 57 of the fragments exhibited identifiable skeletal elements. The distribution of bone is sparse throughout the sequence, with the exception of Spit 12 (55-60cmbs) which contained close to 50% of the recovered bone (Slack *et al.* 2009: 34). Interestingly, these bone fragments are associated with the earliest radiocarbon determination from the site. Species identified a Juukan-1 include bandicoot, kangaroo, wallaroo, native mouse, rat, and one fish fragment (Slack *et al.* 2009: 34).

Analysis of the bone suggests that the assemblage is *in situ*, and the bone has been rapidly buried (Slack *et al.* 2009: 35). Nine bone fragments are burned and the frequency of long bone fragmentation is high. Due to an absence of gnaw marks, Slack *et al.* (2009: 35) suggest that the assemblage was formed by humans.

Juukan-2 rockshelter is located 50m west of Juukan-1. The site consists of two large, south-facing chambers. The west chamber is largest, measuring 10m wide, 10m deep, and 8m high (Slack *et al.* 2009: 35). It also contains a considerable amount of very deep sediment. The east chamber encompasses a smaller area, and bare rock is exposed across most of its floor surface.

A 1.0-x-1.0m test pit was placed in the central floor of the west Juukan-2 chamber. The excavations at Juukan-2 were terminated at 105cmbs at large roof fall, which prevented further excavation. Five stratigraphic horizons were observed in the unit wall section, and at least five hearths were noted (Slack *et al.* 2009: 35). A sizeable assemblage of flaked stone artefacts and faunal remains were also recovered from the sequence.

A radiocarbon determination from charcoal buried 85cmbs (Beta-247332) delivered a result of 20,090±100 BP (Beta-247332). An estimate of 16,160±80 BP (Beta-247331) was obtained on charcoal buried near 55cmbs (Morse 2009: 5; Slack *et al.* 2009: 35). Overlying this date, a radiocarbon determination of 470±40 (Beta-247330) was acquired at 10cmbs (Morse 2009: 5; Slack *et al.* 2009: 35). These age-estimates are in good chronological agreement, and archaeological materials recovered below the lowermost date suggest that initial site occupation is much older than 24,400 to 23,700 cal BP. Slack *et al.* (2009) approximate that at least 50cm of unexcavated sediment remains in the rockshelter, and they plan to expand the excavations in the future.

The Juukan-2 excavation team recovered an assemblage of 272 flaked stone artefacts (Slack *et al.* 2009: 35). Artefacts are present in all excavated spits, with the exception of Spit 16 (75-80cmbs) where no materials were recovered. Artefact discard rates and artefact density are low at the site, with generally less than 15 per spit prior to Spit 4, which Slack *et al.* (2009: 35, 37) suggest to be around 5000 BP based on a depth/age curve. After Spit 4, artefact discard increases by more than 400% during the late Holocene site occupation (Slack *et al.* 2009: 35,37).

Artefact analysis shows that the dominant raw materials used are chert (55.9%), quartz (29%), ironstone (13.6%), chalcedony (1.1%), and siltstone (0.4%) (Slack *et al.* 2009: 35). Chert, quartz, and ironstone appear to be utilised fairly evenly prior to 5000 BP, but after this time there is a reorganisation of raw material use, with chert and quartz comprising the bulk of the mid-Holocene and late Holocene assemblage.

Retouched flakes are present in the assemblage in Spit 14, estimated to date to 19,000 BP (Slack *et al.* 2009: 35-36). Slack *et al.* (2009: 36) also observe a peak in retouching activities and the corresponding appearance of backing technology in Spit 5, which they estimate to be 7000 BP. It is important to note that no radiocarbon determinations were obtained from Spit 5 and this age is merely a depth/age estimate based on the available radiocarbon dates. Future radiocarbon determinations and research will undoubtedly clarify the appearance of backed artefacts at Juukan-2.

The bone assemblage recovered from Juukan-2 consists of 857 fragments (Slack *et al.* 2009: 36). There are a wide-range of species represented in the assemblage, including red kangaroo, common wallaroo, bandicoot, possum, pygmy possum, echidna, bettong, native mouse, native rat, gecko, skink, bird, and fish. Smaller species (*e.g.*, native rodents and herpetofauna) comprise 61% of the bone assemblage, and medium to large-sized macropods (*e.g.*, kangaroos and wallabies) make up 30% of the identified species (Slack *et al.* 2009: 36). Bird and fish together represent only 9% of the bone material.

Bone analysis suggests that 7% of the Juukan-2 assemblage exhibits evidence of burning (Slack *et al.* 2009: 36). Tooth marks are observable on five specimens, and possible cut marks were noted on five specimens from Spit 15, which rests between the radiocarbon determinations of 20,000 and 16,000 BP (Slack *et al.* 2009: 36).

Mesa J Orebody, J23 and J24 Rockshelters

Mesa J is one of several iron ore deposits along the Robe River, at the western end of the Hamersley Plateau. Throughout 1991 and 1992, Hughes and Quartermaine (1992) test excavated twenty rockshelters in Robe River Iron Associates' Mesa J lease. RTIO currently has a 53% operating interest in Robe River Iron Associates. Seven rockshelters did not contain any cultural materials and nine rockshelters contained deposits with less than six artefacts per assemblage (Hughes and Quartermaine 1992: 69). Four rockshelters contained reasonable-sized assemblages, including Site J17 (26 artefacts), J22 (70 artefacts), J23 (301 artefacts), and J24 (226 artefacts; Hughes and Quartermaine 1992: 69). Based on their field observations, Hughes and Quartermaine (1992: 69) assessed that Rockshelter Sites J23 and J24 contained the most archeologically informative deposits and warranted further analysis.

Mesa J23 (P06696, DAA ID 6276) was originally assessed by the investigators as potentially having the most informative archaeological materials (Hughes and Quartermaine 1992: 79). The rockshelter is sizable, with maximum dimensions measuring approximately 9m wide, 10m deep, and 2.5m high, with the deposit being relatively flat. An ephemeral rockhole is adjacent to the rockshelter, capable of holding water for several weeks after a rain. A substantial assemblage of chipped stone artefacts (n=21) were recorded on the ground surface (Hughes and Quartermaine 1992: 79).

Two 0.5-x-0.5 test units (B2 and D4) were opened in the rockshelter in order to test the deposit in different areas of the rockshelter (Hughes and Quartermaine 1992: 79). Unit D4 was placed at the rear of the shelter where the deposit was steeply sloping, and six artefacts were recovered from this trench. Unit B2 was opened near the front of the rockshelter and was extended to a 1.0-x-1.0m unit after excavating through one metre of sediment without reaching bedrock (Hughes and Quartermaine 1992: 79). Excavation of the 1.0-x-1.0m unit terminated at bedrock, with a depth of 148cmbs (Hughes and Quartermaine 1992: 79).

Three charcoal samples were submitted for radiometric dating (see Table 2-3), and the results were reported in the original consulting report (Hughes and Quartermaine 1992: 85), as well as more recently in an article on Sites J23 and J24 (Hughes *et al.* 2011: 59). The two datasets provide conflicting data regarding the spit numbers for the charcoal samples; the 1992 report states that the samples were collected from Spits 3, 4, and 5, while the 2011 article reports that they were collected from Spits 2 through 4. The recent report rectifies an error in the original consulting report (P. Hughes 2012, pers. com., 13 Jan.); thus, the provenance data reported in Hughes *et al.* (2011: 59) is used below.

The deepest radiocarbon date from the site was collected from between 20 to 25cmbs (Spit 4) and is estimated to be 2230±160 BP (Hughes and Quartermaine 1992: 85; Hughes *et al.* 2011: 59). A single lens of dark grey ash was observed at 45cmbs, but no dateable material was processed from this feature. Although no basal date could be determined, Hughes and Quartermaine (1992: 86; Hughes *et al.* 2011: 60) estimate that initial occupation is at least early Holocene in age, but due to the considerable depth of sediment accumulated below the late Holocene layers, it is likely that the site was first used during the late Pleistocene.

A total of 295 artefacts was recovered from the excavation of the 1.0-x-1.0m unit, and more than half (58%) of the artefact assemblage occurs in the top 25cm of deposit (Hughes and Quartermaine 1992: 85). Beneath 25cmbs, artefacts are lightly distributed to bedrock, with the exception of Spit 12, which has no artefacts (Hughes and Quartermaine 1992: 86). Artefact density is the greatest in Spit 3, which dates to 650±190 BP. One diagnostic artefact, a tula, was recovered in Spit 4 (2230±160 BP or 2240±212 cal BP), making this one of the earliest dated tulas in the Hamersley Range. Sizable amounts of charcoal and organics were restricted to the upper portion of the excavation. Sixteen bone fragments from the site resulted in the positive identification of bandicoot, lizard, and large macropod species.

Mesa J24 (P06697, DAA ID 6277) is a medium-sized rockshelter across the gully from Mesa J23, and near the gully floor. The maximum rockshelter dimensions are approximately 6m wide, 6m deep, and 3m high; although, the roof height drops considerably approximately four metres beyond the dripline (Hughes and Quartermaine 1992: 90). The rockshelter is fairly enclosed and cave-like, with a 3.5m wide natural opening. Although Sites J23 and J24 are near to each other, the pattern of occupation at Site J24 is very different to Site J23. Excavations at Site J24 began with a 0.5-x-0.5m unit, but they were expanded to a 1.0-x-1.0m after reaching 60cmbs without exposing bedrock (Hughes and Quartermaine 1992: 91). The excavations were terminated at bedrock, roughly 75cmbs.

Three samples were selected for dating from *in situ* charcoal. It is estimated that the age of Spit 3 is 1400±60 BP, and Spit 9 dates to the late Pleistocene 23,500±350 BP (Hughes and Quartermaine 1992: 91; Hughes *et al.* 2011: 59). Between these dates, there is a 'trough' in artefact discard, with very little associated organic material. The 'trough' is estimated to be 3950±110 BP (Hughes and Quartermaine 1992: 91). The age-depth sequence of the three dates from Site J24 suggests anomalies, particularly between Spit 5 and Spit 9. The large age gap between these samples may suggest extremely low sedimentation between approximately 4000 BP and 23,500 BP. Alternatively, the deposit may have been exposed to erosion prior to 4000 BP, which could have scoured and removed part of the deposit; however, the excavation report does not mention an erosional unconformity.

A total of 225 artefacts was recovered from the excavations (Hughes and Quartermaine 1992: 91). Artefact densities are the greatest in two layers with high ash and charcoal concentrations in Spit 3 and between Spits 8 and 9 (Hughes and Quartermaine 1992: 91, 97). The artefact assemblage includes flakes (n=88, including blades and flake fragments), cores (n=9), grindstones (n=11), manuports (n=6), and a high proportion of flaked pieces (n=90) and chips (n=21) (Hughes and Quartermaine 1992: 95). Interestingly, 36 bone fragments were recovered during the excavation of Site J24, and 77% (n=28) of the bone is associated with the Spit 9 late Pleistocene age determination. The bone was identified as belonging to the Western Chestnut Mouse (*Pseudomys nanus*) (Hughes and Quartermaine 1992: 94), but the report does not indicate if there is any anthropogenic modification of the bone (*e.g.,* burning, cut marks, *etc.*). It is suspected that late Pleistocene bone and charcoal preservation is good at Site J24 because the deposit has

remained dry throughout its history, even at times of heavy rain (Hughes and Quartermaine 1992: 97).

Hughes and Quartermaine (1992: 97) demonstrate the general pattern of artefact discard between Sites J23 and J24 is an inverse relationship. Rockshelter Site J24 shows a pattern of high artefact discard in the late Pleistocene, with 143 artefacts discarded in Spits 7 through Spit 10 (Hughes and Quartermaine 1992: 97). In both shelters, there is an increase in artefact discard around 1500 to 500 BP (Hughes and Quartermaine 1992: 97); however, at Site J24 the late Holocene increase is less pronounced than the Pleistocene discard increase at approximately 23,500 BP. Fine-grained siliceous sediments (*e.g.*, chert, non-banded BIF, *etc.*) and dolerite are the predominant raw materials used for artefact manufacture at both locales.

Hughes and Quartermaine (1992), suggest that their excavations confirm that there is sparse or intermittent occupation of the rockshelter throughout the late Pleistocene and LGM. Artefact density seems to be the lowest during the early Holocene, and then significantly increasing from the mid-Holocene onward. Marwick (2002b: 24) offers a different interpretation, suggesting that the small numbers of artefacts discarded between 23,500 and 4000 BP make any proposals of continuous site use tenuous. He suggests that there may have been very little activity at the site during this time.

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Chapter 3

Banjima Culture and the Hope Downs 1 Mine

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The Hamersley Plateau is the home of numerous Aboriginal groups, each with distinctive customs and cultural traditions. Aboriginal peoples have occupied the region for millennia, and the current custodians of the land have inherited from their ancestors a rich and complex knowledge of the land and a dynamic system of law and culture. This chapter provides anthropological context to the Aboriginal cultures of the Hope Downs 1 area, and briefly summarises the history, customs, and mythological traditions of the local Aboriginal peoples.

3.1 ABORIGINAL TRADITIONAL OWNER GROUPS OF THE HOPE DOWNS 1 MINE AREA

The Hope Downs 1 mine encompasses a large area that includes the traditional lands of several Aboriginal groups. The majority of the Hope Downs 1 mine area is within the traditional lands of the Martidja Banyjima (MIB) people, who have joined with the Innawonga Bunjima (IB) people to form the Banjima People Native Title Group (Figure 3-1). In August of 2013, native title was determined for this combined group over the area shown in Figure 3-1 (Federal Court file no. WAD6096/1998). The mine area overlaps into two neighbouring native title claims by the Nyiyaparli people (Federal Court file nos WAD 6280/1998 and WAD196/2013).

Although some of these groups have distinct languages, there is believed to have been a high level of association between the groups before European colonisation, and these associations continue today (Brehaut and Vitenbergs 2001; Day 2005: 1). Barber (1996; cited in Day 2005: 1), wrote that in particular there is evidence of a long history of intermarriage, co-habitation and shared camping and ceremony between the MIB and IB, and the neighbouring Gurama. A Banjima man (since deceased) spoke about these continued interactions:

> From Mulga Downs and the Fortescue flats wherever, coming up to meet the people from, meet the Innawonga people, Top End Banyjima, Gurama people, like that. Meet all the people like, like people go on a holiday, holiday camp and meet up there. And that a special time, do special things whatever, corroborees, anything there... Yeah. Well it doesn't matter when the culture start, when the culture start it belong to every group. Doesn't matter what group you come from, in that culture camp you all in one... It still happen today, when a meeting start, doesn't matter what tribe you come from, you in one, once you're at the meeting camp. (Carey 2007: 9)

The Banjima and Nyiyaparli also have close associations, and share a boundary area along Weeli Wolli Creek, which runs near and is affected by the Hope Downs 1 mine. Within this area, interests and resources are shared and require joint consultation and management (Parker and Parker 2007; Day 2005: 41). Because of these associations, the central Pilbara has been described by some anthropologists as a 'culture block', made up of different language groups with a 'shared understanding of norms, laws and customs' (Day 2005: 1). They remain, however, distinguishable groups, with quite specific laws and customs related to specific country, albeit within an overarching social structure of shared norms. Brian Tucker (in Parker *et al.* 2010), whose father was Banjima and mother is Nyiyaparli, explains how the Banjima and Nyiyaparli are connected through a common law, whilst maintaining difference:

> They got a *wala wala* on that side. We got a *Wardilba* here. *Wardilba*, meaning about our country here. Here. *Wardilba*, he go far as the Nyiyaparli's boundary, and then we follow the Nyiyaparli then. Nyiyaparli and Banjima close, because of the *Wardilba*.

The Banjima language is common to members of both the MIB and the IB, although with two different dialects, and the groups are known to have interacted with each other historically. Those members of the IB claimant group who identify as Banjima (commonly thought to be called Milyuranpa Banyjima) are sometimes referred to as 'Top End Banyjima' due to their location around Rocklea and Juna Downs, while MIB are referred to as 'Bottom End Banyjima' or Fortescue Banyjima, due to their characterisation as dwellers of the lowland Fortescue River and tributaries and the Mulga Downs area (Day 2005: 32; Dench 1991: 126; McConnell 1997: 7).

Although it is difficult to ascertain from existing ethnographic literature the exact composition of groups, group names, languages and locations as they were before European colonisation, it is generally acknowledged that there was a group known as Banjima, whose members shared a common language, and thereby a common identity, forming a society with a common law and culture, albeit with distinctions within that group, as stated above. They occupied a territory that included the Hamersley Range and the Fortescue River and tributaries, and differentiated themselves from neighbouring groups by virtue of their different language. The Banjima are divided into two different groups corresponding to two different dialects and different geographical areas. Specific named places within those areas are expressed in songs associated with traditional practices. The remainder of this chapter will deal primarily with the Banjima, and in particular, the MIB.

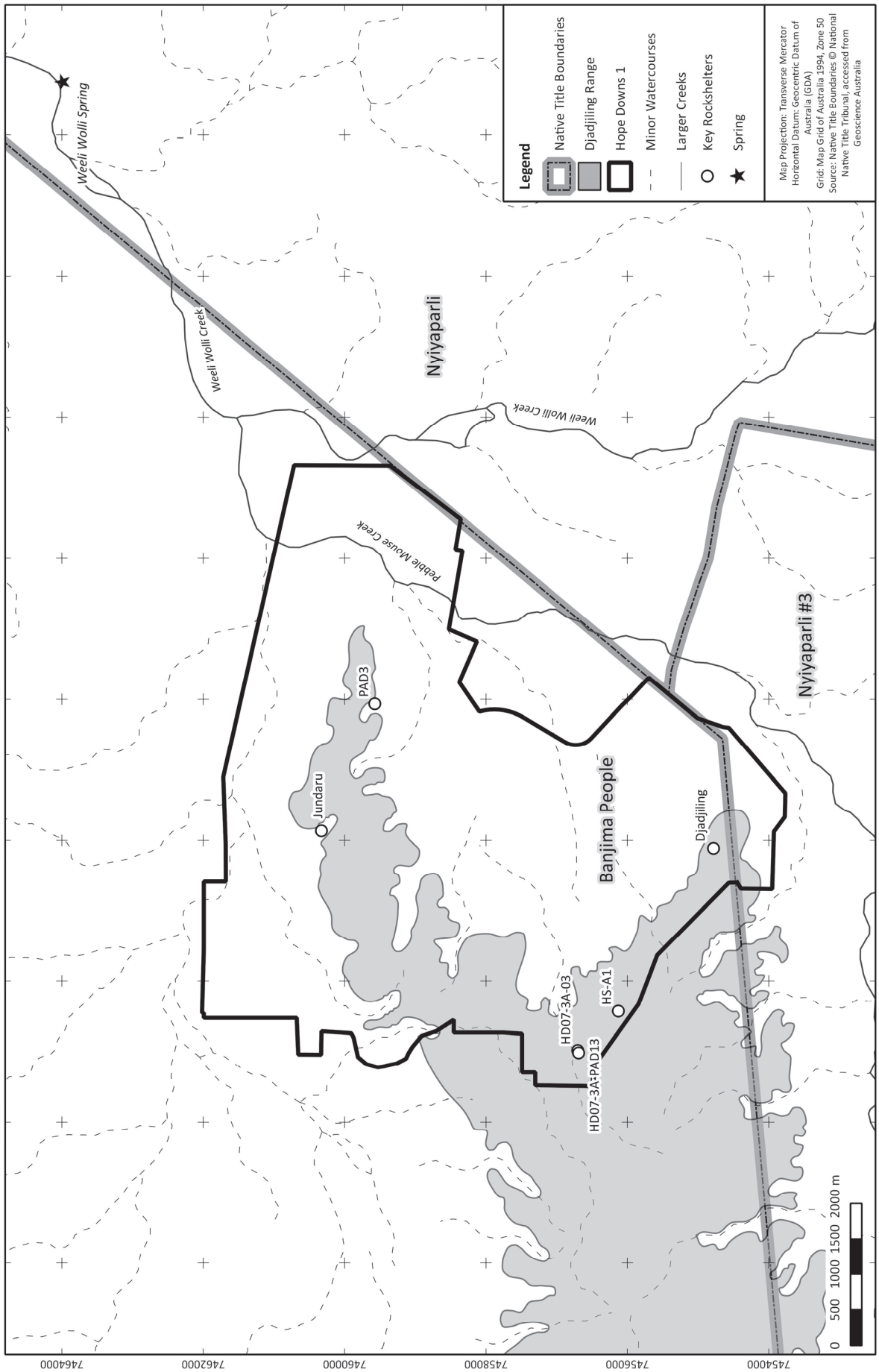

Figure 3-1 Map showing the Native Title boundaries in relation to Hope Downs 1 Mine

3.2 EUROPEAN CONTACT HISTORY

While the official date of acquisition of sovereignty for Western Australia was 1829, the effects of European settlement on the Pilbara region are unlikely to have been felt for several decades. The years following contact were fraught with conflict and violence, as attested to by various accounts archived in the Perth Colonial Secretary's Office, and documented in McDonald (2002). The 'natives' were accused of being troublemakers, stealing the Europeans' possessions and spearing their sheep (McDonald 2002: 1). Both Aboriginal and European people lost their lives in this drawn-out battle, with Europeans being speared, and Aboriginal men being arrested for one crime or another and shot or hanged (Day 2005: 23).

As their lands were encroached upon, local Aboriginal people began to move towards European settlement centres, many of them taking up work on stations such as Rocklea, Hamersley, Mulga Downs, Juna Downs, Newman, and Wittenoom (Day 2005: 24; O'Connor 1996: 4; Olive 1997: 113-115). During this time and despite the disruptive effects of European settlement, Banjima people continued to maintain a connection to their land, and continued to practise their law and culture, with ceremonies occurring frequently on all the different stations (Day 2005: 24). People came together from different groups to show their different dances, and initiation ceremonies continued to take place, as they do today, at remote meeting camps over the Christmas period (Day 2005: 24-25; Olive 1997: 114-115).

In 1967, the implementation of the equal wages law, which should have led to greater equality, had the adverse effect of leading to many Aboriginal station workers being laid off. Families began to move to the larger towns, such as Onslow, Roebourne and Port Hedland, where the children were educated in hostels (Day 2005: 26). This had obvious implications for people's ability to continue to conduct their everyday and ritual activities on the land as they had done before (*cf.*, Hardie 2001: 87-88). Mining has had further implications for people's ability to access their traditional lands. One example is the Wittenoom asbestos mine, which is in close proximity to approximately 20 recorded Aboriginal sites (Day 2005: 59). The dangers of asbestos and the subsequent closure of the mine have led to the Banjima people of that area being prevented from accessing that land and those important sites, and thereby being restricted from maintaining physical cultural links with that area (see Day 2005: 54-60).

However, regardless of the impacts of European settlement on Aboriginal people's abilities to access their traditional lands, the various groups have succeeded in maintaining a spiritual and religious connection to the land, through the conduct of ceremonies and rituals in nearby locations, and through physical connection wherever possible. Elizabeth Dowton, a senior Banjima woman remembers:

> (Our) mother and father ended up in Ashburton looking for jobs. That's where they grew up. People had to leave their country to look for jobs - to keep the family going. Never got much money. People ended up in Onslow looking for jobs and stayed there - but we still know this is our land. (Dowton *et al.* 2008: 2)

Encouraged by the Mabo decision handed down in 1992, the first decision to recognise Native Title in Australia, Banjima and other groups began to take up residence once again on their traditional lands in the central Pilbara, and old Law Grounds were reopened (Day 2005: 28). These continued connections will be discussed in greater detail below.

3.3 SOCIAL ORGANISATION: SKIN GROUPS AND KINSHIP

Central Pilbara societies operate according to a four-section 'skin system', through which individuals are designated a named 'skin colour' at birth, according to that of their mother. This category guides them throughout their life in terms of their interaction with others, social roles in daily life and in ceremony, and eligible partners for marriage. The skin sections also have totemic associations, meaning that each category corresponds to an animal, and a person of that skin colour has a special connection to that animal (Radcliffe-Brown n.d.; Stanner 1965). The names of the four categories vary according to the language group, but the system and its function are similar throughout the region, and variations are accommodated and accepted in inter-community interactions (Day 2005: 2; Palmer 1982: 69-70).

The four skin categories within the MIB society are Burungu, Milanga, Garimarra, and Banaga. The early ethnographer, Radcliffe-Brown (1931), labelled this the 'Kariera' type of social organisation after the similarly organised coastal group he had worked with previously, although he listed the names of these sections slightly differently. Dench (1980: 15-108) describes these four categories as being divided into two 'patri-moieties', which designate generations, such that patri-moiety 'A' comprises Garimarra and Burungu, and patri-moiety 'B' comprises Banaga and Milanga, as shown in the diagram below.



According to this system, a Burungu woman should marry a Milanga man and their children will be Banaga; a Banaga woman should marry a Garimarra man and their children will be Burungu; a Milanga woman should marry a Burungu man and their children will be Garimarra; and a Garimarra woman should marry a Banaga man and their children will be Milanga (*cf.*, Day 2005: 20). Traditionally, a 'wrong way marriage' would cause social condemnation and punishment, and senior people remember incidents of people being speared for this crime. 'He bin get the wrong woman, not the right colour', says Lola Young, an Innawonga Elder (now deceased) who was also married to and had children with MIB Elder Wobby Parker (now deceased) (Young 2007: 4). 'You gotta have the right skin colour, you know. So he got speared in the leg' (Young 2007: 4; *cf.* Berndt 1965). This system is less strictly adhered to today (Day 2005: 20).

Kinship terms are related to this system, such that a person 'A' who does not have a known consanguineal relationship to person 'B', will nonetheless be designated a kinship term to 'B' in accordance with their skin colour and their age relative to that person (Berndt 1965: 169; Dench 1980: 105-107). Kinship terms are often reciprocal between generations, meaning, for example, that the same word will be used by both a man and his father's father, or a woman and her daughter's daughter, to refer to each other (Dench 1980: 106). There are also generalised names for children according to social categories, such as gender and birth order, rather than these terms being confined to one's own children (Day 2005: 21).

Embedded within the skin and kinship systems are avoidance protocols, such that, for example, a man must avoid his mother-in-law, and thereby must employ a certain level of respectful behaviour toward all those classified as father's sister or mother's brother, since all have the potential to become in-laws. Contact should only be made via an intermediary, using a style of language known as Paathupathu. Similarly, a man must follow strict codes of behaviour and avoidance strategies with men involved in his initiation, such as his *mangkalyi*, or 'doctor', although the relationship in this case becomes an important one of lifelong support and guidance. The Paathupathu style of language is rarely used nowadays, but the patterns of language usage, enshrined in the system of social categories, remain and continue to constitute an important part of the Banjima and central Pilbara social organisation (Day 2005: 22; Dench 1991: 128).

3.4 LAW AND CULTURE: CREATION STORIES, SIGNIFICANT SITES AND CEREMONY

As part of his report on the *Royal Commission into Aboriginal Deaths in Custody*, Elliot Johnston QC (1991: 277) wrote of Aboriginal Law, that it was:

> ...undisputed in its ordering of the lives and movements of the people, giving meaning and coherence to social relations with the land, regulating conflict, providing a seasonal and ceremonial framework for action, and clearly defining for each group - men and women, young and old - an accepted and useful place within their society.

Banjima Law, like that of other Aboriginal groups, is a system governed by the stories and songs that tell of the creation ancestors and how they made the world. During the creation period, the ancestors travelled through the land, and as their journeys unfolded, they created the mountains, rivers and other natural features that are now significant and sacred places for Aboriginal people. The stories of the ancestors' travels are passed down the generations, often through song, and knowledge of certain aspects of these stories may be restricted to men or women, or to people who have been initiated to a certain level. As people are entrusted with knowledge of the land by their Elders, they are endowed with greater rights and responsibilities with regard to the land. Rights and responsibilities for a particular place are also gained through descent, by virtue of being born or initiated in a place, and by various other means.

Encoded in the creation stories are rules of social behaviour and ways of surviving in the land, such as how to hunt and prepare food, and how to find one's way through the country. Two senior men, Brian Tucker and Trevor Parker, speak about one of the main creation ancestors:

> Only one fella that gave us these songs here... It's the same God that everybody goes around and talks about, you know. [He] belongs to the country. (Brian Tucker in Parker *et al.* 2008: 2)

> ... And what he put down here, not on a piece of paper. He put it on the land here, and on the rocks, and gave us the songs for these. (Trevor Parker in Parker *et al.* 2008: 2)

> ...passed down through generation to generation, you know. And that's why we still keep it. It's never been written down, it's all... Survive in your country, that's what it all means. You're following your country, you know where to go - there's water there, food. Like this place here, there's honey place for us. (Brian Tucker in Parker *et al.* 2008: 4)

Ceremony and ritual form an important part of the way in which the people of the central Pilbara uphold and maintain their Law, and these rituals are inherently connected to the country and the important sites that tell of the ancestors' journeys through the land.

One type of ritual is that which serves the function of greeting country and speaking to the spirits there. For example, visitors to Weeli Wolli Spring, near the Hope Downs mine, must take a handful of water and blow into it. This introduces the person to the *Warlu* (water serpent) that resides in the spring, and alerts him to the visitors' presence (F. Sutherland, field notes, 14-17 July 2006). Neglecting to perform such rituals and placate the spirits can place the visitor in danger.

There are also rituals performed at sites known as *thalu* or 'increase sites'. Each of these sites is spiritually connected with a natural species or resource, such as honey, and the abundance of this resource can be maintained and increased through the performance of this ritual. As Brian Tucker says, 'that old place that we go... to do ritual things, talk in language you know - ceremonial sites. It's like you're blessing. You're blessing the country' (Brian Tucker in Parker *et al.* 2008: 4).

One of the most important types of ceremony is that of initiation or Law Camp, whereby boys are taken through the Law by their Elders, and become men (see Day 2005: 25). Traditionally this happened towards the end of adolescence. In contemporary times the 'boys' selected for initiation are most commonly young adults. The initiation takes place over the Christmas period and can last for at least a month. Elderly Banjima people remember law ceremonies lasting for four or five months (Parker 2007: 7). The ceremonies take place at ritual grounds, and involve travel in a circuit across the Pilbara, allowing for interaction and exchange between different groups (Day 2005: 27-29). While women are not initiated in the same way, they also play an important role in the ceremonies, singing and dancing at different times during the initiation ceremonial cycle. They are also responsible for collecting water, making sure the camp is tidy, making damper for the travellers and preparing food for exchange (Trisha Parker in Ashburton-Parker *et al.* 2008: 3).

During the time when Banjima people had moved off their country and gravitated towards population centres such as Onslow and Rocklea, it became difficult for them to travel back to their traditional law grounds to conduct ceremonies. Because of this, a neighbouring group allowed the Banjima access to a piece of land to be used as a law ground, at Nanutarra Station. Later, Peedamulla Station was placed under Aboriginal management, and another ground was made available there, along Cane River. In this way, Banjima people were able to continue their cultural practices and maintain the law, despite the interruptions that occurred as a result of European settlement. Eric Carey, a Banjima man (now deceased) explained:

> The old people years ago, they asked for the land, they asked for the bit of land in Cane River to have their, to practice their Law, the Banjima people. That's why the Banjima Law is very strong Law. It still is today, because we been practicing, the old people been practising it... Even though it wasn't in their own country they was practising it, and showing us the law. (Carey 2007: 4)

When people began to move back to their country in the 1990s, Law grounds were re-opened, and people were once again able to practice their law and culture on country. Eric Carey (2007: 4) continued: 'Today everybody back in their own country and

they're practising their Laws in like Five Mile, Youngaleena'. Slim Parker (in Olive 1997: 135-136), a Banjima Elder, says:

> Our young people are still brought up in the traditional ways… The main feature of the Aboriginal law and culture is respect for land, it has to be. We've got our traditional bush tucker, medicines, waterholes, soaks, and life support systems in the land. We also have all of our personal histories and those of our tribes, in our land. There are our ancestors and our spirits there. We must protect the land to keep alive our own identity and for our children's future, so that they can follow the traditions. The importance of land to us is shown in the practice of initiation. There are heaps of things that boys need to be taught. The only way this can be done is back in their own country.

3.5 MAINTAINING CONNECTION THROUGH CONTEMPORARY LAND USAGE

It is not only through ceremonies that the Banjima and neighbouring groups work to maintain a strong connection to their land. In contemporary times, Banjima families undertake various activities on the land that allow them to maintain a physical, as well as a cultural and spiritual connection to their country, regardless of whether they reside there permanently. Activities include travelling onto the land to hunt, gather bush tucker and medicines, to camp, conduct cultural heritage surveys, and to work. It is through these activities that people are able to continue to care for and protect their country and cultural sites, and at the same time, they provide an opportunity for senior people to pass on cultural knowledge of the land to the younger members of the community. Fiona Ashburton-Parker, a Banjima woman, talks about how she and her family go camping on the land:

> My grandparents took me around when I was small, and my uncles and aunties. But lately, myself and my little family, my children, we've been spending time with the people in the community. Every now and again we get a chance to go out to Weeli Wolli, go camping out with Uncle Timmy when he have his days off, Uncle Rex when he have his days off. Sit down under the stars and tell the children their stories and everything. (Ashburton-Parker *et al.* 2008: 4)

She explains how her uncles work out on the land, and when they return to the community with stories of things they have seen, the whole family desires to go and see for themselves. 'So we make a plan to go on a weekend, and we go', she says (Ashburton-Parker *et al.* 2008: 4). On these camping trips, people hunt and fish, collect plants and bush tucker, and the children swim in the water from sunrise to sundown. The whole family attends in a fleet of up to eight vehicles, and the older family members teach the younger ones about which plants are good for collecting, the correct way to kill or prepare a goanna or a kangaroo, and about the stories of the places where their ancestors lived and travelled. They are also taught about how to remain safe on country, by calling out to the spirits to alert them of the presence of visitors, and about the importance of using the correct language and names for a particular section of the country (F. Sutherland, field notes, 14-17 July 2006). The younger people learn the songs and stories that are associated with the land and that instruct people on how to survive and behave in the land. Fiona Ashburton-Parker continues:

> I saw my kids and they really sat up and listened to Uncle Timmy and Uncle Rex when he was telling them about their country and everything. And they always grew up in town. But the last month we've been here, I've seen my kids changed. Every time they mention something about Weeli Wolli, they want to go there, my kids. (Ashburton-Parker *et al.* 2008: 5)

Cultural heritage surveys also provide an opportunity for people to visit their ancestral lands, particularly those areas to which access is restricted due to mining. During these trips, people take the opportunity to hunt, to collect bush tucker, to inspect cultural sites and make sure they are being adequately cared for and protected, and to pass on knowledge to the younger members of the group.

People who live in the area also go hunting on a regular basis, and younger members are taught the rules and customary practices associated with taking and cooking bush foods. There are ways of preparing goanna, kangaroo, and emu that are said to have been handed down by a creation ancestor, and these must be adhered to. Cooking an animal in the wrong way or in the wrong place could have dangerous consequences.

Women in particular, but not exclusively, hold a great deal of knowledge about bush plants, many of which are medicinal. People collect seeds, fruit and honey, and know plants that can be boiled and used to cure sore eyes, swollen legs, asthma, arthritis or 'a crook heart', among other ailments. Senior woman Lola Young (now deceased), wrote a book about the types and usage of bush foods and medicinal plants (Young and Vitenbergs 2007).

As discussed previously, people moved away from their traditional lands as a result of events following European settlement. However, they continued to maintain cultural and spiritual links to the country through work on the stations when they were younger, through the practice of ceremonies on nearby land, and through periodic visits on country during which they learnt about the land from their elders. In the past two decades, Aboriginal people have returned to live on their traditional lands and the practice of passing on cultural and spiritual information and knowledge to the next generations continues.

3.6 ETHNOGRAPHY OF THE HOPE DOWNS MINE 1 SITE: SIGNIFICANT SITES AND SONGLINES

The Hope Downs 1 Mine site lies within an area rich with cultural significance. Of particular importance ethnographically is the Djadjiling Mountain Range, which encompasses the ranges within the mine and continues to the west (Figure 3-1). The Djadjiling Mountain Range is connected to the *Wardilba* songline, a highly secret and important series of songs, telling stories that are directly related to the country and the natural species, and which form the basis of law and religion for Banjima and other groups (see Lawrey *et al.* 2008; Parker *et al.* 2008).

The Djadjiling Mountain Range is also connected to the creation story of *Jundaru* (honey) (Lawrey *et al.* 2008; Parker *et al.* 2008). The *Jundaru* story runs along the mountain range, and includes an important rock shelter and trees. The entire area related to this story is sacred, and is connected by songlines known to many groups, including the Jigalong people and Pitjantjatjara people from central Australia (Parker and Tucker 2007: 1). Certain trees, from which honey can be collected, are also connected to this songline. People cut the trees to extract the honey from hives within the branches, using the bark itself as a carrier, and the songs related to this country tell people where to find the honey and help to make it plentiful. 'It's like an increasing site, you know,' says Dennis Long, a Banjima man (Long *et al.* 2007: 20). 'You sing that song, you go to that particular tree, it should be full, with *Jundaru*' (Long *et al.* 2007: 20). Another man explains:

> You're gonna know by looking at... the hole, that's where, it tells you where the honey is, *Jundaru*... After you've chopped that, you sing now... By learning all that, you know where to live in your country, by knowing this... 'cause they make you understand about your country, what to get, what not to get. [...] ...you know you've got to go and do a certain song, talking, language… (Long *et al.* 2007: 20)

Another Banjima man says:

> Our cultural values and heritage vales around *Jundaru* are very significant - our songs and how we affiliate in *Jundaru*. It's not just a shelter with significant stuff when we go into the salvage program - it's more than that. Cultural knowledge, songs and so on recorded of evidence, thousands of years. (Martidja Banyjima, meeting with RTIO, 19 October 2007)

Another culturally significant place affected by the Hope Downs mine is Weeli Wolli Creek, and also Weeli Wolli Springs (Figure 3-1). Weeli Wolli Creek forms the boundary between MIB and Nyiyaparli country, and the area and resources are shared between the two groups (Day 2005: 41; O'Connor 1994: 3; 1996: 4). Near the creek are burials, an Aboriginal Law ground, and other important ethnographic sites (Day 2005: 44). Senior Banjima people tell that the creek, 'the springs and other natural features in the area were created by the Warlu (water serpent)', and that his spiritual essence still exists there (F. Sutherland, field notes, 14-17 July 2006; Day 2005: 49-50; Rumley and Barber 2004; O'Connor 1994: 8).

In recent times there has been considerable concern about the damage that is being caused to these sites by the dewatering project being carried out as part of the Hope Downs Development Project. The excessive influx of water removes the seasonal variations in the creek, causing the creek to be in constant flood. This has the effect of negating the seasonal cycle that Banjima Elders regard as a spiritually, culturally, and environmentally significant aspect of their traditional law and custom. It also has direct physical effects on the significant cultural heritage sites downstream of the discharge point.

One of the most significant mythological sites downstream from the Hope Downs mine discharge point is *Thalabundha*, which is known as the eye of the *Warlu* because it is the point at which the *Warlu* came to the surface and looked around (Jackson *et al.* 2003: 93). Significant damage has already occurred to this site. Some Banjima women have expressed their concern about what will happen if the sites continue to be damaged, saying that the *Warlu* will be upset by the disturbance, the noise and changes to the water table, and might leave the area. This will cause the water to dry up, the trees to die, and there will be no food for the animals, who will also die. Because of the interconnectedness of the stories, disturbance to the water table can upset *Warlu* over a large area, extending from Weeli Wolli Spring to Karijini National Park (F. Sutherland, field notes, 14-17 July 2006).

The MIB strongly assert their role as caretakers of the area and its natural resources, particularly water, on behalf of neighbouring and other downstream groups who share a stake in these waterways and stories (Day 2005: 44; O'Connor 1994: 9). That is, they have a responsibility to ensure that the water flows remain as they would occur naturally, without interference, and that there is no contamination to water ways in the area or downstream. To end with the words of senior Banjima man Slim Parker:

> This is our country, along with the Nyiyaparli people, Banjima people. We've been working together for years along the Weeli Wolli, and learning it from our elders in terms of the significance of the Weeli Wolli and what it means to us. And this whole area here is what makes us who we are in terms of our identity… as Banjima people. (Parker and Parker 2007: 1)

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Chapter 4

Research Aims and Methods

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The Hope Downs 1 mitigative salvage program was influenced by a number of research themes that have featured prominently in the past 40 years of regional archaeological research. It was the aim of our investigations to collect information that builds upon regional archaeological themes and improves the resolution of our understanding of the Pilbara's ancient Aboriginal past. This chapter outlines the research aims and methods that were employed over the course of the mitigative salvage program.

4.1 RESEARCH AIMS

The Hope Downs 1 archaeological record has the potential to provide information on a number of archaeological themes that are important to the region, including site formation processes, the antiquity and sequence of Aboriginal occupation in the Hamersley Ranges, past human-environment and climate interactions, lithic technology, and hunter-gatherer subsistence and land-use practices. These subjects have featured prominently in many of the regional syntheses of the Pilbara and Western Desert (*e.g.*, Brown 1987; Veth 2005; Veth 1995; Hiscock 2008; Hiscock and Wallis 2005; Marwick 2009; Marwick 2002a). The Hope Downs 1 data contributes significantly to these principal research themes, and as discussed below, aims to improve our understanding of the regional record.

Prior to this project, the earliest evidence for the antiquity of human occupation in the region was 30,000 to 32,000 years ago at Newman Rockshelter (Maynard 1980); however, the breadth and extent of Aboriginal occupation in the Hope Downs 1 area has surpassed previous conceptions of the region (*e.g.*, Law *et al.* 2010). The Hope Downs 1 investigations demonstrate a clear pattern of occupation at a much earlier time than previously reported, and they also provide insight into the extent of occupation throughout the LGM, which has been subject of much discussion and debate by Australian scholars (*e.g.*, Smith 1993; Veth 1993; Marwick 2002b; Hiscock and Wallis 2005; Hiscock 2008; Slack *et al.* 2009). Additionally, the Hope Downs 1 investigation will further our understanding of the Holocene archaeological sequence and assist with refining occupation patterns for the past 10,000 years.

Many researchers have been interested in human interactions with past environmental and climatic conditions. Despite decades of research, there has been very little information available on the ancient environmental and climatic conditions of the inland Pilbara. Much of the regional environmental and climatic record has been inferred from other arid zone regions, so this project aims to develop a local palaeoenvironmental and palaeoclimatic history. In particular, the Hope Downs 1 program will specifically aim to investigate diachronic changes in past environmental and climatic conditions through a series of specialist studies, including macrobotanical charcoal identification, pollen analysis, and phytolith analysis.

Flaked and ground stone artefact technologies easily represent the bulk of the archaeological information discarded across Australia. The manner in which early peoples manufactured stone artefacts and utilised stone tools is important for reconstructing the archaeological record. All of the sites from Hope Downs 1 have been subject to thorough artefact analyses that aim to detect patterns in lithic technology of earlier populations. The previous Aboriginal populations have existed in the region for tens of thousands of millennia. Many of the ways that early peoples adapted and subsisted in this landscape are manifest within the stone artefact assemblages that they left behind. The Hope Downs 1 project aims to demonstrate past patterns of stone artefact manufacture and raw material use. In particular, patterns of flake retouching and core reduction will be investigated to infer or demonstrate past human behaviours. The temporal occurrence of prominent stone tool types, such as tulas, back artefacts, and grindstones will be revised and updated with this study. Additionally, many of the stone tools have been subject to usewear and residue analyses that enable us to make statements about their past function and use history.

The ultimate aim of the study is to reconstruct past Aboriginal land-use and subsistence practices. The ancient record of indigenous Pilbara peoples is long and complex. Over time, people adapted to significant shifts in environmental and climatic conditions. Reconstructing the strategies they employed to secure access to water, plant and animal resources, and raw materials is the essence of the region's archaeological record. Too often, information that enlightens us on the most elementary components of subsistence practices are the most elusive to find.

4.2 ROCKSHELTER EXCAVATION METHODS

The Hope Downs rockshelter salvage methodology utilised conventional archaeological excavation techniques employed widely throughout Australia. The research aim of the salvage work was to test if significant, subsurface archaeological deposits were present, such as burials, well-stratified cultural horizons or cultural features (*e.g.*, hearths, knapping floors, and living surfaces), well-preserved organic remains, or unique archaeological finds. Also considered are:

- What contribution can the recovered materials make to our understanding of the local archaeological record and the greater Pilbara region?
- What is the significance of the rockshelter and its cultural materials to the local Banjima peoples?

The following excavation methodology was developed to assess the heritage significance of each rockshelter deposit and provide best practice heritage management recommendations to the Aboriginal Stakeholders and RTIO. The size and extent of excavations was dictated by the size of the rockshelter, the spatial extent of the floor deposit, and the existence of subsurface cultural features. Previous experience at the Hope Downs mining lease suggested that a strategically placed 0.5-x-1.0m test unit could adequately test the subsurface deposits of most small to medium sized rockshelter deposits (<20m²). If an instance arose where unusual site stratigraphy or a cultural feature was encountered, the test unit was extended to a 1.0-x-1.0m grid square to further investigate the deposit. In large rockshelters with sizable floor deposits (>20m²) or unusual cultural features (*e.g.*, a man-made wall or stacked rock feature), it was often necessary to place more than one test unit within the shelter in order to adequately test the significance of the deposit. While no greater than 10% of the rockshelter deposit was excavated in order to assess the deposit's significance, further excavations were necessary when a significant archaeological deposit was discovered. Upon encountering a significant archaeological deposit, the Traditional Owners and RTIO were advised of the situation prior to undertaking further mitigative work. The field team employed the best practical excavation methodology to adequately sample or mitigate the remaining materials in accordance with the Section 16 and 18 permit conditions.

Throughout the Hope Downs 1 Mitigative Salvage project, the excavation methodology was refined as we gained experience with the techniques and methods best suited to rockshelter excavation in the Pilbara. Insight and suggestions from the many experienced casual archaeologists who collaborated with us on the project were also incorporated into the methodology. An overview of the rockshelter excavation methodology is provided below, and any differences that occurred through the various stages of the project are clearly identified.

Site Preparation Prior to Excavation

Each site was systematically documented prior to excavation; this not only ensured that all sites in the project were recorded in the same manner, but this also provided an opportunity to choose the best location of excavation units, the site datum, and the sieving and sorting stations.

The Hope Downs 1 Mitigative Salvage Project developed a Rockshelter Recording Form, which was completed prior to the excavation of a site. The form prompted users to record information regarding the physical characteristics of the rockshelter (number of chambers, maximum dimensions, opening dimensions, orientation, estimated sediment depth), as well as general attributes within and outside of the rockshelter (presence of roof collapse, ground cover, landform, position of shelter, preservation, *etc.*). Detailed plans and cross-sections of the rockshelter were also illustrated. Standardised planning conventions were used to ensure consistency among the site plans.

A 1.0-x-1.0m grid was established for the site, with the initial test unit positioned near the centre of the rockshelter, allowing for room to expand the excavation if significant subsurface cultural remains or deep deposits were encountered. The excavation units were numbered sequentially, as opposed to using an alpha-numeric code. This enabled us to correlate our main provenance identifier (the bag number) with each unit and facilitating data entry. Quadrants were labelled A to D, and were generally oriented with Quads A and B nearest to the back of the rockshelter (opposite the opening). Zero was always measured from the bottom left corner of Quad C.

An arbitrary vertical datum was established for each site in order to determine the depth below datum during the excavation. Depth below surface measurements were not used as the surface sediment is often extremely powdery and accurate measurements are not possible. During the first two stages of the salvage program, a length of reinforcing bar was positioned next to the excavation unit and line levels were used to establish provenance and elevations. Subsequently, laser line levels were used as they provide a quick and easy way to measure depth. The position of the datum was marked on the rockshelter wall using indelible marker, and surveyors' nails were also hammered into the wall at two points on the line. By marking the site datum on the rockshelter wall, it provided a reliable reference point that could be used trip after trip. Because the laser line level was constantly on and so easy to use, we found that it greatly increased the precision of the excavation.

Excavation Methods

It is ACHM's policy that every rockshelter excavation should continue until bedrock is exposed across the entire excavation trench. Reaching sterile sediment does not provide an indication that there are no cultural remains below the sterile layers. In most cases, the excavation was carried out in arbitrary 5cm layers; however, features were excavated according to the natural stratigraphy (discussed below). The methodology used for excavating features was also employed to excavate natural stratigraphic changes, where deemed appropriate.

The excavation of arbitrary layers was controlled by the unit and quad. Within each unit, the four quads, labelled A to D, were excavated separately in arbitrary 5cm layers. Each quadrant of every layer was assigned a provenance context called a Bag Number. Generally, the bag numbers correspond to the excavation unit number, where Unit 1 would begin with Bag 1000 and Unit 2 would begin with Bag 2000. Each layer was terminated at the nearest 5cm increment below the datum; therefore, the first layer in each excavation unit was typically not a full 5cm-deep layer. For example, if the depth of Layer 1 ranged from 17 to 20cm below datum (cmbd), then Layer 2 would extend from 20 to 25cmbd and Layer 3 would extend from 25 to 30cmbd, and so on.

Comprehensive observations of each arbitrary layer were recorded on a Layer/Feature Form, which included a discussion of the separability of the layer, sediment description, layer morphology, stratigraphy, and excavation techniques. In addition, a detailed plan of each layer was completed on the form, and the location of each *in situ* sample was plotted on the plan. All other samples collected from the layer were also recorded, as was the weight of all excavated sediment, divided by quadrant and then by rock fraction size. Generally, one quadrant was selected as the control in the excavation unit, which was used to make the pH and Munsell colour observations and to take sediment samples. Any variations throughout the layer were noted and abnormal results were re-tested several times in order to verify their accuracy.

Near the end of the salvage program, it was learned through air quality testing that individuals excavating within rockshelters are at significant risk of high exposures to respirable dust and silica. As a result, a policy was implemented that all individuals working within the rockshelter were required to wear fit-tested P2 dust masks. Furthermore, we implemented regular task rotations to minimise exposure and continued the use of an

extractor fan to reduce dust levels. An additional safety protocol was implemented that requires routine air quality monitoring for excavation and sieve personnel at each excavated rockshelter, upon each field trip and throughout the duration of the excavation project.

Excavating Features

Hearths are the most common feature encountered during excavations, and they can range from extremely well-defined layered hearths to ephemeral smears of ash and charcoal. While the former is easy to identify and excavate, the latter can be challenging. When a feature was identified, it was excavated as a natural layer within the 5cm spit where it rests. Features were generally excavated as a single entity (*i.e.*, they were not divided according to quadrants); however, if the feature extended into another excavation unit or it extended beyond the 5cm layer, then these additional areas were excavated as separate contexts. This gave additional control to the excavation, and it allowed the data to be divided both by arbitrary layers as well as by features. Most archaeological reports present data by arbitrary five centimetre layers, so a methodology was used that would provide comparable data while recognising the significance of archaeological features and collecting data from these contexts.

When a feature was first encountered, it was assigned a feature number in the Feature Log; there may be multiple bags and Unit-Layer contexts associated with a single feature. A new Layer Form was created for each feature, and we used a decimal system to break down an arbitrary 5cm layer into the individual contexts relating to the sediment above the feature, the feature itself, and the sediment below the feature. The decimal system makes it easy to group together all of the individual contexts from a single 5cm layer. For example, Unit 3, Layer 1 may be the arbitrary layer that was excavated before identifying the feature; this would be the sediment above the feature, and excavation of this layer would cease once the feature was identified. The next layer that would be excavated would be the feature, which would be excavated as Unit 3, Layer 1.1. All sediment below the feature and within the 5cm arbitrary layer would be excavated as Unit 3, Layer 1.2.

Before excavating a feature, a plan was drawn on the back of the Layer/Feature Form and numerous elevations were recorded. Prior to the excavation of any feature, numerous photographs were taken in order to thoroughly document the extent and nature of the feature. Once the preparatory work was completed, the feature was excavated in section, which helped to identify the shape and extent of the feature. A photograph of the sectioned feature was taken, and then the remaining half of the feature was excavated. The base of the feature was then photographed and drawn.

Sieving and Sorting

All excavated sediment was weighed and sieved through nested 6mm (coarse) and 3mm (fine) sieves. The resulting coarse and fine rock fraction was again weighed before it was subject to flotation. The flotation process not only enabled the collection of macrobotanics, but it also washed the rock, facilitating the identification of flaked stone artefacts, faunal material, and other items of interest during the sorting process.

Sediment buckets were transferred from the excavation to the sieving station, and a member from the sieving team weighed the buckets and entered the weight of each bucket onto the Sediment Weight Log. The buckets were sieved. Sieving generates a significant amount of respirable dust and silica, and we now recommend that all individuals using the sieves wear P2 dust masks and gloves. The rock fraction from the fine and coarse sieves was weighed, but first all rocks over 10cm in length were separated and weighed. All coarse and fine fraction rock that was not subject to flotation on-site was placed into labelled heavy-duty plastic sample bags and stored until it could be processed.

Both the coarse-fraction and fine-fraction were subject to flotation, but they were floated separately to provide an indicator of the amount of cultural material recovered from each size category. A fine sieve was placed into the flotation tank, and water was filled up to just below the edge of the sieve. The rock fraction was agitated and all floating material was sieved from the surface. This process was repeated several times. The floated material was transferred to paper towels, and then placed into labelled geo-chem bags, which are resistant to mould and mildew. All geo-chem bags were hung to dry.

The coarse and fine rock fraction were sorted separately and one or more archaeologists were involved with the sorting process depending on the amount of material being sorted. The primary material recovered during sorting was flaked stone artefacts, which were placed within the labelled small finds bag. All bone, seeds, or other items of interest were collected and placed in appropriately labelled bags. The recovered cultural materials were temporarily curated and stored at the Hope Downs lab prior to further analysis and final curation.

Throughout Stage 1 and 2 of the salvage project, only sieving occurred on-site, and all flotation and sorting occurred at the Hope Downs Archaeology Laboratory; however, during Stage 3, the coarse fraction was subject to flotation and sorting on-site, and the fine-fraction was processed at the laboratory. During the excavation of HD07-3A-PAD13, all flotation and sorting occurred on-site.

4.3 LITHIC ANALYSIS METHODOLOGY

The primary aim of technological lithic analysis is to document how flaked stone artefacts were produced. Essentially, this provides a glimpse into past human behaviour. Each flaked stone artefact retains key attributes, and when considered together, they can reveal the techniques that were used for its manufacture. The term ‘technique’ is defined by the Macquarie Dictionary (2005) as a ‘technical skill’ or ‘way of accomplishing’ a task. Techniques are embedded in daily life: ‘At any given time, techniques form the backdrop of people’s material life as well as part of their systems of meaning’ (Lemonnier 1993: 27). The transmission of prehistoric technologies, such as knapping, would have been passed between generations through observation and imitating (Schiffer and Skibo 1987: 597). This learning environment ‘ensures that they [techniques] are part of the socialisation process through which societies reinforce patterns of thought, interpersonal relationships, while at the same time deeper belief systems and behavioural norms are maintained and reinforced’ (Frankel 2003: 43). A technological approach to lithic analysis goes beyond broad typological categorisation, to consider both reduction strategies and the production of retouched artefacts. By adopting this method of lithic analysis, we gain insight into past behaviour because, done consciously or unconsciously, reduction methods are an expression of a normative learned tradition (Lemonnier 1993). Reduction analysis provides a measureable way to investigate prehistoric problem solving strategies and model past human behaviours. As such,

technological lithic analyses are a powerful analytical tool for examining differences over time and between sites.

The methodology outlined in this appendix was developed with the aim of producing comparable datasets so that variation in raw material use and lithic technology can be evaluated over time and amongst sites. Particular research questions that this analysis aims to address are:

- Do raw material procurement strategies change over the 40,000 year occupation history of the research area, and is there evidence of differential use of particular raw material types at the assemblage level?
- Were non-local raw materials used in the past?
- Is there variation in reduction strategies and knapping techniques both over time and amongst contemporary assemblages?
- Does the proportion of retouched and utilised artefacts remain constant over time, and is there significant variation amongst sites?
- What is the antiquity of backed artefacts, tulas, burins, and grindstones in the project area?

These research questions will be addressed through the results of the lithic analyses combined with the contextual data from the site investigations. While representing a small sample of archaeological sites, this data will provide new insight into past Aboriginal technological strategies and temporal variation for the inland Pilbara.

Lithic analyses are often criticised because of the difficulty of replicating results; the authors have often heard the quip 'get three lithic specialists to measure an artefact, and you will get three different results'. Part of this problem is the lack of methodological clarity, which leads to the development of assumptions. If the results of a lithic analysis are presented without a clearly defined methodology, it is easy to make the mistake of assuming the attributes were recorded in the same way you would. Because many of the attributes recorded during lithic analysis are qualitative, they can be subjective if they are not explicitly defined. With the exception of weight, the same is also true of metric attributes because it is the analyst's decision where to take the measurements. As a result, disparate results can be produced by different analysts. In order to mitigate this problem, the methodology used for the analysis of the Hope Downs 1 assemblages is outlined below, and each recorded attribute is explicitly defined. The attributes selected for this research were chosen carefully to ensure that the datasets are comparable with other analyses. The methodology employed for the lithic analysis is largely based on previous work by Cropper (2006; 2011), which has been modified to specifically suit Australian artefact assemblages and incorporate elements of reduction indices as used by Law (2009). Using this methodology, the author created relational databases for each assemblage using Microsoft Access.

Raw Material Analysis

Raw material procurement is the initial step of flake production, and it is also the starting point for lithic analysis. The availability, quality, and size of the raw material have profound effects on a knapper's reduction methods. In the following paragraphs, raw material attributes and procurement strategies are explored, providing context for the attributes recorded in this research (Table 4-1).

The role of raw material availability has been studied in great detail, and it is suggested that knappers exhibit different behaviour if they have restricted or unlimited access to raw material sources (Jeske 1989; Fitzhugh 2001; Hiscock 1996). Among hunter-gatherers, Jeske (1989) proposes a model of economising behaviour for raw material procurement, testing his hypotheses on Mound City National Monument, a Middle Woodland settlement in Ohio. In this model, raw material procurement is considered to be either expensive or inexpensive. As raw material procurement becomes expensive, requiring high energy and/or time costs, knappers will change their behaviour to economise the raw material (Jeske 1989: 35). Jeske (1989: 36) found that knappers did this by producing more cutting edges from each core, standardising artefact forms (*e.g.*, blades, bifaces), curating retouched artefacts (resulting in smaller tools), and selectively using expensive raw material for curated tools. While these behaviours economise the raw materials, they require greater investments of time and energy for artefact production and maintenance.

Access to raw material sources can be constrained due to increased distance from the source, the nature of mobility (high versus low mobility), depletion of the source, familiarity with the source, and competition over the resource (Fitzhugh 2001: 144). In instances where raw material sources are close to the site, it can be obtained during routine hunting or foraging trips (*e.g.*, Binford 1979); thus, it is not costly. Research by Newman (1994) in the American southwest has shown that as raw materials become increasingly scarce, a knapper will implement reduction strategies that encourage the potential utility of a stone tool. Newman (1994) and Law (2009) demonstrated that flake size decreases with increasing distance from the flake's raw material source. Fitzhugh (2001: 145) also suggests that familiarity with raw material sources will affect reduction strategies. He suggests that when a group moves into a new environment, traditional raw material types will be used conservatively, while knappers will experiment with new raw material types to determine their properties.

Because raw material can affect the organisation of lithic technology, it is an essential element of all lithic analyses. The analysis of procurement strategies often involves a survey to identify possible sources, with collected samples compared to the archaeological material; however, this is not always possible. In this research, raw material types were defined using a method of systematic description of surface features (Gebel 1994), which include the matrix appearance, cortical or weathered surfaces, and geologic context. These attributes were recorded using numerous specimens, which include cortical cores and flakes; artefacts exhibiting evidence of thermal alteration were not used in the raw material analysis. Mineralogical identification of the raw material types was not carried out. Given the variation that can exist in a raw material source, some of the types defined in this research may have originated from the same parent source. Contacts between raw material types were noted, and the raw material types were considered to be related.

Raw material appearance is characterised by the main matrix, as well as by any patterns, inclusions, and voids. The colour range of the main matrix and the degree of variation was noted for each raw material type. All colour notations were made using a 2000 edition of the *Munsell Soil Colour Chart*. Unique patterns, inclusions, and voids help distinguish between raw material types. Siliceous rocks can exhibit a range of different patterns, although speckles, laminations, and bands are most common. The organisation or distribution of these patterns is important to note, as some patterns may not be distributed evenly throughout the rock. For example, laminations may occur only near the cortex; therefore, not all artefacts will exhibit the pattern. Typical inclusions found in raw materials include rock

fragments, ooliths (small, round grain with concentric layers), and fossils (Leudtke 1992). Certain raw material types also exhibit vugs (small hollows), druse (small crystal-lined voids), and quartz-filled veins; these irregularities often cause weaknesses in the raw material. Chert can also have a brecciated appearance, where the chert has naturally cracked and angular chert fragments have re-cemented together by a different matrix. Similarly, some raw material types were formed through conglomeration (*e.g.*, silcrete); hence, they will exhibit rounded clasts that are cemented together by a finer-grained matrix. Raw material types can also exhibit characteristic texture, translucency, and lustre, and because these attributes can vary within a source, observations were made on numerous samples and the general trends were reported. The flaking ability of each raw material type was assessed.

Table 4-1 Raw material attributes

Identification
Raw Material ID
Raw Material Name
Raw Material Type
Banded Iron Formation (BIF)
Chalcedony
Chert
Dolerite
Granophyre
Hornfels
Mudstone
Quartz
Quartz Crystal
Quartzite
Silcrete/Orthoquartzite
Appearance of Matrix
Colour of Main Matrix
Munsell notation
Colour Variation of Main Matrix
Considerable
Moderate
Little
Pattern Character
None
Fine speckled
Coarse speckled
Cloudy
Veins
Streaky
Laminated
Banded
Brecciated
Conglomerate
Colour of Pattern
Munsell notation
Pattern Distribution
Irregular
Discontinuous
Concentric
Isolated
Lustre
Highly Lustrous
Slightly Lustrous
Faintly Lustrous
Dull
Translucency
Completely opaque
Opaque with Slight Translucency at Thin Edges
Slightly Translucent
Milky Translucent
Vitreous
Matrix Texture
Very fine-grained
Fine-grained
Slightly coarse grained
Coarse grained
Very coarse grained
Matrix Homogeneity
Non-homogeneous
Homogenous
Indeterminate
Inclusions and Fossils
Calcareous fragments
Ooliths
Fossils
Other
Clefts & Hollows
Quartz veins
Vugs (small hollows)
Druse (small crystals lining hollows)
Inclusion Silicification
Not silicified
Partly silicified
Silicified
Inclusion Distribution
Irregular
Discontinuous
Parallel condensed with cortex
Regular (density)
Flaking Ability
Problematic - parameters to be discussed
Barely manageable
Manageable
Very manageable
Cortical and Weathered Surfaces
Cortical and Cleft Surfaces of Bedrock Material
e.g., formed in geologic source: chemical weathered cortex formed in bedrock/bedrock-fresh cortex, partly silicified/silicified cortex, hard/scratchable/easily worn cortex
Cortex Thickness
Thin (3mm and less)
Medium (3-7mm)
Thick (8mm +)
Character of Contact (between cortex and silicified core)
Clear separation
Gradual transition
Indistinct contact area
Rolled Surfaces
e.g., cobble cortex from abrasive processes, smoothed chalky cortex, only silicified cortex parts left by abrasion, transport batterings and chippings, removals in flake sizes, *etc.*
Characteristic Patination
e.g., heavy/light patination, patination colour(s), evidence in-soil/surface patination types, desert varnish, *etc.*
Geologic Context
Geological context/allocated resource areas

The natural surface of the raw material can be defined as having fresh cortical surfaces or a weathered rind. This is a particularly significant attribute of the raw material analysis, as it can provide an indication of where and how raw material was obtained. Rock can be weathered either chemically or mechanically. Mechanical weathering is the physical breakdown of the rock, such as transport battering, abrasion, or spalling due to temperature differences (Leudtke 1992: 98). In contrast, chemical weathering alters the chemistry of the rock through processes such as oxidation, reduction, solution, or precipitation (Leudtke 1992: 98). Chemical weathering can dramatically change the appearance of raw materials. Chert may develop a white patina, dark patina, glossy patina, and desert varnish (Leudtke 1992: 100). The development of weathered rinds varies among raw material types. Moreover, patinas can help identify re-use of older artefacts. Discarded patinated cores and flakes may be picked up, re-used, and then discarded. These artefacts can be identified if they show fresh, unpatinated flake scars removed from a patinated surface. Alternatively, if weathered artefacts do not show fresh flake scars, but are found in good stratigraphic contexts alongside 'fresh' artefacts, it generally can be assumed that they were collected and re-used (Hiscock 1985: 93).

Finally, the size and shape of the raw material was examined. The maximum dimension of the raw material types were recorded by identifying the largest core or flake in each assemblage. This attribute provides an estimate of the size of the raw material that was selected for knapping. The shape of the raw material can vary depending on how it was formed and if it was exposed to weathering processes. Cores that had some of the cortex preserved were used to indicate the shape of the raw material, whether it be blocky, nodular, tabular, or rounded cobbles. Where this was not possible, evidence was gained from flakes (*e.g.*, flakes with transport battering on the cortical areas were recorded as having a cobble shape; tabular pieces were recorded as being parallel-sided).

Raw Material Types at Hope Downs

During the analysis of the flaked stone assemblages recovered during the Hope Downs 1 Mitigative Salvage Project, 29 unique raw material types were identified, including many geologic rock types such as chert, quartz, shale, and banded iron formation (BIF). Raw material types were defined based on the type of rock, as well as macroscopic attributes of the matrix and cortical surfaces. Each raw material type was assigned a description-based name (*e.g.*, dark grey chert, speckled black chert, *etc.*) as a method of quickly identifying each type and facilitating data entry. The raw material types are described in detail, according to the methods outlined above, but first, classification of the broad rock types will be discussed.

Numerous geologic rock types are used for the manufacture of flaked stone artefacts, and each offer different properties to the knapper. Classification of geologic rock types helps to build an understanding of resource use and material preference. The raw material types identified amongst the Hope Downs 1 flaked stone assemblage includes numerous varieties of chert, as well as quartz. The local geology of the region is characterised by iron formations and BIF. It provided the past occupants with an inexhaustible resource of BIF and shale, as well as altered varieties of these rocks, such as goethitised shale and martite-goethite. ACHM worked closely with the RTIO geologists in order to refine the classification of these rock types.

Quartz is a rock composed of crystalline silica, and it can occur as macrocrystalline quartz, which is characterised by the formation of crystals (often hexagonal), or as aggregates of microcrystalline to cryptocrystalline quartz crystals (Hefferan and O'Brien 2010). The transparency of quartz can vary from completely transparent to a milky appearance, and it can appear in a variety of colours (*e.g.*, red, orange, pink, grey, yellow, and brown) or it may be colourless. Quartz crystals fracture conchoidally, but massive vein quartz tends to fracture both conchoidally and unevenly, with the force of percussion following incipient fractures, faults, or crystal lattice planes in the material.

Chert is a broad term that refers to a sedimentary rock composed primarily of microcrystalline or cryptocrystalline quartz (Leudtke 1992: 5), and like quartz crystal, it fractures conchoidally. Chert can be further classified according to particular characteristics, and these chert types can include chalcedony, agate, and jasper (Leudtke 1992: 5). Chalcedony can only truly be identified by its microscopic structure, in which the quartz particles are fibrous instead of granular (Leudtke 1992: 23). Agate is a translucent chert that is often pale in colour and displays banding, moss-like structures, or cloudy areas (Leudtke 1992: 31). Jasper is a chert that contains impurities of iron oxide, which often produce colours of red, gold, or brown (Leudtke 1992: 104). Of note, metamorphism (exposed to high temperature and pressure) can alter cherts, causing recrystallisation or coarsening grading into metaquartzite, resulting in a sugary or foliated appearance (Leudtke 1992: 27). Opal is also a silicate similar to chert; however, it is composed of amorphous quartz and is often slightly softer with a waxy texture (Hefferan and O'Brien 2010).

Iron formations and BIF dominate the geology of the study area, and this local raw material was often utilised for the production of flaked stone artefacts. Iron formation refers to sedimentary rock with high iron formation, and it may include BIF, as well as iron-rich shales, slates, and carbonates (Trendall and Blockley 1970: 26). BIF is defined as having thin bands of fine-grained quartz, iron oxides, carbonates, and silicates, and iron-rich and iron-poor bands often alternate through the formation (Trendall and Blockley 1970: 26-27).

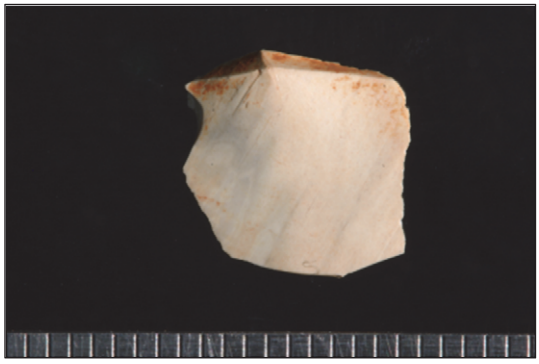
The Marra Mamba Iron formation is exposed throughout the Hope Downs 1 Mine, and it is comprised of three members. The uppermost Mount Newman member predominantly consists of thick magnetite-rich bands that have high silica and carbonate contents, which alternate with thinner shaly bands with a high silicate, carbonate, chert content (Blockley *et al.* 1993). The middle MacLeod member has a shaly appearance and is comprised of interbedded shale (black and stilpnomelane), chert, carbonate, and BIF (usually magnetite poor) (Blockley *et al.* 1993). The lowermost member, the Nammuldi Member, is made up of a sequence of chert (oxidised yellow and brown and often pod-like in appearance) with thin bands of hematite, BIF (often with distinct black, yellow, and brown bands), and shale (Blockley *et al.* 1993).

In many instances, the BIF has been altered through weathering, while the shale bands are somewhat more resistant. Martite-Goethite is altered form of BIF through which magnetite was oxidised to hematite (martite), iron silicates and carbonates were oxidised and hydrated to goethite, and carbonates and quartz were leached out and replaced by goethite (Taylor *et al.* 2001: 8). Goethite is a common mineral among the enriched rock types on the Hope Downs 1 lease, and it is characterised as being brittle, iron-rich mineral that can have varied lustre (highly lustrous, silky, metallic, or dull). In a similar manner, some of the shale has also undergone goethitisation (*e.g.*, goethitised shale). Identification of many of these rock types can be initially difficult for the non-geologists, as they often grade into different rock types. For example, some goethitised

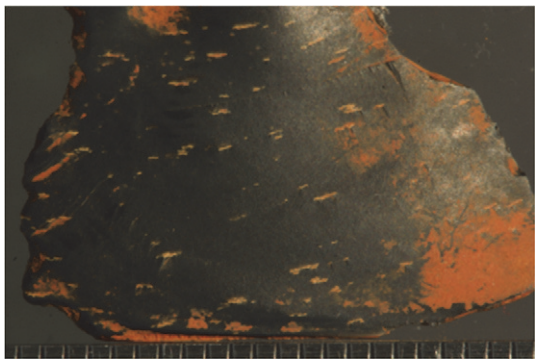
shale outcrops have a similar appearance to chert due to the glossy appearance of the goethite; however, once it has been identified as goethitised shale the characteristic metallic sheen makes it easily recognisable. In addition, the altered rock types retain the structures of the precursor rocks (*e.g.*, banding), making identification more challenging.

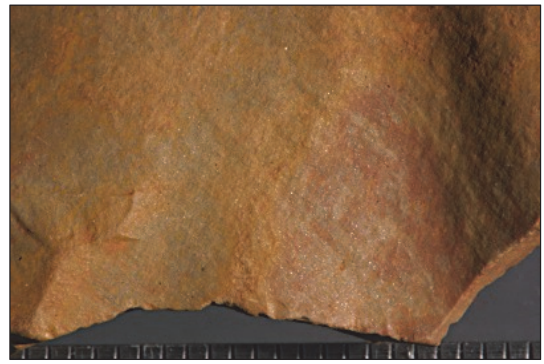
The macroscopic attributes for each of the 29 raw material types identified during the analysis of the assemblages from the Hope Downs 1 Mitigative Salvage project are described in Table 4-2 below. While a specific raw material survey was not conducted as part of our study, the raw materials all appear to be derived from the local geological formations, and this theory is supported by discussions with the RTIO geologists

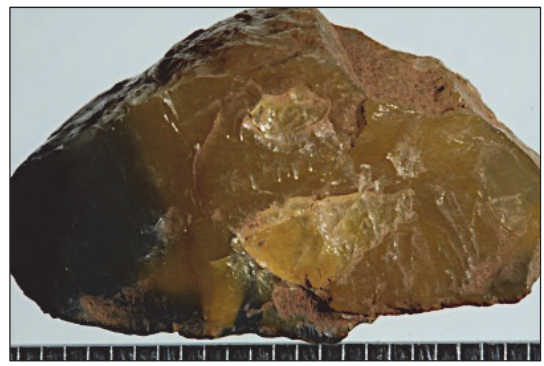
Table 4-2 Raw material types in the Hope Downs 1 assemblages

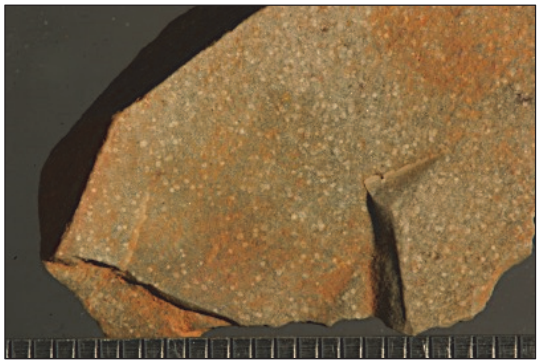
Name	**Brown Shale (ID 16)**	
Raw Material Type	Shale	
Colour	Brown (7.5YR 4/2 to 4/4)	
Colour Variation	Little	
Pattern Character	Rare dark grey lamina; rare quartz veins	
Coloured Patterns	Dark grey (N 4/0)	
Pattern Distribution	Irregular	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Slightly coarse grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	Irregular	
Clefts/Hollows	Quartz veins, vugs	
Flaking Ability	Manageable	
Patination	Some oxidizaiton	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Indistinct contact	
Rolled Surfaces	Some specimens exhibit rolled sufaces, indicating the source was a river cobble	
Geological Context	Locally available throughougt the Marra Mamba Iron Formation and as rolled river cobbles in the numerous ephemeral streams throughout the lease.	
Other Characteristics	Brown shale ranges from extremely fine-grained to coarse-grained, and some specimens can have internal flaws (*e.g.*, HD07-A1-04, Artefact 47); the colour can also very significantly. Brown shale is distinguished from cherts because the grains are visible. It is finer-grained than BIF and has a 'muddier' appearance.	
Name	**Creamy Grey Chert (ID 24)**	
Raw Material Type	Chert	
Colour	White (7.5YR 8/1) to light grey (N 7/1)	
Colour Variation	Moderate	
Pattern Character	Some mottling of both the white and light grey, and some very faint laminae	
Coloured Patterns	White (7.5YR 8/1) to light grey (N 7/1)	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Very fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Some specimens have a opaque white patina	
Cortical surfaces	Indeterminate	
Cortex thickness	Indeterminate	
Character of contact	Indeterminate	
Rolled Surfaces	Some specimens have rolled surfaces indicating that the source was a river cobble.	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material type is rare. It is extremely fine-grained.	

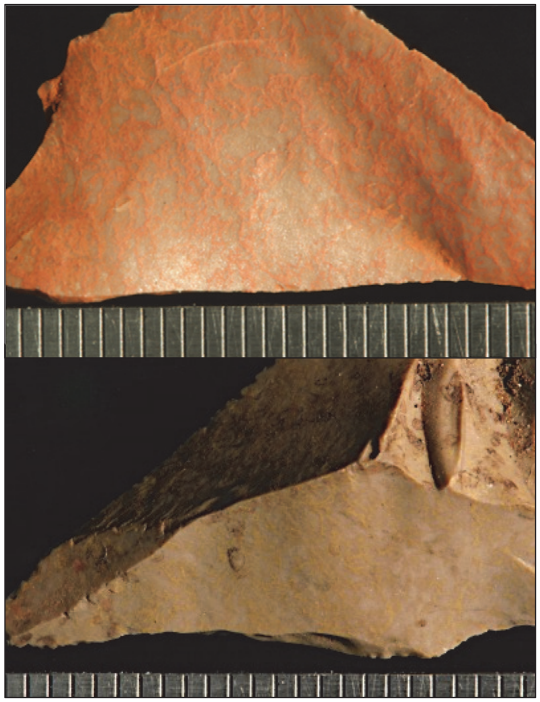
Name	**Dark Grey Chert (ID 3)**	
Raw Material Type	Chert	
Colour	Dark grey (N 4/0), very dark grey (N 3/0), black (5Y 2.5/1), greenish black (5GY 4/1, 10G 3/1)	
Colour Variation	Little	
Pattern Character	Some banding with slightly ligher colours (brown, dark grey, dark greenish grey)	
Coloured Patterns	Dark grey (N 4/0), brown (7.5YR 4/3), dark greenish grey (10Y 4/1)	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	Rare specimens have rolled surfaces	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	Speckled black chert and dashed black chert are likely variants of this raw material type. It is possible that this chert had a shale precursor, similar to those at North Pole Dome (Orberger *et al.* 2006). There is definately variation within the group, as there are specimens that are dull, while others are lustrous; this may be due to the silica content. The material can range from very dark black to dark brown to greenish grey. When knapped it has a very chert-like appearance, but natrual fractures show fractures more similar to shale.	

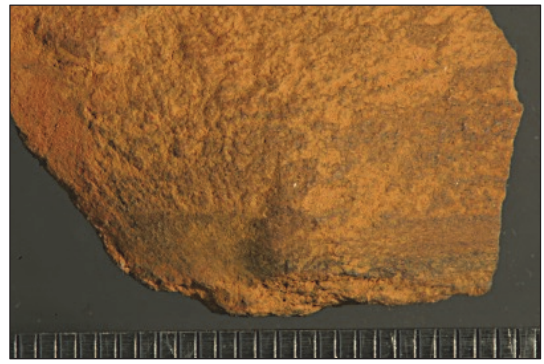
Name	**Dashed Black Chert (ID 8)**	
Raw Material Type	Chert	
Colour	Very dark grey (N 3/0)	
Colour Variation	Little	
Pattern Character	Dahed lines (*ca.* 1.5mm long, 0.2mm wide), all oriented the same way, suggests band of material that is getting pinched off.	
Coloured Patterns	Pale yellow (5Y 7/3)	
Pattern Distribution	Regular	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	Dashed lines are likely carbonate inclusions	
Inclusion Silicification	Partly silicified	
Inclusion Distribution	Regular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Possibly loss of colour	
Cortical surfaces	Grey silicified weathered rind	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This is a likely variant of dark grey chert and speckled black chert.	

Name	Dragonsblood (ID 18)	
Raw Material Type	Indeterminate	
Colour	Olive green (5Y 5/3)	
Colour Variation	Moderate	
Pattern Character	Has a mottled appearance of either red or yellowish material	
Coloured Patterns	Weak red (10R 5/4) & lighter olive green	
Pattern Distribution	Irregular	
Lustre	Dull to waxy	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Manageable	
Patination	Indeterminate	
Cortical surfaces	Indeterminate	
Cortex thickness	Indeterminate	
Character of contact	Indeterminate	
Rolled Surfaces	Indeterminate	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material type is very rare. One of the distinguishing characteristics of this raw material is its softness and its mottled pink and green appearance. The raw material has a slightly soapy feel; hence, it is possible that it may be argillite (indurated clay). It is also possible that this it is aventurine, which is a variety of quartzite or gangue quartz that is often green in colour, but brown and yellow colours can be caused by iron-rich minerals, such as goethite. Mica is a common feature of aventurite. A similar looking, although more green, rock type has been identified in the Pilbara as fuchsitic chert, where it has also been called dragon stone, dragon's blood stone, and prase (Archer 2003-2009). This raw material type has similar colouration to the type pink and green banded chert and bears some similarity to mottled greyish brown chert; however, it is much softer than these varieties of chert. All of the specimens have rounded arrises, and mica appears throughout the matrix giving it a sparkly appearance.	

Name	Green Quartz (ID 22)	
Raw Material Type	Quartz	
Colour	Very dark greenish grey (5GY 3/1) to yellowish brown (10YR 5/4 to 5/6)	
Colour Variation	Considerate	
Pattern Character	None	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Lustrous	
Translucency	Slight translucency	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Barely manageable	
Patination	Indeterminate	
Cortical surfaces	Crystal faces	
Cortex thickness	3mm or less	
Character of contact	Indistinct contact	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material type is rare. There are two main colours, dark green and yellow, which can occur in the same specimen. It is very probable that iron has caused the colouration, and there are several varieties of yellow and green quartz, including citrine and green quartz ((Deer *et al.* 2004: 98), as well as ferruginous quartz . The yellow and green colouration is likely due to the effects of iron minerals; goethite can the quartz to take on a deep yellow colour.	

Name	Green Shale with White Speckles (ID 4)	
Raw Material Type	Shale	
Colour	Greenish grey (10Y 6/1 to 5/1) to dark greenish grey (10Y 4/1)	
Colour Variation	Moderate	
Pattern Character	Speckles, some densely packed others more widely distributed. Rare specimens do not have speckles.	
Coloured Patterns	White to light greenish grey (10Y 8/1)	
Pattern Distribution	Irregular	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	White speckles are likely calcareous inclusions	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Manageable	
Patination	Tends to become either light greenish grey 10Y 7/1 to greenish grey 10Y 6/1	
Cortical surfaces	Silicified weathered rind (*in situ* weathering of bedrock)	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	Some samples have slightly rounded arrises suggesting some clay content.	

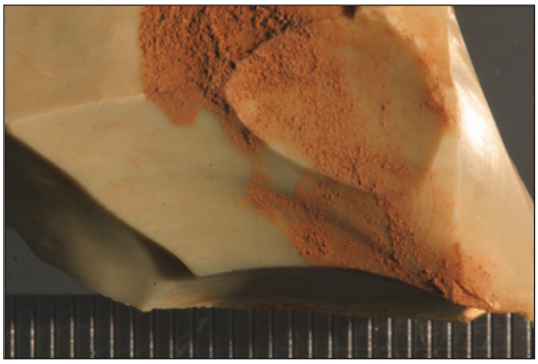
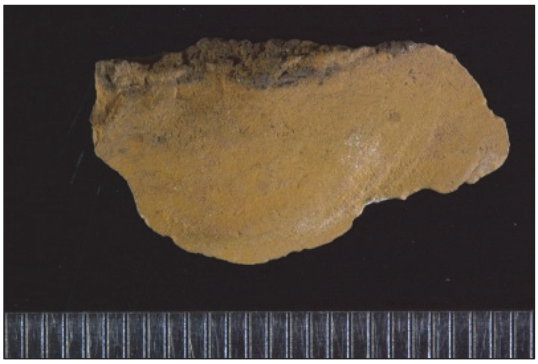
Name	Greyish Brown Chert (ID 1)	
Raw Material Type	Chert	
Colour	Greyish brown (10YR 5/2) to dark greyish brown (10YR 4/2)	
Colour Variation	Little	
Pattern Character	Red or yellow veins with a 'squiggly' appearance. Some specimens have very fine spherical hollows - outlined in dark grey, while the main matrix fills the spherules. The majority of the specimens have patterns, but rare examples have no patterns.	
Coloured Patterns	Very dark grey (10YR 3/1)	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Fine grained, but slighly granular	
Matrix Homogeneity	Homogeneous	
Inclusions	Spherical microstructures (possibly microfossils)	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	Indeterminate	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material seems to be very sensitive to heat and can take on a wide variety of appearances; the greyish brown material can become lighter and the mottling can become reddened. In some cases, the red or yellow material is dominant and the greyish brown material is the mottling. The greyish brown matix generally has a satiny appearance. HN-A9 Artefact 12307 shows contact between speckled black chert and greyish brown chert.	

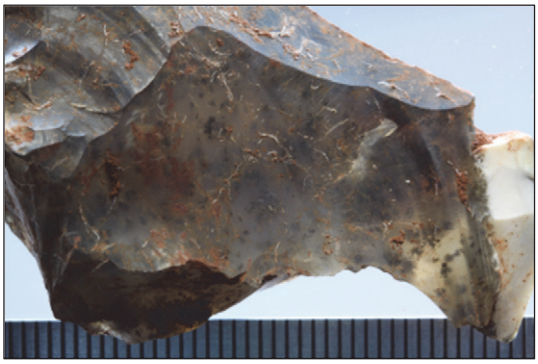
Name	Homogenous BIF (ID 11)	
Raw Material Type	BIF	
Colour	Dark grey (N 4/0) to strong brown (7.5YR 5/4)	
Colour Variation	Considerate	
Pattern Character	Some thick bands of slightly transparent coarse-grained chert	
Coloured Patterns	Strong brown (7.5YR 5/4)	
Pattern Distribution	Banded	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Coarse grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	Silicified	
Inclusion Distribution	Parallel with cortex	
Clefts/Hollows	Vugs	
Flaking Ability	Manageable	
Patination	Many specimens are oxidized due to high iron content; this is why there is such a considerate colour change	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Widely available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	Tiny voids and vugs occur near the cortical surface on some specimens. There is a significant range of variation within BIF due to the banded nature of this rock, which includes bands of coarse-grained chert.	

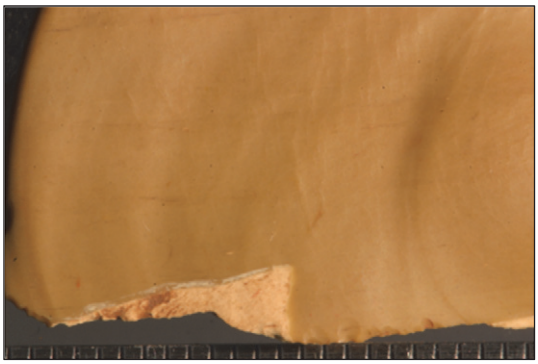
Name	Ironstone (ID 14)	
Raw Material Type	Martite goethite	
Colour	Dark grey (N 4/0) to very dark grey (N 3/0)	
Colour Variation	Little	
Pattern Character	None	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Coarse grained	
Matrix Homogeneity	Homogeneous	
Inclusions	Mica	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Barely manageable	
Patination	Oxidization	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Widely available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	Distinguished from BIF by its very heavy weight in relation to its size, its blue-grey colour, and the presence of mica, which give it a glittery appearance. This raw material replaces the BIF; therefore, some of the residual parent structures can sometimes be seen (*e.g.*, laminations and bands).	

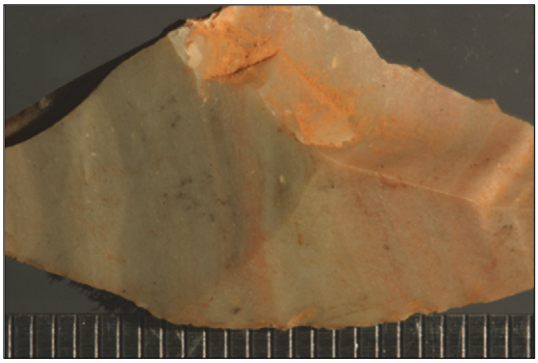
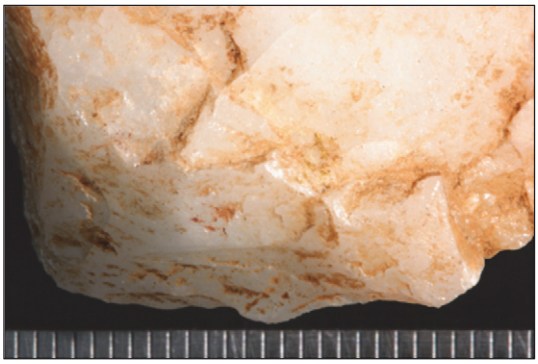
Name	Jeerinah Dolerite (ID 29)	
Raw Material Type	Dolorite	
Colour	Greenish grey (10Y5/1 to 5GY 6/1)	
Colour Variation	Moderate	
Pattern Character	None	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Coarse grained; holocrystalline texture	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	Silicified	
Inclusion Distribution	Regular	
Clefts/Hollows	Vugs	
Flaking Ability	Problematic	
Patination	Indeterminate	
Cortical surfaces	Indeterminate	
Cortex thickness	Indeterminate	
Character of contact	Indeterminate	
Rolled Surfaces	Indeterminate	
Geological Context	Closest dolerite source - metadolerite sills intruded into the Jeerinah formation of the Fortescue Group. Medium to coarse-grained massive grey green rock, usually foliated (Newman 1:250 000 geological map sheet SF50-16).	
Other Characteristics	Not a good knappable rock. Better for groundstone artefacts. Dolerite (aka diabase) is an igneous rock with a holocrystalline texture. The rock forms in dikes and sills and the size of the crystals are determined by how quickly the magma cooled. Dolerite outcrops along the upper reaches of Pebble Mouse Creek and Weeli Wolli creek, and can be viewed from the Newman-Hedland Road near Pebble Mouse Creek.	

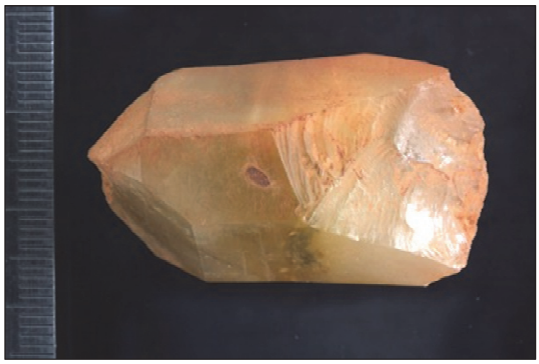
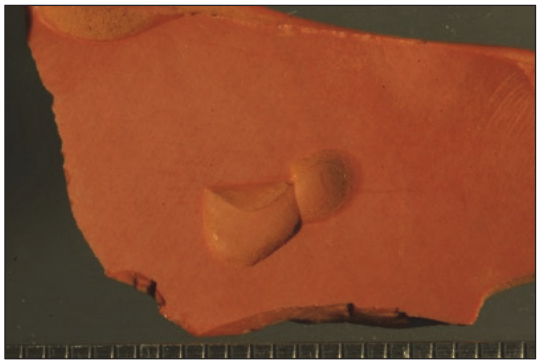
Name	Laminate BIF (ID 12)	
Raw Material Type	BIF	
Colour	Dark grey (N 4/0) to strong brown (7.5YR 5/4)	
Colour Variation	Considerate	
Pattern Character	Laminae	
Coloured Patterns	Dark grey (N 4/0)	
Pattern Distribution	Regular	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Slightly coarse grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Manageable	
Patination	Many specimens are oxidized due to high iron content; this is why there is such a considerate colour change	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Widely available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	Distinguished from homogenous BIF by the very fine laminae (homogeneous BIF can have thick bands).	

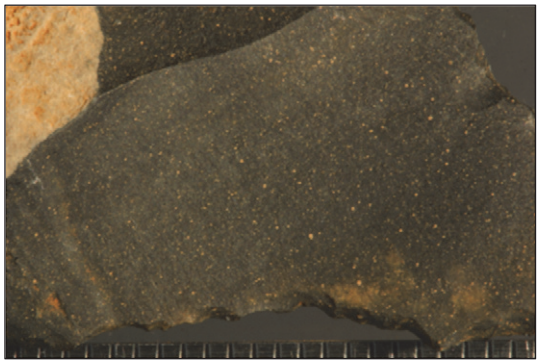
Name	Light Greenish Gray Chert (ID 17)	
Raw Material Type	Chert	
Colour	Light greenish grey (10Y 7/1) to greenish grey (10Y 5/1 to 10Y 6/1)	
Colour Variation	Little	
Pattern Character	Has laminated and banded appearance; some of these structures are not as distinct & have a mottled appearance	
Coloured Patterns	Lighter greenish grey and bluish grey (5B 5/1)	
Pattern Distribution	Laminated	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Opaque white	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	There is a thin white chert rind beneath cortical surface. This raw material takes on a reddish brown hue (2.5YR 4/4) hue when heated.	
Name	**Limonite (ID 15)**	
Raw Material Type	Limonite	
Colour	Yellowish red (5YR 4/4 to 5YR 4/6), yellowish brown (10YR 5/6), brownish yellow (10YR 6/6), and very pale brown (10YR 7/4 to 10YR 8/4)	
Colour Variation	Moderate	
Pattern Character	None	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Coarse grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Problematic	
Patination	Darkened colour; oxidization	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Widely available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	Rarely used for flaked stone artefacts; however, isolated artefacts have been identified. Limonite is a hydrated iron oxide, which includes earthy goethite.	

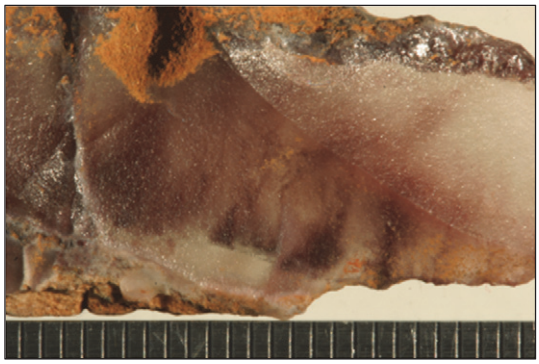
Name	Moss Agate (ID 28)	
Raw Material Type	Chert	
Colour	White to light grey (10YR 7/2; translucent)	
Colour Variation	Little	
Pattern Character	Green patches and fillaments that have a mossy appearance	
Coloured Patterns	Very dark greenish grey (10Y 3/1)	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Transparent	
Matrix Texture	Fine grained	
Matrix Homogeneity	Non-homogeneous	
Inclusions	Green mossy patches	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	Indeterminate	
Cortex thickness	Indeterminate	
Character of contact	Indeterminate	
Rolled Surfaces	Indeterminate	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material type is rare. A small number of specimens show contact with opaque white chert, and this may be a band near the cortex. The largest flake recovered was from HD07-3A-PAD13, and this was from a rotated core.	

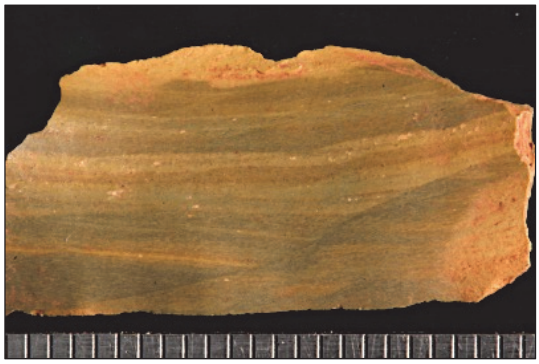
Name	Olive Chert with Darker Laminae (ID 6)	
Raw Material Type	Chert	
Colour	Olive green (2.5Y 5/4) to yellowish brown (10YR 5/3)	
Colour Variation	Little	
Pattern Character	Dispersed laminae (<1mm thick) of slightly darker olive green; sometimes a very thin lamina (<1mm thick) of white chert under the cortex	
Coloured Patterns	Olive brown (2.5Y 3/3)	
Pattern Distribution	Parallel	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Very fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	Non-silicified calcareous areas (some quite large)	
Inclusion Silicification	Not silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex often with a ferrigenous outer rind	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified. Possibly yellow Jasper.	
Other Characteristics	This raw material is very homogenous and may be related to the more highly laminated thylo chert. It becomes glossy and reddened when heated (*e.g.*, HD07-1A-04, Artefact 323).	

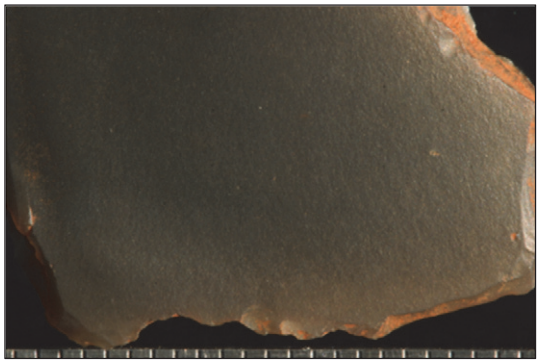
Name	Pink and Green Banded Chert (ID 19)	
Raw Material Type	Chert	
Colour	Greenish grey (10Y 5/1)	
Colour Variation	Moderate	
Pattern Character	Alternating bands or laminae of the different colours; the greenish grey colours are predominant, and in some cases the pink laminae are slighly less distinct	
Coloured Patterns	Greenish grey (10Y 6/1), red (10R 4/4), and dark grayish brown (10YR 4/2)	
Pattern Distribution	Laminated	
Lustre	Slightly lustrous	
Translucency	Slight translucency	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	Rare calcareous inclusions	
Inclusion Silicification	Partly silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	Indeterminate	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material type may be variant of light greenish grey chert.	
Name	**Quartz (ID 20)**	
Raw Material Type	Quartz	
Colour	White to transparent	
Colour Variation	Little	
Pattern Character	Some specimens have veins	
Coloured Patterns	Red (2.5YR 4/6 to 4/8)	
Pattern Distribution	Irregular	
Lustre	Lustrous	
Translucency	Slight translucency	
Matrix Texture	Very fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	Quartz veins, vugs	
Flaking Ability	Barely manageable	
Patination	Dull oxidized patina	
Cortical surfaces	Weathered rind, often oxidized patina	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	Rounded surfaces common, angular surfaces rare	
Geological Context	Widely available throughougt the Marra Mamba Iron Formation. Likely massive milky quartz.	
Other Characteristics	Numerous veins and natural faults cause step terminations and make knapping difficult in some specimens.	

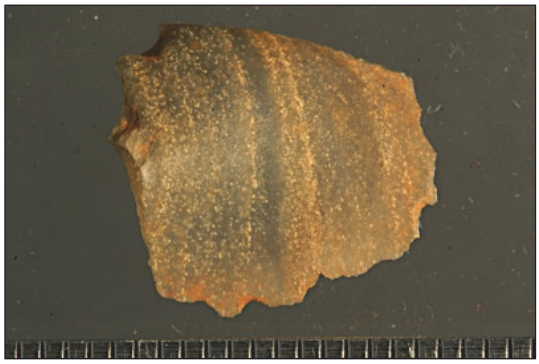
Name	**Quartz Crystal (ID 21)**	
Raw Material Type	Quartz	
Colour	Clear to translucent reddish yellow (7.5YR 6/6)	
Colour Variation	Considerate	
Pattern Character	None	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Lustrous	
Translucency	Transparent	
Matrix Texture	Very fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	Quartz veins	
Flaking Ability	Very manageable	
Patination	None	
Cortical surfaces	Crystal faces, often exhibiting horizontal striations	
Cortex thickness	3mm or less	
Character of contact	Indistinct contact	
Rolled Surfaces	Rare	
Geological Context	Locally available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	Macrocrystalline quartz that is characterised evidence of large crystal growth (*i.e.*, crystal faces). This raw material category includes clear varieties as well as varieties with slight colour (possibly ferrigenous quartz); however, it excludes specimens that are dark yellow and dark green in colour (Green Quartz).	
Name	**Red Chert (ID 9)**	
Raw Material Type	Chert	
Colour	Weak red (10R 4/3 to 4/4)	
Colour Variation	Little	
Pattern Character	None	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	Rare specimens have rolled surfaces	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified. Possibly red Jasper.	
Other Characteristics	Red chert is locally available; however, some specimens are also reddened due to heat; therefore, it may not be possible to determine between those specimens that are naturally red and those that have been heated, except where there is clear evidence of heat fracture.	

Name	Speckled Black Chert (ID 7)	
Raw Material Type	Chert	
Colour	Very dark grey (N 3/0)	
Colour Variation	Little	
Pattern Character	Tiny speckles, which range from high to low density	
Coloured Patterns	White (N 8/0)	
Pattern Distribution	Irregular	
Lustre	Dull	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	White speckles are likely lime inclusions	
Inclusion Silicification	Partly silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	4-7mm	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	Likely related to dark grey chert and dashed black chert. An example from HN-A9 (Artefact 2575) shows contact between black speckled chert and yellow chert with speckles; however, this differs from the translucent yellow chert and the olive chert with darker laminae. HN-A9 Artefact 12307 shows contact between speckled black chert and greyish brown chert.	

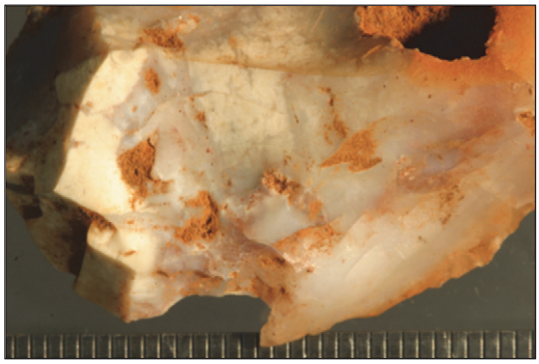
Name	Sugar Chert (ID 2)	
Raw Material Type	Chert	
Colour	White (N 8/0) to greenish grey (10Y 6/1)	
Colour Variation	Moderate	
Pattern Character	Some specimens exhibit thin parallel bands, while others have irregular veins and brecciation	
Coloured Patterns	Weak red (10R 4/2) to very dark grey (N 3/0)	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Slight translucency	
Matrix Texture	Fine grained, but granular	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	White (see Artefact 3 from Hope 1-35)	
Cortical surfaces	Silicified rough cortex formed in bedrock	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This is a very distinctive raw material due to its grainy texture. The sugary appearance may indicate that it was altered (metamorphosed). Brecciation may occur, suggeting contact deformations between layers or fault lines.	

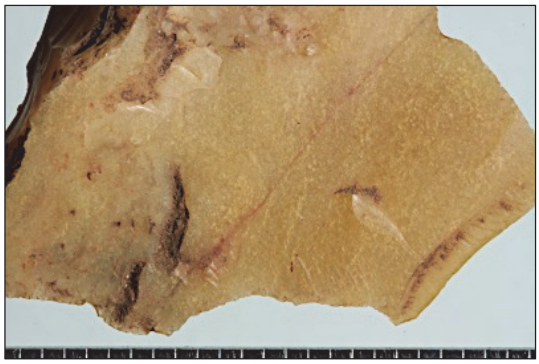
Name	Thylo Chert (ID 23)	
Raw Material Type	Chert	
Colour	Yellow (10YR 7/8)	
Colour Variation	Little	
Pattern Character	Dark grey laminae (up to 1mm thick), some of the laminations are pinched out.	
Coloured Patterns	Very dark grey (10YR 3/1) to olive gray (5Y 4/1)	
Pattern Distribution	Parallel	
Lustre	Slightly lustrous	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified. Possibly yellow jasper.	
Other Characteristics	This raw material type is likely related to olive chert with darker laminae; however, in this raw material, there are always very regular and distinct dark grey laminae. There are also examples of 'reverse' thylo chert, where the predominant colour is olive grey and the stripes are yellow. There are often clear fault lines in the raw material where the structures are interrupted. This material becomes reddened and purplish when heated.	

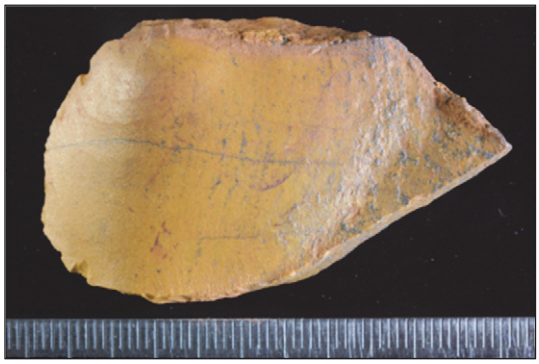
Name	Translucent Dark Grey Chert (ID 25)	
Raw Material Type	Chert	
Colour	Very dark grey (N 3/0 to 10YR 3/1)	
Colour Variation	Little	
Pattern Character	Rare specimens with thin bands of chert	
Coloured Patterns	Olive brown, red, or translucent	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Slight translucency	
Matrix Texture	Fine grained, but slightly grainy	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified. Possibly occuring as bands in the BIF.	
Other Characteristics	This raw material is defined by its slightly translucent appearance and grainy texture. The texture is not as coarse as in sugar chert, but it may indicate that it was altered (metamorphosed). Few cortical specimens have been identified; however, one specimen shows evidence that it occurred within a band of BIF. Rare specimens have a thick white chalky band under the cortex.	

Name	**Translucent Green Chert (ID 10)**	
Raw Material Type	Chert	
Colour	Greenish grey (10Y 5/1) to dark grayish brown (2.5Y 4/2)	
Colour Variation	Little	
Pattern Character	Speckles in laminae. Large pieces show some banding of a black material (looks like vitreous goethite) and strong brown chert (7.5yr 4/4)	
Coloured Patterns	Pale yellow (5Y 7/3) to strong brown (7.5YR 4/4)	
Pattern Distribution	Regular	
Lustre	Slightly lustrous	
Translucency	Milky translucency	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	Calcareous speckles; bands of quartz	
Inclusion Silicification	Partly silicified	
Inclusion Distribution	Regular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	White chalky cortex	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	Possibly related to pink and green translucent chert. This raw material is characterised by its bands of specked material (*e.g.*, HN-A9, Artefact 21189), but rare specimens exhibit bands of quartz. This material reddens with heat (*e.g.*, HN-A9, Artefact 1191).	

Name	**Vitreous Goethite (ID 26)**	
Raw Material Type	Vitreous goethite	
Colour	Black (N 2.5/0) very dark brown (10 YR 2/1)	
Colour Variation	Little	
Pattern Character	NA	
Coloured Patterns	NA	
Pattern Distribution	NA	
Lustre	Glassy to pearly	
Translucency	Slight translucency to opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Manageable	
Patination	Indeterminate	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Clear separation	
Rolled Surfaces	None	
Geological Context	Locally available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	This raw material varries in appearance, from obsidian-like to metallic. Specimens can also have a botryoidal or globular form. This material is often brittle and with numerous internal flaws.	

Name	White and Translucent Chert (ID 5)	
Raw Material Type	Chert	
Colour	White (2.5Y 8/1) to pale yellow (2.5Y 8/2)	
Colour Variation	Moderate	
Pattern Character	Banding near cortex, some brecciated appearance (cloudy white with transparent areas), some weak red cloudy veins, and some grey cloudy areas	
Coloured Patterns	Transparent, weak red (10R 5/4), dark grey (N 4/0)	
Pattern Distribution	Irregular	
Lustre	Dull	
Translucency	Milky translucency	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	Breccious material, vugs	
Flaking Ability	Very manageable	
Patination	Material tends to become opaque white. Hd07-1a-04 artefact 164 shows a white weathered rind 2mm thick	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	Some pieces have worn abraded cortex, while others have fresh cortex	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	There is quite a bit of variety among the white and translucent chert, which can become yellowed when stained or reddened when heated.	

Name	Yellow Translucent Chert (ID 27)	
Raw Material Type	Chert	
Colour	Yellow (10YR 7/6) to brownish yellow (10YR 6/6)	
Colour Variation	Little	
Pattern Character	Opaque yellow speckles throughout, with occasional strong brown veins	
Coloured Patterns	Yellow (10YR 7/8), strong brown (7.5YR 5/6)	
Pattern Distribution	Irregular	
Lustre	Slightly lustrous	
Translucency	Milky translucency	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	Calcareous speckles	
Inclusion Silicification	Silicified	
Inclusion Distribution	Irregular	
Clefts/Hollows	None	
Flaking Ability	Very manageable	
Patination	Indeterminate	
Cortical surfaces	Indeterminate	
Cortex thickness	Indeterminate	
Character of contact	Indeterminate	
Rolled Surfaces	Indeterminate	
Geological Context	Likely locally available throughougt the Marra Mamba Iron Formation, but no local sources have been identified.	
Other Characteristics	This raw material type is likely related to the translucent green chert, as they have similar textures; however, the speckles in this raw material do not form regular bands like in the translucent green chert.	

Name	Yellowish Brown SHG (ID 13)	
Raw Material Type	Goethitised shale	
Colour	Dark yellowish brown (10YR 4/4 to 4/6) to olive brown 2.5Y 4/3	
Colour Variation	Little	
Pattern Character	Some banding of slighlty darker & coarser SHG (almost looks like a contact between a fine-grained and slighly coarse-grained SHG), some infilled cracks	
Coloured Patterns	Dark yellowish brown (10YR 3/4 to 3/6)	
Pattern Distribution	Irregular	
Lustre	Lustrous with sligh metallic sheen	
Translucency	Opaque	
Matrix Texture	Fine grained	
Matrix Homogeneity	Homogeneous	
Inclusions	None	
Inclusion Silicification	NA	
Inclusion Distribution	NA	
Clefts/Hollows	None	
Flaking Ability	Manageable	
Patination	Indeterminate	
Cortical surfaces	Fresh cortex (rough)	
Cortex thickness	3mm or less	
Character of contact	Gradual transition	
Rolled Surfaces	None	
Geological Context	Widely available throughougt the Marra Mamba Iron Formation.	
Other Characteristics	This raw material type has a wide colour range and a chert-like apperance, but goethite has replaced other minerals in the shale; therefore, the structure of the shale remains. Goethitised shale is generally quite brittle leading to flake breakage, crushed platforms, and step terminations.	

who have obtained samples of similar materials from the lease. Raw material types do appear differentially throughout the lease, with the coarser-grained rock types common to the Marra Mamba Iron formation being more prevalent than chert. For example, BIF, shale, goethitised shale, martite-goethite, and limonite outcrop across the lease, whereas not a single high-quality chert outcrop was observed during our 23 field trips to the Hope Downs 1 Lease.

Chert is the most varied raw material type utilised by past occupants of the Hope Downs 1 lease, and numerous varieties have been defined based on differences in the colours, patterns, and textures. Moss agate was also identified and is included among the chert varieties as it often grades into white and translucent chert where no moss-like structures can be seen. In several cases, artefacts were identified that have contacts between two different chert varieties, and this has been explicitly stated within the raw material descriptions. It is plausible that some of the varieties may be from the same source, as banded chert is known to occur within the lease. The sources of these particular varieties could not be located; therefore, we took the cautious approach by individually identifying each variety. Three varieties of quartz were identified, including two types of macrocrystalline quartz (quartz crystal and green quartz).

There are a range of coarser-grained raw materials that are derived from the local iron formations, including varieties of BIF, shale, limonite, and goethite-rich rock types (goethitised shale, martite-goethite, and vitreous goethite). Dolerite was also identified, as was an indeterminate rock type that was termed ‘dragonsblood’ based on a local nickname.

Core Analysis

A core is any piece of stone from which flakes were removed. A core will only exhibit negative scars, and will never have a ventral surface or bulb of percussion, features exclusive to flakes and retouched flakes (Hiscock 1989; Hiscock and Mitchell 1993) A core will have one or more striking platforms, which is a surface that receives the fracturing blow to detach a flake (Andrefsky 2005). While cores are present in the assemblage in their final discarded state, they offer significant insight into the range of reduction strategies employed at a site. Table 4-3 lists the attributes recorded for each core, which are described in the following paragraphs.

In Australia, cores are typically reduced through direct percussion using a hard hammer percussor to strike the flake from the core. Hard percussors, or hammerstones, are generally fist-sized rocks, often in the form of rounded river cobbles, but they can also occur in a wide-range of forms. Soft percussors can include wood, bone, and antler (in continental regions outside Australia). Ethnographic observations demonstrate that boomerangs and bone awls were used for soft-hammer percussion (Moore 2004: 62; McCarthy 1976: 11). Alternatively, knappers can strike the core on a stationary rock or anvil. Indirect percussion can also be used, where an object or punch is placed on the core, and then it is struck.

An archaeological core type represents a deliberate choice made by a knapper to produce flakes in a specific way. This decision can be influenced by numerous factors, such as the size, shape, or quality of the raw material (Jeske 1992: 468), the desire to produce a specific flake shape or size (Pelcin 1997b), the effort to conserve raw material (Hiscock 1996; Pelcin 1997b), and normative behaviour (Frankel 2003: 43). Five core types were used in this research: unidirectional, bidirectional, rotated, alternate, and bipolar. With the exception of bipolar cores, core types are defined according to the direction of the applied force, which represent an ordered and specific reduction strategy. Unidirectional cores occur in various shapes, and all flakes are struck in the same direction from one striking platform. Bidirectional cores have two opposing striking platforms that may or may not be on the same face of the core. Rotated cores have at least two striking platforms that are roughly perpendicular to each other; they may not be on the same face of the core. Alternate platform cores have at least one bifacial

striking platform where flakes are struck alternately from the edge; the flakes do not necessarily radiate around the entire core.

Unlike the cores discussed above, which are hand-held during knapping, bipolar cores are placed on a flat hard surface or anvil while flakes are removed. Cores reduced using the bipolar technique exhibit a crushed surface opposite the direction of removals (Holdaway and Stern 2004: 12). Bipolar reduction strategies are a particularly useful method for reducing both very large and very small pieces of rock and can extend the life of cores that are too small to be knapped using other techniques (Andrefsky Jr 1994; Hiscock 1996: 152; Jeske 1992: 472).

Raw Material & Alterations

Raw material can affect the size and shape of artefacts, and its availability can lead to different reduction strategies; hence, it is a critical variable of lithic technology. The raw material type, material alterations, and evidence of thermal alteration were recorded for each specimen. Raw material types were assigned according to prominent geological rock types found throughout the Pilbara and additional raw material characteristics observed throughout the assemblage. The dominant colour of each artefact was assigned using a standard Munsell soil colour chart (2000 edition). Evidence of abrasion, patination, staining, oxidisation, and concretions were recorded, as they can indicate material alterations through taphonomic processes. Physical or chemical alteration of the raw material can obscure artefact attributes; for example, it can be difficult to assign raw material type and colour to highly oxidised, stained, or patinated artefacts. In contrast, alterations such as calcareous concretions may help preserve usewear and residue.

Thermal alteration of raw material can include intentional heat treatment or inadvertent heat exposure. Intentional heat treatment of cores can improve the flaking quality of the raw material. Heating can cause changes in the lustre, colour, and translucency of siliceous rock; however, raw material types react differently to heat (Leudtke 1992: 94). Reddish or pinkish hues are often cited as evidence of thermal alteration; however, some raw materials may not become reddened when heated, while reddish coloured chert can occur naturally or can be a result of heating either at low or high temperatures (Quintero 1998: 108). Leudtke (1992: 95) notes that most types of heat-treated chert attain a glossy or greasy appearance on freshly knapped surfaces, and this is one of the best indicators of heat alteration.

Thermal damage can occur due to high temperatures and rapid heating or cooling (Mercieca and Hiscock 2008). Common effects of thermal damage are fracture, potlid fracture, crazing, loss of colour, and loss of lustre; these flaws render the raw material unsuitable for knapping (Leudtke 1992: 97). Thermal damage can result from rapid heating, direct contact with the fire, or excessive heating temperatures (Leudtke 1992: 105). In an experimental study using mudstone and silcrete, Mercieca and Hiscock (2008: 2636) determined that the threshold for

Table 4-3 Core attributes

Category
Unidirectional
Bidirectional
Rotated
Alternate
Bipolar
Indeterminate
Raw Material Attributes
Raw Material Type
Colour - main colour defined by Munsell chart
Grain size
Fine
Medium
Coarse
Heat Affected
Crazing
Pot Lidding
Loss of Colour
Reddening
Glossy
Darkened Colour
Material Alterations
None
Abraded
Patinated
Striking Platform Attributes
Striking Platform Type
Plain
Facetted
Cortex
Missing
Number of Striking Platforms
Overhang Modification (under 5mm)
Facetted
Abraded
No modification
Cortex And Shape Attributes
Cortex
None
1-32%
33-65%
66-99%
100%
Cortex Type
Cortex
Patina
River-rolled/abraded
Nodular
Tabular
Core Status And Condition
Scar Type
Flake
Blade
Mixed flake/blade
Number of Scars (over 5mm)
Termination Type (main types)
Hinge
Feather
Overshot
Step
Status
Complete
Fragment
Condition
Viable
Exhausted
Metrics
Maximum Measurements
Maximum Length (mm)
Maximum Width (mm)
Maximum Thickness (mm)
Weight (g)
Maximum Flake Metrics
Length (mm)
Width (mm)
Minimum Flake Metrics (over 5mm)
Length (mm)
Width (mm)

thermal damage (cracking, followed by fracture) is related to the temperature and artefact size, and it varies between raw material types. One of their key findings is there is an inverse relationship between artefact size and failure rates, whereby large artefacts fail at lower temperatures than small artefacts (Mercieca and Hiscock 2008: 2636).

Experimental research has shown that heat treatment can be achieved by different strategies, which favour either quick or slow approaches. (for a review see Mercieca and Hiscock 2008). As Mercieca and Hiscock (2008: 2637) describe, the slow approach can take nearly three days (48 hours to heat, 20 hours to cool) and may be labour intensive, requiring a large pit with layers of charcoal and sediment. In the quick approach, materials are placed closer to the heat source (*e.g.*, by slightly burying it, placing it on cooling ashes, or caking it in clay), exposing it to higher temperatures for a short duration (Mercieca and Hiscock 2008: 2638). In Australia, current research suggests that heat treatment of siliceous materials occurred as early as 20,830±810 BP of 25,692 to 20,096 cal BP (Hanckel 1985: 100), and there is evidence for the use of slow heat treatment strategies by 1500 years ago (Hiscock 1993; Mercieca and Hiscock 2008).

Thermal alteration of siliceous rock is not always intentional. Artefacts may be inadvertently heated due to taphonomic processes; discarded artefacts may be heat affected by an overlying campfire, or by a bushfire (Leudtke 1992: 97). Fire-cracked rocks are common at archaeological sites, as heated rocks are used in a variety of activities such as cooking or baking (Holdaway *et al.* 2002) and resin production (Binford 1984: 168). If siliceous rocks were used, the fragments may resemble thermally damaged artefacts. Ethnographic research in central Australia has demonstrated that heat can be used to break apart large rocks, rendering smaller fragments that are more suitable for use as a core (Binford and O'Connell 1984: 418). In this example, improved flaking quality may be an inadvertent result.

Throughout our analysis, instances of possible heating were recorded when the raw material type was identifiable and the specimen demonstrated thermal damage or a change in lustre, colour, or translucency. For each artefact, the type(s) of thermal alteration was noted.

Striking Platform Attributes

The striking platform of a core is the surface that is struck in order to remove a flake, and as such, it plays a significant role in the reduction process. A core's striking platform can be a cortical or a flaked surface. A knapper can choose to prepare a platform in many different ways, which may be influenced by factors such as the type or size of flake needed or the desire to conserve raw material. Through a core's reduction, the preparation of the striking platform can change (Andrefsky 2005: 90); thus, striking platform types were recorded for both cores and flakes. The number of striking platforms was counted by identifying any preserved striking platforms, as well as looking for scars originating from earlier striking platforms that had been obscured by later flaking. The type was recorded for each preserved striking platform.

Prior to the removal of a flake, the edge of the striking platform can be modified through faceting or abrasion. The purpose of edge modification is to strengthen the striking platform by removing the thin overhang that was left after the removal of previous flakes (Holdaway and Stern 2004: 143-144), which may lead to crushing or stepping along the edge of the platform. Andrefsky (2005: 97) notes that the force of percussion can be altered when it encounters small step fractures or multiple flakes; therefore, edge modification may reflect the level of care taken by a knapper. Evidence of edge modification was noted among cores and flakes.

Negative Flake Scars

The organisation or pattern of a core's negative flake scars records the sequence of reduction, revealing the decisions a knapper took when reducing the core. Through understanding the sequence of reduction, continuums between core types can be identified. For example, if flake scars on bidirectional and rotated cores show that flakes were removed from one platform until it was exhausted, then rotated to use a new striking platform, it demonstrates the progression or continuum from a unidirectional core to a rotated or bidirectional core. In contrast, if flakes were removed alternately from two platforms, then there is no continuum.

Flake size is largely dependent on the size of a core; however, the size of negative flake scars can vary significantly on a core. Putting core size constraints aside, flake size can be controlled by the knapper; consequently large cores and production of large flakes are not necessarily associated, as a knapper can use large cores to generate small flakes. To provide an estimate of the range of flakes produced relative to core size, the largest and smallest negative flake scars were measured for each complete core. To minimise confusion over small flake scars and preparation of the striking platform overhang through faceting, only flakes over 5mm were measured.

A distinction is often made between flake and blade production. In some instances, blades may be inadvertently produced, but at times they are a predetermined product of core reduction. Cores used for deliberate blade production are characterised by negative scars that are twice as long as they are wide. Blade cores typically require more shaping than flake cores, often including the preparation of a ridge that guides the force of percussion (Inizan *et al.* 1992: 59). Maintenance requirements of blade cores are also higher than for most flake cores. In order to recognise if particular reduction strategies were used for the production of flake and blade cores, the type of negative flake scars were recorded for each core. This attribute is also used to determine the ratio of flake type to core type (*e.g.*, blades to blade cores), to identify if production occurred on-site or if there are continuums between blade cores and flake cores.

Core Status and Condition

A core can enter the archaeological record by various means; a knapper may discard a core because it was too small, had flaws, or was no longer needed. Alternatively, it may have been lost or put aside for future use. Attributes associated with core status and condition include the evaluation of size, problematic terminations or platforms, the number of negative scars, and the amount of cortex. Only through consideration of these attributes can we gain an understanding of why or if a core was discarded. The size of a core can affect how a knapper chooses to reduce a core; it can restrict the size of the flakes produced by the core, as well as indicate the point at which it is no longer considered viable. For this research, maximum core dimensions were recorded. Core length was measured parallel to the striking axis on the dominant flaked surface (Figure 4-1). Where multiple platforms were used, the face with the highest number of flake scars was considered the dominant debitage surface. Core width was measured perpendicular to the length. Core thickness was measured perpendicular to the striking axis.

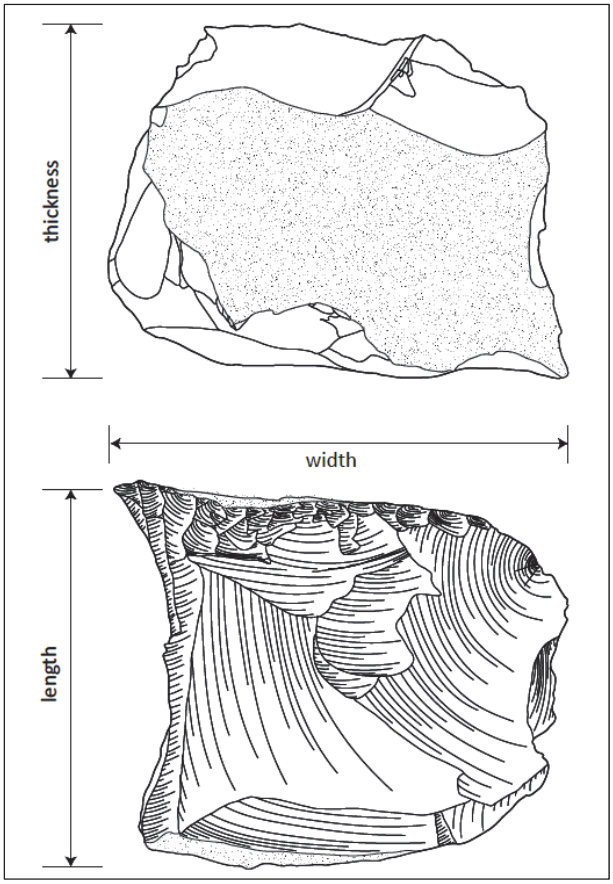


Figure 4-1 Core measurements (after Cropper 2011)

The amount of cortex remaining on a core, combined with the number of flake scars provides an indicator of the intensity of reduction and can be related to the availability of raw material. Because knapping is a reductive process, the number of flake scars on a core will only represent the minimum number of flakes removed from the core, with later flakes removing traces of earlier flake scars. However, the number of negative flake scars on a core can provide an estimate of reduction intensity. All negative flake scars were counted (*i.e.*, scars over 5mm), and a visual estimate of the proportion of cortex remaining on the core was recorded. The type of cortex (*i.e.*, fresh cortex or weathered rind) was recorded to help to identify raw material procurement patterns.

As discussed above, the status of a core is dependent on a range of factors: size, completeness, raw material quality, platform condition, and evidence of problematic terminations. A core was considered viable if a knapper could continue to use it to produce flakes. Conversely, an exhausted core is unfit for further reduction. Through reduction, cores can become too small and are no longer suitable for flake production; similarly, a core can break, rendering it ineffective. Significant damage to the striking platform through crushing or stepping along its edges can also render it exhausted. Equally, problematic flake scar terminations, such as large step or hinge terminations, can make it extremely difficult for a knapper to remove subsequent flakes without hinge or step terminations. A knapper may also test a cobble by removing one or two flakes and decide that the raw material is not suitable.

Flake Attributes

The products of knapping can broadly be categorised by two groups, flakes and flaked pieces. A flake is a fragment of rock that is struck from a core and exhibits a striking platform, as well as a dorsal and ventral surface. A flake can potentially have a multitude of informative attributes, and Table 4-4 lists the attributes that were recorded on each flake specimen subject to analysis, as discussed below.

Flakes exhibit evidence of applied force on the ventral surface, which includes the ringcrack (a cone shaped crack created from where the hammer initiated contact on the flake platform), bulb of percussion, compression lines, lances, and éraillure scars (Odell 2004: 55-56; Cotterell and Kamminga 1987). The dorsal surface records the events that occurred prior to the removal of the flake, and it can exhibit cortex surfaces and negative flake scars.

From a technological perspective, flakes are a well-defined artefact category, exhibiting a common array of reduction attributes (*e.g.*, ventral surface, platform, ringcrack, bulb of percussion, *etc.*); however, for analytical purposes, many flakes can be divided into subgroupings based on their appearance and by the knapping method employed during manufacture. Flakes produced using the bipolar method are identified by a series of attributes, including diffuse bulbs of percussion, small striking platforms with distinct ring cracks, and crushing on multiple edges (Odell 2004: 61; Jeske 1992: 472). A blade is an elongated flake that is twice as long as it is wide; therefore, only complete flakes can be subcategorised as blades. A burin spall is a flake that is produced through burin retouch; the resulting negative is a burin facet. Generally, spalls are narrow and elongated with parallel or sub-parallel lateral margins; they often have step or hinge terminations (Odell 2004: 121). The first burin blow removes a primary spall; if the edge of the flake is not modified, the primary spall typically has a triangular cross section; if the edge is retouched (*i.e.*, prepared), then the cross-section is trapezoidal (Inizan *et al.* 1992: 79). These prepared spalls should not be confused with backed blades (Inizan *et al.* 1992: 79; Hiscock 1993: 71). Subsequent spalls removed from the same edge often have a trapezoidal cross section, which is produced by arrises of the first spall.

Flakes can have attributes that are specific to core preparation or maintenance, including platform rejuvenation flakes and ridge flakes. These unique flake types can provide insight into the knapping sequence. A platform rejuvenation flake removes part or a core's entire striking platform, renewing the platform by creating an entirely new surface, or by altering the platform angle (Odell 2004: 201). It is characterised by the retention of the striking platform, including flake negatives, which typically occur on the lateral edges of the core tablet. Ridge or crested flakes are defined by the characteristic unifacial or bifacial ridge that runs parallel with the force of percussion. The prepared ridge acts to guide the force of the flake and generally produces parallel arrises on the core, which guide subsequent flakes. Ridge flakes are used in the initial shaping of cores, particularly blade cores, as well as in core maintenance.

A flaked piece is a chipped stone artefact produced by knapping, but due to either extreme reduction or taphonomic processes, lacks the necessary attributes to categorise it as a core or flake (Hiscock 1989). This category is reserved for special cases of ambiguity amongst the chipped stone artefact specimens. Heat shatter does not exhibit flake characteristics. In contrast to knapped flakes and flake pieces, heat shatter is fractured through exposure to heat. Similarly, a potlid is a natural flake that can occur when chert is exposed to heat. Potlids are circular to oval and have a plano-convex cross section. A manuport is a natural rock that has been moved from its original location.

Table 4-4 Flake attributes

Category
Flake
Bipolar Flake
Burin Spall
Blade
Ridge Flake
Platform Rejuvenation Flake
Flake Piece
Heat Shatter
Potlid
Manuport
Retouched Flake
Flake Fragmentation
Transverse Status
Complete
Proximal Fragment
Medial Fragment
Distal Fragment
Indeterminate
Longitudinal Status
Complete
Left Fragment
Middle Fragment
Right Fragment
Indeterminate
Right Longitudinal Cone Split
Left Longitudinal Cone Split
Metrics
Maximum Measurements - all artefacts
Maximum Length (mm)
Maximum Width (mm)
Maximum Thickness (mm)
Axis Measurements - only complete artefacts
Axis Length (mm)
Axis Width (mm)
Axis Thickness (mm)
Platform Measurements - only complete platforms
Platform Width (mm)
Platform Thickness (mm)
Platform Angle (degrees)
Weight (g)
Proximal and Distal Attributes
SP Type
Cortex
Faceted
Plain
Dihedral
Chapeau de Gendarme
Winged
Missing
Not Applicable
Bulb of Percussion
Prominent
Small
Missing
Not Applicable
Overhang Modification
None
Abrasion
Facetted
Crushed
Missing
Lipping
Yes
No
Termination
Feather
Plunge
Hinge
Step
Cortical - Axial
Axial
Retroflexed
Indeterminate
Dorsal Removals
Dorsal Cortex
None
1-32%
33-65%
66-99%
100%
Scar Count - count of all scars over 5mm
Direction of Dorsal Removals
Unidirectional
Bidirectional
Rotated
Indeterminate
Not Applicable (*i.e.*, Cortex)
Shape
Form
Expanding Distally
Block
Parallel-Sided
Sub-Parallel-Sided
Contracting Distally
Indeterminate
Leaf
Transversal Section
Trapezoid
Symmetric triangle
Left Triangle
Right Triangle
Lens
Indeterminate
Profile
Straight
Concave
Convex
Twisted
Indeterminate
Raw Material Attributes
Raw Material Type
Colour - main colour defined by Munsell chart
Grain size
Fine
Medium
Coarse
Heat Affected
Crazing
Pot Lidding
Loss of Colour
Reddening
Glossy
Darkened Colour
Material Alterations
Abraded
Patinated

The analysis of these artefacts, particularly flakes, can reveal a wealth of information regarding knapping methods, techniques, and technical procedures, as well as indicating raw material preferences and patterns in blank selection for retouched and utilised artefacts. The attributes recorded for all flakes and flake pieces are defined in the following sections and their significance is discussed.

Fragmentation

Flakes can break by a variety of means: during production, through use, as well as by various taphonomic processes, such as trampling and burial. This research recorded the transverse (complete, proximal, medial, or distal) and longitudinal (complete, left, medial, right, left longitudinal cone split, or right longitudinal cone split) status of each flake (Figure 4-2). The assessment of flake fragmentation can reveal characteristic breakage patterns for an assemblage, and it makes it possible to estimate the original size of the flake assemblage. In addition, the analysis of flake fragmentation creates a valuable analytical tool that can be used to isolate specific groups of artefacts during the analysis. For example, the number of dorsal removals should only be counted for complete flakes, while striking platform attributes can be assessed for complete flakes and proximal fragments that are also laterally complete.

Hiscock (2002: 254) proposes that the minimum number of flakes (MNF) in an assemblage can be calculated, where MNF = C + T + L. Summarising Hiscock (2002: 254), in this calculation C represents the number of complete flakes, T is the largest category of transverse fragments that are longitudinally complete (excluding medial fragments), and L is the number of longitudinal fragments, where L = CL + BL. CL is greater of left or right longitudinal fragments without transverse breakage, and BL is the largest of the four relevant categories of transversely broken longitudinal fragments (*i.e.*, right/proximal, left/proximal, right/distal, and left/distal). Hiscock's (2002: 255) experimental study of flake fragmentation amongst conjoin sets found that distal flake fragments were also more commonly represented that proximal flake fragments. His research indicated that artefact calculations that focus on flake initiations consistently yield results that considerably underestimate the number of specimens, while the MNF index produces results that are much closer to the actual number of specimens (Hiscock 2002: 255).

Flake Size

Stone artefact dimensions (*i.e.*, length, width, thickness, *etc.*) and weight are physical attributes that can be measured to estimate artefact size. Artefact size can be affected by a range of variables. Through experimental studies, researchers have found that the force with which a core is struck does not affect flake size (Dibble and Rezek 2009); rather, the exterior platform angle, platform thickness, the angle of the applied force, and percussion technique are the key variables that control flake size (Dibble and Pelcin 1995; Dibble and Rezek 2009). Flakes produced through hard hammer techniques tend to be thicker and shorter than those produced by soft-hammer techniques, while technique did not appear to affect flake width (Pelcin 1997a). Increased platform thickness led to increased length, width, and thickness for flakes produced using both techniques (Pelcin 1997a; Dibble and Rezek 2009). Raw material availability and size can affect stone artefact dimensions.

For every artefact, the mass and the maximum length, width and thickness were recorded (Figure 4-3. Length is defined as the maximum measurement parallel to the striking axis running through the bulb of percussion. Width is the maximum measurement perpendicular to the length. Maximum thickness was measured parallel to the width. Among artefacts that could not be oriented according to the force of percussion (*e.g.*, flake pieces, heat shatter, and potlids) the length was defined as the longest measurement, with width perpendicular to the length, and thickness perpendicular to the length axis. Axis measurements were taken for all complete flakes. Maximum thickness was measured perpendicular to the width. Axis length is perpendicular to the striking axis, but is taken at the point of impact. Axis width is perpendicular to the axis length and is taken at the midpoint of the axis length. Axis thickness is taken at the midpoint of the axis length. Where flake dimensions are presented in the text, they follow the format: length-x-width-x-thickness.

Proximal and Distal Attributes

With each flake that is struck from a core, part of the core's striking platform is removed; therefore, each flake retains evidence of how it was produced. Attributes recorded for each flake with a complete striking platform (complete flakes, and proximal flakes that are laterally complete) include the size and type of striking platform, evidence of overhang modification, and exterior edge angle. These attributes may control flake size (Dibble and Pelcin 1995; Pelcin 1998; Davis and Shea 1998; Dibble 1998; Dibble and Rezek 2009), shape (Dibble and Rezek 2009), and termination type (Pelcin 1997c). Attributes of the ventral flake surface, including the bulb of percussion and lipping, provide further information regarding knapping techniques.

A knapper can either leave the striking platform of a core in its natural, cortical state, or can choose to prepare it in a number of different ways. The terminology used in this research follows the striking platform types defined by Inizan *et al.* (1992: 80-82). Flakes with a plain striking platforms exhibit a continuous flat, knapped surface. Dihedral striking platforms have two flaked surfaces, divided by an arris, while facetted platforms have multiple surfaces created by the removal of several flakes from the platform. The width of a linear platform can vary, but it is characterised by its extremely thin (usually less than 1.5mm) linear appearance. Winged platforms have a plain surface and are wing-shaped; they are formed when two superimposed flakes are removed from the core. The chapeau de gendarme striking platform is facetted and wing shaped.

The exterior striking platform angle is the contact between the striking platform and the dorsal flake surface. This angle has a significant impact on flake morphology, and it has been demonstrated that flake size increases as the exterior platform angle increases (Dibble and Rezek 2009; Pelcin 1997a). In addition, Dibble and Rezek (2009) have found that flakes tend to be more elongated when the exterior platform angle is high. Using a goniometer, the exterior striking platform angle was measured in line with the axis of percussion and was taken at the point of impact. Where dorsal topography made it impossible to measure the angle at the point of impact, it was measured elsewhere on the platform while remaining parallel with the axis of percussion. In instances where the exterior angle could not be determined (*e.g.*, some linear platforms) a value of 90 was recorded. The exterior platform angle is often modified prior to detachment as a means of strengthening the platform by removing an overhang on the core. Any modifications, such as abrasion, crushing, or facetting, were noted.

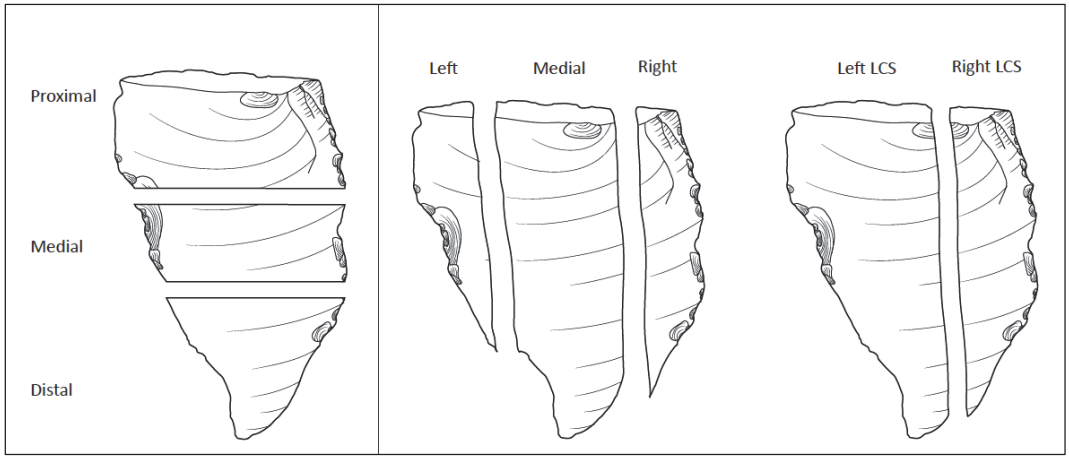


Figure 4-2 Flake fragmentation

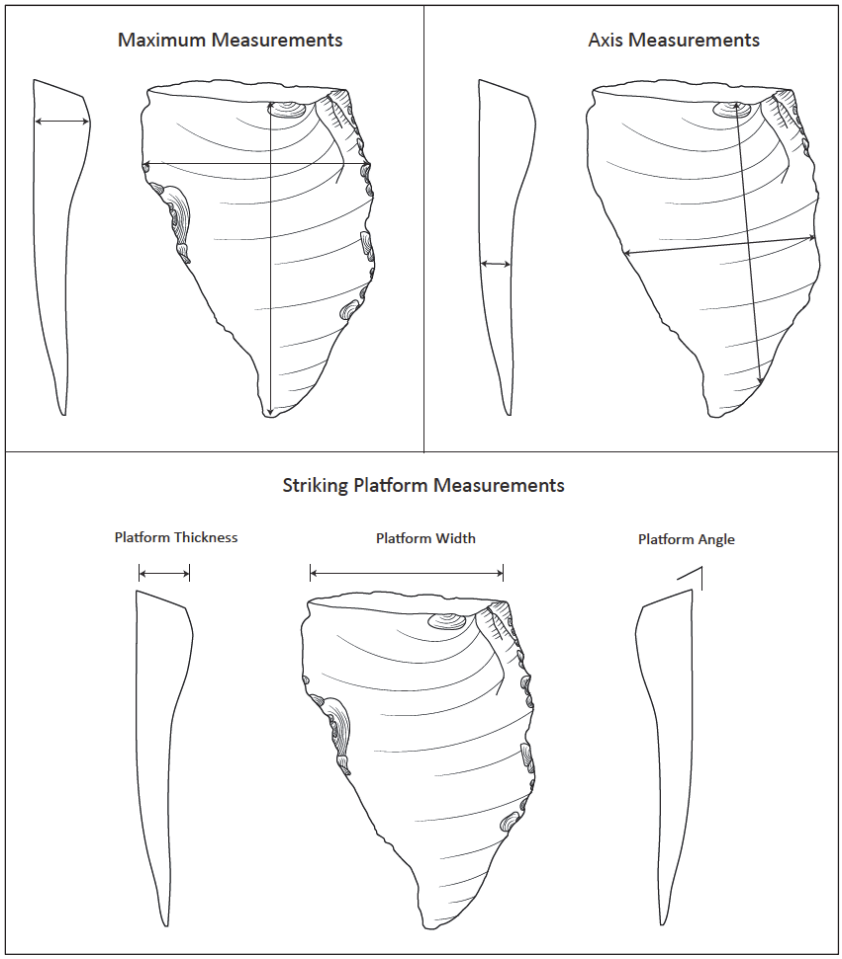


Figure 4-3 Flake measurements

The bulb of percussion is a convex protrusion on the ventral surface of a flake, just below the striking platform. This feature, distinctive of conchoidal fracture, is formed by a partial hertzian cone or radiating cone fracture, while other types of crack initiation, such as wedging (common in bipolar methods) and bending (common at low exterior platform angles and in soft-hammer techniques), do not yield prominent bulbs of percussion (Cotterell and Kamminga 1987: 685-691). Prominent bulbs of percussion are typically associated with hard-hammer techniques, while diffuse bulbs are indicative of reduction through soft-hammer techniques (Ohnuma and Bergman 1982: 165). This belief has been challenged by experimental research. Pelcin (1997a: 617) found that the length of the bulb of percussion has a direct relationship with platform thickness and that bulb length values overlapped between the two percussion techniques. In addition, he demonstrated that while platform thickness values are low, soft-hammer flakes have thinner bulbs than hard-hammer flakes, but as platform thickness increased, the two techniques could not be distinguished (Pelcin 1997a). Thus, while the prominence of bulbs of percussion may not distinguish between hard and soft-hammer reduction techniques, it may provide insight on the different types of fracture initiation.

Lipping is a slight projection of the edge where the striking platform meets the ventral surface of a flake. Many researchers suggest that lipping is characteristic of soft-hammer techniques (*e.g.*, Inizan *et al.* 1992; Odell 2004: 59; Crabtree 1972: 74); however, experimental research demonstrates that it can be produced through both hard-hammer and soft-hammer percussion (Pelcin 1997a: 618). Instead, Pelcin (1997a: 619-620) suggests that lipping is due to a high angle of force, which is more prevalent in the soft-hammer technique than in the hard-hammer technique.

The termination of a flake is the distal point from which it detaches from the core. Like the proximal attributes of a flake, the termination is also an indicator of knapping methods and appears to be related to exterior platform angle (Dibble and Whittaker 1981: 288) and platform thickness (Cotterell and Kamminga 1987: 700-701). There are five termination types: feather, hinge, step, plunging, and axial (Cotterell and Kamminga 1987). Feather terminations are often considered to be the ideal termination types, while hinge, step, and plunging terminations are often regarded as knapping errors; however, they can also be produced intentionally for particular types of retouched artefacts. For instance, preferences have been shown for hinged terminations for the manufacture of the pirri graver (Kamminga 1985). Similarly, a study of tula adze technology at Camooweal, Queensland has shown that flakes with axial terminations were specifically produced as tula blanks (Moore 2004).

Feather terminations are defined by their characteristic 'v' shape that is formed as the thickness between the dorsal surface and the fracture path or crack gradually decreases. Hinge terminations are easily recognised by their rounded shape, but should not be confused with fractures caused by bending (for further discussion see Cotterell and Kamminga 1986)). This type of termination occurs when 'the direction of force is deflected suddenly toward the outside of the core' (Odell 2004: 57). Hinge terminations may be related to high exterior platform angles, and they increase the chances of further hinge terminations in the same area of the core (Cotterell and Kamminga 1987: 701). Step terminations occur when a flake transversely breaks from the core at its distal end with a 'snapped' termination that occurs at a 90° angle (or near) to the ventral surface. This type of termination occurs when the fracture path stops suddenly because it has run out of energy or it has intercepted a flaw (Cotterell and Kamminga 1987: 700). A plunging termination occurs when the distal end of a flake does not bend towards the outside of the core, but instead bends towards the opposite side of the core thereby removing the bottom of the core. Plunging terminations are most likely related to the shape of the core and the thickness of the striking platform (Odell 2004: 58), and they tend to occur if the striking platform is too thick (Cotterell and Kamminga 1987: 701). Dibble and Whittaker (1981: 288) have demonstrated that there is an increased incidence of hinge and plunge terminations as the exterior striking platform angle increases. Axial terminations occur when a flake terminates at the bottom of the core, with the flake possessing parts of both the core's striking platform and bottom, which may or may not be cortical. Odell (2004: 58) associates axial termination with bipolar method, but they can also occur among very thick flakes if the fracture path continues straight through the core (Cotterell and Kamminga 1987: 700). Three types of finial terminations (retroflexed, inflexed, and pseudo-bifurcation) have also been identified, which are formed as the fracture of hinged and stepped terminations nears the ventral surface, becoming unstable and suddenly changes direction (Cotterell and Kamminga 1986: 453).

Dorsal Attributes

A flake's dorsal surface retains attributes that provide a glimpse of the knapping strategy that took place prior to the flake detachment, and at the assemblage level, it can provide insight into the organisation of reduction. The dorsal surface of a flake can exhibit both negative flake scars and cortex. The proportion of dorsal cortex remaining on flakes can be used as an indicator of the amount of reduction that took place on-site. For example, cores may be initially shaped and reduced at the raw material source, with either the shaped core or the flakes brought back to the site; alternatively, a core can be completely reduced on-site. If an assemblage contains no cortical flakes, then it would suggest that the primary reduction or initial shaping of the core took place off-site. For all complete flakes, a visual estimate of the proportion of dorsal cortex was recorded.

The number and orientation of negative flake scars on the dorsal flake surface reveals information about the reduction sequence. The directionality of dorsal scars is an important indicator of the history of the core and may indicate if unidirectional, rotated, or bidirectional reduction methods were used. Among specimens that show rotated or bidirectional flake scars, the sequence of removals can provide insight into how a knapper used multiple striking platforms. The number of dorsal removals over 5mm long was counted for each complete debitage product to serve as an indicator of the intensity of core reduction. Flake scars less than 5mm long were not counted, as they may represent preparation of the striking platform edge.

Flake Morphology

Flake shape, including its marginal form, lateral profile, and transverse cross section, was recorded for all complete flakes (Figure 4-4). These morphological attributes were recorded to determine if there were any preferences for the blank shapes in the production of different types of retouched artefacts. Classifications of marginal flake form include distally expanding, distally contracting, leaf-shaped, parallel-sided, and sub-parallel-sided. These qualitative form classifications allow comparison with the parallel index, which is the ratio of platform width to axis width where values less than one represent distally contracting flakes, values greater than one represent distally expanding flakes, and values of one are indicative of parallel-sided flakes (Hiscock 1986: 48). Flake profile was assessed as being straight, twisted, concave, or convex (Nishiaki 2000: 45). The transversal section types include trapezoid, symmetrical triangle, left triangle, right triangle, plano-convex, and other (Nishiaki 2000: 45).

Retouched and Utilised Flake Analysis

Flakes can be retouched for a variety of reasons: to sharpen an edge dulled by use, to create an ideal edge or artefact shape, to blunt an edge, or to facilitate hafting. Retouch can be accomplished through soft or hard hammer direct percussion, indirect percussion, or through pressure flaking. Pressure flaking is accomplished by applying direct pressure to a blank with a sturdy object. In North America, Europe, Africa, and Asia, antler is often used; however, wood or bone can also be used. In Australia, pressure flaking through biting has also been ethnographically observed (Gould *et al.* 1971: 157-158). In many cases, flakes are used without any intentional retouching whatsoever. An utilised flake edge may then exhibit evidence of microscopic usewear, such as striations, rounded edges, polishing, or edge fracture (Kamminga 1982: 4).

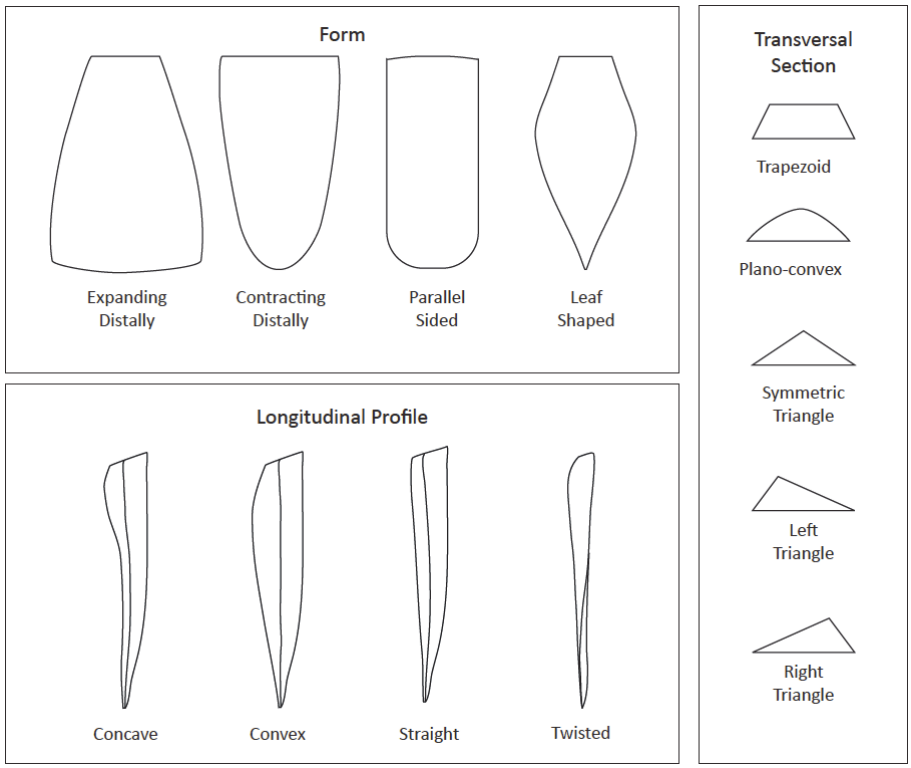


Figure 4-4 Flake morphology

Two levels of recording were completed for all flakes exhibiting evidence of retouch or use. The first level of analysis documents the type and subtype of the retouched or utilised artefact (Table 4-5), which includes well-defined retouched artefact types such as backed artefacts, tulas, burrens, eloueras, pirri gravers, and burins. This research also aims to look at patterns among non-formal retouched and utilised flakes.

Backed artefacts can be divided into those that have a symmetrical form and those that are asymmetrical (*e.g.*, Bondi points). Typical symmetrical backed artefact forms include triangles, crescents, and trapezes. Two additional symmetrical subtypes are also used in this research, trapeze with no lateral backing and elongated crescents. The former is used to distinguish between trapezoidal specimens that exhibit backing along the entire margin and those that do not. Elongated crescents bear similarity to Bondi points but they have a symmetrical crescentic form and are clearly different from standard crescents; therefore, they have been assigned into this new symmetrical backed artefact subtype.

Care should be taken when identifying backed artefacts; they should not be confused with prepared spalls (Inizan *et al.* 1992: 79; Hiscock 1993: 71), ridge flakes (Hiscock and Attenbrow 1998), or platform rejuvenation flakes. It is generally thought that artefacts are backed to facilitate hafting, where the edge is blunted, creating a stronger edge that can withstand the stresses placed on the hafted edge while in use. However, it is possible that some backed artefacts were also hand-held. The lateral margin opposite the backed edge is often referred to as the chord.

Recently, backed artefacts were found embedded in and in association with the Narembeen skeletal remains, and McDonald *et al.* (2007) argue that this is the first unequivocal evidence that backed artefacts were used as projectile spear armatures; however, it is possible that they may have been hafted into other composite weapons (Robertson *et al.* 2009: 297-298). Robertson *et al.* (2009) conducted usewear and residue analyses on over 150 backed artefacts from the Upper Mangrove Creek catchment in eastern Australia, demonstrating that they were multi-functional composite tools used in both subsistence-based and craft-based activities.

An elouera is essentially a large backed crescent, which typically ranges in length between 30 and 120mm (Holdaway and Stern 2004: 264; Kamminga 1982: 95). Unlike most backed artefacts, the backed margin of an elouera is very thick, providing a very strong edge for hafting. In a study of elouera usewear, Kamminga (1982: 97-100) concluded that they were used as a hafted adze or scraper for shaping light wood and bark objects, and that they were not used for shaping hardwood

Tulas are produced on large flakes that exhibit a prominent bulb of percussion; the distal margin of the flake is dorsally retouched, producing a steep-angled, rounded edge (Hiscock and Veth 1991: 333). Through resharpening, the length of the tula decreases until the retouched edge nearly abuts the platform, and at this exhausted stage it is referred to as a tula slug (Holdaway and Stern 2004: 253). In some cases, the delineation of retouched distal margin is transformed from convex to concave, and examples have been found where the proximal end has been retouched as well. Numerous ethnographic observations of tula production and use have been made (see Moore 2004: 62-64), showing that the tulas were affixed to the end of a long wooden haft, then used as an adze to cut and shape wooden objects. In his analysis of tula manufacture at Camooweal, Queensland, Moore (2004: 64-69) found that there was a systematic reduction sequence, which is briefly summarised here. Tula blanks were produced with axial terminations and winged platforms, forming a concave ventral surface and a convex dorsal surface. The tula blank was then roughly shaped in order to remove all cortical edges, the dorsal surface of the striking platform was thinned through retouch, and the distal end of blank was retouched and resharpened

Table 4-5 Attributes for retouched artefacts

Retouched Artefact Type and Subtypes
Type
Retouched Flake
Asymmetrical Backed Artefact
Symmetrical Backed Artefact
Tula
Elouera
Burren
Burin
Utilised Flake
Utilised Core
Subtype
Crescent
Crescent - E
Triangle
Trapeze
Trapeze - NLB
Bondi Point
End Scraper
Side Scraper
Nose Scraper
Thumbnail Scraper
Slug
Unifacial
Bifacial
Alternate Edge
Alternating

Status
Length
Complete
Proximal Fragment
Medial Fragment
Distal Fragment
Indeterminate
Width
Complete
Left Fragment
Middle Fragment
Right Fragment
Indeterminate
Other
Perimeter Length - only for complete artefacts
Retouch Length - only for complete artefacts
Residue
Yes/No
Usewear
Yes/No

Burrens have a similar appearance to tulas; however, burrens are retouched along the lateral edges, while tulas are retouched along the distal margin. The angle of lateral retouch is steep, generally ranging between 60 and 80° (David and Lourandos 1999: 114). Care should be taken not to confuse burrens with ridge flakes. Gould (1971: 154) suggests that there was little functional difference between a burren and a tula; both were used as adzes.

The pirri graver is a relatively rare-occurring artefact type. Defined by Kamminga (1985), the pirri graver is distinguished by its convex ventral surface and continuous dorsal retouch, which forms a working edge along one or both of the short lateral margins. The working edges typically show rounding, polish, or striations from woodworking, but there are ethnographic reports of pirri gravers also being used on occasion for drilling (Kamminga 1985: 11, 16). Kamminga (1985: 11) notes that pirri gravers are often misidentified as tula slugs or burren adzes. Pirri gravers would have been used as a composite tool, with the haft providing more leverage. There are ethnographic specimens that show a pirri graver hafted at one end and a tula hafted at the opposite end (Kamminga 1985: 14-15).

Burination is a particular type of retouch, where a long thin flake, called a burin spall, is removed from the edge of a flake. The resulting negative scar or burin facet creates a sharp edge where the facet meets the striking platform; this is often referred to as the burin bit or burin edge (Figure 4-5. Burins are characterised as having at least one burin facet, and there are numerous types of burins, which are defined depending on the orientation of the facet (lateral, transverse, or angle), the preparation of the striking platform (simple, on truncation, on notch, on break, *etc.*), and the occurrence and position of multiple facets (single, double, triple, quadruple) (Inizan *et al.* 1992: 77-78; Barton *et al.* 1996: 112).

Burin technology has been in use in the Middle East and Europe since the Middle Palaeolithic period (Tomáŝková 2005). Researchers have puzzled over the burin function, proposing various uses for its different features, including: 1) burin bit was used as an engraver or small chisel, 2) burin facets facilitated hafting, 3) the facet edge was used for cutting or scraping, and 4) the burin was used as a core to produce burin spalls (Barton *et al.* 1996: 111; Stafford 1977). Usewear studies of assemblages from Europe and the Middle East have demonstrated that burin function is not one dimensional; rather, burination produces both spalls and sharp edges that can be used for a variety of tasks (Tomáŝková 2005; Barton *et al.* 1996: 112). Kamminga's (1982: 92-93) examination of usewear on burins from Australia showed a very low proportion of utilised artefacts (5.6 of 143 burins), leading him to conclude that 'burins do not form a cohesive functional group'. Where usewear was identified, it generally supported either engraving or scraping activities (Kamminga 1982: 93). With such a low proportion of usewear on the burins studied by Kamminga, it is possible that they may have been used for the production of spalls. This theory is supported by Hiscock's (1993) research in Hunter Valley of New South Wales, which documented the manufacture of Bondi points. Hiscock (1993) describes a reduction sequence employing transverse burination to produce spalls, which were used as blanks for Bondi points. Finally, it is relevant to note that burination can occur inadvertently as the result of impact damage (Lombard 2005: 115).

Tremendous variation can occur among retouched flakes, including artefacts with short discontinuous retouch as well as those with continuous steep retouch, which are often referred to as scrapers. While some researchers may define scrapers as a standardised formal tool type (Holdaway and Stern 2004: 227-232,234-235; McCarthy 1976: 34), the author's experience has shown that scraper identification can be subjective and can vary significantly between researchers. Furthermore, research has demonstrated that a morphological continuum between retouched flakes and scrapers can occur (Hiscock and Attenbrow 2005). For the purpose of this research, retouched flakes are classified as being unifacial, bifacial, alternate edge, or alternating (see Inizan *et al.* 1992: 94). Unifacially retouched flakes have retouch restricted to either the dorsal or the ventral surface, whereas bifacially retouched flakes have at least one

locale that exhibits retouch scars on both the dorsal and ventral surfaces. Alternate edged retouched artefacts have dorsal retouch along one lateral edge and have ventral retouch on the opposite lateral margin. In contrast, alternating retouched flakes have areas of dorsal retouch and ventral retouch along at least one margin. Through use, negative scars can occur on flake margins, but distinguishing between deliberate retouch and usewear can be both difficult and subjective. In order to produce repeatable results, flakes that exclusively exhibited negative scars less than 1mm long were considered utilised flakes. Like retouched flakes, all complete utilised flakes were sub-classified according to the distribution and location of the usewear (*e.g.*, unifacial, bifacial, alternating, or alternate edge).

Additional attributes recorded for retouched artefacts include the status (*i.e.*, completeness), perimeter length, and retouch length. Artefacts exhibiting potential for usewear or residue analysis were also highlighted. The lateral and longitudinal completeness of each retouched artefact was assessed, which allows observations of breakage patterns. In addition, this attribute is a useful analytical tool. Complete retouched artefacts include complete flakes with retouch, as well as broken and snapped flakes that have retouch along all broken edges. The perimeter length was recorded for retouched artefacts that are laterally and longitudinally complete, and this measurement is used to determine the perimeter retouch index (discussed below). To calculate the artefact perimeter accurately, multiple measurements were taken following the morphology. The total retouch length of complete artefacts was calculated using the length of each retouch area (discussed below).

The second level of analysis for retouched and utilised artefacts examines each instance of retouch or use. By recording individual retouch areas, we are documenting how a flake becomes a retouched or utilised artefact, rather than simply relying on typological classifications. This analysis enables comparisons of how all retouched artefacts are produced, and by also including typological categories, we can discern if particular retouch techniques are used for the production of different formal tool types. In addition, this data can be used to look at changes in retouch and use patterns over time (*e.g.*, intensity of reduction, preference for dorsal versus ventral retouch, *etc.*). In addition, this method allows future researchers to use this data even if they have different typological definitions (*e.g.*, scrapers versus retouched flakes).

A series of qualitative and quantitative attributes were recorded for every instance of edge modification, and the location of the edge modification was recorded by assigning a location number as designated in Figure 4-6. The qualitative attributes are based on those defined in the Wembach method (Baird *et al.* 1995; Rollefson 1994; Rollefson 1995). To build upon the qualitative attributes of the Wembach method, quantitative attributes were recorded using measurements based on the geometric index of unifacial reduction (Kuhn 1990; Eren and Sampson 2009; Hiscock and Clarkson 2009; Hiscock and Clarkson 2005a) and the perimeter reduction index (Barton 1988).

The predominant edge modification types are retouch and usewear; however, the distinction between intentional edge modification through retouch and edge damage caused by use can be blurred. While acknowledging that retouch and edge damage through usewear are both reductive processes, this research considers all scars less than 1mm long to be usewear and all scars over 1mm to be retouch. Various types of retouch are defined based on differences of technique, delineation, and location; these retouch types include backing, burin, notch, and truncation. Backing is defined as continuous steep (nearing 90°) retouch along a flake margin (Inizan *et al.* 1992: 76). Backing typically occurs on the lateral margins of the artefact, but continuous backing from the lateral margin often modifies the distal and proximal margins as well. Burin retouch or burination is the removal of a burin spall from the edge of an artefact, producing an elongated facet (Inizan *et al.* 1992: 70). A notch is 'a concavity created by one or more retouch scars receding perceptively from an edge and measuring more than 5mm in width and 1.5mm in depth' (Hiscock and Clarkson 2007: 180). A retouched notch is created through the removal of a series of flakes, while a single notch is a concavity produced by the removal of a single flake. Retouch is classified as being a truncation where retouch is continuous and extends across the entire distal or proximal end of an artefact (Inizan *et al.* 1992: 100).

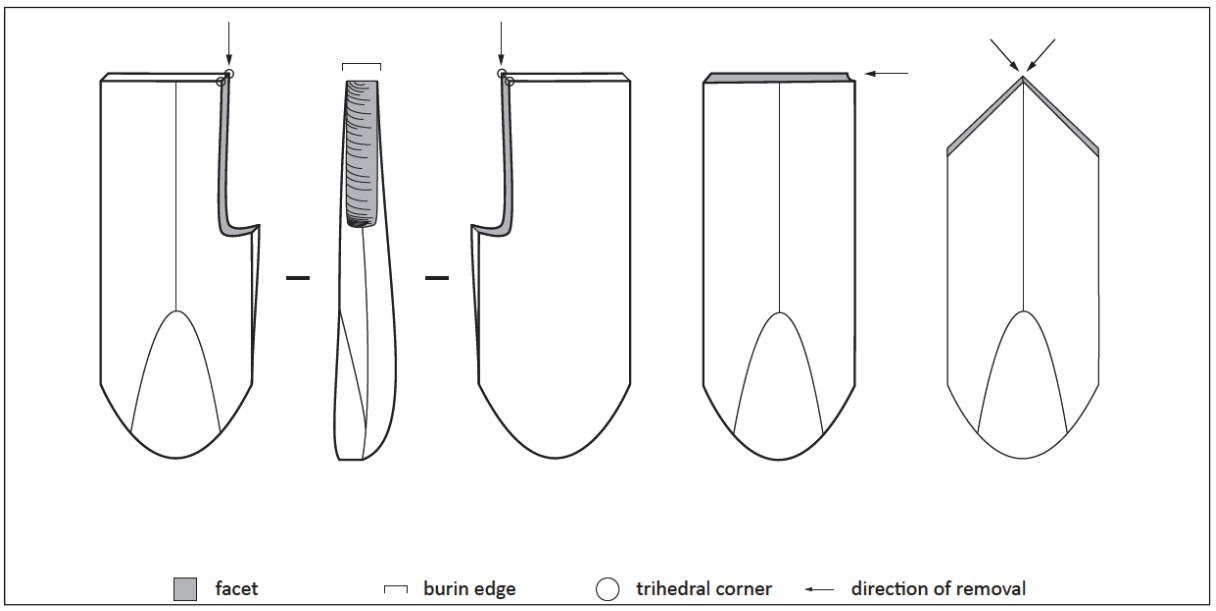


Figure 4-5 Burin terminology (after Cropper 2011)

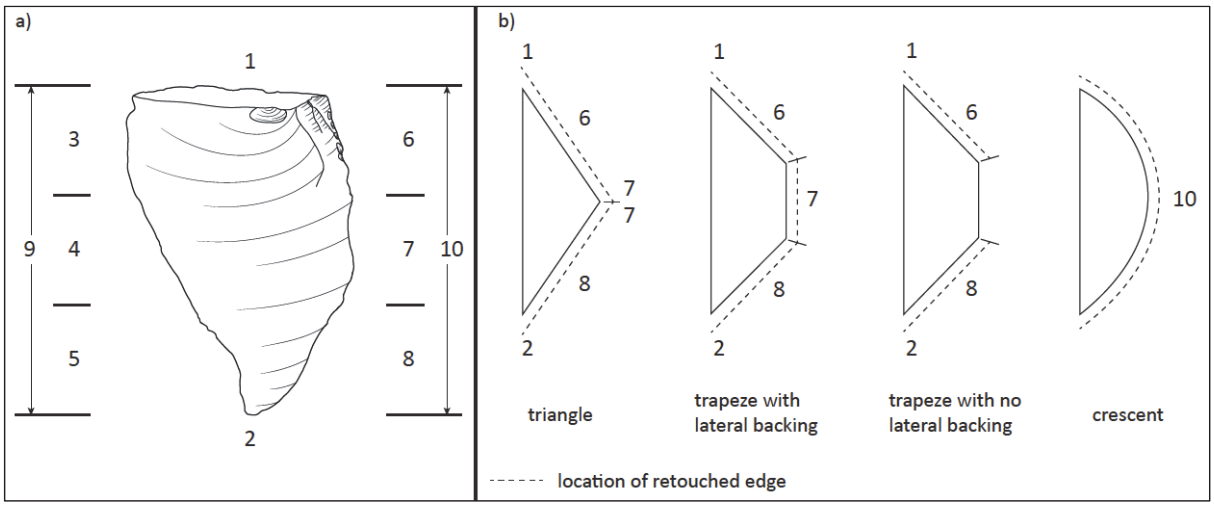


Figure 4-6 a) Retouch location map and b) examples of retouch locations on typical symmetrical backed artefacts

Qualitative retouch and use attributes include its position, angle, morphology, extent, distribution, and delineation. Retouch morphology is the appearance of the retouch scars, whether they have a scaled, stepped, parallel, or sub-parallel appearance; these definitions are based on Inizan *et al.* (1992: 91). Retouch extent can range from short to covering, where short retouch remains close to the margins of the artefact, long retouch can extend up to the midline of the artefact, invasive retouch can extend over the midline of the artefact, and covering retouch obscures the entire surface. Retouch delineation describes how retouch has altered the shape of an edge, with the exception of regular delineation where the retouched edge follows the natural shape of an artefact.

The length of the retouched or utilised area was recorded, and to provide an accurate measurement for specimens with irregular or curved edges, multiple measurements were taken following the shape of the edge. This attribute is used in the calculation of the perimeter reduction index (PRI), which is the proportion of an artefact's edge that has been retouched. The PRI is the ratio of the sum of retouch length (RL) to the perimeter length (PL), where ΣRL/PL yields a value between zero and one (Barton 1988). A value of zero represents no retouch, while a value of one indicates that the entire margin is retouched. The PRI can be used on all complete retouched flakes since marginal breakage is the only criterion that affects the accuracy of the index. PRI has been used to investigate changes in retouch or reduction intensity over time and among different raw material types (*e.g.*, Clarkson 2002; Law 2009).

Another method for investigating retouch intensity is through the geometric index of unifacial reduction (GIUR), which is an estimate of the extent of retouch or the amount of material lost through retouch (Eren and Sampson 2009; Hiscock and Clarkson 2005a; Hiscock and Clarkson 2005b; Hiscock and Clarkson 2009; Kuhn 1990; Dibble 1995). The GIUR is calculated as the ratio of the retouch scar thickness (t) to the flake thickness (T), where GIUR = t/T. This ratio yields values between zero and one, where zero indicates no retouch and one indicates maximum retouch (Hiscock and Clarkson 2005a: 1016). This method is limited to complete artefacts that have dorsal retouch along their lateral margins; therefore, it is not appropriate for investigating artefacts that have retouch along the distal or proximal margins or for those that have bifacial, alternating, or ventral retouch. The GIUR 'assumes an ideal flake form' (*i.e.*, a flake with a triangular cross-section; Kuhn 1990: 586); however, archaeological assemblages are often far from theoretical ideals. Dibble (1995) and Kuhn (1990) have pointed out that the GIUR is not suitable for all retouched flakes, and they suggest that the ideal specimen should have a symmetrical triangular cross section. It is also acknowledged that this method has shortcomings amongst artefacts with rounded ventral surfaces and those with flat cross-sections (*i.e.*, the flat-flake problem). Flakes with rounded ventral surfaces affect the ratio because they get thicker towards the midline, thereby naturally increasing the 'T' measurement and decreasing the GIUR value. Similarly, Dibble (1995: 330) has highlighted the inconsistency between comparisons of flakes with symmetric triangular cross-sections and flat flakes (*e.g.*, those with trapezoidal cross-sections), as retouch on flat flakes will approach the maximum GIUR value much more quickly than retouch on flakes with symmetric triangular cross-sections. Hiscock and Clarkson (2005a) carried out experiments examining the effect of flake morphology on the GIUR, and they found cross-section shape had little effect on GIUR values. While there are shortcomings of this method, it does provide a useful indicator of reduction intensity for artefacts with unifacial retouch along the lateral margins.

Kuhn (1990: 586) indicates that the GIUR measurements themselves are a potential source of error, and he suggests that these errors can be minimised either by taking the measurements at the same position on each artefact or by using mean values for multiple measurements. When using the GIUR to explore reduction intensity amongst a diverse assemblage of retouched artefacts, as opposed to a single retouched artefact type (*e.g.*, scraper), it is impossible to take the index measurements in the same location for each artefacts. Additionally, some instances of retouch are very small, making multiple measurements redundant. The project managers weighed risk of measurement error against the practicalities of applying the GIUR to the Hope Downs 1 assemblages. It was decided that for the purpose of this research, one set of measurements for the GIUR would be taken for each instance of retouch that was suitable for the index. A representative flake scar was selected and the thickness was measured, and at the same point, the maximum thickness of the flake was measured perpendicular from the ventral surface to the dorsal ridge.

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PART 2: ROCKSHELTER EXCAVATIONS

Chapter 5

Excavations at Jundaru (HN-A9) Rockshelter

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Excavations at HN-A9 (DAA ID 18195), a small rockshelter centrally located in Hope North (Figure 5-1 and Figure 5-2), revealed an exceptionally rich occupation history spanning approximately 36,000 years. The site is more commonly referred to as 'Jundaru', in reference to the Banjima word for native honey. Jundaru is considered by the Traditional Owners to be an important mythological and ceremonial site as well as a site for native honey.

The site was first identified during the heritage surveys conducted by McDonald, Hales and Associates Pty Ltd (MHA) between 1992 and 1993, and it was subsequently subject to test excavations in 1994 (Edwards *et al.* 2001: 30). This initial work found evidence of habitation dating as early as 24,314 cal BP (20,360±320 BP, Wk-3210), making it one of a handful of Pleistocene sites identified in the Pilbara at that time (Edwards *et al.* 2001: 68). The significance of the site was heightened by the rich assemblage of artefacts and faunal remains recovered from the excavations. Based on the outcomes of the initial excavation, Edwards *et al.* (2001: 179) assessed the site as having an extremely high level of archaeological significance and recommended that if the site could not be preserved, mitigative archaeological research would be required, including detailed recording, excavation, and analysis (Edwards *et al.* 2001: 189). During the fieldwork conducted by MHA, the site was initially named 'Malea' in consultation with the Traditional Owners working with the team (Edwards *et al.* 2001: 60); however, as *Malea* is the Nyiyaparli word for native honey, and this name is no longer used to refer to the site.

Despite the significance of the site, its location made it impractical to preserve (being centrally positioned within the proposed Hope North mine pit), and RTIO was granted the appropriate ministerial consents from the DAA to allow disturbance to the site with the condition that a mitigative salvage program be undertaken. ACHM carried out salvage excavations at Jundaru over four field trips between May and August 2008. An area of 7.5 square metres was excavated, including the resumption of the two excavation units opened by MHA. The excavations revealed a 171cm-deep deposit that had numerous well-preserved hearths, ash lenses, and charcoal lenses. A new series of radiocarbon dates demonstrates the site was first inhabited as early as 35,978±653 cal BP, extending the occupation history an additional ten millennia over the previously reported chronology. Jundaru further confirms the pattern of early occupation in this region during the Pleistocene, albeit with a slightly later initial occupation than HS-A1, HD07-3A-PAD13, and Djadjiling. An extensive assemblage of cultural materials and samples was recovered over the course of the excavation, including 26,181 artefacts, 330 samples for radiocarbon dating, 297 sediment samples, over 3500 faunal specimens, nearly 30kg of floated macrobotanical remains, and numerous other unique items. A range of specialist studies have been conducted on materials from Jundaru that provide invaluable context for the archaeological sequence.



Figure 5-1 Photograph of Jundaru (facing northeast)

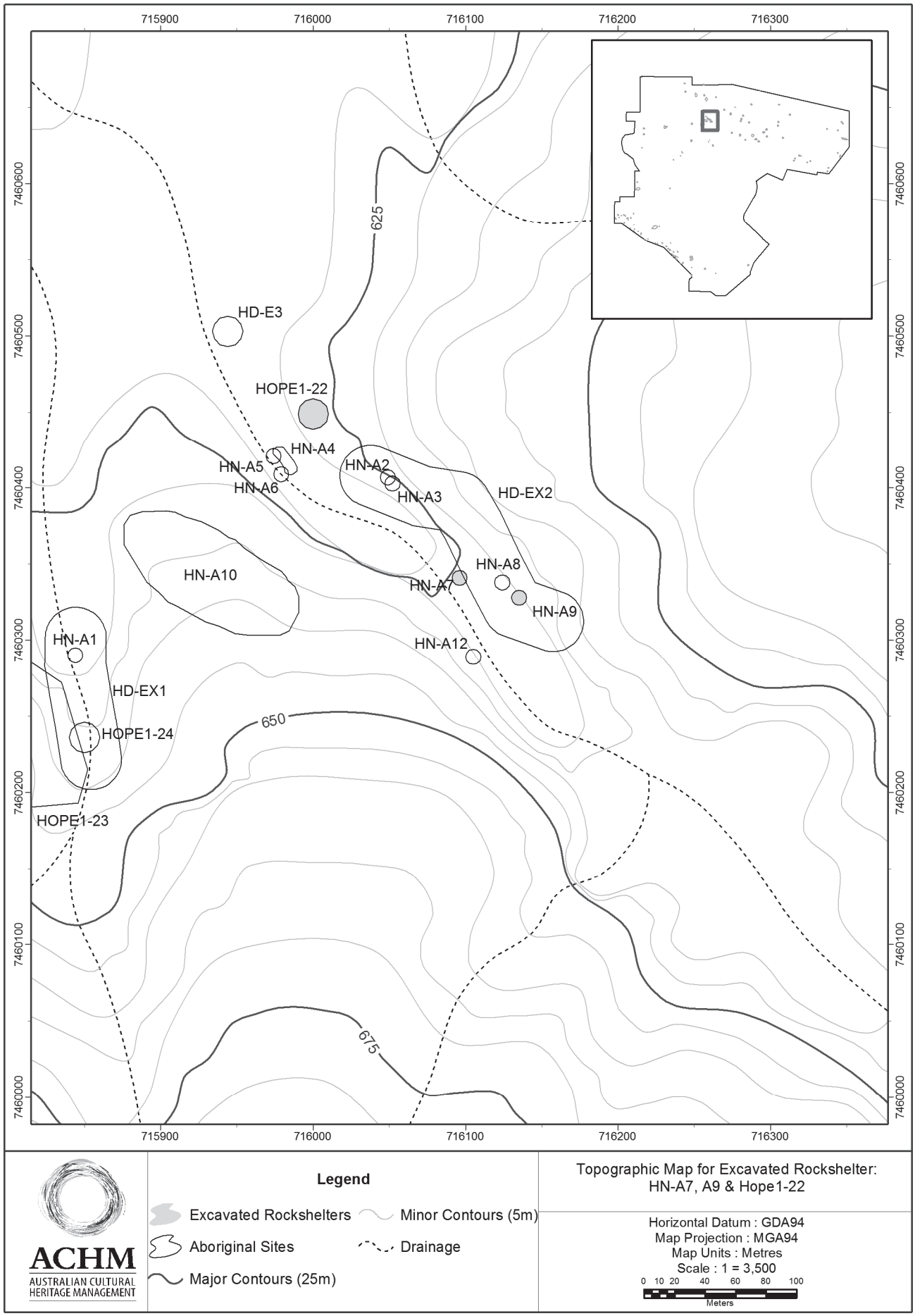

Figure 5-2 Topographic map for Jundaru

5.1 SITE SETTING AND DESCRIPTION

Jundaru was situated within a steep-sided gully on the north side of the large range that dominates Hope North and is the focus of the Hope North mine pit. The ephemeral drainage channel that follows the gully ran from the southeast to northwest, and during heavy rainstorms, water flowed through the drainage channel and formed a waterfall just upstream from the rockshelter. Water would have collected in ephemeral rockpools during such events, and several such rockpools have been identified upstream from the rockshelter.

Within the same gully were a number of other archaeological sites, including a large cave site immediately across from Jundaru (HN-A7), several small rockshelters (HN-A2, HN-A3, HN-A4, HN-A5, HN-A6, HN-A7, HN-A8, and Hope 1-22), and a man-made structure (HN-A12). MHA tested HN-A2, HN-A3, HN-A4, HN-A5, HN-A6 and HN-A8 (Edwards *et al.* 2001), and no further work was carried out at these sites as they had shallow deposits and limited artefact assemblages. ACHM carried out excavations at HN-A7 and found evidence of limited site use since the mid-Holocene. The lack of combustion features and the small artefact assemblage draw a clear distinction between HN-A7 and Jundaru (for further detail see Cropper 2013). Evidence of a walled feature was also found at HN-A7, from which several artefacts were recovered. At the far end of the gully was a tree from which honey was extracted by the Traditional Owners during the MHA 1992 heritage survey, and it was subsequently recorded as site HD-E3.

Jundaru was situated high on a steeply-inclined hillslope on the east side of the gully, approximately 11m above the gully base. Looking at the rockshelter from across the gully, the site appeared deceptively large, with an expansive area having been weathered away to form the uppermost overhang, but in reality, there was only a small area within the shelter that could have been utilised (Figure 5-3). Below the high overhang were two lower overhangs that restricted the height of the northern side of the shelter to less than a metre in height in many areas (Figure 5-4). At its broadest extent, Jundaru measured 13.94m across.

The rockshelter was naturally divided into two areas of relatively flat ground, including areas at the south and north ends of the rockshelter. The north end was larger and better protected from the elements, and had a an area of relatively flat ground surrounded by raised ridge of roof collapse along the front of the shelter. This area of the shelter measured 7.8m wide and 4.2m deep (Figure 5-4). The ground surface sloped down to the north towards the walled feature. The smaller area to the south also had a flat powdery surface that may have been I, but there was limited protection from the overhang in this area. Between the two areas of the shelter, the elevation differed by 1.5m. Due to the extremely limited work area at the rockshelter, the southeast end of the site was not excavated but was used for the sieving and sorting station.

A large ridge of roof collapse accumulated along the southwest edge of the shelter below the drip line (Figure 5-5). The blocks of roof collapse created an elevated area around the edge of the shelter, and this may have been an important factor in the accumulation and preservation of sediment at the site. The boulders formed a protective barrier on the exterior of the site, and without this protection the sediment would have been exposed to erosion from wind and rain. Edwards *et al.* (2001: 60) suggest that the roof fall may have acted as a trap for 93acetin sediment, and the excavation findings concur with this theory.



Figure 5-3 The shelter floor at Jundaru (facing north); note: the pegs mark the west corner of Unit 10 and the east corner of Unit 11

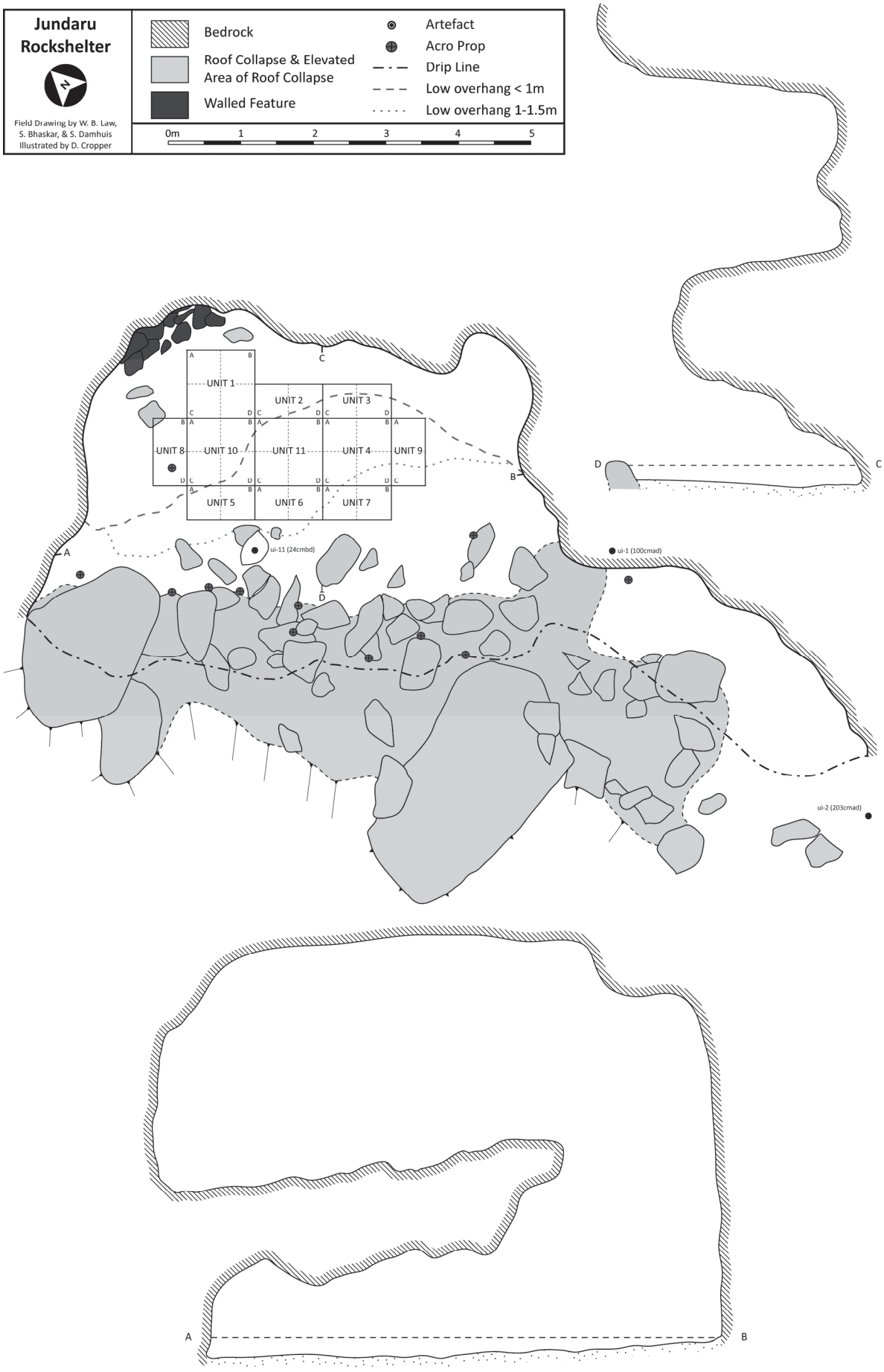

Figure 5-4 Jundaru rockshelter plan and cross-sections

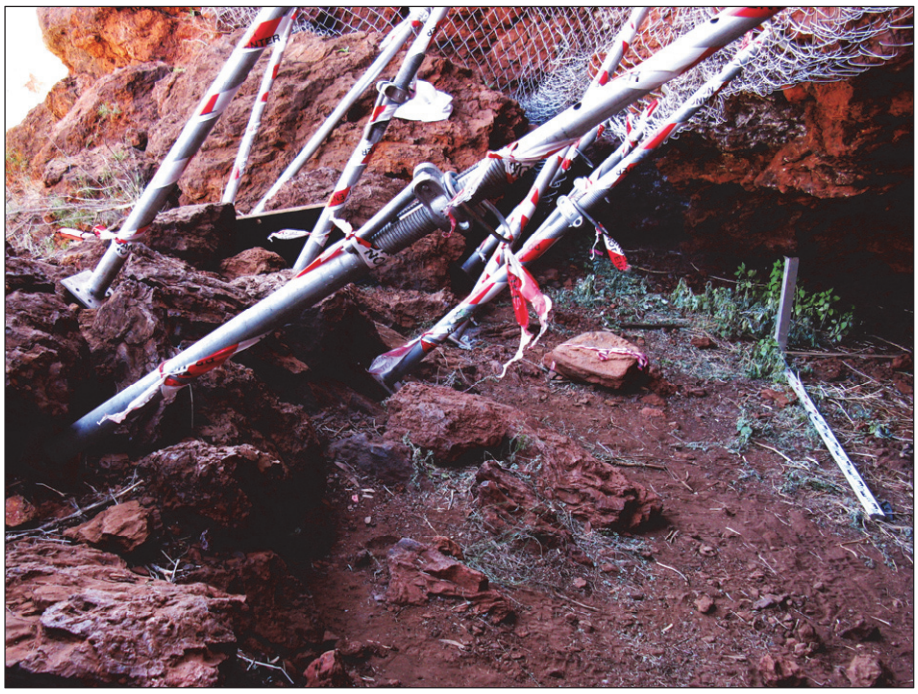

Figure 5-5 The roof collapse and surface grindstone (Artefact 26,150) along the edge of Jundaru with acrow props in place (facing north)

Jundaru rockshelter formed within the Newman Member of the Marra Mamba Iron Formation, and the walls had a homogenous reddish-brown appearance. The bedding of the bedrock sloped down towards the northwest, and some bands within the formation appeared to have eroded at faster rates. There were deposits of white mineral precipitates on the rockshelter walls (a negligible amount in comparison with sites such as HS-A1) that demonstrated that water continued to seep through the bedrock.

Unlike many of the other rockshelters investigated in Hope Downs 1, the ground surface of Jundaru had a high component of powdery loam, with a relatively low proportion of angular rock fragments. The proportion of rock fragments is greater on the elevated ridge of roof collapse, and this may be due to the more exposed nature of this part of the rockshelter, with finer sediment being eroded away by wind and rain. A small amount of vegetation was present in the rockshelter prior to excavation and was even growing in the backfilled sediment of the MHA excavation units. Leaf litter and macropod scats occur across the site. Ten stone artefacts were identified on the surface of the shelter, including a large lower grindstone and the two artefacts found during the investigation of the walled feature. The position of these artefacts was mapped, but it is probable that they have been moved in the recent past.

On the hillslope below the rockshelter, trees and shrubs are abundant. This is consistent with the vegetation survey carried out by Mattiske Consulting Pty Ltd (2009), which shows that the vegetation along the entire length of the gully is characterised as tall acacia shrubland (C3 community; see Table 1-2). Hummock grasslands (S1 community) occupy the upland areas surrounding the site and gully.

5.2 SUMMARY OF FIELD INVESTIGATIONS

Excavations were carried out at Jundaru by MHA in 1994 and by ACHM in 2008. The test excavations conducted by MHA yielded significant results, with their work revealing the site was occupied as early as 24,314 cal BP (20,360±320 BP, Wk-3210) (Edwards *et al.* 2001: 68). Not only did their work establish Jundaru as one of the few Pleistocene sites in the inland Pilbara, but it also demonstrated the rich assemblage of artefacts and faunal remains. Edwards *et al.* (2001: 179) assessed the site as having an extremely high level of archaeological significance, recommending that if the site could not be preserved, further mitigative salvage investigations would be required (Edwards *et al.* 2001: 189).

Previous Investigations at Jundaru

MHA carried out test excavations at Jundaru in 1994, excavating a total surface area of two square metres (Edwards *et al.* 2001: 60). Initially, excavation began in the 0.5-x-0.5m northwest quadrant of Unit D5 using arbitrary 5cm spits, but this soon revealed that there was significant depth to the deposit and well-preserved stratified cultural material (Edwards *et al.* 2001: 60). It is unclear how far the excavation of the quadrant progressed before the team made the decision to expand the excavation to encompass then entire 1.0-x-1.0m area. After reaching a depth of between 60 to 70cmbs, an adjacent 1.0-x-1.0m unit (E5) was opened to facilitate excavation under safe working conditions. Edwards *et al.* (2001: 60) reported that excavation of Unit E5 ceased when bedrock was encountered at approximately 120cmbs. The section illustrations indicate that the excavation team believed that undulating bedrock was encountered across the entire excavation trench (Edwards *et al.* 2001: 65).

Subsequent to the excavation, the Department of Exploration Geophysics at Curtin University of Technology was engaged to carry out a ground penetrating radar survey of the rockshelter (Edwards *et al.* 2001: 66). On 22 November 1997, readings were taken along seven traverse lines with five lines running in a north to south alignment and two lines oriented east to west (Edwards *et al.* 2001: 66-68). The data suggested that bedrock would be encountered at depths between 0.8 and 1.4m below the surface (Edwards *et al.* 2001: 66-68). Edwards *et al.* (2001: 68) used this data to estimate that there is approximately 28 cubic metres of sediment within the rockshelter.

Edwards *et al.* (2001: 66) described the deposit as fairly homogeneous and comprised of reddish brown to dark reddish

brown that was deposited through 96acetin processes as well as the *in situ* weathering of the rockshelter itself. The pH of the sediments shows a broad division, with the first 15 spits being neutral to weakly acidic, whereas the lower deposit had acidic to strongly acidic pH values (Edwards *et al.* 2001: 66). Edwards and Murphy (2003: 45) suggest that the pH of the sediment may be influenced by the prevalence of ashy sediments, which are more frequent in the upper layers of the deposit. Ash lenses, burned sediment, charcoal lenses, and diffuse ash are all illustrated on the section drawing (Edwards *et al.* 2001: 65), but there is no discussion of these features.

Five charcoal samples were submitted for radiocarbon determinations (see Table 5-2). The samples are described as diffuse charcoal and only arbitrary spit contexts are provided for the samples (Edwards *et al.* 2001: 68), suggesting that none of the samples were collected *in situ,* but were bulk samples. The radiocarbon dates are in good chronological order and were chosen to provide an age estimate for the occupation of the site as well as context for key changes in the artefact assemblage (Edwards *et al.* 2001: 68). The radiocarbon dates, together with evidence from the artefact assemblage, indicate that the site was occupied from 20,950±330 BP (25,075-23,505 cal BP, Wk-3210) to as recent as the last several hundred years (290±50 BP, 492- -1 cal BP, Wk-3209). Edwards *et al.* (2001: 69) argue that the site provides evidence for Aboriginal occupation of the Pilbara during the LGM.

Artefact Assemblage

MHA estimated 30,000 to 40,000 artefacts were recovered from the excavation, based on the analysis of a sample from the northeast quadrant of Unit E5, which included a total of 4,577 flaked stone artefacts (Edwards *et al.* 2001: 69). The assemblage is comprised of a range of artefact types including flaked pieces (n=3488), flakes (n=1067), rejuvenation flakes (n=5), and cores (n=3) (Edwards *et al.* 2001: 69). The assemblage was divided into four chronologically bracketed analytical units based on the radiocarbon dates: A, 0-2820 BP; B, 2820-6570 BP; C, 6570-15,230 BP; D, 15,230-20,360 BP (Edwards *et al.* 2001: 69). The artefact discard rates are initially very low, but increase significantly and peak in AU A (Edwards *et al.* 2001: 70).

Patterns of raw material use show that ironstone/BIF was a constant resource used throughout the occupation, although it ranges in frequency between 24.8% (AU A) and 84.5% (AU D) (calculated from Edwards *et al.* 2001: 72, Table 12). While there is a diversity of other raw materials present in the assemblage, chert and quartz are the only raw materials used with any regularity. Over half of the artefacts in AU A (53.1%) were produced on chert, but this figure drops significantly in AU B (13.2%), C (14.4%), and D (6.4%), suggesting that the use of chert is a preference of the late Holocene knappers (calculated from Edwards *et al.* 2001: 72, Table 12). There is a sharp peak in quartz use in AU 3 (32.9%), while it is much less common in the other analytical units (AU A, 9.7%; AU B, 7.3%; AU C, 5.7%) (calculated from Edwards *et al.* 2001: 72, Table 12).

Three core fragments were identified in the assemblage including two cores from Spit 15 and one from Spit 3. The lowermost cores were produced on quartz and silicified shale, while the more recent core was produced on silicified mudstone (Edwards *et al.* 2001: 87).

While limited information can be gleaned from the cores, the analysis of the flakes indicates that there was little core preparation as only 31 artefacts were found that exhibited evidence of platform preparation (Edwards *et al.* 2001: 87). The majority of the complete flakes had plain striking platforms (n=536, 60%). Edwards *et al.* (2001: 87) observed that the platform types changed over time, with plain platforms preferred in AU C (82%), but decreasing to slightly over 50% in AU A; they suggest that the knappers may have struck the core closer to its edge, which led to higher incidences of crushed and battered platforms in AU A and AU B. Few primary and secondary flakes were identified in the assemblage, which may indicate initial reduction away from the site (Edwards *et al.* 2001: 87). The size statistics for complete ironstone/BIF, quartz, and chert flakes demonstrate that ironstone/BIF flakes are the largest, followed by quartz flakes, while chert flakes are the smallest (Edwards *et al.* 2001: 80-82).

Fourteen retouched artefacts were identified in the sample, including ten specimens from AU A, three from AU B, and one from AU D (Edwards *et al.* 2001: 91). Ten of the specimens are non-formalised I artefacts, but a steep-edge scraper and three geometric microliths were also identified (Edwards *et al.* 2001: 91). The lowermost geometric microlith was recovered from Spit 6, which is dated to 2280±80 BP (Edwards *et al.* 2001: 91). The I artefacts were produced on ironstone/BIF, silicified mudstone, and chert, whereas the geometric microliths were made on ironstone/BIF, chert, and calcrete/clay; the scraper was produced on a chert flake.

Faunal Assemblage

A large faunal assemblage was recovered from the excavations, including 6987 fragments weighing 1667g (Edwards *et al.* 2001: 93). The distribution of faunal remains through the four analytical units peaks between AU C and AU D (Edwards *et al.* 2001: 101). Burned bone was identified throughout the deposit, and there are relatively consistent proportions (by weight) amongst AU A through AU C (AU A, 3.7%; AU B, 5.2%, and AU C, 5.4%), while only 0.3% of the bone in AU D exhibited evidence of burning (Edwards *et al.* 2001: 93). Along with the larger assemblage size at Jundaru, there are also higher numbers of identified specimens, many of which were only identified in this particular assemblage. Several of the identified specimens were found in association with hearth features, but there were no usewear signs indicative of butchery or human consumption (Edwards *et al.* 2001: 99). Importantly, Edwards *et al.* (2001: 101) point out that previous research has demonstrated that large quantities of burned bone is not a common product of Aboriginal cooking methods.

Throughout all analytical units, a significant proportion of the identified assemblage was classified as small and large macropods (Edwards *et al.* 2001: 95-96), suggesting that kangaroos and wallabies were a central economic food resource for the past occupants of Jundaru rockshelter. A number of macropod specimens were further identified to the species level, including *Macropus robustus* (Common Wallaroo), *Macropus rufus* (Red Kangaroo), *Petrogale rothschildi* (Rothschild's Rock Wallaby), *Lagorchestes conspicillatus* (Spectacled Hare Wallaby), and *Lagorchestes hirsutus* (Rufous Hare Wallaby) (Edwards *et al.* 2001: 96-97). Spectacled Hare Wallaby specimens were identified in Spits 3, 10, and 13 demonstrating that they were used throughout the occupation of the site; however, their modern distribution no longer includes the Pilbara, possibly due to changes in the distribution of its main food source, spinifex, that may have occurred as a result of European contact (Edwards *et al.* 2001: 95-97). A single Rufous Hare Wallaby specimen was identified in association with a hearth feature (Unit D5, Spit 5A), and this species is now locally extinct, possibly due to a combination of pastoralism and predatory feral animals (Edwards *et al.* 2001: 95, 97).

A wide range of mammals were identified in the Jundaru assemblage, including bettongs (*Potoroidae spp.*), dasyurids (*Sminthopsis 97aceti, Ningaui spp.*), bandicoots (*Isoodon auratus, Isoodon spp.,* and *Perameles spp.*), rodents (*Zyzomys argurus, Pseudomys chapmani, Pseudomys nanus, Pseudomys spp.,* and *Mus musculus*), and bats (Edwards *et al.* 2001: 97-99). The common rock rat was the most prevalent identified species in the assemblage, and Edwards *et al.* (2001: 98) have suggested that they are not necessarily associated with food procurement activities by the past occupants of Jundaru; instead, it is possible that the rockshelter may have been a natural habitat for these animals. Rodent bones can enter an archaeological assemblage through various means, including human subsistence procurement and introduction by non-human predators; they may be drawn to the site due to the human occupation (Morlan 1994). At least one specimen appears to have been deposited at the site in an owl or raptor pellet; therefore, the role of predatory birds on the accumulation of faunal remains at Jundaru must not be discounted particularly for the smaller species of rodents, reptiles, dasyurids (Edwards *et al.* 2001: 100). Two species present in the assemblage are no longer found in the Pilbara, including *Isoodon auratus* and *Perameles spp.*; conversely, the house mouse was only recently introduced to the Pilbara region (Edwards *et al.* 2001: 98).

Three reptile families are represented in the assemblage: *Scincidae* (skinks), *Agamidae* (dragons), and *Varanidae* (goannas/monitors) (Edwards *et al.* 2001: 99). Reptile bones were identified throughout the deposit, with the lowermost specimen identified in Unit E5, Spit 12 (Edwards *et al.* 2001: 95-96). None of the specimens could be identified to the species level.

The faunal analysis also identified a small amount of avifaunal material, including a bird eggshell, emu eggshell, bird feather, and bird bone (Edwards *et al.* 2001: 99). The lowermost egg shell fragments were identified deep within the deposit of Unit D5; emu eggshell fragments were recovered from Spit 11 and the bird eggshell fragment was found in association with a hearth feature in Spits 11/12 (Edwards *et al.* 2001: 96).

Recommendations

Edwards *et al.* (2001: 179) assessed Jundaru as having an 'extremely high level of archaeological significance', and this assessment is based on the well-preserved deeply stratified deposit together with the large artefact and faunal assemblages, which represent at least 23,500 to 25,000 years of Aboriginal occupation at the site. Avoidance or minimisation of site disturbance was recommended, but if unavoidable, further archaeological advice with regard to additional salvage requirements was recommended in combination with consultation with the Traditional Owners and DAA.

ACHM's Investigations at Jundaru

ACHM's investigations at Jundaru were carried out over four field trips between May and August 2008. The team excavated an area of 7.5 square metres in 11 excavation units, including continued work in the two excavation units opened by MHA. Over the course of the excavation, 26,181 artefacts were recovered and 24 combustion features were identified. The work carried out at Jundaru is briefly summarised below.

To ensure the safety of the individuals working at Jundaru, wire mesh was installed over the entire rockshelter overhang, using anchors drilled into the bedrock. Eleven acrow props were positioned along the edge of the rockshelter, with care taken that their location would not impede excavation. The floor of the shelter was covered with geocloth in order to protect the sediment from trampling and possible rockfall during the installation of the safety system. A sheet of plywood was also I during the process to act as a slide to deflect any falling rock away from the floor of the shelter. While these safety measures were necessary for a safe working environment, the acrow props reduced the already confined rockshelter, making excavation challenging at times (Figure 5-6).

Before any further salvage work could be carried out at Jundaru, the backfill in the previously excavated units (Squares D5 and E5, re-named Units 10 and 11 respectively) was removed. Upon removing the backfill the team determined that the previous excavations had not terminated at bedrock, but at large roof collapse. The sections of the excavation trench were cleaned and drawn in order to establish continuity between the two excavation programs.

After the backfill was removed, the excavation grid was re-established. Initially, eight new excavation units (Units 1-8) were planned, and Unit 9 was added subsequently. The numbering of the excavation units was done arbitrarily. Numbers were chosen over the letter-number grid system I by MHA, as numeric values are integral to our provenance system. Squares D5 and E5 were re-named Units 10 and 11 respectively.

The excavation units were laid out in three rows, with a row nearest to the back of the rockshelter (Units 1-3), a central row (Units 4 and 8-10), and a row nearest to the entrance (Units 5-7). Units 1 to 3 were planned to be 1-x-0.5m in size, but Unit 1 was later expanded to a full 1-x-1m unit during the last field trip. The central row is comprised of five excavation units. On the far west side is Unit 8 (0.5-x-1m), followed by three 1-x-1m units (Units 10, 11, and 4). Unit 9 (0.5-x-1m) is on the far east side of the central row and was only excavated during the last excavation trip. The final row of excavation units comprises three 1-x-0.5m units (Units 5-7) that were positioned inside the elevated area of roof collapse that runs along the entire length of the rockshelter overhang.

The surface of the excavation units sloped from the southeast down to the west. As a result, Unit 9 had considerably higher surface elevations (14-22.5cmbd) than Unit 1 (30-35cmbd) and Unit 8 (31-34.5cmbd). Due to the slope, the first arbitrary excavation layer of each unit was excavated to different depths. Layer 1 in Unit 9 was excavated to a depth of 25cmbd, Units 3 to 7 were excavated to 30cmbd, and Units 1, 2, and 8 were excavated to a depth of 35cmbd. To enable the maximum exposure across the site, the entire trench was brought down to a level surface at each 5cm interval, and photographs of the entire trench were taken. This provided the team with a better understanding of the stratigraphy across the site, and it helped in the excavation of features that extended across excavation units.

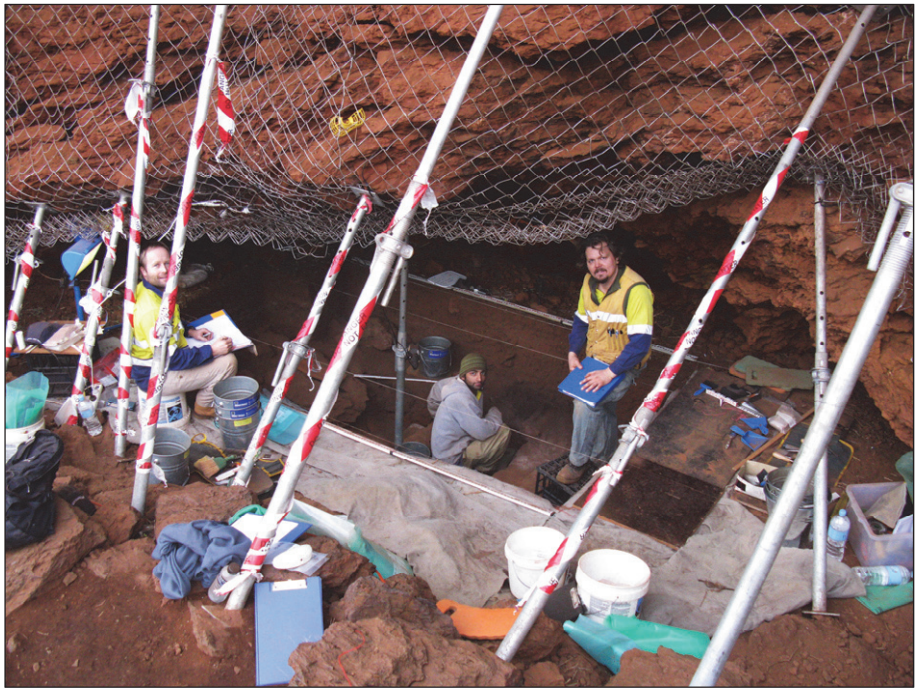

Figure 5-6 Excavating at Jundaru with the acrow props in place. S. Damhuis, S. Bhaskar, and W. B. Law pictured (left to right)

Before excavation could resume in Units 10 and 11 (the units initially opened by MHA), the large block of roof collapse needed to be removed from Unit 10. Removal of this block would have been very difficult during the MHA excavation as a small portion of the rock continued into Unit 8. Only once the excavation units surrounding the rock had been excavated was it possible to extract it from the excavation trench. The block of roof collapse had a very high iron content and was extremely heavy; hence, it could not be removed as a single piece. Using a mallet and a cold chisel, the block was carefully broken down into smaller more manageable pieces. Other methods were considered, but this method was deemed to be the least likely to have deleterious effects on the rest of the excavation. Collapse of the excavation baulks was a serious concern if vibrations were too strong. Plastic was laid down across the bottom of the trench in order to protect the unexcavated deposit from contamination in the event of a section collapse. The rock was successfully removed with no damage to the excavation trench. The rock fragments weighed approximately 500kg.

The basal elevations of the MHA excavations in Units 10 and 11 varied considerably. In Unit 10, much of the sediment had been excavated to a depth of 103cmbd around the large rock. There was a sharp drop on the south side of the unit where it bordered with Unit 11, and here the elevations ranged between 111cmbd and 120cmbd. The first excavated layer of Unit 10 (Layer 18) was a bulk layer that excavated to a depth of 120cmbd. A large number of artefacts were recovered, including 80 flakes, one core, seven flaked pieces, and one potlid. The artefacts were produced from a very limited range of raw materials (predominantly BIF, quartz, and brown shale), and there are no clearly intrusive elements amongst the sample.
MHA excavated Unit 11 to depths ranging from 140 to 147cmbd; however, a large block of roof collapse took most of the northeast half the unit (Quads A-B). Like the boulder in Unit 10, this boulder also had to be broken down into smaller fragments using a mallet and chisel, in order to allow further excavation. The acrow prop that had been placed in the unit was removed to allow for further excavation. The first arbitrary excavation layer of Unit 11 (Layer 25) was excavated down to a level surface at 150cmbd. Seventeen flaked stone artefacts were recovered from this arbitrary layer, including 13 flakes, two retouched flakes, and two potlids. The artefacts were produced on similar raw materials, and there do not appear to be any intrusive elements.

Excavations at Jundaru concluded with the exposure of bedrock across the entire trench, with the exception of Unit 8 where excavations ceased at depth of 140cmbd for the installation of an acrow prop. The excavation revealed a deposit up to 171cm deep. ACHM was able to extend the excavation units previously tested by MHA by a further 48cm (maximum) in Unit 11 and 103cm (maximum) in Unit 10.

Following the excavation of the rockshelters, the two walled features identified at Jundaru were investigated, including a low walled niche at the north end of the shelter and another walled feature approximately 35m to the southeast. In respect of ethnographic advice received from MIB and IB elders, the internal composition of the man-made structures at Jundaru were only investigated during the final trip.

The first walled feature investigated was within the rockshelter at Jundaru (Figure 5-7). The present day entrance to the cavity is very low (<30cm) and is partially blocked by ten medium-sized cobbles. The rocks were loosely stacked in the opening, with sizeable gaps at the east end as well as along the top of the wall. Sediment does not appear to abut the walled feature; instead, the rocks lie atop the surface of the shelter suggesting the feature was constructed in the recent past. The wall was dismantled with the supervision of senior Banjima representatives, with the aim of trying to determine the function of the feature. The cavity was found to be approximately 1m wide and it extended back 3.5m. The space is confined, with less than 30cm of roof height. No cultural materials, objects, or human remains were observed within the cavity itself; although, two artefacts (Artefacts 26145 and 26144) and pieces of charcoal (c-1161 and c-1162) were recovered from beneath one of the rocks in the walled feature. The fact that the walled feature was constructed atop of two artefacts and there was no sediment accumulated around the rocks, suggests that the feature was constructed in the recent past. As Feature 1 was

dated to 176±86 cal BP, it is likely that the walled feature post-dates the feature and may reflect one of the last uses of the site. Thirty surface artefacts were recovered from Jundaru, including a grindstone, flakes, cores, and retouched artefacts.

The cavity may have been much larger in the past, especially considering that nearly two metres of sediment may have accumulated in this area. When the floor surface was lower, as it would have been when the site was first occupied, it is possible that this area could have been I.

The second walled feature was identified during the Jundaru investigations. The feature consists of at least 50 rocks that range in size from 80cm to 5cm, with the majority of rocks being between 5 and 30cm. The main component of the feature blocks a niche under a small overhang. The rocks were loosely stacked upon a large slab of roof collapse and in most areas the rocks continue up to the top of the overhang. There are three small areas where it was possible to peer into niche. Rocks were also found stacked in a crevice in the flat expanse of bedrock in front of the overhang. In order to fully explore the walled niche, the feature was dismantled, and this process was videotaped. No cultural material was identified behind the walled feature, but the team noted a small amount of light at the back of the niche. The source of the light was investigated, and a second entrance to the niche was identified. This entrance was also blocked by several larger rocks.



Figure 5-7 The man-made structure at Jundaru rockshelter

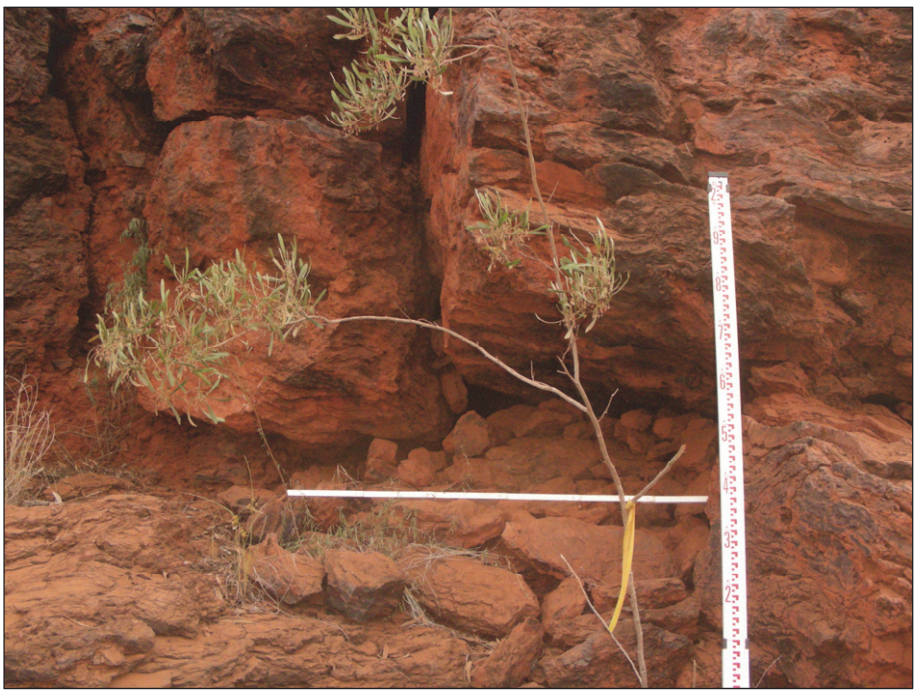

Figure 5-8 The second walled feature at Jundaru rockshelter

5.3 STRATIGRAPHY

The 2008 excavations revealed an accumulated deposit with a maximum depth of 171cm. Sloping bedrock was exposed across the trench, with the higher elevations on the southeast side and lower elevations on the west side of the trench. The deposit was shallowest in Unit 9 where bedrock was encountered at 121cmbd. The bedrock sloped steeply down into Unit 4, where elevations ranged between 141 and 173cmbd. The deepest point in the excavation trench was a small depression in Unit 6, which reached 199cmbd; however, the bedrock in remainder of the unit ranged in depth between 189 and 195cmbd. The deposit in Unit 10 (177.5-186cmbd, with a pocket at 194.5cmbd) and Unit 1 (174-189.5cmbd) were slightly shallower that Unit 6, showing that there was also a slight southwest slope in the bedrock.

Accumulation of the Deposit

The accumulation of sediment at the rockshelter was the result of a number of processes, including natural weathering processes (*i.e.*, geogenic), from the animals and plants that have occupied the shelter (*i.e.*, biogenic), and through anthropogenic sediment deposition. As with many rockshelters, most of the deposit was derived through natural erosional processes. Over time, small angular rock fragments exfoliated from rockshelter roof and walls and accumulated on the ground surface. Occasionally, large roof collapse events also occurred, when much larger rocks and even boulders fell from the rockshelter roof. These rocks are mixed amongst the fine sediment component, which was deposited through 100acetin (windblown) processes as well as *in situ* chemical breakdown of the rocks in the shelter. Jundaru had a fairly high component of loam in comparison to other rockshelters in similar settings, such as Djadjiling and HS-A1. The high proportion of silty sediment may be related to the southwest aspect of the rockshelter. If there were easterly prevailing winds in the past, sediment would have been blown into the rockshelter, and the large accumulation of roof collapse likely helped trap the sediment and reduce erosion.

Along the west and southwest side of the excavation trench, the large boulders of roof collapse followed the line of the lower overhang. At the southeast end of the excavation trench, particularly in Units 4 and 9, there was much less roof collapse (Figure 5-9). The low overhang over these excavation units was thicker and adjoined near vertical rockshelter wall (see Figure 5-3), suggesting this area was more stable and less resistant to weathering. Above Unit 7, the lower overhang was thinner and over time, it is presumed that large blocks have fallen from this overhang creating the large accumulation of roof collapse in the excavated deposit. While the lower proportion of rock fall in this area may be due to the natural weathering patterns of the rockshelter, it is also possible that the people routinely cleared rocks from these areas to make them more comfortable.

The high position of the rockshelter above the base of the gully meant that it was not prone to flooding or scouring, and while the shelter was very open, the large accumulation of roof collapse along the dripline protected the deposit from wind and rain; although, minor erosion may have occurred. No obvious colluvial deposits were identified, but some colluvium may have been deposited into the main area of the shelter from the small elevated area to the southeast, which is very exposed.

There was mineralogical evidence of water moving through the bedrock, and this would have occurred during or after significant rain events. In the deepest layers of Jundaru, cemented sediment was encountered (Figure 5-10). A sample of the cemented sediment was submitted for analysis to Professor Robert Gilkes and Emielda Yusiharni of the School of Earth and Environment at the University of Western Australia (Gilkes and Yusihami 2013). The results of the analysis demonstrate that the major crystalline compounds present in the sample include gypsum, quartz, and hematite, as well as trace amounts of kaolin, sylvite, and an unknown magnesium/sodium salt(s). This data shows different compositions of the precipitates at Jundaru and HS-A1, with halite being the major crystalline component at HS-A1 (Gilkes and Yusihami 2013). The degree of cementation at Jundaru was not as severe as at HS-A1, and the excavated sediment did not need to be soaked to be separated. The cemented sediment primarily occurred in Units 1 and 2, with lesser amounts in Units 10 and 11. Based on the location of the cemented sediment, it can be surmised that the water seeped through the bedrock and into the sediment, with the salt-saturated water depositing salts as it flowed from the bedrock.

Gypsum is a readily dissolvable salt that can both accumulate and dissolve on a relatively fast time scale due to its high water solubility (Warren 2006: 515). As a result, it is not possible to determine when the salts were deposited at Jundaru; although, deposition clearly occurred after the accumulation of the deposit (given that artefacts and charcoal were incorporated into the cemented sediment). Salts are a natural preservative (Warren 2006: 2), and it is possible that their presence at Jundaru may have aided the preservation of organic remains. Faunal remains were recovered down to a depth of 180 to 185cmbd (U1-L31; peramelid molar fragment; McDowell, this volume), and three-quarters of the faunal remains recovered from below 100cmbd were from Unit 1.

The animals and plants that occupied the shelter also contributed to the accumulation of sediment, and in some cases, they have caused disturbance to the deposit. Biogenic sediment was a small component of the accumulated deposit at Jundaru. The greatest proportion of organic matter in the sediment occurred from approximately 55cmbd to the surface, but there was a slow and steady increase in organic matter up through the deposit (Wallis, this volume; Haberle *et al.*, this volume). Degrading macropod scats were commonly observed, as were insect casings. A small proportion of the faunal assemblage is classified as being natural, meaning that these remains were likely accumulated as part of natural death assemblages not related to the human occupation of the site (McDowell, this volume). Mud wasp brood chambers were also observed in the deposit, but they were generally isolated specimens and never occurred in large numbers like that found at HD07-3A-PAD13. Brood chambers were reported in 58 separate contexts, ranging from the first arbitrary excavation layer to a maximum depth of 155 to 160cmbd, and they were most common in Units 4, 5, 6, 7, and 9. Mud wasps were rare in Units 1, 2, 3, and 8. Mud wasps may have occupied the site because it was one of the few rockshelters to have powdery loam on the surface, which could be I for building their brood chambers. Their presence also suggests that water was available nearby. Samples of the brood chambers were collected and have been archived for future research. The mud wasp brood chambers would not have caused disturbance to the deposit, as the chambers would have been constructed on the rockshelter roof and walls and subsequently fallen to the ground.

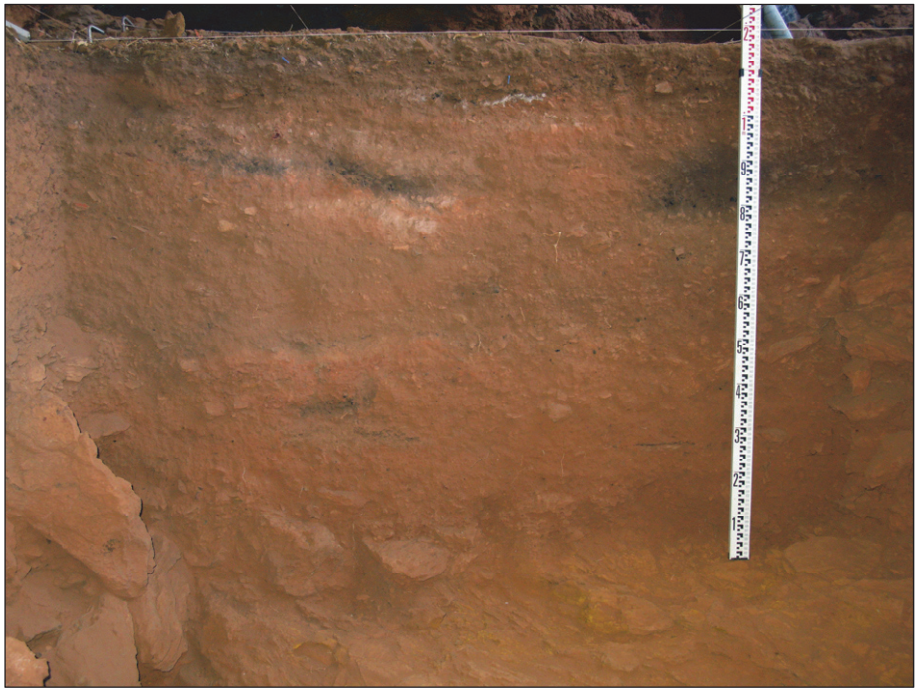

Figure 5-9 The southeast profile of Units 3, 4, and 7; note the limited roof collapse



Figure 5-10 Cemented sediment on Artefact 5781

Fine roots were observed throughout the entire sequence, and they contributed to the organic matter in the deposit. The fine roots would have not caused any significant disturbance to the sediment, but they appear to have contributed to the breakdown of the basal bedrock as they extended into cracks and fissures. Some of the rocks in the deposit had tiny rhizoliths that formed by localised cementation around roots.

There was considerable evidence relating to the accumulation of anthropogenic sediment at the site. In total, 24 combustion features were recorded by the excavation team and these are discussed in detail in Section 5.5. Many other less well-defined ash and charcoal lenses were also identified. In addition to the ash and charcoal in the deposit, the human occupation introduced a wide range of materials to the site, including flaked stone artefacts, ground stone artefacts, faunal remains, and macrobotanical remains.

Through the stratigraphic profile, there was a general decrease in the pH values; although, some variation occurred. From the surface to approximately 85cmbd, the pH values are generally slightly alkaline, with minor deviations to neutral and slightly acidic values, and below this depth, the sediment became consistently acidic, with pH values of 4.5 to 5 being most common. This pattern correlates well with the evidence from the MHA test excavation (Edwards *et al.* 2001: 66). There is

some variation between the pH values in the different excavation units. For example, Unit 2 remained alkaline for much longer with the transition occurring around 105cmbd. The opposite pattern is demonstrated in Units 5, 6, and 7, where the first layer was either neutral or slightly acidic, and all of the layers below are acidic. It is possible that the lower anthropogenic use of these units and the high proportion of roof collapse may have resulted in more acidic deposits. Additionally, the combustion features often showed minor variation from the surrounding matrix. Most features had pH values between 8 and 9, with some being acidic (Features 7, 16, 19, 22, 23, 24), particularly those in the lower sequence.

It is assumed that the deposit at Jundaru, like most rockshelters, had some degree of disturbance because of their frequent use by macropods (as demonstrated by the abundance of scat) and from its past human occupants. Termite bioturbation occurred in the same levels as the mud wasp brood chambers. Additionally, a burrowing water-holding frog (possibly *Cyclorana platycephala*) was encountered during the excavation of Feature 2 (U4-L2.2) at a depth of 10cmbs. The frog created a cocoon around itself and could have displaced artefacts and disturbed sediment as it burrowed, but this disturbance would have been fairly localised.

Division of Stratigraphic Layers

Five stratigraphic layers were identified at Jundaru based on changes in the matrix composition and colour (Figure 5-11). As with all of the rockshelters investigated in Hope Downs 1, the stratigraphy was strongly influenced by the geogenic sediment component. The numerous hearths and ash or charcoal lenses generally align with the stratigraphic layers, and are typically well-defined. The exception is in SL3, where there appeared to have been a high degree of mixing of anthropogenic and geogenic sediment.

Stratigraphic Layer 5 – SL5 was a fine yellowish red (5YR 4/6) silty layer with a high proportion of degraded bedrock (70% soil, 15% fine rock, 10% small rock, 10% coarse rock). The layer only occurred in areas near the lowermost areas of exposed bedrock, including in Units 1, 6, 10, and 11. The distribution of this layer may be related to the areas of the bedrock that exhibit the greatest degree of weathering. The layer was very thin with average depth of 10cm in these areas. There were mottled mineral lenses throughout the layer where the bedrock had chemically dissolved into smaller particles, leaving yellow and white lenses throughout the deposit. The sediment was generally very powdery; although, there were areas of cemented sediment, particularly in Units 1 and 2.

Stratigraphic Layer 4 – SL4 was comprised of fine yellowish red (5YR ¾) to strong brown (7.5YR 4/6) loam with fragments of roof collapse (70% soil, 15% fine rock, 10% small rock, 5% coarse rock). The layer was extensive, with an upper limit ranging in depth between approximately 95 and 120cmbd and extending through to bedrock in many areas of the shelter. The upper limit of the deposit was greater on the southwest side of the excavation trench, as the ashy deposit of SL3 intruded into this layer on the northeast side (discussed further in the following paragraph). The bottom half of the layer was cemented by precipitated salts (predominantly gypsum; see discussion above) along the back of the rockshelter in Units 1 and 2, and to a lesser degree in Units 10 and 11. The cemented area of the layer was designated as SL4b (moderately cemented) and SL4c (highly cemented). There was a significant accumulation of roof collapse in SL4, and it was concentrated on the west side of the trench, particularly in Units 5 and 6.

Stratigraphic Layer 3 – SL3 was only evident on the northeast side of the excavation trench, possibly due to the large amount of roof collapse on the opposite side of the trench. The colour was similar to the previous layer (brown, 7.5YR 4/4), but it was mottled with grey ashy sediment that gave the layer an overall greyish appearance. The layer was comprised of loam with fragments of roof collapse and charcoal (60% soil, 15% fine rock, 15% small rock, 10% coarse rock), and it was fairly loose. This layer was interpreted to be a zone of mixing related to Features 17 and 20. With the use and re-use of these features, ash was likely dispersed around this localised area of the site. Due to the powdery nature of the sediment at the site, the ash would have been mixed with underlying sediment as well as sediment that was deposited after the use of the hearth, resulting in the band of greyish brown sediment. The archaeomagnetic analysis of sediment samples collected adjacent to these features support this theory (Herries 2013). The high proportion of roof collapse on the west side of the excavation trench may have meant that this part of the shelter was less extensively I; hence, the ashy sediment was not dispersed to this area.

Stratigraphic Layer 2 – SL2 was a layer of reddish brown (5YR 4/4) silty loam with mottled areas of ashy sediment, fragments of roof collapse, and frequent fragments of charcoal (80% soil, 10% fine rock, 10% small rock).. Numerous hearth features, ash or charcoal lenses, and patches heat-reddened sediment were recorded in the layer. There were a number of large boulder-sized blocks of roof collapse within this layer, as well as many smaller fragments of roof fall. Once again, the rock was concentrated in southwest corner of the site, particularly in Units 5 and 6. In contrast, Units 3 and 4 were virtually devoid of large rock fragments in this stratigraphic layer. It is possible that this area was cleared of rock to make it more habitable. Bioturbation was more frequently observed in this layer than in the underlying stratigraphic layers; however, the hearth features are largely well preserved. In addition, mud wasp nests were numerous throughout the layer. SL2 had its greatest extent along the southeast and southwest portion of the site, where SL3 was not identified. Here, the layer extended from roughly 95cmbd to approximately 10cm below the surface, where SL1 began.

Stratigraphic Layer 1 – SL1 was comprised of powdery dark brown (7.5YR ¾) loam with fragments of roof collapse (80% soil, 15% fine rock, 5% small rock). The layer had a much higher component of organic material than the underlying layers. The majority of the organic matter was decomposing macropod scats, but leaf litter was also present. Roots were particularly numerous in the first two layers of the excavation due to the presence of annual plants throughout the surface of the excavation area. Bioturbation was also noted, including small tunnels, insect larvae, and friable sediment (possibly due to bioturbation), and mud wasp nests were present. Charcoal flecks and ashy lenses were observed throughout the deposit.

5.4 RADIOMETRIC DATES

Nine out of the 330 charcoal samples were submitted for AMS radiocarbon dating at the University of Waikato Radiocarbon Dating Laboratory (Table 5-1). These dates provide chronological context for the cultural remains at the site, indicating that Jundaru was occupied by as early as 35,978±653 cal BP and likely even slightly earlier. The AMS ages are plotted in Figure 5-12, and they show a strong linear trend. This trend suggests that there was relatively constant sediment deposition through the sequence with some minor deviations that are discussed in more detail below.

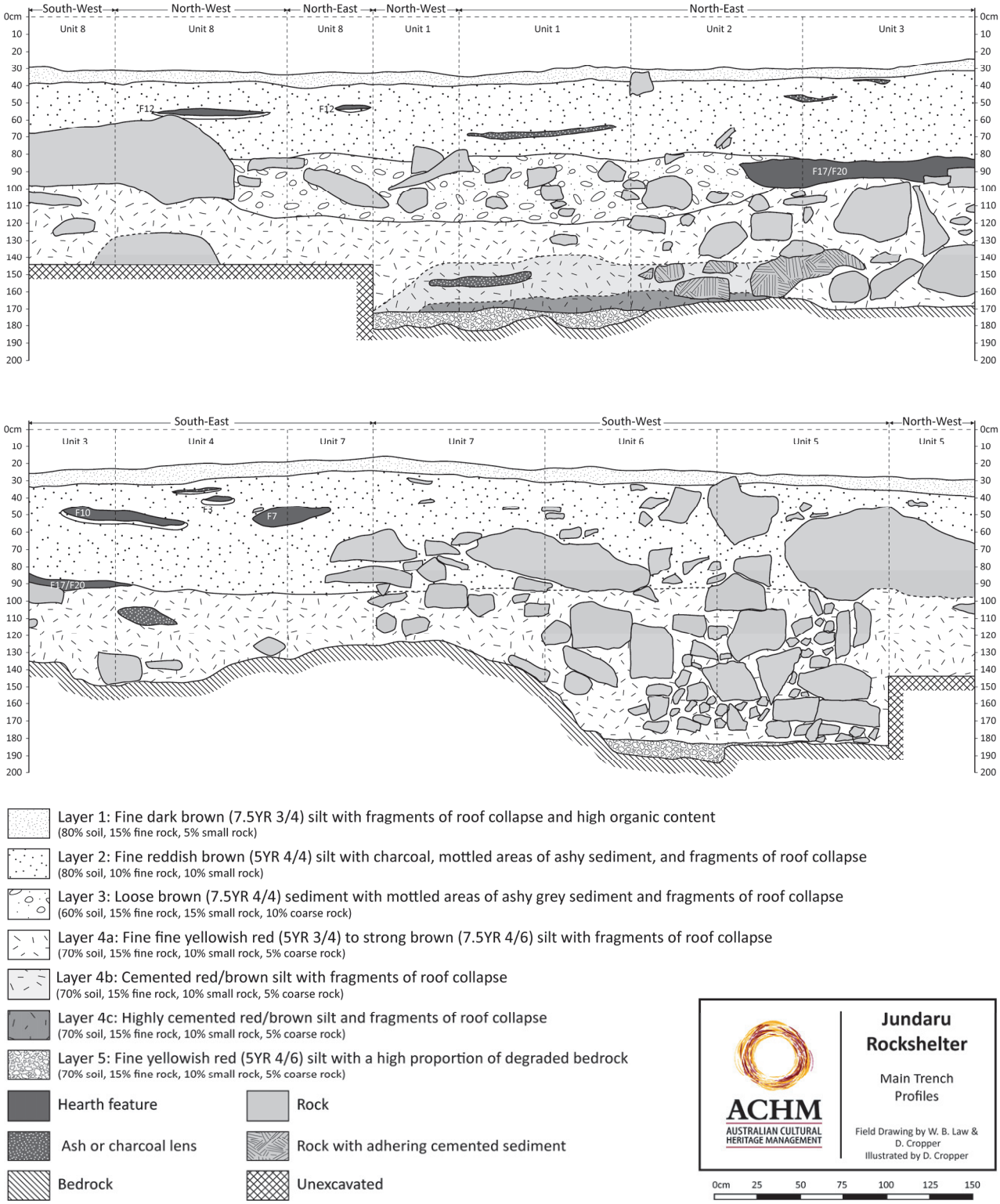

Figure 5-11 Stratigraphic sections of Units 1 to 8, Jundaru rockshelter

The radiocarbon samples were carefully selected to provide chronological context to the archaeological sequence. Five samples were selected from feature contexts, and four samples were selected from arbitrary layer contexts at key points through the archaeological sequence. As the charcoal samples were plotted *in situ*, the surface elevations presented in Table 5-1 have been calculated using the surface elevation nearest to the location of the charcoal sample to mitigate the sloping surface in many of the excavation units.

Charcoal from features was preferred for dating, particularly as it reduces the risk that the charcoal is from intrusive or disturbed contexts. In some cases it is not possible to use charcoal from features, particularly in the earliest phases of the occupation. The uppermost five charcoal samples submitted from the site were collected *in situ* from features, and their ages range from 19,820±172 to 176±86 cal BP (Features 23 to 1). The charcoal sample from the lowermost feature (Feature 24; c-1137) was deemed to be a less suitable sample than the sample from Feature 23, as it is comprised of very small fragments. No

features were identified below Feature 24; hence, only charcoal that was recovered from arbitrary contexts could be submitted for dating.

In order to date the archaeological sequence below the features, four charcoal samples were chosen that were collected *in situ* during the excavation of arbitrary layers. Each of the selected samples mark important moments in the occupation of Jundaru. Sample c-2096 was selected to date a significant roof collapse event (18,659±74 cal BP). Sample c-1157 was selected near a concentration of artefacts midway through the lower half of the deposit (33,255±651 cal BP). Sample c-2118 is the lowermost charcoal sample recovered from Jundaru and was chosen to date the initial occupation (35,978±653 cal BP).

The lowermost date provides an age estimate for the boundary between SL5 and SL4, indicating that this change in deposition occurred around 35,978±653 cal BP. Fifteen stone artefacts were recovered below this sample, suggesting that the initial occupation of the site may have occurred slightly before 35,978±653 cal BP. This interpretation is consistent with the chronology of the initial occupations of Djadjiling, HS-A1, and HD07-3A-PAD13, discussed later in this monograph.

Charcoal sample c-1157 was collected from SL4b amongst cemented sediment and it yielded a date of 33,255±651 cal BP. The large charcoal fragments underwent the same chemical pre-treatment as the other samples submitted for AMS dating, and no potential issues were raised with this sample. Now that it has been established that the precipitates in the sediment are salts, there is no concern that the cemented sediment may have contaminated the sample. While this sample provides chronological resolution for the early occupation sequence at Jundaru, it was also specifically selected as it marks a small peak in artefact discard rates. Dated to 26,793±369 cal BP, sample c-2137 is the mid-point of SL4. This sample was amongst the second round of samples submitted, and it was selected to provide an age estimate between the samples dating to 18,659±74 and 33,255±651 cal BP. The charcoal was collected from Layer 22 of Unit 1, which marked the end of the roof collapse layer and corresponded with an increase in artefact numbers. The age-depth trend line (Figure 5-12) suggests that there was a slightly lower sedimentation rate during the period between 33,255±651 and 26,793±369 cal BP. This period corresponds with the initiation of cooler and more arid conditions (see Fitzsimmons *et al.* 2013).

Sample c-2096 was selected to date a period of roof collapse, and due to its depth, it was expected to be older than Feature 23. The sample yielded an age of 18,659±74 cal BP and creates a minor inversion with the estimated age of Feature 23 (19,820±172 cal BP). The charcoal was collected *in situ* and it is well-preserved. The charcoal was directly under a boulder-sized block of roof collapse and was considered to be a sealed sample that may be useful in providing a date for when the block fell to the ground. What was not taken into account was the force of the boulder falling to the ground and compressing the sediment beneath. Even though this piece was collected at 123cmbd, it yielded an more recent date than a piece of charcoal from Feature 23, which was collected at 101cmbd. A contemporary radiocarbon age was determined for a sample from the MHA excavation, collected from 72.5 to 79.6cmbs (Table 5-2; Wk-3382, 18,410±264 cal BP). The age and depth of the two samples are consistent, which suggests that it is the sample collected from under the rockfall that does not follow the age-depth trend. The date of the roof collapse event is slightly earlier than the use of the hearth. When the large boulder fell, it appears to have compressed this particular area of sediment. The impact of the roof collapse is believed to be relatively localised as the features that pre-date the roof collapse event (Features 22, 23 and 24) have been preserved. It seems likely that the transition between SL4 and SL2 occurred at some point around this roof collapse event (18,659±74 cal BP). This interpretation also has broader consequences, indicating that the context of archaeological remains in areas with large amounts of roof collapse are likely to be compromised to some degree.

The charcoal samples selected from the features document the roughly the second half of the site's occupation, from 19,820±172 to 176±86 cal BP. The results from the features have provided a sequential series of dates, which correspond well with the data from the initial excavation. Dating to 10,774±135 cal BP, Feature 19 diverges from the trend line. The sample has a lower depth than is predicted by the trend line, which assumes regular rates of sediment deposition over time. As is discussed in the following section, Feature 19 is a charcoal lens that is believed to be contemporary with a large hearth, Feature 20. The charcoal sample was collected mid-way through Feature 19 at 88cmbd, while the feature had a maximum depth range of 82 to 93cmbd (*ca.* 57-68cmbs). As the feature had a plano-convex cross-section, the living surface is assumed to be at approximately 82cmbd (*ca.* 57cmbs), and this depth aligns the sample much closer with the trend line, so this is one possible explanation for the deviation from the trend line. However, this does not seem to have affected the other features that were dated. Feature 19 is very thick and has a very distinct plano-convex cross-section, while the other features are thinner and have lenticular cross-sections. The lenticular cross-section is significant in that charcoal fragments from the middle of the feature will have a similar elevation to the associated living surface. It is also possible that there may have been a significant change in the sedimentation rates between the deposition of Feature 23 (19,820±172 cal BP) and the terminal Pleistocene. This period covers the end of the LGM and transition to post-glacial periods, when other sites have also demonstrated low sedimentation rates (*e.g.*, HD07-3A-PAD13 and Djadjiling).

The age-depth relationship of the two uppermost radiocarbon dates from the ACHM series suggests that sedimentation rates were higher during the late Holocene. While it is unlikely that geogenic sedimentation changed at Jundaru, the artefact densities at the site were particularly high during this period. There are many hearth features dating to this period, and it is possible that anthropogenic sedimentation led to the increased deposit accumulation at this time. Additionally, these layers generally have a higher proportion of organic matter than the lower layers (Wallis, this volume; Haberle *et al.*, this volume), which may appear to affect the deposition rates.

These new radiocarbon dates complement the five radiocarbon dates previously determined for Jundaru (Table 5-2). The two series of dates provide an effective chronologic record for Jundaru. In order to compare the two data sets, Figure 5-13 plots the calibrated dates according to the sample depth below the surface. The difficulty in comparing the results of the two series is that precise context of the MHA samples is not certain. The dates are reported with depth ranges (cmbs), which are generally around 5cm or the depth of an excavation spit (Edwards *et al.* 2001: 68; Edwards and Murphy 2003: 45). It is not clear from which excavation square the samples were collected. In the subsequent article on the radiocarbon results, Edwards and Murphy (2003: 45) note that the samples submitted for analysis were of 'diffuse charcoal'. It is possible that the samples are bulk samples that were not collected *in situ*, which could account for some of the minor differences between the two data sets. As depth ranges were reported for the samples (see discussion below), the average depth has been plotted along with error bars to represent the depth range for each sample.

The date series from the initial testing of Jundaru correlates well with ACHM's results. The two series are consistent, with only a small amount of variation. The most notable variation occurs between 19,820±172 and 7686±34 cal BP, and there are two factors that may have caused variability during this period. The first is a phase of roof collapse that occurred around 18,659±74 cal BP, which affected some areas of the site. The second possible cause of the variation is changes in the sedimentation rate. It has been suggested previously, that sedimentation rates declined between 18,659±74 cal BP and 10,774±135 cal BP. There is considerable discrepancy in the depth of the two dates dating to approximately 7500 years ago. While the ACHM occurs near the trend line, Wk-5748 (7477±52 cal BP) diverges from it. Both of these samples occur during a phase of intense site occupation, during which there was repeated site use and when a number of features were created (Features 20, 19, 17, 18, 15, and 16). The variation in these samples may be due to mixing of the sediment due to the use of pit-hearths, hearth maintenance, and trampling.

Table 5-1 AMS radiocarbon results, Jundaru rockshelter

Lab Code	Sample No.	Material	Context	Strat. Layer	Depth (cmbd)	Depth (cmbs)	δ13C	^{14}C Age (BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-26720	c-1007	Charcoal	F1 (U4-L01.1)	½	31	~8	-23.5±0.2	162±30	287 to -3	176±86
Wk-26719	c-1041	Charcoal	F10 (U4-L06.1)	2	56	~33	-25.0±0.2	3594±30	3978 to 3834	3899±45
Wk-32636	c-2045	Charcoal	F15 (U1-L08.1)	2	72	~39	-24.6±0.2	6859±30	7782 to 7617	7686±34
Wk-26718	c-1114	Charcoal	F19 (U4-L12.2)	3	88	~67	-25.0±0.2	9502±38	11,071 to 10,608	10,774±135
Wk-26717	c-1130	Charcoal	F23 (U4-L16.2)	4	101	~77	-24.2±0.2	16,686±67	20,153 to 19,553	19,820±172
Wk-26716	c-2096	Charcoal	U10-L19-QA	4	123	~90	-24.5±0.2	15,430±58	18,822 to 18,539	18,659±74
Wk-32637	c-2137	Charcoal	U1-L22-QA	4	139	~107.5	-24.5±0.2	22,267±114	27,589 to 26,219	26,793±369
Wk-26715	c-1157	Charcoal	U11-L26-QA	4	154	~126	-21.5±0.2	28,738±404	34,517 to 32,059	33,255±651
Wk-26714	c-2118	Charcoal	U1-L29-QC	5	173	~139	-23.8±0.2	31,539±576	37,362 to 34,865	35,978±653

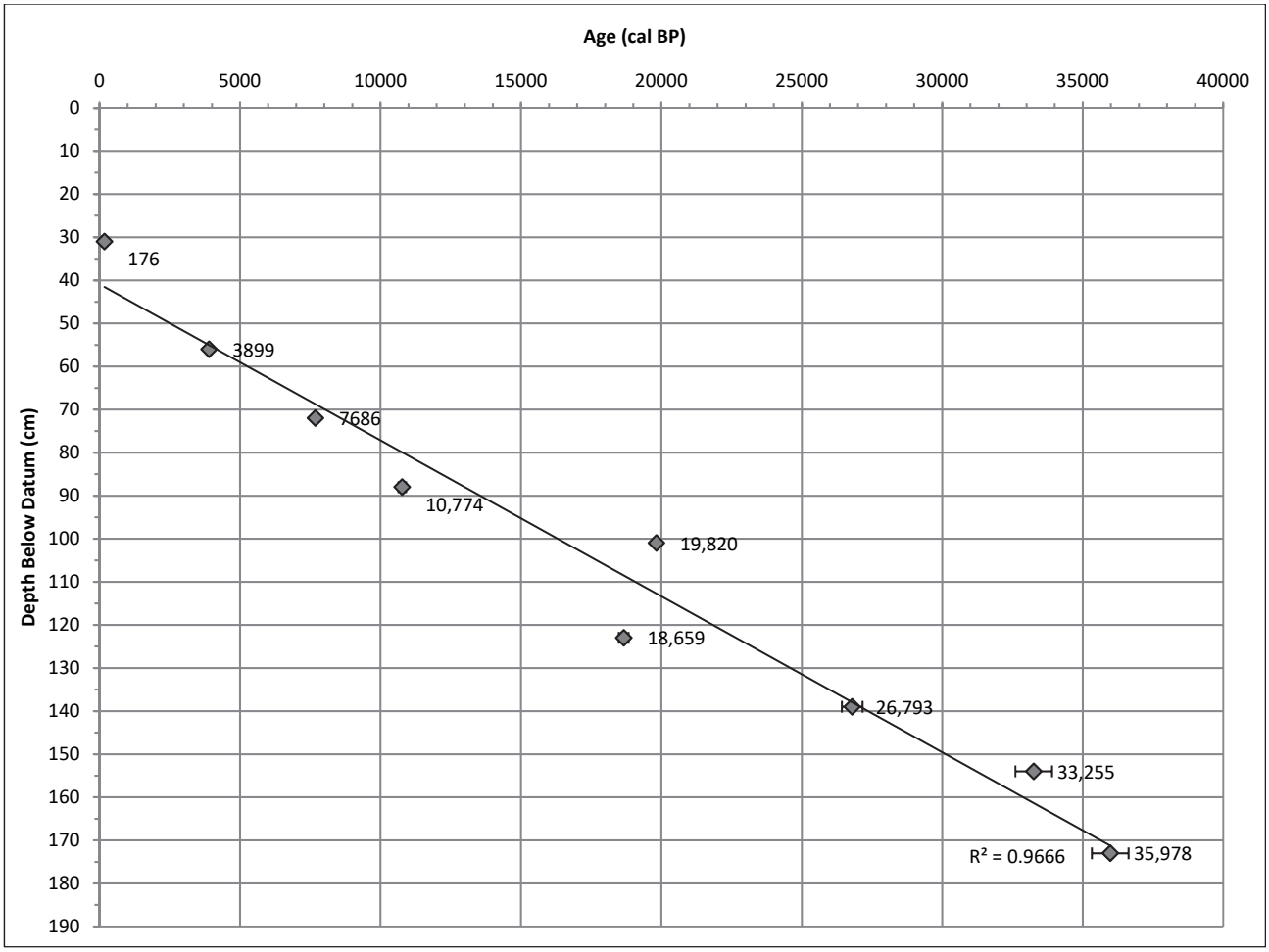

Figure 5-12 Age-depth plot of calibrated radiocarbon dates for Jundaru rockshelter with linear trend line (ACHM series)

5.5 COMBUSTION FEATURES

Twenty-four features were identified during the 2008 investigations, including hearths, ash lenses, and charcoal lenses (Table 5-3). For the purpose of this research, hearths are defined as combustion features that retain evidence of *in situ* burning, such as reddened sediment beneath the hearth. These features generally had a layered appearance that consists of a light ashy layer, followed by dark grey charcoal-rich layer over heat-affected sediment. Some hearths were ash-rich and did not exhibit the dark grey layer, but had a light grey matrix over reddened sediment. Hearths with similar ash-rich compositions were observed amongst the Alyawarra in central Australia and were the result of smouldering fires (O'Connell 1987: 80). It is also possible that the lack of charcoal may be due to the fuel selection. If small twigs and branches were I, it is less likely that charcoal would be produced.

Ash and charcoal lenses did not exhibit evidence of *in situ* burning and were classified as being either ash-rich or charcoal-rich. The lack of reddened sediment beneath the lenses suggests that they are not hearths, as even minimal burning typically produces this effect (see Mallol *et al.* 2007). Instead, these lenses may be discrete secondary deposits that were created through cleaning and maintenance of hearths located elsewhere at the site. The maintenance of hearths is a good indication that the site was occupied for a considerable period of time, rather than briefly. If the site was abandoned soon after the hearth was constructed, there would have been no requirement to maintain the hearths. Hearth maintenance may also indicate that artefacts and faunal material may have been redistributed across the site; however, most of the ash and charcoal lenses have only small artefact and faunal assemblages, suggesting that this would have had a limited effect on the distribution of artefacts.

The size and shape of the hearths at Jundaru varied considerably, from large oval hearths with mixed sediment (suggesting re-use) to small discrete layered hearths that may have been used for a short period of time. It is possible that the morphological variation may be related to function, including food preparation and cooking, heating, and object and materials manufacture. While ethnographic research has shown that it can be very difficult to determine feature function through strictly archaeological means (see Mallol *et al.* 2007), there is a clear distinction between the large pit-like hearths and the small and shallow layered hearths at Jundaru. The large deep hearths with mixed deposits are believed roasting pits. The Traditional Owners continue to use this method to cook large game, and there are numerous ethnographic accounts for the widespread use of roasting pits (Binford 2002: 168; Gould 1967 ; Calvert 1892: 28) .

Table 5-2 Radiocarbon results from the MHA excavation (Edwards *et al.* 2001: 68; Edwards and Murphy 2003: 45), Jundaru rockshelter

Lab Code	Spit	Depth (cmbs)	^{14}C Age (years BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-3209	2	6.3-9.9	290±50	492 to -1	375±85
Wk-3381	6	27.0-30.4	2820±80	3161 to 2764	2943±107
Wk-5748	11	55.0-60.0	6570±60	7578 to 7333	7477±52
Wk-3382	16	72.5-79.6	15,230±230	18,877 to 17,928	18,410±264
Wk-3210	19	97.3-102.1	20,360±320	25,075 to 23,505	24,314±404

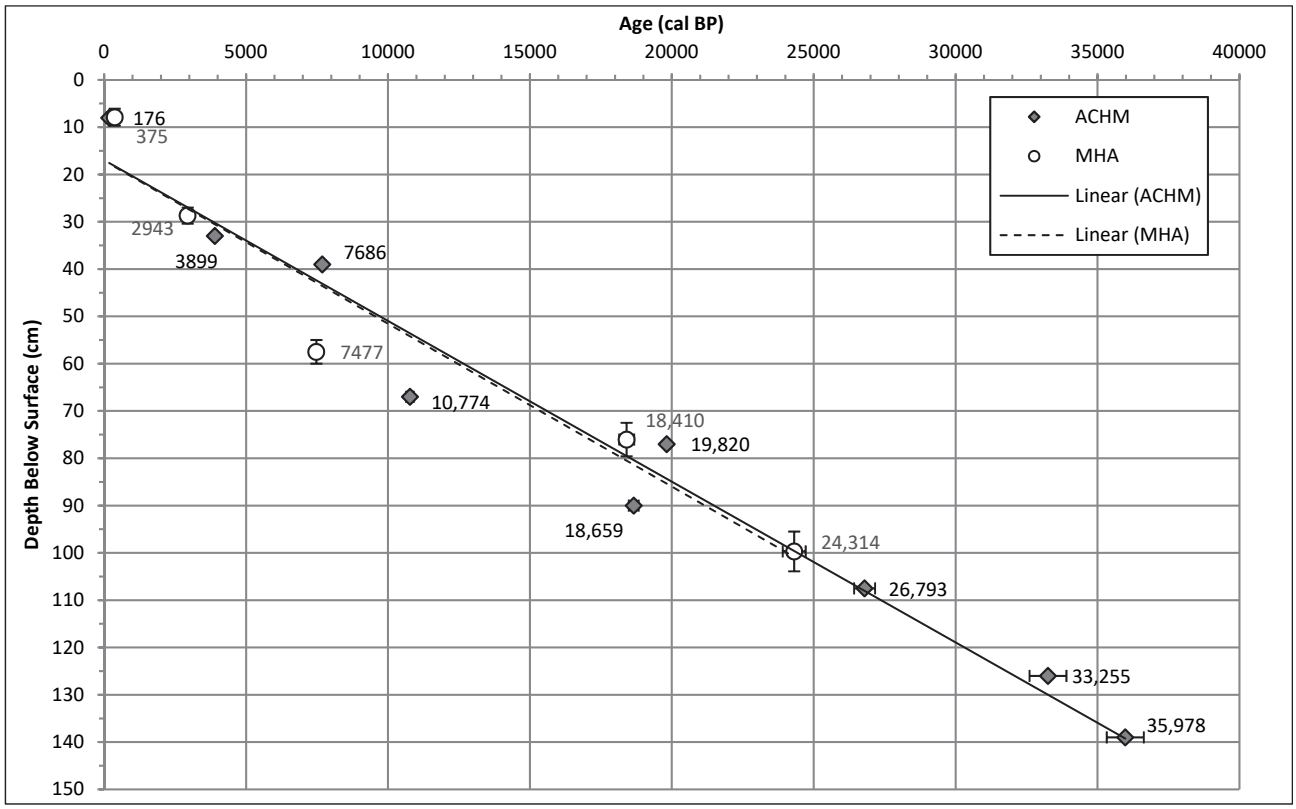

Figure 5-13 Age-depth plot for ACHM and MHA series (cmbs), Jundaru rockshelter

Table 5-3 Combustion features, presented from oldest to youngest, Jundaru rockshelter

Feature Number	Feature Type	Excavation Unit(s)	AU	Max Depth Range (cmbd)	Approximate Depth Range (cmbs)	pH	Median Calibrated Age (cal BP)	Comments
24	Charcoal Lens	4	6	105-110	82-85	4.5		
23	Hearth	4	6	100-103.5	75-78.5	4.5	19,820±172	
22	Charcoal Lens	4	6	101-105	76-80	4.5		Likely contemporary with F23
21	Hearth	1, 2	5	95-103	64-72	9		
20	Hearth	2, 3, 4	4	83.5-100.5	52.6/61-70.5/72.5	8-9		Pit-like hearth; likely contemporary with F19; emu shell present
19	Charcoal Lens	4	4	82-93	57-68	4-4.5	10,774±135	
17	Hearth	2, 3, 4	4	73-89	42.5-61.5	8		Pit-like hearth; likely contemporary with F15
18	Ash Lens	1	4	70.5-77	39.5-46	8		Likely contemporary with F15
15	Ash Lens	1	3	67.5-72.5	36.5-39	8	7686±34	
16	Ash Lens	8	3	68.5-75	36-42.5	5.5		Likely contemporary with F15
14	Ash Lens	8	3	62.5-66	30-33.5	8.5		Likely contemporary with F13
13	Hearth	8	3	61-67.5	28.5-35	8.5		Likely contemporary with F14; emu shell present
10	Hearth	3, 4, 9	2	51-57	25-32	8.5	3899±45	Charcoal rich
11	Ash Lens	2	2	53.5-59.5	22.5-28.5	8		
7	Charcoal Lens	4, 7, 9	2	44-57	21.5/24-34.5/37	4.5		Likely contemporary with F8; contained spinifex resin
8	Ash Lens	4	2	45-49	20-22	8		Likely contemporary with F7
12	Hearth	8	2	51.5-62	19-29.5	7.5		Ash rich; emu shell present
9	Hearth	2	2	50.5-53.5	18.5-22	8.5		Ash rich
6	Charcoal Lens	8	2	47-51	14.5-18.5	8		
3	Ash Lens	4, 9	2	40-45	15-20	8		
5	Hearth	2	2	41.5-47	10.5-16	8		
4	Hearth	2	2	40-44	9-13	8		
2	Hearth	4	1	32-39	7/9-14	6.5		
1	Hearth	4, 7	1	30-32.5	6-8.5	8	176±86	Layered appearance

Pleistocene Features

Six Pleistocene features were identified at Jundaru, including Features 19 through 24, and their distribution is illustrated in Figure 5-14 below. The Pleistocene features were all relatively small and thin, perhaps indicating single-use fires, with the exception of Feature 20, which is interpreted to be the remains of a cooking pit.

Feature 24 – Feature 24 was the lowermost feature identified at Jundaru, and this small lens of charcoal was identified in Quad C of Unit 4 and excavated as Layer 17.1. This feature was distinguished from Feature 23, which was identified in Unit 4 Quad D during the excavation of the overlying arbitrary excavation layer. Based on the provenance of the features, Feature 24 is believed to be slightly older than Feature 23 (19,820±172 cal BP) and was perhaps created prior to 20,000 years ago.

The oval-shaped feature was defined on the basis of a high concentration of charcoal in a localised area, measuring 21cm wide by 31cm long. The feature had a plano-convex cross-section, with the upper elevations ranging between 105 and 107cmbd (*ca.* 80-82cmbd), and the maximum depth was recorded in the centre of the feature at an elevation of 110cmbd (*ca.* 85cmbs). The maximum thickness of the charcoal lens was 3.5cm.

The sediment within the feature had the same pH value as the sediment from the surrounding arbitrary excavation layer (pH=4.5), and the colour was slightly darker (2.5YR ¾) than the surrounding sediment (2.5YR 3/6). The feature is not typical of well-preserved combustion features, as it did not exhibit layering or reddened sediment.

No artefacts or faunal remains were recovered from the matrix of the feature. The macrobotanical analysis of the wood charcoals demonstrates that gum was the dominant wood selected for fuel, but there was a considerable proportion of *Acacia* Type 3 (Fairbairn 2013). Unlike the varied patterns observed throughout the sequence at HS-A1 and Djadjiling (Fairbairn 2013, 2012), this pattern remains consistent amongst the features at Jundaru until the late Holocene, when there is a decline in the abundance of *Acacia* (Fairbairn 2013).

Feature 23 – A small hearth was identified in Quad D of Unit 4 (U4-L16.2) that appears to have been roughly contemporaneous with Feature 22. A charcoal sample from the feature was submitted for radiocarbon dating, returning a date of 19,820±172 cal BP. This indicates that this small combustion feature was created during the height of the LGM.

The feature was identified on the basis of a colour change from reddish brown (5YR 4/6; throughout Layer 16) to dark reddish brown (5YR 3/3) with a dense concentration of charcoal. The team observed lenses of burned soil and heat-affected rock below the feature, indicating *in situ* burning. While the matrix of the feature had a pH of 4.5, the sediment immediately adjacent to it was neutral (pH=7). The rest of Layer 16 had a pH value of 5.5. It is possible that the past human activity at Jundaru affected the soil chemistry within this layer.

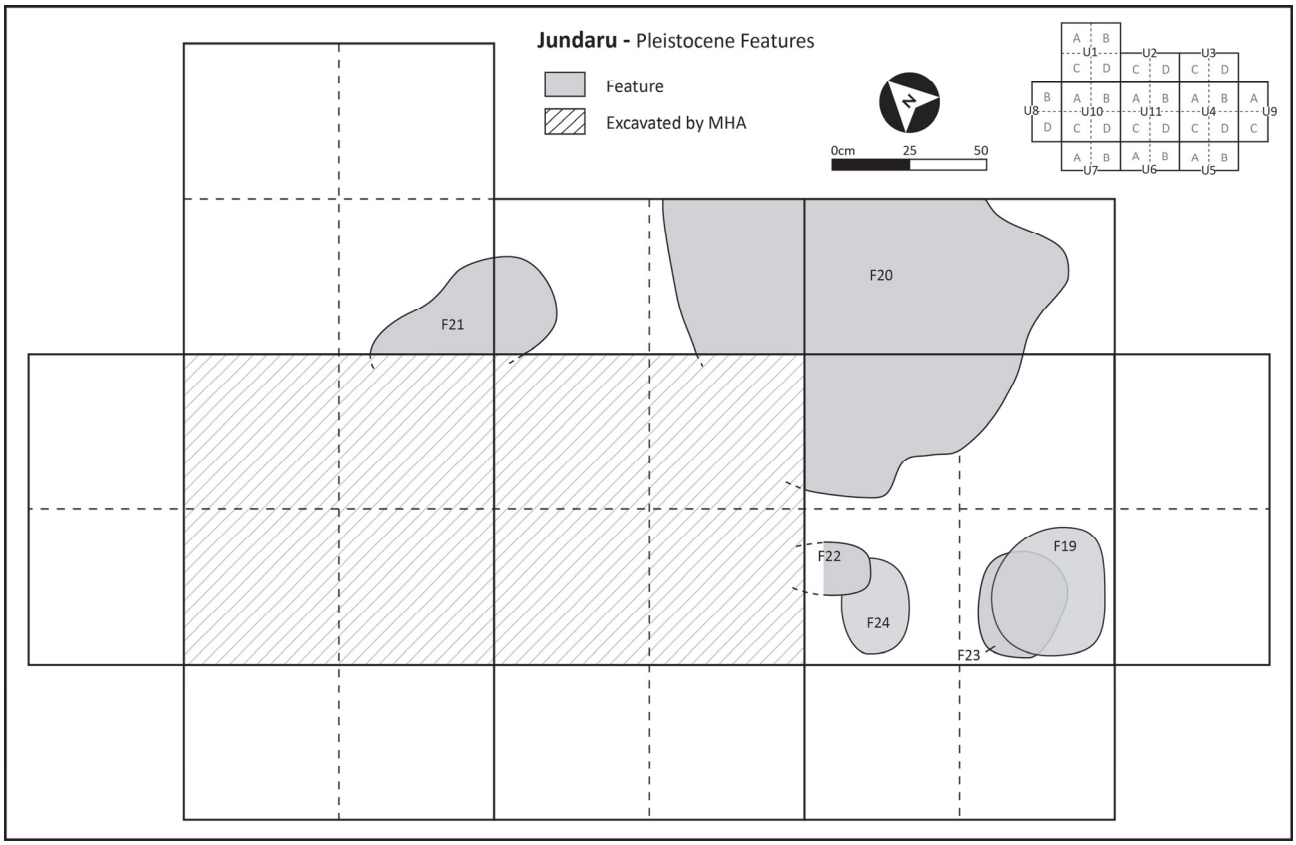

Figure 5-14 Distribution of Pleistocene combustion features, Jundaru rockshelter

The horizontal extent of this circular feature was limited, with an average diameter of 30cm. The feature had a plano-convex cross-section with upper elevations ranging from 100 to 101cmbd (75-76cmbs). The lower elevations showed a slight slope to the south, with a maximum depth of 103.5cmbd (78.5cmbs) recorded in the southern-most extent near the border with Unit 7. Here the feature had a maximum thickness of 2.5cm, demonstrating its ephemeral nature.

Herries (2013) found that this feature exhibited one of the lowest magnetic susceptibility values of hearths at Jundaru. This indicates that the hearth was not intensively used. This is consistent with ephemeral nature of the feature and the lack of artefacts or faunal remains.

Feature 22 – Feature 22 was identified in Unit 4 (Quad C; U4-L16.1) just slightly above Feature 24. The feature consisted of a charcoal lens with dense concentration of charcoal and dark sediment, which was considerably darker (2.5YR 4/4) than the matrix of the arbitrary excavation layer (5YR 4/6; U4-L16). The feature had a plano-convex cross-section, with upper elevations of 101cmbd (76cmbs) and a maximum lower elevation of 105cmbd (80cmbs). The feature was very small and would have extended into slightly further to the northwest; however, there was a minor collapse of the Unit 4 baulk so the full extent of this feature could not be determined. As it was excavated, the feature measured 13cm wide and 16cm long.

This charcoal lens did not have any layering nor did it have reddened sediment beneath it. Considering that Features 22 and 23 had the same upper elevations, it is presumed that they are contemporary and may represent the same phase of occupation or even the same combustion event. Some of the charcoal may have been moved from Feature 23, possibly through hearth maintenance or for some other purpose. This would explain why no heat-affected rock or burned soil was observed in the feature. No artefacts or faunal remains were recovered from feature matrix.

Feature 21 – Feature 21 was a large hearth that extended across Unit 1 (Quad D; U1-L14.1) and Unit 2 (Quad C; U2-L14.1). The stratigraphic relationship of the feature demonstrates that it is younger than Features 22 and 23, but older than Features 19 and 20; based on its context, it is estimated to post-date the LGM.

The feature was well defined by its very dark brown colour (10YR 2/2), which was easily distinguished from the surrounding brown sediment (7.5YR 4/3). The feature had a mottled appearance with a high proportion of charcoal. At the base of the feature, reddened sediment and rocks were encountered demonstrating the fire had generated enough heat to affect the underlying sediment.

The maximum width of the feature across Units 1 and 2 measured 60cm. The length of the feature could not be determined as it would have extended into Units 10 and 11, which had been previously excavated by MHA to this depth. The upper elevations were consistent, ranging between 95 and 95.5cmbs (*ca.* 64-65.4cmbs). The excavated portion of the feature had a plano-convex cross-section. The lower elevations show that the feature had the maximum depth in Unit 1 (103cmbd or *ca.* 72cmbs), near what was assumed to be the centre of the feature with a thickness of 8cm.

Macrobotanical analysis of the wood charcoals indicates that various wood types were used as fuel, including gum (mostly *Eucalyptus* type 1) and *Acacia* (Type 3) (Fairbairn 2013). The distribution of wood charcoals from this feature show a similar pattern to the other Pleistocene, early and mid-Holocene features analysed.

Numerous artefacts were recovered *in situ* during the excavation of the feature, and 63 artefacts were recovered from the feature matrix. Faunal remains were also recovered, including molar fragments from *Macropus* and *Petrogale*, as well as non-diagnostic bone fragment (McDowell, this volume). All specimens were interpreted as being likely cultural and most were burned (McDowell, this volume). A maxilla fragment of a common brushtail possum (*Trichosurus vulpecular;* McDowell, this volume) was recovered *in situ* from the adjacent arbitrary excavation layer (U1-L14). The archaeomagnetic analysis suggested that this feature was not intensively used (Herries 2013), which does not correspond with the large size and thickness of the feature or the number of artefacts and faunal. The mottled nature of the feature may have affected the archaeomagnetic results, due to a mixture of sediment that had and had not been burned.

Feature 20 – Feature 20 was a large hearth that extended over Units 2, 3, and 4. The feature appeared to have an oval shape; although, the full extent of the feature cannot be determined as it continued into the unexcavated area of Unit 2 and 3 (Quads A and B) and into the previously excavated portion of Unit 11. The excavated maximum dimension of the hearth was 132cm along a north-northeast axis. Due to its large horizontal and vertical extent (max 17cm), Feature 20 was excavated in ten separate contexts, including four contexts in Unit 2 (L11.1-L11.4) and three contexts each in Unit 3 (L10.6-L10.8) and Unit 4 (L10.6-L10.8).

Delineating the feature was difficult at times due to the mottled nature of the sediment. The feature matrix exhibited a high proportion light grey ashy sediment intermixed with reddened sediment, heat-shattered rock, and dark grey sediment (more predominant in Unit 2). The colour recorded for the feature matrix (5YR 5/4, reddish brown) did not reflect the distinct difference in colour change observed in the field. The feature's mixed deposit (including burned sediment), size, and depth all suggest that it may have been an ash or charcoal cooking pit. The mixed sediment may be a result of hearth maintenance or inserting and removing the food item. Similar features were identified at Djadjiling and HS-A1, as well as elsewhere in the Pilbara, where they were interpreted as cooking or roasting pits (see Brown and Mulvaney 1983; Brown 1987: 24, 41). The preservation of the feature was compromised by bioturbation in Unit 4, with a live termite nest identified in the northeast corner of Quad A.

The upper elevations of the feature show that it sloped down towards the east, following the lay of the rockshelter (Unit 2: 83.5cmbd or *ca.* 52.5cmbs; Unit 3: 86-88cmbd, *ca.* 55-57cmbs; Unit 4, 86.5-89cmbd, *ca.* 59-61.5cmbs). The feature was basin-shaped and reached its deepest points in Unit 2 (100.5cmbd) and in Unit 4 (100cmbd). The feature had a maximum thickness of 17cm.

A large number of artefacts were recovered from the matrix of this feature (n=389), including several heat-affected specimens. Two fragments of ochre were also recovered during the sorting of the rock fraction, but it is not certain if they have a cultural origin or are naturally occurring specimens. Ochre has been identified on several of the grindstones from Jundaru; however, they do not show conclusive evidence of ochre grinding (R. Fullagar 2013, pers. com. 20 Jan.). The feature also yielded a large faunal assemblage (n=264), including a small number of identifiable specimens and a large number of non-diagnostic or unidentifiable specimens. The identified specimens include *Macropus* ssp., *Dromaius novaehollandiae* (emu), *Isoodon auratus* (golden bandicoot), *Varanus* sp. (goanna), an elapid (poisonous snake), and macropod. One of the unidentifiable specimens has two deep parallel cuts. Most of the faunal remains are burned and are interpreted to have a cultural origin (McDowell, this volume). The emu eggshell fragments may indicate this feature was I in the autumn or winter.

The age of this feature has not been determined, but its upper elevations in Unit 4 are very similar to that of Feature 19, which has been dated to the Pleistocene-Holocene transition (10,774±135 cal BP). The two distinct features are 20cm apart, and they may be contemporaneous. The hearth has a similar spatial distribution to Feature 17, but the excavation team was able to distinguish between these two features that were clearly created at different periods in the site's occupation history.

Feature 19 – Feature 19 was a small charcoal lens identified Unit 4 (Quad D) on the basis of a colour change to dusky red (2.5YR 3/2) and the high concentration of charcoal. The sediment surrounding the feature only had occasional flecks of charcoal and was much lighter in colour (5YR 4/4, reddish brown). The excavation team observed that there did not appear to be any reddening of the rock or sediment beneath the feature, and that the proportion of charcoal decreased with increasing depth.

The feature had a roughly circular shape with a diameter of approximately 35cm. The feature was first encountered at 82cmbd (*ca.* 57cmbs), and because it was fairly thick (max 11cm), it was excavated in three separate contexts (U4-L12.1, U4-L12.2, and U4-L12.3). With the plano-convex shape of the feature, each successive layer of the feature was considerably smaller than the overlying layer. The lowest portion of the feature extended into arbitrary Layer 14, and reached a maximum depth of 93cmbd (*ca.* 68cmbs).

A charcoal sample collected from the middle of the feature was submitted for dating, and it indicates that the feature dates to 10,774±135 cal BP. While the upper elevation is slightly lower than Feature 20, these two features may be contemporary. Feature 19 is approximately 20cm south of Feature 20, and it is possible that the charcoal in this secondary deposit that originated from the large Feature 20 hearth. Fourteen flakes were recovered from the matrix of this feature, but no faunal remains were identified.

Early Holocene Features

One of the most prominent combustion features identified at Jundaru dates to the early Holocene and is interpreted to be the remains of a large roasting pit (Feature 17). Several ash lenses were also identified during this period of site use The distribution of the early Holocene features is displayed in Figure 5-15.

Feature 17 – Feature 17, complex pit-like hearth, appears to have been the first Holocene feature at Jundaru. While the feature has not been directly dated, its provenance indicates that it was created after Feature 19, which was dated to 10,774±135 cal BP. Feature 17 was likely I towards the end of the early Holocene, as suggested by the close stratigraphic similarity to Features 15 and 18. It is possible that Feature 17 may be contemporary with these ash lenses and may even be the hearth from which the ash originated.

Feature 17 exhibited an ashy matrix with mottling of brown sediment, darker grey sediment, and charcoal. The wood charcoals were analysed and are predominantly gum (*Eucalyptus* Type 1) and *Acacia* Type 3 (Fairbairn 2013). The mottled matrix, large size, and considerable thickness suggest that this feature was used as a roasting or cooking pit.

The bulk of Feature 17 was excavated by MHA in Unit D5 (Unit 11); however, it extended into Units 2, 3, 4, and 10. Because of the considerable horizontal and vertical extent of Feature 17, it was excavated in ten separate contexts, including three layers in Unit 2 (L09.1-L09.4), three layers in Unit 10, (L10.2, L10.4, and L10.5), and four layers in Unit 4 (L10.1-L10.5). In Unit 2, Feature 17 only extended into the south corner of the excavation unit. The feature continued to Unit 3, where it only occurred in the west corner of Quad C. The maximum excavated extent (by ACHM) measured 90cm long and 60cm wide.

In all excavation units, the feature was first encountered at 73cmbd, which equates to between 42.5cmbs (Unit 2, Quad D) to 45.5cmbs (Unit 4, Quad A). The feature had a maximum depth of 89cmbd in Unit 4 (*ca.* 61.5cmbs) along the very extreme edge with Unit 11. In most other areas, the lowermost elevations were slightly less (*ca.* 85cmbd). The maximum thickness of Feature 17 was 16cm, but it is possible that the thickness of the feature may have been greater in Unit 11; however, there is no discussion of this feature in the MHA report (Edwards *et al.* 2001). The east section drawing of the MHA excavation shows an extensive area of diffuse ash with a patch of charcoal in Unit 11 or D5 (Edwards *et al.* 2001: 65, Figure 11). The lens predominantly appears between 45 and 55cmbs, with the uppermost extent being at approximately 40cmbs. The position and elevation of the ashy deposit excavated by MHA corresponds well with Feature 17.

A large number of artefacts was recovered from Feature 17, including 52 flakes (and flake fragments), 10 flaked pieces, one retouched flake, and six potlids. A piece of ochre was also recovered during the sorting of the rock fraction. While it is not certain if the ochre is a cultural item or a naturally occurring specimen, it is worth noting that several of the Jundaru grindstones exhibited ochre residues, but did not show conclusive evidence of ochre grinding (R. Fullagar 2013, pers. com. 20 Jan.). Amongst the faunal remains, 101 individual specimens were recorded in addition to the non-diagnostic bone fragments from 11 contexts. Specimens of identified faunal remains include *Macropus* sp., *Isoodon auratus* (golden bandicoot), *Bettongia* sp. (bettong), and *Muridae* (McDowell, this volume). Many of the bone and tooth fragments are burned, including some at lower temperatures, as well as blackened and calcined specimens (McDowell, this volume). Temperatures of at least 450° to 500°C are required for calcination or prolonged exposure to fire (over 3-4 minutes) (David 1990: 69).

While Features 17 and 20 have a similar spatial distribution, they clearly represent distinct events that are likely separated by several millennia. A thin layer of brown sediment separates the two features, and the plan of the features is slightly different. Feature 17 appears to have been concentrated in Unit 11, with only small areas extending into Units 2 to 4. In contrast, the location of Feature 20 was more to the northeast, with more of the feature being in Units 3 and 4. It is possible that this was an ideal location for the creation of such features, so this area was re-used by the occupants over a period of time.

Feature 15/18 – Features 15 and 18 were extensions of a large ash lens in Unit 1. A charcoal fragment submitted for radiocarbon dating yielded a date of 7686±34 cal BP. The stratigraphy and composition of the feature suggests that there was a close relationship with both Features 17 and 16, and it is possible that these features represent a single phase of site occupation.

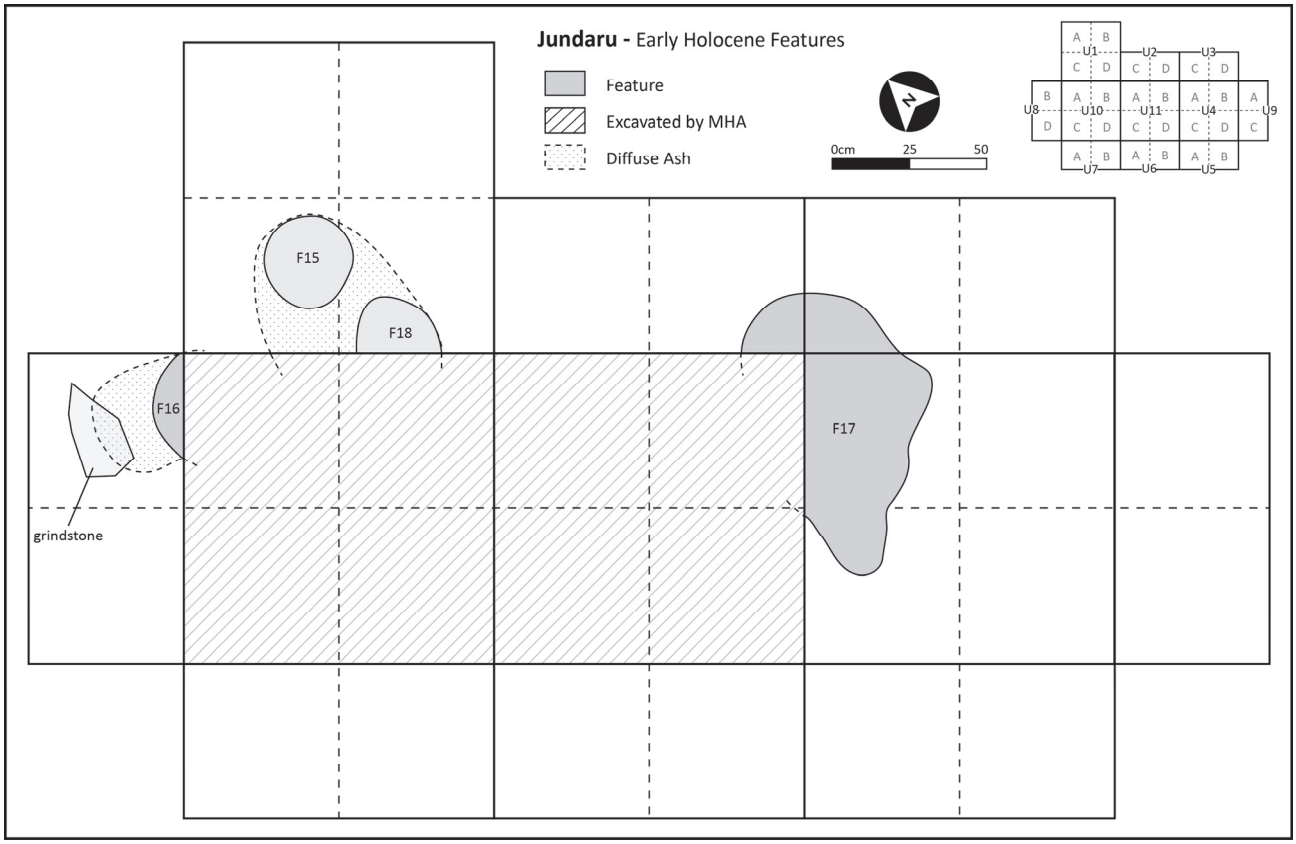

Figure 5-15 Distribution of early Holocene combustion features, Jundaru rockshelter

Feature 15 was encountered first and interpreted to be an ash lens near the centre of Quad C, while Feature 18 was initially believed to be a second ash lens in Quad D at a slightly lower elevation. Upon reviewing the field notes, photographs, and the MHA report, it seems likely that these two ash lenses represent a continuation of the same secondary ash deposit. Feature 15 had slightly higher elevations than Feature 18, and this was presumably due to the fact that the ash was discarded on a large rock that protruded slightly above the ground surface.

The upper elevations of the feature ranged from 67.5 to 70cmbd for Feature 15 and 70.5 to 72cmbd for Feature 17, giving a depth range below surface from approximately 36.5 to 41cmbs. Feature 15 was much shallower than Feature 18, as the deposit was atop of a large rock and only reached 72.5cmbd. Feature 18 reached its maximum depth of 77cmbd (*ca.* 46cmbs) along the southeast edge of Unit 1. In this area of the feature, its maximum thickness was 5cm.

Feature 15/18 had an ash-rich matrix with a small number of charcoal fragments, which are predominantly gum (*Eucalyptus* Type 1) and *Acacia* Type 3 (Fairbairn 2013). The colour of the matrix was light reddish brown (5YR 6/4), suggesting that the ash was slightly mixed with brown sediment, perhaps when the ash was moved from its original context. In some areas the ashy deposit was firm, particularly along the exposed Unit 1 section.

A similar feature was encountered in Unit 8 (Feature 16), and it is possible that these features are associated. As the area between these features had been excavated previously by MHA, it is not possible to definitively determine if these features represent one large ash lens. However, the Features 15/18 and 16 all have a similar wood charcoal composition.

Eleven artefacts were recovered from the feature, including seven flakes, two flaked pieces, and two potlids. A sizeable sample of faunal remains was also recovered, including 17 long bone fragments (mammal), many of which exhibit spiral fractures that indicate the break occurred near the time of the animals' death (McDowell, this volume). Macropod faunal remains were identified amongst the sample (3 vertebra fragments, a fibula fragment, and molar and incisor fragments), as well as a *Permaelidae* sp. (indeterminate bandicoot) tooth fragment (McDowell, this volume).

Feature 16 – Feature 16, a mottled ash lens, was identified on the southeast edge of Unit 8 in Quad B (U8-L08.1). The feature was distinguished on the basis of a colour change due to the presence of grey ash that also changed the texture of the sediment. Burned sediment and rocks were intermixed with the ashy sediment, but there was no distinct layer of burned sediment beneath the ash lens. Small fragments of charcoal were identified throughout the matrix, and analysis of the wood charcoals indicates that gum (*Eucalyptus* Type 1) and *Acacia* Type 3 were the main wood fuels (Fairbairn 2013).

The feature would have largely been removed during the MHA excavation, as it extended into Unit 10. As noted above, it is possible that it would also have joined with Feature 15/18. The excavated extent of Feature 16 measured 10cm wide and 34cm long, with the upper elevations ranging between 68.5 and 69cmbd (*ca.* 36-36.5cmbs). The base of the feature was deepest near the edge of the excavation unit, where it measured 75cmbd (*ca.* 42.5cmbs). The maximum excavated thickness of the feature was 6.5cm.

The provenance of this feature suggests that it was contemporary with Feature 15/18. Four flake fragments were recovered in the feature matrix. The ashy sediment appeared to have been deposited over a large grindstone (Artefact 25,052), which was recovered from the adjacent arbitrary excavation layer (U8-L09). The artefact and ash deposit may be contemporary, as the lowermost elevation for the grindstone was 72.5cmbd. The grindstone was submitted for usewear analysis, which identified the presence of ochre along with grinding on one surface (Fullagar 2013); however, the function of the artefact is not definitive without examination of the residues (R. Fullagar 2013, pers. com. 20 Jan.). Three mammal long bone fragments were recovered from the feature matrix, including two calcined specimens and one with a spiral fracture (McDowell, this volume). Additionally, a number of blackened non-diagnostic bone fragments were collected from the fine rock fraction (McDowell, this volume). All of the faunal remains were assessed as likely having a cultural origin (McDowell, this volume).

Mid-Holocene Features

Five mid-Holocene features were identified at Jundaru (Figure 5-16), including two ash lens (Features 14 and 11), two small hearths (Features 13 and 10). The low abundance of combustion features during the mid-Holocene is interesting considering that artefact abundance began to increase towards the end of this period.

Feature 14 – Feature 14 was an ashy lens identified in the north corner of Unit 8 (Quad B; U8-L07.4). The feature had a very distinct colouration, with its pale ashy matrix easily distinguished from the surrounding brown sediment. No reddened sediment was detected under the ashy lens. The wood charcoals from Feature 14 are mainly gum (*Eucalyptus* Type 1) and *Acacia* Type 3 (Fairbairn 2013).

The ash lens extended into the northeast baulk of Unit 8, so the full dimensions of the feature could not be determined. As it was excavated, it appeared to be sub-oval in shape, measuring 22cm wide and at least 24cm long. The feature had a plano-convex cross-section, with upper measurements of 62.5 to 63cmbd (*ca.* 30-30.5cmbs) and a maximum depth of 66cmbd (*ca.* 33.5cmbs). Feature 14 was near to Feature 13, with the latter being slightly shallower and possibly slightly younger or even contemporary with this combustion event. It is possible that ash in this deposit originated from Feature 13, and this may explain why there was no ash atop most of the hearth.

Eleven flakes and one flaked piece were recovered amongst the feature matrix. In contrast to Feature 13, the only faunal remains from this feature are the small calcined non-diagnostic bone fragments that were collected from the fine sieve fraction (McDowell, this volume).

Feature 13 – Identified in Unit 8, Feature 13 was a small sub-circular hearth that measured approximately 39cm wide and 32cm long. The extent of the feature was distinguished from the surrounding brown soil by the distinct colour change to dark grey. Throughout most of the feature, little ashy sediment was observed, with the exception of the southeast side, where there was pocket of ashy sediment. The sediment beneath the feature was reddened. The feature matrix has a somewhat mottled appearance, suggesting that there may have been some type of disturbance. Roots extended through the feature and some insect bioturbation was observed. Like the other mid-Holocene features, the wood charcoals are predominantly gum (*Eucalyptus* Type 1) and *Acacia* Type 3 (Fairbairn 2013).

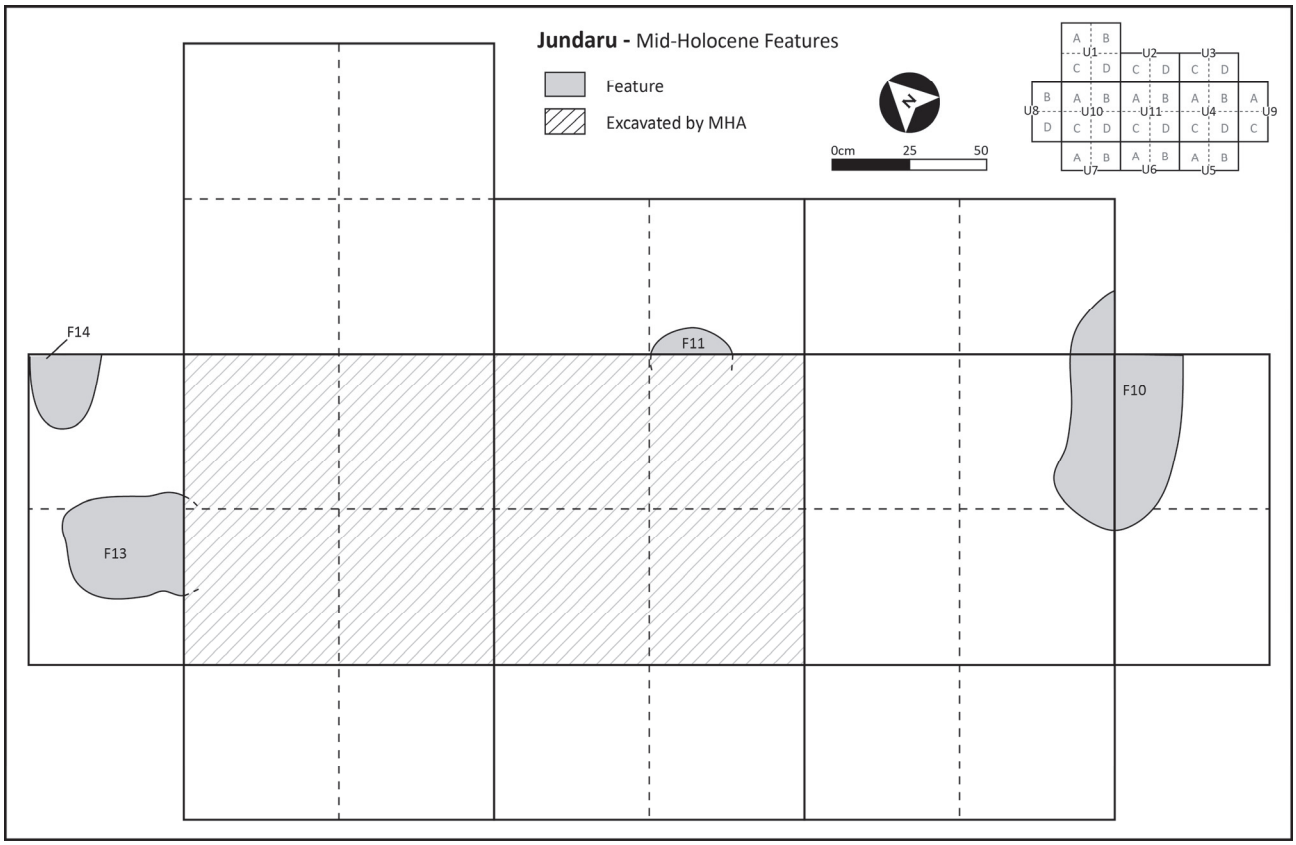

Figure 5-16 Distribution of mid-Holocene combustion features at Jundaru

The feature exhibited a plano-convex cross section, with the top of the feature measuring consistently at 61cmbd (*ca.* 28.5cmbs). The deepest point was at the centre of the feature, where it measured 67.5cmbd (35cmbs), resulting in an overall maximum thickness of 6.5cm.

Burned bone fragments were distributed throughout the matrix. McDowell (this volume) identified emu eggshell fragments, *Macropus* sp. bone and teeth fragments, and *Petrogale* sp. (indeterminate rock wallaby) molar fragments, in addition to a number of unidentifiable and non-diagnostic mammal bones. The small non-diagnostic bone fragments recovered from the fine sieve fraction were calcined, and the macropod remains were either calcined or blackened (McDowell, this volume).

Feature 10 – Feature 10 was a small charcoal-rich hearth in Units 3, 4, and 10. A charcoal sample selected from near the base of the feature (56cmbd) was submitted for radiocarbon dating, and it yielded an age of 3899±45 cal BP. This radiocarbon date demonstrates that this hearth was I towards the end of the mid-Holocene.

While the full extent of the feature was not excavated, the plan of the feature appeared to be sub-oval, and its maximum dimensions were determined to be 75cm long by 40cm wide. The excavation team delineated the feature on the basis of its dark grey colour (7.5YR 3/2) and abundance of charcoal. The feature did not have a light ashy layer, but there was reddened sediment beneath the feature demonstrating *in situ* burning. The pH of the sediment was slightly more alkaline (pH=8.5) than the surrounding sediment (pH=8).

The feature exhibited a lenticular cross-section that sloped from the east down to the south, with the highest upper elevations between Unit 3 and 4 (51 to 51.5cmbd), and the lowermost point recorded from the feature was along the southeast edge in Unit 4 where it reached 57cmbd. The feature had a maximum thickness of 6cm. As the feature was predominantly in Unit 4, its average surface elevation (25cmbd) was used to calculate the approximate depth of the feature below the surface. It is estimated that the upper limit of the feature ranged from approximately 25 to 28cmbs, and it would have extended to depth of 32cmbs.

In total, 25 flaked stone artefacts were recovered from the matrix of Feature 10 in Units 3 and 4, including 24 flakes and one flaked piece. Several blackened and calcined bone fragments were identified, including macropod tooth fragments (McDowell, this volume). The bones in the assemblage are likely anthropogenic.

Feature 11 – Feature 11 was a small ash lens in Unit 2 that would have continued into Unit 11, and the majority of the feature was likely removed during the MHA excavations. The stratigraphic relationship of this feature suggests a similar age to Feature 10 (3899±45 cal BP), or may be slightly younger. The sediment on the northwest side of the feature appeared to be slightly reddened, but no consistent reddened layer could be identified beneath the feature matrix; hence, it was defined as an ash lens.

While the feature shared a close spatial relationship with Feature 9, they were separated by a layer of brown sediment (U1-L05.2). The sediment had an ashy and powdery texture with charcoal inclusions. The ash was mixed with the surrounding sediment, resulting in only a minor colour difference between the feature (7.5YR 4/4) and the surrounding deposit (5YR 4/4). Charcoal from this feature is predominantly gum (*Eucalyptus* Type 1) and *Acacia* Type 3 (Fairbairn 2013). The plan of the feature appeared to have been circular, with the portion in Unit 1 measuring 26 by 9cm. The width of the feature suggests that the original size may have been approximately

26cm in diameter. The feature was slightly lenticular in cross-section, and the upper boundary sloped down slightly from the east (53.5cmbd or *ca.* 22.5cmbs) to the north (55cmbd or *ca.* 24cmbs). The feature was deepest near its centre, where it reached 59.5cmbd (*ca.* 28.5cmbs).

Three flake fragments and a potlid were recovered from Feature 11. A small number of non-diagnostic faunal remains was also recovered from the feature matrix. The macrobotanical analysis shows that the wood charcoals are dominated by *Acacia*, which comprise nearly half of the sample. Gum charcoals are second in abundance, and 16% of the sample could not be identified (Fairbairn 2013). Feature 11 is the first feature encountered at Jundaru to include *Acacia aneura* amongst the wood charcoals (Fairbairn 2013).

Late Holocene Features

Combustion features were abundant in the late Holocene, marking a period of intense site utilisation; the distribution of features is illustrated in Figure 5-17. Most of the features were identified to be hearths, based on the presence of reddened soil beneath the feature; however, two ash lenses and two charcoal lenses were also identified.

Feature 7 – Feature 7 was a small charcoal lens that was uncovered Units 4 and 7; the feature extended into the southeast baulk of Unit 7 and slightly into Unit 9. The feature first appeared in the last centimetre of arbitrary excavation Layer 4 in both Units 4 and 7, and it was excavated in two separate contexts in each unit (U4-L04.3, U4-L04.4, U7-L04.1, and U7-L04.2). The stratigraphy suggests that it had a close temporal relationship with Feature 8.

The feature was defined on the basis of a colour change to dark dusky red (2.5YR 2.5/2) along with the inclusions of fire-cracked rock and a high density of medium to small charcoal fragments. The presence of heat-affected rock suggests that it is a secondary deposit, and this interpretation is supported by the lack of reddened sediment beneath the feature. The matrix was very loose, and roots extended through it.

The feature had a lenticular cross section, with the highest point being at 44cmbd, the lowermost point being 57cmbd, and a maximum thickness of 13cm. The edges pinched out at approximately 46cmbd.

An assemblage of 56 flaked stone artefacts was recovered from Feature 7. Fairbairn (2011) identified possible spinifex resin amongst the floated macrobotanic remains, as well as unidentified seed fragments. The presence of spinifex resin in the feature may indicate that the hearth was used in its manufacture or in the maintenance of hafted artefacts or other items where spinifex was I. Spinifex resin was used in various ways including as hafting adhesive, for repairing and waterproofing items, and creation of ornaments and ceremonial objects (Pitman 2010). While it is not possible to identify how it was used in this context, numerous artefacts found at the same depth (throughout the entire excavation trench) exhibited possible resin residues, including two eloueras and eight backed artefacts (see Fullagar, this volume). A number of unidentifiable burned bone fragments were also identified.

Feature 8 – A small ash lens that was identified on the northwest side of Unit 4 (Quads A and C) that would have extended into Unit 11 and been excavated by MHA. Feature 8 was visible in the southeast section of Unit 11 after the backfill had been removed and sections cleaned. Feature 8 may be contemporary with Feature 7, which was also excavated in Unit 4.

The feature was defined by its ashy appearance and its slightly lighter colour (2.5YR 5/4) than the surrounding sediment (2.5YR 4/4). Neither charcoal, burned soil, nor heat-affected rock was observed within the feature. When the feature was excavated, it was noted that the sediment had a slightly greasy texture. This type of texture had been previously observed in other features excavated at other sites (see PAD 3), but it is not common. Highly fragmented calcined non-diagnostic bone fragments were recovered from the feature matrix (McDowell, this volume). It is possible that the burned faunal remains were the source of the greasy texture in the feature.

The feature had a lenticular cross-section, with the uppermost point being at 45cmbd and the edges pinched out at 47cmbd. The lowermost point was 49cmbd. Using the surface elevation of Unit 4, it is estimated that the feature had a maximum range of 20 to 22cmbs. Twenty-eight flaked stone artefacts were recovered from the feature matrix, including three pieces of heat shatter.

Feature 12 – A large and distinct hearth was excavated in Unit 8 that continued into the unexcavated areas of the unit (Quad A and B), so its full extent could not be determined. Additionally, the feature would have extended into Unit 10, where it was removed previously by MHA. The feature was exposed in the southeast profile of Unit 8, where its plano-convex cross-section is clearly seen (Figure 5-18).

The feature sloped down from the east to the south, with upper elevations ranging from 51.5cmbd to 58cmbd (*ca.* 19 to 25.5cmbs). The basal elevations ranged from 54 to 62cmbd (*ca.* 21.5-29.5cmbs), once again following the same slope. The maximum thickness occurred on the edge of Unit 8, where the feature is up to 7cm thick. The plan of the excavated portion of the feature was irregular, and due to the limited exposure of the feature in Unit 8, it was not possible to determine the original plan of the feature.

The matrix of the feature was ash-rich, and while it was obvious in the section, the Munsell colour (5YR 4/4) only indicates that it was a shade lighter than the surrounding sediment (5YR ¾). This is likely due to slight mixing of the feature sediment with the surrounding brown sediment while excavating. There was a concentration of charcoal on the southwest side of the feature, while the remainder of the feature had little charcoal.

Twenty-five artefacts were recovered amongst the feature matrix, including 23 flakes, one flaked piece, one piece of heat shatter, and one potlid. On the edge of the hearth, a large vertically-oriented BIF flake was recorded *in situ* (Artefact 24793). It is possible that this flake was deliberately placed in this manner. It exhibited evidence of being exposed to the heat of the fire (potlidding) and ash adhered to the flake. Quite a sizeable faunal assemblage was recovered from the feature, including emu eggshell fragments, *Macropus* molar fragments, a macropod tibia fragment, a rib fragment from a reptile, several long bone fragments (mammal), and numerous non-diagnostic bone fragments (mammal) (McDowell, this volume). Several of the specimens were burned (calcined or blackened). Only the reptile bone is interpreted as not being related to the past human occupation (McDowell, this volume), possibly due to its small size.

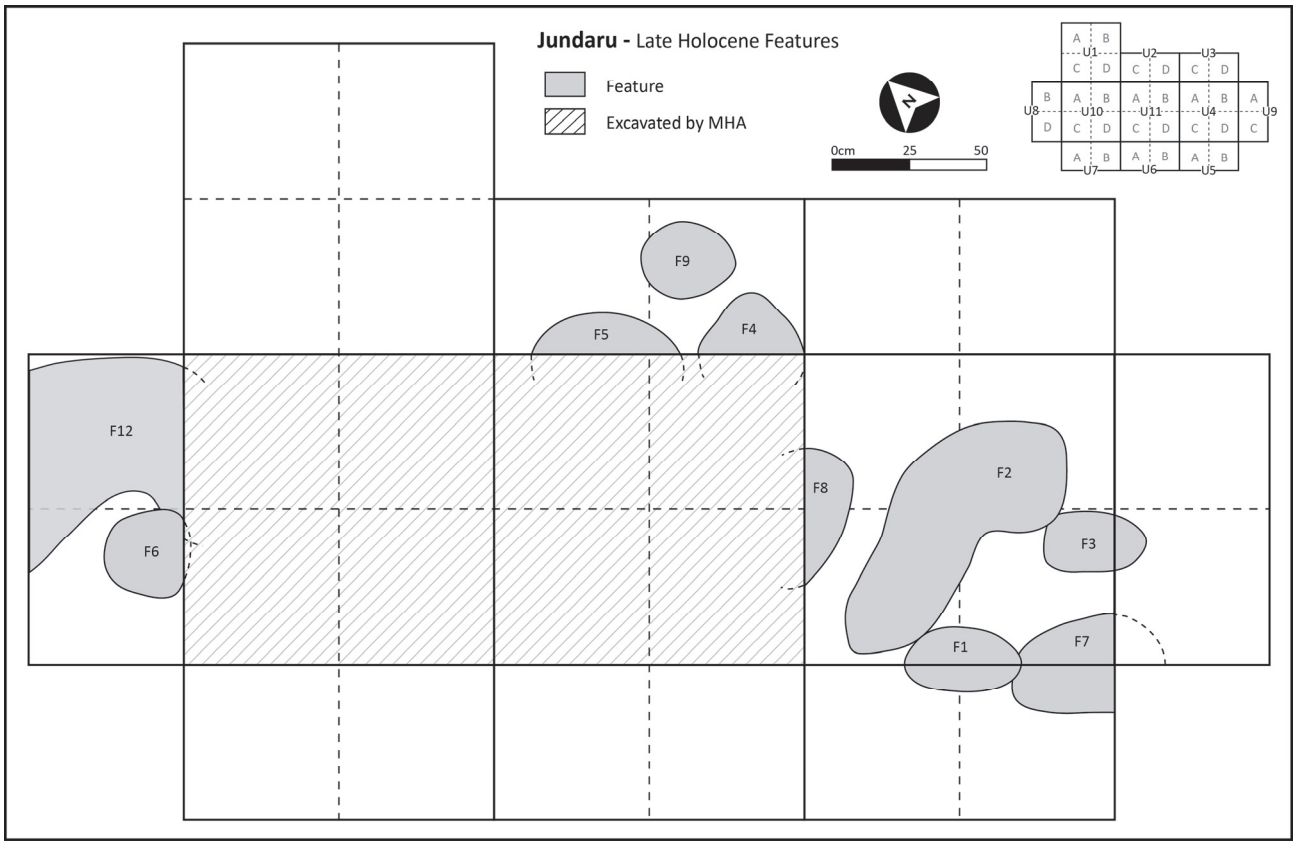

Figure 5-17 Distribution of late Holocene combustion features at Jundaru

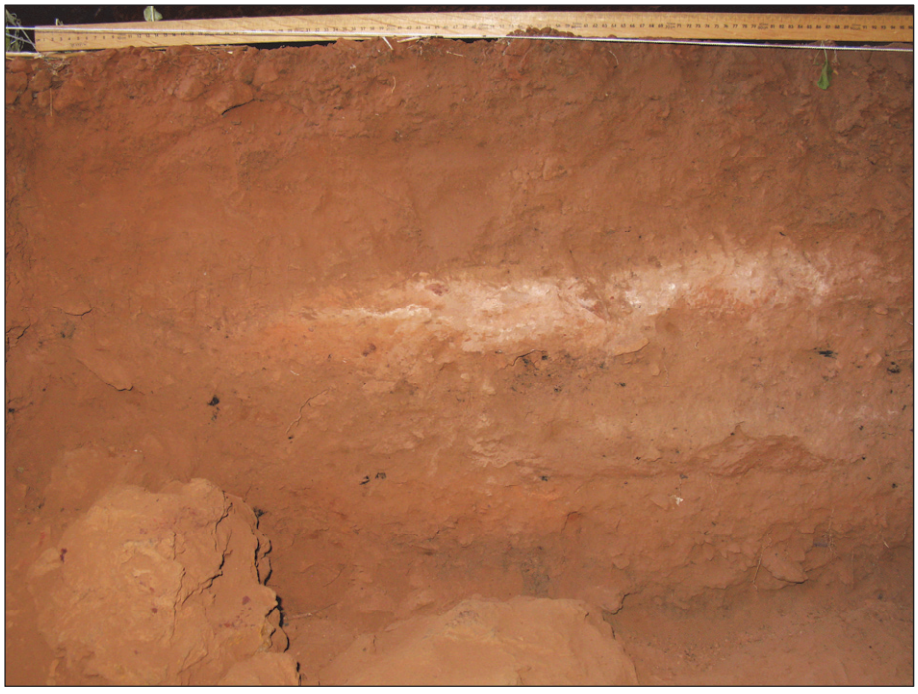

Figure 5-18 Feature 12 cross-section in the southeast profile of Unit 8 prior to excavation

Feature 9 – Feature 9 was a small hearth that was excavated in Unit 2 (U2-L05.1) that measured 39cm wide and 27cm long. The excavator identified the feature due to a change in sediment colour (5YR 5/4); a shade lighter than the surrounding sediment (5YR 4/4). The feature was not a typical hearth, which generally have a light ashy layer followed by a dark grey layer. This hearth only consisted of a light ashy layer atop of reddened sediment, and there were very small charcoal fragments in the matrix. It is possible that the low proportion of charcoal and lack of a dark grey layer may be related to the fuel selection; however, the wood charcoals from Feature 9 were not analysed.

The feature exhibited a plano-convex cross-section, with upper elevations of 50.5 to 51cmbs (*ca.* 18.5 to 19cmbs). The feature was slightly deeper along the west half, where the maximum depth was recorded as 53.5cmbd (*ca.* 22cmbs). Heat-affected

rock was observed along the north and east edges of the hearth, and reddened sediment was also identified below the ashy layer. Nineteen artefacts were amongst the feature matrix, including 16 flakes, two pieces of heat shatter, and one retouched artefact. Bone fragments were recovered from the fine sieve fraction; however, they are non-diagnostic and show no evidence of burning (McDowell, this volume).

Feature 6 – Feature 6 was a small well-defined charcoal lens feature that was identified in Unit 8 based on its dark reddish brown (2.5YR 2.5/2) colour and high concentration of small charcoal fragments. Neither reddened soil nor heat-affected rock was observed amongst the feature matrix or underlying the feature. A small portion of the feature would have extended into Unit 10; however, the excavated extent in Unit 8 shows it to have had a roughly circular shape with an average diameter of 28cm. The feature was first encountered at 47cmbd (*ca.* 14.5cmbd) with the edges being slightly lower (47.5cmbd). Due to its lenticular cross-section, the feature is deepest near the centre where it reached 51cmbd (*ca.* 18.5cmbd).

The wood charcoals from Feature 6 show a different composition from all of the earlier features, with no *Acacia* wood charcoals identified (Fairbairn 2013). Instead, the sample is comprised of *Eucalyptus* (Type 1 and Type 2), Myrtaceae, *Eucalyptus* Type 2, and unidentified types. This feature marks a significant change in the selection of wood fuels used in the combustion features at Jundaru. In his analysis of the wood charcoals from the feature, Fairbairn (2011) found only a small component of mulga in the gum-dominated assemblage, which may be indicative of a transition in the surrounding vegetation due to environmental changes.

The excavation team collected 12 artefacts from the feature matrix, including ten flakes, a retouched artefact, and a potlid. An unburned bone fragment also was recovered.

Feature 3 – Feature 3 was a small ashy lens identified in Unit 4 and extending slightly into Unit 9. The ashy grey feature was first identified at 40 to 41cmbd (*ca.* 15-16cmbs) and its maximum depth was 45cmbd (*ca.* 20cmbs); hence, the feature had a maximum thickness of 5cm. The feature had a sub-circular shape with a maximum width of approximately 30cm.

Despite its small size, a surprisingly large number of flaked stone artefacts were recovered. In total, 44 artefacts were collected from Feature 3, including 30 flakes, seven flaked pieces, six fragments of heat shatter, and one retouched blade (Artefact 15,142). The retouched blade was submitted for usewear analysis, and Fullagar (2013) has suggested that it may have been used as an awl for piercing skin. No faunal remains were recovered from the Feature 3 matrix.

To the north of the feature, the excavation team observed an area of very reddened soil; however, no ash or charcoal was identified in association with the heat-affected sediment. It is possible that there was a large combustion feature in the adjacent area (Unit 11), which had been previously excavated; alternatively, a fire had been constructed in one area, and then the warm ashes were moved to another area.

Feature 5 – Feature 5 was identified on the southwest edge of Unit 2 with a similar spatial extent to Feature 4; however, a thin layer of brown sediment separated the two hearths. Feature 5 had an ashy grey matrix with large pieces of charcoal atop reddened sediment. The excavation team noted small scattered pieces of charcoal in the surrounding matrix. The feature would have been largely excavated by MHA in Unit 11, and the remaining portion in Unit 2 measured 45cm wide by 12cm long. Based on the overall shape of the feature, it appears to have had a circular plan with a diameter of at least 45cm. The surface of the feature sloped up from Quad C to Quad D with elevations that ranged from 43.5 to 41.5cmbd (*ca.* 12.5 to 10.5cmbs); the deepest portion of the feature was near its centre where it reached 47cmbd (*ca.* 16cmbs).

The composition of the wood charcoals is similar to Features 4 and 6 (*Eucalyptus* Type 1, Myrtaceae, *Eucalyptus* Type 2, and unidentified types); however, the sample also includes a small amount of *Acacia.* (Fairbairn 2013). Thirteen artefacts were recovered from the feature matrix, including some specimens exhibiting signs of having been burned. One burned bone fragment was also identified, in addition to a number of non-diagnostic bone fragments.

Feature 4 – Feature 4 was a small hearth that was identified in Unit 2 (U2-L03.1) on the basis of a colour and texture change and the high proportion of light grey ash. Reddened sediment was observed beneath the feature demonstrating *in situ* burning. Some disturbance to the feature may have occurred in the past as insect bioturbation was noted by the excavation team.

Like Feature 5, most of Feature 4 was previously excavated by MHA in Unit 11. The excavated extent of Feature 4 in Unit 2 measured 35cm wide and 20cm long. The upper elevations ranged between 40 and 40.5cmbd (*ca.* 9-9.5cmbs) along the southwest edge of the quadrant, sloping down to 41.5cmbd (*ca.* 10.5cmbs) at the far northeast edge. The feature had a plano-convex cross-section, with the deepest point being on the southwest edge of the quadrant (44cmbd or *ca.* 13cmbs). The maximum thickness of the feature was at this point, where it reached 3.5cm.

Ten artefacts were found amongst the feature matrix and all were classified as flakes. The specimens were produced on a variety of materials, including brown shale, dark grey chert, olive chert, red chert, and quartz. An ulna fragment of an unidentified mammal bone fragment were recovered from the feature matrix (McDowell, this volume). Like the wood charcoals from Feature 5, a small proportion of *Acacia* wood charcoals are also present in Feature 4 (including *Acacia aneura*), but the charcoals are dominated largely by gum species (Fairbairn 2013).

Feature 2 – Feature 2 was a large hearth identified in Unit 4 (U4-L02.2). The provenance of Feature 2 indicates that this combustion feature was created before Feature 1, with enough time passing between the events for thin layer of sediment to accumulate. The feature had a mottled appearance with a large amount of light grey ashy sediment intermixed with dark grey sediment and charcoal (Figure 5-19). The thick layer of heat-reddened sediment beneath the feature demonstrates *in situ* burning.

The feature had a sub-oval shape with the long axis oriented roughly east to west. Along this axis, the feature measures 92cm, with the maximum width being just under 40cm. The upper elevations of the feature ranged between 32 and 34cmbd, with the maximum depth reaching 39cmbd near the middle of Quad D. The average depth below the surface was 7 to 9cm, with a maximum depth of 14cmbs and a maximum thickness of 6cm. The feature has a lenticular cross-section, which is very slight along the upper portion of the feature.



Figure 5-19 Top of Feature 2, Jundaru rockshelter

In total, 44 flaked stone artefacts were recovered from the Feature 2 matrix. Burned faunal remains were also recovered and are interpreted to be of cultural origin (McDowell, this volume). While the wood charcoals continue to be dominated by gum, there is a small *Acacia* component, including *Acacia aneura* (Fairbairn 2013).

When excavating Feature 2 (U4-L2.2), a burrowing water-holding frog, *Cyclorana platycephala,* was encountered. The frog had burrowed down approximately 10cm into the sediment, and formed a cocoon around itself. The frog had the potential to displace artefacts and disturb the feature; however, the disturbance is likely to have been very localised.

Feature 1 – Feature 1 was the uppermost combustion feature identified at Jundaru, and it occurred at the transition between SL1 and SL2. A charcoal sample from the feature was dated to 176±86 cal BP. This feature, along with the numerous flaked and ground stone artefacts, attests to the recent use of the site. In Layer 1 of Unit 4 alone, 145 artefacts were recovered in addition to the six artefacts recovered from the matrix of Feature 1. Of the artefacts plotted *in situ* in Layer 1, many were concentrated in the area around Feature 1.

The feature was mainly in Unit 4 (centred on southwest side of Quads C and D), with a small portion extending into Unit 7. Because only a small portion of the feature extended into Unit 7, it was excavated as a single context originating in Unit 4 (U4-L01.1). The oval-shaped feature (38cm by 18cm) had a plano-convex cross section, with a surface elevation of 30cmbd an 32.5cmbd for the base. The feature was approximately 6 to 8.5cm below the modern surface.

Despite its close proximity to the modern surface, the small feature remained relatively well preserved. The feature retained a layered structure with white to light grey ash at the top followed by a dark grey charcoal-rich layer with numerous large charcoal fragments. This distinct colour made the feature easily distinguishable from the surrounding brown sediment. The wood charcoals in the feature are comprised of gum species and 14% unidentified specimens; no Acacia wood charcoals were identified (Fairbairn 2013). Unidentifiable seed fragments were also identified in the feature matrix (Fairbairn 2013).

5.6 ARTEFACT ANALYSIS

ACHM's salvage excavations recovered a total of 26,181 artefacts from Jundaru, including a large assemblage from the excavated layers and features as well as 30 artefacts from the surface of the shelter and during the removal of the backfill from the previously excavated units. The artefacts were analysed by Dawn Cropper and W. Boone Law according to the methodology outlined in Chapter 4. Due to the large size of the assemblage, it was not possible to fully analyse each artefact due to budgetary and time constraints of the project. The methodology employed for the sampling is outlined below.

In order to explore variations in temporal artefact patterns, artefacts from individual excavation units were analysed without sampling until approximately 10,000 artefacts were analysed and all the artefacts from the entire excavation unit were analysed. Upon reaching approximately 10,000 analysed artefacts, the remaining artefacts were subject to sampling. The sampling methodology focused on recording artefacts that would provide the greatest amount of information, including cores, complete flakes, retouched/utilised flakes, grindstones, and manuports. If these artefacts were encountered after the sampling threshold was reached, they were fully analysed. Only basic attributes (artefact category, fragmentation, raw material type, and weight) were recorded for all remaining artefact types, including broken flakes, flaked pieces, heat shatter, and potlids. By employing this sampling strategy, the size and composition of the assemblage was documented, rather than estimating the assemblage size. It was also possible to examine temporal and spatial patterns of raw material use and flake breakage patterns.

All artefacts from Units 1 (Artefacts 1-5971), 3 (Artefacts 11,492-14,102), and 9 (Artefact 10,000-11,491) were analysed without sampling (n=10,074), and the remaining 16,107 artefacts were subject to sampling. Amongst the artefacts subject to sampling are 5139 complete flakes, 74 cores, 580 retouched/utilised artefacts, ten grindstones, and six manuports

that were fully analysed. These artefacts greatly increase the sample size and result in a much stronger dataset. Additionally, basic attributes were recorded for 8420 broken flakes, 1085 flaked pieces, 625 potlids, and 168 pieces of heat shatter.

Division of Analytical Units

The size of the assemblage recovered from Jundaru is unparalleled at any other site in the Pilbara documented thus far, and it provides a unique opportunity to explore changes through time. With such a large assemblage recovered from the site that represents millennia of occupations, it is necessary to divide it into smaller analytical units in order to explore changes through time. As Edwards *et al.* (2001: 69) point out in their division of analytical units at Jundaru, any arbitrarily imposed division of the assemblage brings with it the risk of overshadowing minor variations within the assemblage. We often focus on the possible temporal changes in the assemblage, but there is also the potential for identifying spatial patterning. Considering the size of the assemblage, Jundaru provides the opportunity to explore possible activity areas across the site.

The sequence has been divided into seven discrete analytical units according to depth, chronology, and feature associations. The Holocene and late Pleistocene analytical units are divided into 15cm-thick units, while the Pleistocene deposit is divided into 25cm-thick units. The different sizes of the units were chosen as the Holocene deposit has a much higher proportion of artefacts, providing a greater opportunity to identify changes over time, particularly within the late Holocene. As combustion features were excavated stratigraphically as opposed to arbitrary 5cm layers, some of these features extend over the arbitrary depth range of the analytical units. The features were assigned an analytical unit by taking into account their surface elevations and provenance.

The chronology of the analytical units is established primarily using the ACHM radiocarbon series. In some instances, there are no dates for the transitions between analytical units and tentative estimates are provided using the age-depth trend line for the ACHM date series. There are inherent problems with any age-depth model (see Telford *et al.* 2004), and these estimates should not be considered as definitive ages for the analytical units, but they are useful as broad indicators of chronology.

Analytical Unit 8 – AU8 is the lowermost phase of occupation at the site, and it incorporates all artefacts below 150cmbd. This analytical unit comprises the lower third of SL4. The oldest radiocarbon date for the site is 35,978±653 cal BP, and as there were artefacts a further 17cm below this charcoal sample (173cmbd), the initial occupation may be slightly earlier. The upper boundary for this analytical unit has not been directly dated, but a sample collected four centimetres below the boundary was dated to 33,255±651 cal BP. Based on the age-depth trend line for the ACHM date series, it is expected that the upper boundary of AU8 dates to approximately 30,000 years ago.

Analytical Unit 7 – AU7 includes all artefacts recovered between 125 and 150cmbd, which correlates to the middle of SL4. As is indicated above, the boundary between AU8 and AU7 has not been dated, but it is estimated to be approximately 30,000 cal BP. Near the mid-point of this analytical unit, a charcoal sample was dated to 26,793±369 cal BP (139cmbd), and this corresponds well with the lowest date from the MHA radiocarbon series, 24,314±404 cal BP. Using the age-depth trend line for the ACHM date series, it is expected that the transition between AU7 and AU6 dates to about 23,000 years ago. It is estimated that AU7 spans a period of roughly 7,000 years during the glacial period.

Analytical Unit 6 – AU6 extends from 125 to 100cmbd and comprises the upper third of SL4. The lower boundary AU6 occurs at 125cmbd, approximately 23,000 years ago after the onset of peak LGM conditions. AU6 continues through the cold and arid glacial conditions until about 16,000 years ago, as estimated by the age-depth trend line. This phase of site occupation includes the three lowermost features, including a hearth (Feature 23, dated to 19,820±172 cal BP) and two charcoal lenses (Features 24 and 22).

Analytical Unit 5 – AU5 includes all artefacts between 100 and 85cmbd and incorporates Feature 21, a small hearth that was identified in Units 1 and 2. This analytical unit spans the transition between SL4 and SL3 along the west side of the trench (the back of the shelter) and SL2 along the west side (near the rockshelter entrance). The age-depth trend line suggests that the analytical unit spans from roughly 16,000 to 12,000 cal BP, covering a period of approximately 4,000 years. The chronology suggests that this period of site use occurred during an early warming period after peak LGM conditions.

Analytical Unit 4 – AU4 represents the transition from the Pleistocene into the early Holocene and includes all artefacts between 85 and 70cmbd. All artefacts recovered in association with Features 17, 19, and 20 are also included in this layer. This analytical unit correlates to the lower portion of SL2 and incorporates some of SL3 on the west side of the trench. While the dated charcoal sample from Feature 19 was recovered from 88cmbd (10,774±135 cal BP) it is likely that this date is more representative of the surface level of the feature, 82cmbd. The age-depth trend line suggests that this analytical unit may extend back to 12,000 years ago. The age upper boundary of the analytical unit occurs slightly prior to 7686±34 cal BP, as this date was determined for one of the lower features in AU3. It is estimated that the period covered by AU4 is 4,000 years.

Analytical Unit 3 – AU3 includes all artefacts recovered between 70 and 55cmbd, and this analytical unit occurs within SL2. Feature 15 provides a date for the lower boundary of the analytical unit, 7686±34 cal BP. Several features were identified in this occupational phase, including four ash lenses (Features 14, 15, 16, and 18), and one hearth (Features 13). The unit continues until just prior to 3899±45 cal BP (Feature 10, AU2), indicating a duration of over 3500 years and possibly up to 3787 years.

Analytical Unit 2 – AU2 comprises a 15cm-thick unit at the top of SL2, extending from 40 to 55cmbd. The analytical unit encompasses ten archaeological features, including five hearths (Features 12, 10, 9, 5, and 4), three ash lenses (Features 11, 8, and 3), and two charcoal lenses (Features 7 and 6). A charcoal sample from Feature 10 (3899±45 cal BP) provides an age estimate for the lower boundary of this analytical unit, indicating that this phase of site use corresponds to the transition between the middle to late Holocene. The upper limit of the analytical unit has not been directly dated, and chronology of the boundary between AU2 and AU1 is difficult to pinpoint with precision, as the two youngest radiocarbon dates for Jundaru do not correspond with the trend line. The relationship of the four uppermost radiocarbon dates for Jundaru suggests that sediment deposition was greater in the late Holocene and that this analytical unit began approximately 1000 years ago.

Analytical Unit 1 – AU1 is the uppermost analytical unit and it is the most recent phase of site occupation at Jundaru. The unit includes all excavated artefacts from the surface layer down to 40cmbd, and it corresponds to the transition layer from SL2 through to the end of SL1. As the surface of the site slopes, this unit is slightly thicker for excavation units in the southeast portion of the site and slightly thinner for those in the west side. AU1 includes two hearths (Features 1 and 2), with Feature 1 dating to 176±86 cal BP. As discussed above, the precise chronology of this phase is difficult to establish, but it is estimated to have begun approximately 1000 years ago.

Artefact Distribution

The Jundaru assemblage includes 26,151 artefact specimens and 30 additional artefacts from secondary provenances. The secondary provenances include five artefacts from the surface of the shelter outside of the excavation area (Artefacts 26,143, 26,146, 26,147, 26,148, and 26,150), two artefacts collected during the inspection of the walled feature (Artefacts 26,144 and 26,145), and 23 artefacts from the cleaning of excavation unit sections (primarily during the preparation of Units 10 and 11 for excavation; Artefacts 26,142, 26,149, and 26,151-26,171). Several of the surface artefacts appear to have been moved in the past; for example, Artefact 26,147 was located upon a bedrock ledge and may have been placed there by one of the many visitors to the site. Artefact 26,150 is a large grindstone that was found on the surface of the shelter, southwest of the previously excavated test units. In contrast, the artefacts that were recovered from within the walled feature are considered to be *in situ*, as there is no evidence that the feature had been previously disturbed or investigated. Artefacts were also retained when the excavation unit walls were cleaned as well as during the initial removal of the backfill from the MHA excavation trench. The provenance of these artefacts is not known, but they remain part of the assemblage. No attempt has been made to try and determine the provenance of these artefacts.

Amongst the eight analytical units defined in the previous section, there are 26,151 artefacts and their distribution is presented below in Table 5-4 and Figure 5-20. Although the 30 artefacts recovered from the surface, walled feature, and from cleaning contexts are presented in Table 5-4, they are not included in the following discussion of the artefact analysis results. The reason for their exclusion from this discussion is due to the lack of provenance and the different collection methodology.

The excavated assemblage is dominated by diagnostic artefact types, which account for nearly 88% of the sample. Flakes are the most common diagnostic artefacts, and 21,767 flakes and flake fragments were identified in the assemblage. A large number of retouched or I artefacts were also recovered from Jundaru; however, they account for only 3.89% of the assemblage. Likewise, the site has the largest sample of cores of any excavated site from Hope Downs 1, yet they comprise less than one percent of the excavated artefacts. The excavation team also identified 26 grindstones from Jundaru, with most specimens concentrated in the four uppermost analytical units.
There are three categories of non-diagnostic artefacts in the Jundaru assemblage: flaked pieces, heat shatter and potlids, and manuports. The first two types comprise the bulk of the non-diagnostic artefacts, with only seven manuports identified amongst the assemblage.

Distribution of Artefacts through Time

Throughout the sequence at Jundaru, artefact density remains high in comparison with the other Pleistocene sites from Hope Downs 1. Jundaru is the only site at Hope Downs 1 where a sizeable assemblage was recovered from the Pleistocene layers, including 5324 artefacts from AU8 through AU5 and a further 2773 artefacts from AU4 (the phase between the transition from the Pleistocene and early Holocene). Based on the density of artefacts, site use increased during the Holocene and was particularly high during AU2 and AU1.

During the initial occupation of Jundaru in AU8 (*ca.* 36,000-30,000 cal BP), artefact densities are modest, showing that there was repeated occupation of the site throughout this period. The number of artefacts suggests that the site was not occupied for long durations, with 1029 artefacts deposited over an estimated span of 6000 years. This suggests the site was visited intermittently and there were long periods of disuse. The archaeomagnetic analysis found that sediment samples below 170cmbd were largely the result of natural depositional processes (Herries 2013), and only a small number of artefacts were found below this level. This perhaps indicates that the site was only very briefly occupied during these initial visits, and perhaps no campfires were I, thereby limiting the anthropogenic alteration of the sediment.

In AU7, there is a slight decline in artefact densities per 5cm arbitrary excavation layer and an overall decline in the number of artefacts. In total, there are 939 artefacts in AU7, which is estimated to have extended over roughly 7,000 years between 30,000 and 23,000 years ago. This period in the site's history occurred during the glacial period, but prior to peak LGM conditions. Throughout this period, the site appears to have been used ephemerally and sporadically; although, the assemblage size from this period remains the largest of any contemporary site investigated at Hope Downs 1.

The proportion of artefacts suggests that there was a steady increase in site utilisation that began towards the end of AU6 and continued through the following analytical units. AU6 corresponds with the onset of peak LGM conditions and dates from approximately 23,000 to 16,000 years ago. Mid-way through AU6 there is a rise in artefact numbers, which coincides with the earliest appearance of features at the site (a hearth and two charcoal lenses). Similar data from Djadjiling and HD07-3A-PAD13 show low site use during peak LGM conditions. The data seems to support reduced use of the rockshelters in the immediate region during the LGM.

AU5 is the first of the thinner, 15cm-thick, analytical units and is estimated to extend between 16,000 and 12,000 cal BP. The artefact counts demonstrate that there is a significant increase in artefact density, suggesting that site use either became more frequent or the site was occupied for longer periods of time. As both Table 5-4 and Figure 5-20 illustrate, the greatest intensity of site use was during the last two analytical units. Feature 10, which is dated to 3899±45 cal BP, provides an age estimate for this florescence of site use. Artefact discard patterns show that people continued to visit the site on a regular basis through the late Holocene, and it is only in the last stages of AU1 where there is a minor drop in artefact numbers.

Distribution of Artefacts across the Site

The distribution of artefacts across the site suggests that different areas of the rockshelter were used more intensely during different phases of occupation. As some excavation units were larger than others, this comparison was made using the

artefact density of each quadrant. The distribution of artefacts suggests that Unit 1 was used to a greater extent from the initial occupation (AU8 and AU7), particularly Quads A-B. Unit 10 (Quad B) also shows a peak in use in AU8 (between 155-165cmbd), and this area is adjacent to Unit 1. In AU6, the density of artefacts in Unit 1 declines and most quadrants show similar proportions of artefacts; although, Quads A and B of Unit 1 continue to have a slightly higher artefact density than the other units. The three combustion features identified in AU6 (Features 24-22) were all located in Unit 4. Mid-way through AU6 (from 110cmbd), Unit 1 again shows an increased utilisation over other areas of the site, but this shifts to Unit 2 at the beginning of AU5 (95-90cmbd). Feature 21 was identified in Units 1 and 2, and it also occurs at the beginning of AU5. Quad B of Unit 8 shows a minor increase in use at the end of AU5 (between 90-85cmnd), and there are similar proportions of artefacts in both quadrants of Unit 2.

At the start of AU4 (85-80cmbd), there is a slight shift in the distribution of artefacts, with the highest proportion of artefacts in Unit 2 (Quad D), Unit 3 (Quad C), and Unit 4 (Quad A). This suggests that the centre of the site (but towards the back of the shelter) was the most intense area of site use. The features in AU4 show a similar spatial distribution, with the exception of Feature 18, an ash lens. It is possible that as this area was no longer heavily I, the ash was discarded in this area. Throughout most of AU4 and AU3 (from 80 to 60cmbd) there are similar distributions of artefacts across the site. Artefact density peaks for all units in AU2, and Units 2 (Quad D), 3 (Quad B), and 4 (Quads A-B) show the highest artefact densities. During this phase, hearths, ash lenses, and charcoal lenses appear across the site. Units 5 (Quad A) and 1 (Quad A) show greater utilisation towards the end of AU2 (between 45 and 40cmbd). Through the entire sequence, Unit 7 has the lowest artefact density, followed by Unit 9.

The distribution of cores and retouched/utilised artefacts across the site generally parallels the patterns for the assemblage. An exception is a peak in retouched and I artefacts in Unit 6 (Quad A) in AU1 (between 35 and 40cmbd). Units 3 (Quad D) and 5 (Quad D) show peaks in the proportion of formalised retouched artefacts in AU2 (from 50 to 45cmbd), and this shifts to Unit 6 (Quad B) during the transition to AU1 (from 45 to 35cmbd). However, there is generally a low density of formalised retouched artefacts at the site.

If the density of artefacts is correlated to the intensity of use, the data suggests that during the initial occupation, the north area of the shelter was more heavily I. Over time, the area to the east becomes more heavily I, particularly Units 2, 3, and 4. It is presumed that Unit 11 would have had high artefact densities during this time, but this area had been previously excavated by MHA. The shift in activity areas may be due to the accumulation of sediment. When there was little sediment in the rockshelter, the north area was favoured. This area has a low overhang, and may have been I to a lower degree as sediment accumulated in the shelter. This may have caused the activity area to shift over to the east. It is interesting that Units 7 and 9 show the lowest density of artefacts, as these units are in an open area. Equally, the excavation units along the area of roof collapse generally show lower artefact densities. This suggests that people preferred to use the areas near the back of the shelter. The back of the shelter may have offered more protection from the elements than at the front of the shelter. The distribution of artefacts may also be related to how people oriented themselves in relation to the rockshelter opening (*i.e.,* people preferred to sit at the back of the shelter, perhaps facing the entrance), or it could suggest that the back of the shelter served as a refuse area where artefacts were discarded.

Conjoining Artefacts and their Distribution

While there was no concerted attempt to conjoin artefacts in the assemblage, 34 conjoin sets were identified (Figure 5-21). Most of the conjoin sets are simple conjoins between two artefacts, typically either two flakes or a flake and a potlid. In several cases, broken artefacts were refitted (*e.g.*, Figure 5-21 b-d), and these artefacts can provide useful information. Conjoin Set 9 consists of distal and proximal flake fragments (Artefacts 3919 and 4195 respectively), and the distal portion was reddened through heat exposure, while the proximal portion shows no evidence of thermal alteration. The artefacts were found *in situ* with a difference in depth of 5.5cm and a horizontal difference of 51cm (to the midpoint of each artefact). The reddened distal portion was found close to Feature 5 and above the proximal fragment, suggesting that it may have been incorporated with the feature matrix, and perhaps its original context was disturbed through the use of the feature. Conjoin Sets 32 and 33 from AU8 are excellent examples of artefacts that were broken due to the impact of roof collapse.

Only four conjoin sets include a core (Set 4, core and a flaked piece; Set 18, core and a retouched/utilised flake; Set 25, core and a flaked piece; Set 30, core and a flake) and none show multiple events. Conjoin sets were identified in each of the eight analytical units, with the greatest number being from AU6 and AU8. With lower numbers of artefacts in these layers, it was potentially easier to recognise conjoining artefacts. While there were only three conjoin sets in each AU2 and AU1, there is certainly a great potential for conjoining artefacts in these analytical units. While a systematic refitting study was not carried out, the data demonstrates that despite the considerable amount of roof collapse that has occurred throughout the deposit, there remain good artefact associations.

Table 5-4 Artefact distribution by analytical unit, Jundaru rockshelter

Artefact Type	Other		AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diagnostic	30	100	4369	86.63	8962	87.26	2455	89.57	2427	87.52	1687	90.31	1303	87.57	844	89.88	902	87.66	22979	87.77
Core	3	10.00	19	0.38	36	0.35	14	0.51	18	0.65	17	0.91	17	1.14	7	0.75	10	0.97	141	0.54
Flake	20	66.67	4069	80.69	8483	82.60	2374	86.61	2362	85.18	1636	87.58	1241	83.40	781	83.17	821	79.79	21787	83.22
Ret./Utl. Flake	6	20.00	275	5.45	436	4.25	59	2.15	45	1.62	33	1.77	44	2.96	56	5.96	70	6.80	1024	3.91
Grindstone	1	3.33	6	0.12	7	0.07	8	0.29	2	0.07	1	0.05	1	0.07	0	0.00	1	0.10	27	0.10
Non-Diagnostic	0	0.00	674	13.37	1308	12.74	286	10.43	346	12.48	181	9.69	185	12.43	95	10.12	127	12.34	3202	12.23
Flaked Piece	0	0.00	340	6.74	785	7.64	165	6.02	235	8.47	149	7.98	125	8.40	52	5.54	114	11.08	1965	7.51
H. Shatter/Potlid	0	0.00	334	6.62	523	5.09	119	4.34	110	3.97	32	1.71	60	4.03	43	4.58	13	1.26	1234	4.71
Manuport	0	0.00	0	0.00	0	0.00	2	0.07	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	3	0.01
Total	**30**	**100**	**5043**	**100**	**10270**	**100**	**2741**	**100**	**2773**	**100**	**1868**	**100**	**1488**	**100**	**939**	**100**	**1029**	**100**	**26181**	**100**

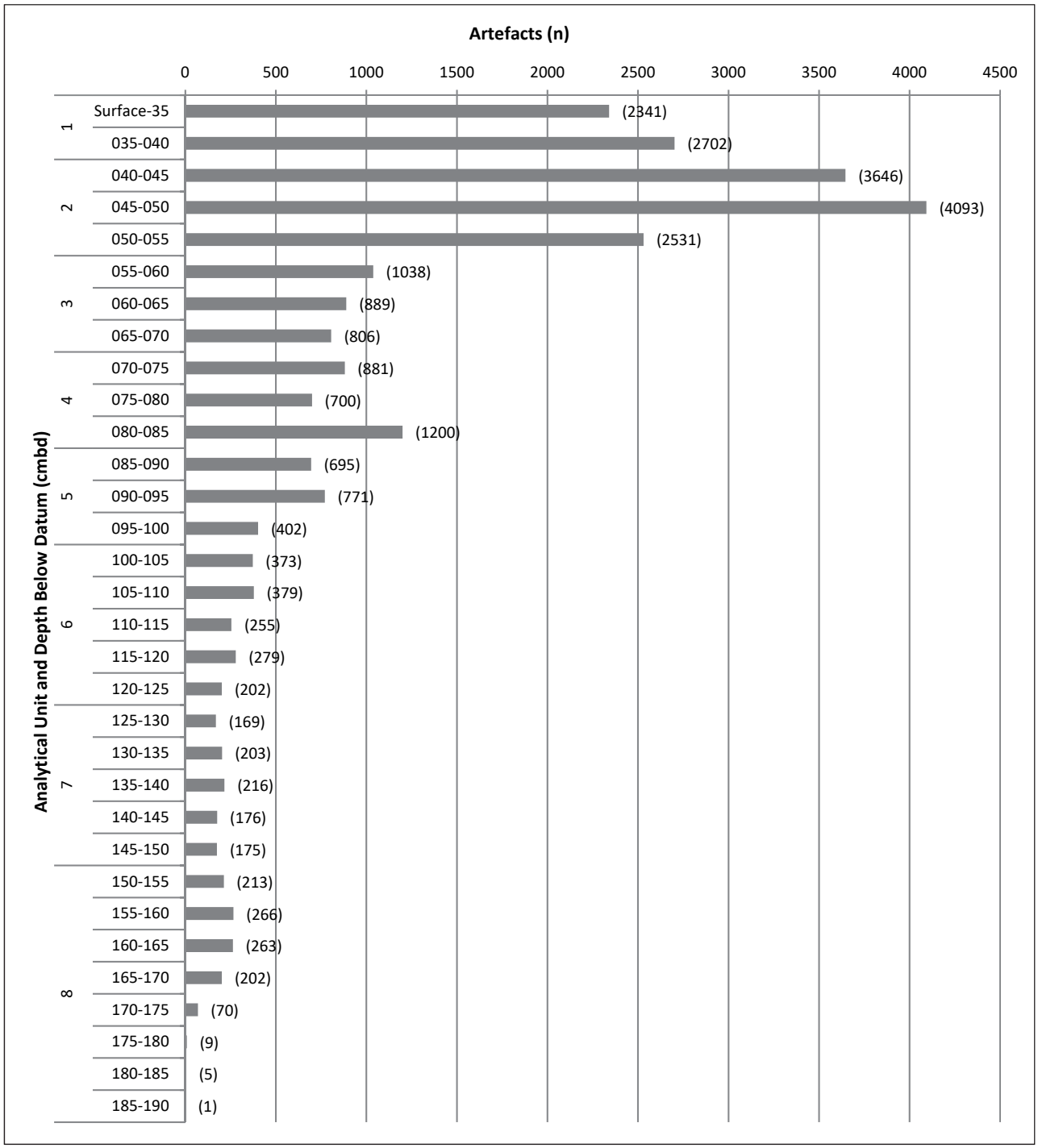

Figure 5-20 Distribution of artefacts at Jundaru rockshelter by analytical unit and average depth (cmbd)

In most cases the conjoining artefacts were found in the same unit and excavation layer, and this is expected due to how the artefacts were analysed (by quadrant and layer for each unit). Conjoin Set 16 consists of a retouched artefact and an I artefact that were recovered from Layer 25 of Units 1 and 11. These artefacts were produced from a quite distinctive raw material (olive chert), making it easier to identify the conjoin set between the two excavation units. This set points to the likelihood of many more conjoining artefacts in the assemblage. In seven instances, the artefacts were distributed between two consecutive arbitrary excavation layers (*e.g.*, artefacts from Conjoin Set 9 are from Layers 4 and 5 of Unit 1).

Vertical displacement of artefacts is common at archaeological sites, but it is often not recognised, as refitting is not carried out. There are three conjoin sets (Sets 1, 2, and 19) that have artefacts from disparate elevations within the same excavation unit. Conjoin Set 1 is comprised of a retouched flake (Artefact 2264) and a potlid (Artefact 2450) that were recovered from Layers 16 and 20 in Unit 1. Also in Unit 1, Conjoin Set 2 is comprised of a flake (Artefact 2343; L17) and two potlids (Artefact 2377, L18; and Artefact 2424, L19). Conjoin Set 19 is comprised of a badly shattered flake with approximately 25 fragments that were refitted to form a retouched flake (Artefact 9376) from Layer 22 and a potlid (Artefact 9426) from Layer 25 of Unit 2. In each instance where there appears to have been some vertical movement of artefacts, the specimens exhibit heat fractures. In each case, the smaller potlids were in lower layers than the larger conjoining flakes or retouched artefacts. The vertical movement may be due to post-depositional

disturbances, such as trampling by humans and bioturbation (*e.g.*, macropods), with smaller fragments and potlids moving more down through the deposit than the larger artefacts. The degree of vertical movement that has occurred throughout the entire assemblage is difficult to assess without a very time-consuming refitting study; however, it is possible that the higher degree of site use at Jundaru may have contributed to a greater degree of minor artefact displacement. This may also account for minor variation of radiocarbon dates from the trend line, particularly for charcoal samples that were not recovered from combustion features.

Raw Materials

The raw material of each artefact was classified according to the types defined in Chapter 4. In total, 28 various materials were identified, in addition to an indeterminate category. The raw material varieties occur within a limited number of geologic rock types, including BIF, shale, quartz, and chert. The relative proportions of the artefacts by material type are presented by analytical unit in Table 5-5. The distribution of materials by mass is presented in Table 5-6. The discussion of the raw material in the following section focuses on the absolute and relative frequency of artefacts rather than the mass, as there are considerable differences in the weight of each raw material type. Iron-rich raw materials, such as BIF and martite-goethite, are much heavier than siliceous materials like quartz and chert; therefore, the data is skewed towards the heavier materials. The weights of each material type have been included below in the event that it may be useful for inter-site or regional comparisons. The data for the surface artefacts have not been included in the tables below.

The data suggests that raw material preferences changed over time; however, chert generally is dominant in the assemblage, followed by BIF, shale, and quartz. Only trace quantities of goethitised shale, martite-goethite, vitreous goethite, and limonite are present in the assemblage. BIF, shale, and quartz are widely distributed throughout the area immediately surrounding the site, and together, they account for over 55% of the assemblage. These materials would have been much easier to procure in comparison to chert, which is relatively scarce in the immediate gully. Based on the cortical surfaces of the chert cores and flakes, chert was procured mainly as river cobbles.

The relative abundance of chert and BIF artefacts fluctuates considerably through the sequence. The occurrence of BIF was initially low in AU8, followed by a sharp rise in AU7, where the peak abundance was recorded. From AU6 to AU5 there was a considerable decline in frequency of BIF artefacts, but it increased to near peak proportions again in AU4 and AU3. At the beginning of AU2, the use of BIF fell sharply and this is continued into AU1. The proportions of chert in the assemblage show a similar pattern, albeit in reverse. In AU8, there was modest use of chert, which declined continuously with a low of 14.03% in AU5. In AU4, the use of chert began to rise again until reaching a sequence high of 54.8% in AU2. In AU1, there was a slight decline, but it remained the predominant raw material type.

Shale and quartz are the two other key raw materials I throughout the sequence. Shale artefacts are fairly consistent over time, but this material shows a similar pattern to chert with a decline from AU8 to AU5, followed a rise from AU4 to AU1. While the quality of shale varies, the vast majority of the brown-shale artefacts were produced from fine-grained material, which has good knapping qualities. Perhaps the reasonably constant use of this material was due to its quality and relative abundance.

On the other hand, the frequency of quartz in the assemblage is highly variable. Quartz use was initially moderate in AU8, and then it dropped to trace amounts in AU7. Quartz use peaked in AU5 where this material was used to produce over a third of all artefacts, and during this time, chert use was at its lowest. The frequency of quartz artefacts declined between AU4 to AU2 and then rose again in AU1. Unlike the Djadjiling assemblage, most of the quartz artefacts are flakes with the frequency of flaked pieces being on par with that for the assemblage or slightly higher, with proportions ranging between 6.1% and 12.65% and an average of 9.6%.

Artefacts were produced from 16 chert varieties, yet there are only cores of seven chert types (dark grey, greyish brown, olive, red, translucent dark, and white and translucent chert). Several specimens provide evidence to indicate that they may originate from a small number of sources despite their strikingly different appearances. The dark grey chert appears to be a common denominator and there are artefacts with contacts between this material and other varieties (*i.e.*, one flake that has both materials), including olive chert (Artefacts 576, 16714, 16878, 22276, 24363), creamy grey chert (Artefacts 12057, 12353, 14165, 15432, 16006, 16007, 16011, 16670), red chert (Artefacts 15493, 15551, 15901, 19374, 23458). Other contacts in raw materials have also been found between olive and red chert (Artefact 5580), speckled black chert and speckled yellow chert (Artefact 2575; see Chapter 4), and speckled black chert and greyish brown chert (Artefact 12307). These artefacts demonstrate that while there are considerable visual differences amongst these varieties, many likely derive from the same source.

Given the association between dark grey chert and many other varieties, it is not surprising that there are more dark grey chert artefacts than any other chert variety, but the abundance of dark grey chert is followed closely by red chert artefacts. Greyish brown chert, olive chert, and white and translucent chert also are prevalent in the assemblage. The proportions of chert types are not consistent through the sequence, suggesting that there may have been preferences or differential availability of materials over time. Dark grey chert remained the principal chert type in all analytical units, with the exception of AU3, when it is surpassed by red chert and is closely followed by greyish brown chert. The relative proportion of greyish brown chert is greatest for AU3 and AU2; these periods also show higher than average proportions of olive chert. Olive chert is also much more common earlier in the sequence, particularly in AU7. Red chert only comprises a small proportion of the sample in the early analytical units, but increases considerably in AU3 to AU1. This corresponds with a much greater number of hearth features at the site, and perhaps many of the red specimens are heat-affected. White and translucent chert artefacts are fairly common from AU5 through AU3; however, they are not a large component of the chert artefacts prior or subsequent to this phase. Many of the chert varieties are relatively rare and there are only a couple of specimens in each analytical unit (if any). The moss agate symmetrical backed artefact is an excellent example, as it is the only artefact of this material found at Jundaru (this material has been identified at numerous other sites).



Figure 5-21 Conjoin sets from Jundaru rockshelter: a) conjoin set 11 from AU5, b) conjoin set 28 from AU1, c) conjoin set 9 from AU2, d) conjoin set 33 from AU8, and e) conjoin set 32 from AU8

Table 5-5 Distribution of raw material types by count and analytical unit, Jundaru rockshelter

Raw Material	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
Subtype	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
BIF	*532*	*10.55*	*1196*	*11.65*	*1138*	*41.64*	*1196*	*43.01*	*536*	*28.69*	*574*	*38.58*	*418*	*44.52*	*175*	*17.01*	*5765*	*22.05*
Homogenous BIF	527	10.45	1190	11.59	1120	40.98	1185	42.61	521	27.89	567	38.10	413	43.98	170	16.52	5693	21.77
Laminate BIF	5	0.10	6	0.06	18	0.66	11	0.40	15	0.80	7	0.47	5	0.53	5	0.49	72	0.28
Chert	*2304*	*45.69*	*5629*	*54.81*	*763*	*27.92*	*512*	*18.41*	*262*	*14.03*	*240*	*16.13*	*203*	*21.62*	*292*	*28.38*	*10205*	*39.02*
Creamy Grey	10	0.20	53	0.52	8	0.29	0	0.00	3	0.16	3	0.20	1	0.11	0	0.00	78	0.30
Dark Grey	885	17.55	1400	13.63	152	5.56	152	5.47	87	4.66	83	5.58	61	6.50	94	9.14	2914	11.14
Dashed Black	18	0.36	39	0.38	1	0.04	0	0.00	2	0.11	0	0.00	1	0.11	6	0.58	67	0.26
Greyish Brown	336	6.66	1228	11.96	141	5.16	82	2.95	29	1.55	29	1.95	16	1.70	30	2.92	1891	7.23
Light Green-Grey	49	0.97	72	0.70	7	0.26	5	0.18	6	0.32	5	0.34	12	1.28	18	1.75	174	0.67
Moss Agate	0	0.00	1	0.01	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.00
Olive	183	3.63	647	6.30	96	3.51	20	0.72	18	0.96	36	2.42	48	5.11	36	3.50	1084	4.15
Pink and Green	23	0.46	61	0.59	6	0.22	1	0.04	0	0.00	9	0.60	9	0.96	10	0.97	119	0.46
Red	568	11.26	1351	13.15	173	6.33	72	2.59	26	1.39	29	1.95	9	0.96	8	0.78	2236	8.55
Speckled Black	18	0.36	35	0.34	3	0.11	8	0.29	3	0.16	2	0.13	2	0.21	1	0.10	72	0.28
Sugar	10	0.20	42	0.41	7	0.26	21	0.76	34	1.82	7	0.47	2	0.21	25	2.43	148	0.57
Thylo	11	0.22	25	0.24	1	0.04	2	0.07	1	0.05	1	0.07	4	0.43	0	0.00	45	0.17
Trans. Dark Grey	19	0.38	80	0.78	17	0.62	6	0.22	3	0.16	1	0.07	1	0.11	0	0.00	127	0.49
Trans. Green	54	1.07	92	0.90	22	0.80	13	0.47	1	0.05	12	0.81	15	1.60	21	2.04	230	0.88
White & Trans.	113	2.24	446	4.34	126	4.61	123	4.42	46	2.46	18	1.21	19	2.02	41	3.98	932	3.56
Yellow Trans.	7	0.14	57	0.56	3	0.11	7	0.25	3	0.16	5	0.34	3	0.32	2	0.19	87	0.33
Goethitised Shale	*39*	*0.77*	*146*	*1.42*	*88*	*3.22*	*121*	*4.35*	*129*	*6.91*	*175*	*11.76*	*110*	*11.71*	*96*	*9.33*	*904*	*3.46*
Limonite	*2*	*0.04*	*6*	*0.06*	*3*	*0.11*	*1*	*0.04*	*1*	*0.05*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*13*	*0.05*
Martite-Goethite	*74*	*1.47*	*78*	*0.76*	*84*	*3.07*	*80*	*2.88*	*42*	*2.25*	*34*	*2.28*	*18*	*1.92*	*9*	*0.87*	*419*	*1.60*
Quartz	*992*	*19.67*	*936*	*9.11*	*228*	*8.34*	*415*	*14.92*	*683*	*36.56*	*239*	*16.06*	*33*	*3.51*	*246*	*23.91*	*3772*	*14.42*
Quartz	940	18.64	900	8.76	0	0.00	0	0.00	675	36.13	231	15.52	31	3.30	244	23.71	3659	13.99
Quartz Crystal	41	0.81	23	0.22	225	8.23	413	14.85	8	0.43	8	0.54	2	0.21	2	0.19	89	0.34
Green Quartz	11	0.22	13	0.13	3	0.11	2	0.07	0	0.00	0	0.00	0	0.00	0	0.00	24	0.09
Shale	*1060*	*21.02*	*2230*	*21.71*	*399*	*14.60*	*419*	*15.07*	*188*	*10.06*	*211*	*14.18*	*145*	*15.44*	*202*	*19.63*	*4854*	*18.56*
Brown Shale	1022	20.27	2188	21.30	351	12.84	376	13.52	165	8.83	176	11.83	114	12.14	127	12.34	4519	17.28
Green Shale	38	0.75	42	0.41	48	1.76	43	1.55	23	1.23	35	2.35	31	3.30	75	7.29	335	1.28
Vitreous Goethite	*20*	*0.40*	*23*	*0.22*	*25*	*0.91*	*37*	*1.33*	*24*	*1.28*	*14*	*0.94*	*8*	*0.85*	*7*	*0.68*	*158*	*0.60*
Indeterminate	*20*	*0.40*	*26*	*0.25*	*5*	*0.18*	*0*	*0.00*	*3*	*0.16*	*1*	*0.07*	*4*	*0.43*	*2*	*0.19*	*61*	*0.23*
Dragonsblood	0	0.00	0	0.00	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.00
Indeterminate	20	0.40	26	0.25	4	0.15	0	0.00	3	0.16	1	0.07	4	0.43	2	0.19	60	0.23
Total	**5043**	**100**	**10270**	**100**	**2733**	**100**	**2781**	**100**	**1868**	**100**	**1488**	**100**	**939**	**100**	**1029**	**100**	**26151**	**100**

While two types of BIF have been defined here, both derive from the same formation. Homogeneous BIF accounts for the vast majority of all BIF artefacts and includes all specimens that do not show fine laminae. The laminated BIF tends to be finer-grained with distinct laminae, but only 72 such specimens were identified in the assemblage. There does not appear to have been a deliberate attempt to procure one type over another, as BIF generally seems to have been used as a readily-available material for expedient artefact production.

Shale is divided into two types: brown shale and green shale with speckles. The brown shale is a high-quality material and it accounts for 93.12% of all shale artefacts. The green shale is much more coarse-grained and was seldom I; although, its relative proportions are much greater in AU8 through AU3 as compared with AU2 and AU1. Within each analytical unit, flakes were recovered from across the site. The low incidence of green shale could be related to both its relatively rare occurrence in the landscape and coarse texture.

There are three quartz varieties in the assemblage, including quartz, quartz crystal, and green quartz. The vast majority of all specimens were classified as quartz; however, there are some excellent examples of quartz crystal artefacts. Only 89 quartz crystal artefacts were recovered from the site; hence, this is a scarce material. Its occurrence begins with the onset of occupation at the site, but there is a much higher incidence in AU2 and AU1. The largest, and arguably the most spectacular, quartz crystal specimen is Artefact 26132, a bipolar core. This artefact is also the oldest lowermost quartz crystal artefact and was recovered from AU8. Three additional cores were produced on complete quartz crystals (from AU5, AU4, and AU2), and a quartz crystal manuport was also recovered (Artefact 9284; AU6). Trace quantities of green quartz are also present, with 24 specimens identified. This material only occurs in AU2 and AU1 and the artefacts were distributed across the site.

Table 5-7 explores the raw material patterns for the major diagnostic artefact types: cores, flakes, and retouched/utilised artefacts. As flakes comprise the majority of the assemblage, their raw material trends mirror that of the assemblage. In comparison to the relative proportions for the assemblage, the cores show a much lower frequency of chert and shale specimens. In contrast, cores produced from BIF, quartz, goethitised shale and martite-goethite are over-represented. There is also a very low proportion of cores in comparison to the number of flakes. This pattern suggests that many of the chert and shale cores were taken away from the site. While shale is a relatively abundant raw material in the region, perhaps the finer-grained cobbles were slightly less common; hence, worth transporting. The higher proportion of coarser-grained cores and quartz cores suggests that these widely available materials were used in a more expedient manner. If the knappers knew that they would have been able to replace these cores easily, there would have been little need to take them from the site.

Table 5-6 Distribution of raw material types by weight and analytical unit, Jundaru rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
Subtype	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%
BIF	*3731.72*	*62.39*	*3605.52*	*45.11*	*3296.99*	*56.81*	*4805.42*	*72.26*	*2326.42*	*60.43*	*2381.94*	*65.62*	*1242.53*	*65.00*	*1556.46*	*65.18*	*22947.00*	*60.06*
Homogenous BIF	3714.1	62.10	3541.53	44.31	3242.491	55.88	4777.86	71.84	2287.10	59.41	2362.37	65.08	1197.10	62.62	1551.36	64.96	22673.91	59.35
Laminate BIF	17.62	0.29	63.99	0.80	54.5	0.94	27.56	0.41	39.32	1.02	19.57	0.54	45.43	2.38	5.10	0.21	273.09	0.71
Chert	*767.06*	*12.82*	*1722.94*	*21.56*	*355.09*	*6.12*	*296.65*	*4.46*	*252.78*	*6.57*	*153.97*	*4.24*	*225.67*	*11.81*	*239.61*	*10.03*	*4013.78*	*10.51*
Creamy Grey	0.86	0.01	6.23	0.08	4.16	0.07	0	0.00	0.40	0.01	0.08	0.00	0.02	0.00	0.00	0.00	11.75	0.03
Dark Grey	281.71	4.71	415.11	5.19	42.71	0.74	91.74	1.38	101.10	2.63	53.34	1.47	64.85	3.39	104.74	4.39	1155.30	3.02
Dashed Black	7.74	0.13	9.88	0.12	0.11	0.00	0	0.00	5.59	0.15	0.00	0.00	3.88	0.20	6.52	0.27	33.72	0.09
Greyish Brown	125.14	2.09	390.31	4.88	57.23	0.99	46.05	0.69	21.45	0.56	15.62	0.43	20.59	1.08	17.87	0.75	694.26	1.82
Light Green-Grey	13.26	0.22	39.47	0.49	1.89	0.03	0.24	0.00	9.36	0.24	0.73	0.02	14.11	0.74	8.70	0.36	87.76	0.23
Moss Agate	0.00	0.00	0.32	0.00	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00
Olive	77.87	1.30	242.87	3.04	75.61	1.30	13.63	0.20	2.70	0.07	16.26	0.45	31.33	1.64	35.51	1.49	495.78	1.30
Pink and Green	41.28	0.69	27.57	0.34	1.01	0.02	0.56	0.01	0.00	0.00	14.07	0.39	18.99	0.99	13.69	0.57	117.17	0.31
Red	149.25	2.50	341.32	4.27	55.923	0.96	17.29	0.26	22.77	0.59	8.84	0.24	20.95	1.10	2.22	0.09	618.56	1.62
Speckled Black	5.13	0.09	30.79	0.39	1.56	0.03	20.75	0.31	0.23	0.01	10.09	0.28	2.33	0.12	1.80	0.08	72.68	0.19
Sugar	2.96	0.05	14.20	0.18	14.51	0.25	7.49	0.11	73.05	1.90	7.74	0.21	1.14	0.06	10.85	0.45	131.94	0.35
Thylo	6.36	0.11	53.69	0.67	0.04	0.00	5.13	0.08	0.04	0.00	0.62	0.02	4.49	0.23	0.00	0.00	70.37	0.18
Trans. Dark Grey	3.93	0.07	22.14	0.28	15.57	0.27	24.87	0.37	0.95	0.02	0.02	0.00	1.12	0.06	0.00	0.00	68.60	0.18
Trans. Green	26.01	0.43	34.07	0.43	39.97	0.69	15.45	0.23	0.32	0.01	9.01	0.25	17.77	0.93	30.55	1.28	173.15	0.45
White & Trans.	21.81	0.36	87.27	1.09	44.68	0.77	52.47	0.79	14.65	0.38	2.92	0.08	23.40	1.22	6.64	0.28	253.84	0.66
Yellow Trans.	3.75	0.06	7.70	0.10	0.12	0.00	0.98	0.01	0.17	0.00	14.63	0.40	0.70	0.04	0.52	0.02	28.57	0.07
Goethitised Shale	*41.30*	*0.69*	*216.86*	*2.71*	*428.63*	*7.39*	*292.27*	*4.39*	*164.99*	*4.29*	*229.17*	*6.31*	*128.88*	*6.74*	*191.75*	*8.03*	*1693.85*	*4.43*
Limonite	*0.42*	*0.01*	*13.10*	*0.16*	*3.15*	*0.05*	*0.16*	*0.00*	*0.80*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*17.63*	*0.05*
Martite-Goethite	*206.77*	*3.46*	*481.58*	*6.03*	*1067.19*	*18.39*	*582.06*	*8.75*	*564.43*	*14.66*	*257.45*	*7.09*	*83.78*	*4.38*	*61.25*	*2.56*	*3304.51*	*8.65*
Quartz	*413.83*	*6.92*	*247.73*	*3.10*	*101.09*	*1.74*	*205.72*	*3.09*	*246.32*	*6.40*	*197.07*	*5.43*	*50.53*	*2.64*	*173.05*	*7.25*	*1635.34*	*4.28*
Quartz	392.91	6.57	229.21	2.87	100.71	1.74	203.17	3.06	238.67	6.20	191.10	5.26	50.44	2.64	147.88	6.19	1554.09	4.07
Quartz Crystal	10.59	0.18	7.14	0.09	0.38	0.01	2.55	0.04	7.65	0.20	5.97	0.16	0.09	0.00	25.17	1.05	59.54	0.16
Green Quartz	10.33	0.17	11.38	0.14	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.71	0.06
Shale	*794.38*	*13.28*	*1687.86*	*21.12*	*493.4*	*8.50*	*459.25*	*6.91*	*282.39*	*7.34*	*399.10*	*10.99*	*177.47*	*9.28*	*161.98*	*6.78*	*4455.83*	*11.66*
Brown Shale	771.43	12.90	1674.49	20.95	451.39	7.78	399.97	6.01	147.89	3.84	269.62	7.43	138.86	7.26	83.04	3.48	3936.69	10.30
Green Shale	22.95	0.38	13.37	0.17	42.01	0.72	59.28	0.89	134.50	3.49	129.48	3.57	38.61	2.02	78.94	3.31	519.14	1.36
Vitreous Goethite	*19.76*	*0.33*	*9.15*	*0.11*	*43.7*	*0.75*	*8.85*	*0.13*	*9.60*	*0.25*	*11.09*	*0.31*	*1.48*	*0.08*	*3.85*	*0.16*	*107.48*	*0.28*
Indeterminate	*6.06*	*0.10*	*7.27*	*0.09*	*13.85*	*0.24*	*0*	*0.00*	*1.84*	*0.05*	*0.06*	*0.00*	*1.21*	*0.06*	*0.09*	*0.00*	*30.38*	*0.08*
Dragonsblood	0.00	0.00	0.00	0.00	0.22	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00
Indeterminate	6.06	0.10	7.27	0.09	13.63	0.23	0	0.00	1.84	0.05	0.06	0.00	1.21	0.06	0.09	0.00	30.16	0.08
Total	**5981.30**	**100**	**7992.01**	**100**	**5803.094**	**100**	**6650.38**	**100**	**3849.57**	**100**	**3629.85**	**100**	**1911.55**	**100**	**2388.04**	**100**	**38205.80**	**100**

Retouched and I artefacts show the most striking evidence for raw material preferences. While chert accounted for 39.02% of the assemblage, 54.13% of the retouched and I flakes were produced from this fine-grained material. Through the sequence, the use of chert for retouched and I artefacts varies considerably. Chert dominates the samples from AU8, AU7, AU2, and AU1, while it is similar to the use of BIF in AU6 through AU3. The combined average indicates that BIF and quartz are considerably under-represented amongst the retouched and I artefacts despite the regular occurrence of these materials in the assemblage. BIF has not always been less preferable than chert and between AU6 and AU3 it was used with similar frequency as chert.

The preference for chert is most pronounced in the later stages of the site's occupation and appears to relate to the introduction of new retouched artefact technologies and forms where coarser-grained materials would have been less suitable. Apart from one burin in AU6, the first formalised retouched artefacts occur in low numbers in the mid-Holocene (at the end of AU3; backed artefacts and one scraper), with numbers increasing considerably in AU2 and AU1. The formalised retouched artefacts were predominantly produced from chert flakes, with a smaller number manufactured on brown shale flakes; this is true of backed artefacts, tulas, burins, and burrens. Two of the three eloueras were produced on brown shale flakes, but there is also a BIF elouera (fine-grained and cherty material). The scrapers also show a different pattern, with a greater proportion having been produced from shale (70%) than chert (30%).

In total, 15,870 artefacts were examined for evidence of thermal alteration (*e.g.*, reddening, crazing, potlid fractures, loss of colour, *etc.*), and over three-quarters of the sample exhibited no signs of having been heated (77.33%). Under three-quarters (n=3598 artefacts or 22.67%) of the sample appeared to have been thermally altered. The frequency of heated artefacts is much lower in the earlier stages of the site's occupation, and there is a slight rise in AU4 (n=234, 14.50%) that continues into AU3 (n=347, 19.51%). There is a considerable rise in the proportion of thermally altered artefacts in AU2 and AU1, accounting for approximately 30% of the sample (AU2, n=1857, 30.31%; AU1, n=787, 28.78%).

The increase in thermal alteration coincides with the intensification of combustion features at the site. Under half of the heated artefacts show severe thermal shock (crazing, potlidding, and loss of colour; n=1723). With the exception of AU3 and AU2, artefacts with either potlidding or crazing are more frequent than those that exhibit more subtle signs of heating (*e.g.*, reddening, darkened colour, or glossy appearance). The high number of artefacts in AU2 that exhibit subtle heating (n=1109) as opposed to thermal shock (n=748) skew the average for the assemblage as a whole. The data for AU3 shows a much closer ratio between burned (n=171) and gently-heated (n=178) artefacts.

Table 5-7 Raw material trends for cores, flakes, and retouched and utilised flakes, Jundaru rockshelter

Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
Raw Material	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cores	*19*	*100*	*36*	*100*	*14*	*100*	*18*	*100*	*17*	*100*	*17*	*100*	*7*	*100*	*10*	*100*	*138*	*100*
BIF	3	15.79	4	11.11	2	14.29	5	27.78	9	52.94	6	35.29	3	42.86	5	50.00	37	26.81
Chert	4	21.05	10	27.78	2	14.29	4	22.22	2	11.76	1	5.88	0	0.00	1	10.00	24	17.39
Goethitised Shale	1	5.26	1	2.78	3	21.43	3	16.67	0	0.00	2	11.76	1	14.29	2	20.00	13	9.42
Martite-Goethite	0	0.00	1	2.78	3	21.43	1	5.56	3	17.65	3	17.65	1	14.29	0	0.00	12	8.70
Quartz	8	42.11	8	22.22	2	14.29	5	27.78	3	17.65	3	17.65	1	14.29	2	20.00	32	23.19
Shale	3	15.79	12	33.33	1	7.14	0	0.00	0	0.00	2	11.76	1	14.29	0	0.00	19	13.77
Vitreous Goethite	0	0.00	0	0.00	1	7.14	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.72
Flakes	*4069*	*100*	*8483*	*100*	*2367*	*100*	*2369*	*100*	*1636*	*100*	*1241*	*100*	*781*	*100*	*821*	*100*	*21767*	*100*
BIF	459	11.28	1073	12.65	1035	43.73	1078	45.50	479	29.28	506	40.77	376	48.14	150	18.27	5156	23.69
Chert	1807	44.41	4619	54.45	612	25.86	373	15.75	223	13.63	191	15.39	158	20.23	187	22.78	8170	37.53
Goethitised Shale	29	0.71	126	1.49	71	3.00	100	4.22	116	7.09	139	11.20	86	11.01	78	9.50	745	3.42
Limonite	2	0.05	6	0.07	3	0.13	1	0.04	1	0.06	0	0.00	0	0.00	0	0.00	13	0.06
Martite-Goethite	45	1.11	56	0.66	71	3.00	70	2.95	34	2.08	27	2.18	14	1.79	9	1.10	326	1.50
Quartz	891	21.90	823	9.70	209	8.83	356	15.03	604	36.92	207	16.68	28	3.59	227	27.65	3345	15.37
Shale	812	19.96	1749	20.62	343	14.49	361	15.24	162	9.90	162	13.05	114	14.60	163	19.85	3866	17.76
Vitreous Goethite	13	0.32	15	0.18	19	0.80	30	1.27	14	0.86	8	0.64	3	0.38	6	0.73	108	0.50
Indeterminate	11	0.27	16	0.19	4	0.17	0	0.00	3	0.18	1	0.08	2	0.26	1	0.12	38	0.17
Retouched/Utilised	*275*	*100*	*436*	*100*	*59*	*100*	*45*	*100*	*33*	*100*	*44*	*100*	*56*	*100*	*70*	*100*	*1018*	*100*
BIF	10	3.64	20	4.59	18	30.51	17	37.78	10	30.30	10	22.73	11	19.64	12	17.14	109	10.61
Chert	162	58.91	279	63.99	20	33.90	17	37.78	9	27.27	8	18.18	28	50.00	28	40.00	550	54.13
Goethitised Shale	2	0.73	9	2.06	3	5.08	2	4.44	5	15.15	11	25.00	5	8.93	10	14.29	47	4.62
Martite-Goethite	3	1.09	1	0.23	1	1.69	2	4.44	0	0.00	1	2.27	1	1.79	0	0.00	9	0.88
Quartz	11	4.00	0	0.00	2	3.39	0	0.00	5	15.15	2	4.55	0	0.00	2	2.86	22	2.16
Shale	87	31.64	126	28.90	14	23.73	7	15.56	4	12.12	12	27.27	11	19.64	17	24.29	277	27.31
Vitreous Goethite	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.43	1	0.10
Indeterminate	0	0.00	1	0.23	1	1.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.20
Total	**4363**	-	**8955**	-	**2440**	-	**2432**	-	**1686**	-	**1302**	-	**844**	-	**901**	-	**22923**	-

While there are many artefacts that have been thermally-altered, there is no definitive evidence to support intentional heat-treatment of artefacts at Jundaru. It is likely that most artefacts (if not all) have become heat-affected as the result of post-depositional heating or through intentional discard of artefacts in hearths. One retouched BIF flake (Artefact 8143) exhibits a glossy and reddened appearance only on its three invasive retouch scars. The retouch scars were clearly created after the flake had been heated, but it is not certain that the flake was intentionally heated. It is possible that an unintentionally heated flake may have been picked up from the surface of the shelter and re-used. Both the flakes and retouched/utilised flakes show a greater frequency of heating over burning, particularly in AU3 through AU1. If intentional heat-treatment occurred at Jundaru, it would be expected that there would be cores with a double patina (such as that on Artefact 8143); yet, the cores show a higher incidence of thermal shock than the flakes, which indicates that they were rapidly heated in an uncontrolled manner. It should be acknowledged that many cores appear to have been removed from the site, which may affect the data.

Additional material alterations affected 7.83% of the artefacts that were fully analysed (n=15,870), including abrasion, patination, coatings (*e.g.*, concretion), staining, and high degrees of oxidisation. There are 257 quartz artefacts that exhibit a yellowish colouration on the exterior surface. The yellowed appearance may be due to thermal alteration (see Ballin 2008: 51-52), but it is also possible that this may be a rust-like coating. An oxidised or rusty appearance is common for many of the coarser-grained raw materials, but this appears to be a natural weathering process of these iron-rich rocks.

Some artefacts exhibit a mineralised coating over at least one surface (n=443) that precipitated onto the artefacts. The deposit often obscures the attributes of the artefact. The coatings generally have two different appearances. The most common is a matt reddish brown colour (similar to the surrounding sediment). Encrustations of cemented sediment are less common. The mineralised coatings are a natural post-depositional process, but they can lead to accelerated artefact weathering and hamper artefact analysis. The precipitates can degrade the artefacts; for example, Artefact 5781 is a large BIF core that had cemented sediment covering one surface (see Figure 5-10). Prior to analysis, the artefact was soaked in water to help loosen the adhering deposit. The precipitates appear to have caused accelerated breakdown of the rock through salt weathering, a process that is similar to freeze-thaw. In this case, it appears that gypsum crystals expanded in small cracks in the core, resulting in spalling. Four spalled fragments of the core were found within the cemented sediment, with one such fragment still adhering to the core cemented by gypsum.

Forty artefacts were identified with a patinated appearance, and half of the specimens occur in AU2. Many of the patinated flakes are chert (n=24), and it is possible that they may be older artefacts that were collected and re-used. For example, Artefact 7217 is a spall that has a patinated dorsal surface and appears to have been struck from an older flake, as the ventral surface does not show the same patina.

Twenty artefacts exhibit abrasion, including nine flakes, six retouched flakes, one core, three manuports, and one grindstone. Specimens with this alteration type were recovered from each analytical unit with the exception of AU6. The flakes and retouched artefacts generally exhibit rounding of the dorsal arrises, indicating that the wear has occurred subsequent to knapping. As the artefacts do not have rounding over the entire surface, it is possible that it is usewear. One of the manuports, a quartz crystal, was submitted for usewear analysis. Fullagar (2013) believes that the abraded surface on this artefact is

typical of stone-on-stone rubbing. It is not possible to determine how this artefact was I, whether it was a utilitarian implement or if it had some other significance.

Cores

Jundaru has a large sample of cores, including 138 cores and core fragments from the excavated assemblage as well as three complete cores from secondary contexts. In the excavated assemblage, there are 103 complete cores and 35 core fragments. The data for the cores from secondary contexts is not included in the following discussion. Cores are present in each analytical unit, with the greatest number being in AU2. Despite the greater number of cores in AU2 and AU1, they occur in lower proportions in these phases of site occupation in comparison to the earlier stages of site use.

In the previous section, it was observed that chert and shale cores are under-represented in the assemblage, while material types that are coarser-grained or are not suited for formalised retouched artefact manufacture are more common (*e.g.*, BIF, quartz, *etc.*). Thus, the possibility of cores having been removed from the site was proposed as a theory to explain this pattern in the data. When the ratio of complete flakes to cores is examined, it becomes apparent that it is unlikely that the cores in the assemblage could have possibly been used to manufacture all of the complete flakes, let alone the estimated MNF (see Section 19.3.4) or retouched and I flakes.

The complete flake to core ratios (including core fragments) indicate that for every core there are 64 complete flakes. When the MNF is used, the ratio increases to 109 flakes per core. This does not take into account retouched and I artefacts. When the ratios are compared for the different material types, there is a much greater ratio for chert flakes and cores (149:1) than any other material type. While the ratio is high through the sequence, the disparity between complete chert flakes and cores is greatest in AU2 (206:1) and AU1 (182:1). This data seemingly supports the theory that high-quality materials were transported from site to site; however, in the later stages of the occupation, high ratios also exist for BIF cores and flakes.

Through the sequence, the complete core to flake ratio increases from a low of 33 flakes per core in AU8 to a high of 99 flakes per core in AU2, dropping slightly in AU1 (80 flakes/core). There are several scenarios that could explain this pattern. It appears that initially, many of the artefacts that occur in the assemblage were produced on-site as suggested by the relatively low complete flake to core ratios. Some flakes may have been brought into the site, and some cores may have been removed. In these early periods, chert cores may have been removed, as they are the only material type to show consistently high flake to core ratios. Later in the sequence, particularly from AU3 through AU1, the ratio increases considerably, possibly indicating that many cores were removed from the site. Chert, BIF, and shale cores generally have the greatest complete flake to core ratio. While it is understandable that knappers would take high-quality materials such as chert and shale, it is less convincing that cores produced from heavy and abundant BIF would also be transported to another site. Alternatively, it is possible that some core reduction occurred off-site and only flakes were brought to the site. No such reduction areas have been documented in the project area, but that does not preclude their possible existence. Another potential explanation is that cores were discarded in other areas of the site that were not excavated or perhaps were even discarded outside of the rockshelter when they were no longer needed. As there is limited floor space in the shelter, the occupants may have wanted to keep it free of larger debris. While there are many plausible theories, all that can be certain is that the cores used to produce the flakes in the assemblage are not all present. As a result, there is the slight possibility that the cores in the assemblage do not represent the full range of reduction methods employed by the knappers; hence, this assemblage highlights the necessity for considering the data from both cores and flakes.

Qualitative Core Attributes

Unidirectional and rotated reduction strategies are predominant in the Jundaru assemblage (Table 5-8: A; Figure 5-22). Complete rotated cores generally exhibit between two (n=22) or three (n=19) striking platforms, but there are also four cores that have four platforms and two cores with five platforms. Through the sequence there is some minor variation with rotated cores being slightly more common in AU6 and AU2, while unidirectional cores are the principal core type in the rest of the analytical units. When the raw materials of the two main core types are examined over time, there are no clear patterns in the data as there are so few cores within each raw material type. Other core types, such as alternate, bidirectional, and bipolar cores are rare. Bidirectional cores may also be an expression of core rotation, with the two platforms just happening to be opposed. These bidirectional cores show no evidence that flakes were removed alternately from the opposed platforms. Artefact 3396 (Figure 5-22: c) shows that the two platforms were used independently. The first platform may have been abandoned due to a large hinge termination, and large step terminations on the second platform likely led to its discard. Alternate and bipolar cores I different reduction strategies than unidirectional and rotated cores, which tend to show that a single platform was reduced unidirectionally before it was discarded or rotated. Alternate cores have at least one bifacial platform, and this is often due to the shape of the cobble that is being reduced (often flat or disc-shaped cobbles). Two bipolar cores were identified in the assemblage, one in AU8 and one in AU2. The lowermost specimen, Artefact 26,132 (Figure 5-22: a), was produced on a large hexagonal quartz crystal, while the other specimen was produced on a piece of quartz. Several bipolar flakes were also found in the assemblage.

All of the cores in the assemblage exhibit solely flake scars (Table 5-8: C), and this is unusual as there are often a small number of cores with mixed flake and blade scars (*e.g.*, HD07-3A-03 and HD07-3A-PAD13). This pattern is shared with the cores at HS-A1, as they also only exhibited flake scars. Because knapping is a reductive process, the lack of blade scars on the cores does not mean that blades were not removed from the cores during earlier stages of reduction. It is possible that subsequent removals may have obscured an occasional blade scars. Blades are not common, but they do comprise 5.3% of all complete flakes so it is expected that some cores would exhibit blade scars. As discussed previously, it appears that many of the cores used to produce the assemblage have not been recovered, and this may offer a potential explanation for the lack of blade scars on the cores.

For the sample as a whole, there is a fairly similar distribution of cores with plain and cortical striking platforms (Table 5-8: B). While some analytical units show a similar proportion of plain and cortical platforms (*e.g.*, AU8, AU5, AU4, AU3, and AU1), there is a predominance of plain striking platforms in AU7, AU6, and AU2. Plain striking platforms are most typical of rotated cores, but a small number of unidirectional cores also have plain platforms, as the knapper I a flat, naturally fractured surface that does not exhibit cortex.

Four cores exhibited a combination of platform types. The dominance of cortical and plain platforms together with unidirectional and rotated cores throughout the sequence shows that there was relative conservatism in the reduction methods over time. Flake manufacture was carried out expediently, but this was a successful strategy that did not need modification, even when new formalised retouched artefact types were introduced later in the Holocene.

The average number of scars per core can be a broad indicator of how intensely the core was reduced; although, larger cores have the potential to produce more flakes. Due to the reductive nature of knapping, later flake removals will obscure many of the flakes removed in the earlier stages of reduction; hence, the number of scars visible on a core will only provide an estimate of the minimum number of flakes produced by the core. The data shows that chert cores have a slightly higher average number of scars (Table 5-8: D), but they are followed closely by BIF and shale cores. In AU2, the BIF cores have a much greater average number of scars than the chert cores, but the BIF cores are also consistently larger than the chert cores. The relationship between size and reduction potential does not always hold true. The goethitised shale cores in AU3 are large, yet they produced few flakes. Similarly, martite-goethite cores are typically large, but they have a low average number of scars. In contrast, quartz cores are consistently the smallest cores on average, yet they have higher average numbers of flake scars than martite-goethite and goethitised shale cores. The complete rotated cores show a positive relationship between the number of core rotations and negative scars. Rotated cores with two platforms have an average of 6.5 scars per core, but chert and shale cores have much higher averages (chert=9 and shale=12). This suggests that these materials were more intensely reduced, even when just two platforms were I. Cores with three platforms show a significant increase in the number of scars (avg=9.5), and the average continues to increase for cores with numerous platforms.

Most of the cores in the assemblage were assessed as having been discarded in a viable state (Table 5-8: E); that is, these cores have the potential to be further reduced. Under a quarter of the sample was considered to be exhausted, and most of the exhausted cores were identified in AU2. Reasons why cores were considered to be exhausted include small size, problematic terminations (step, hinge, or plunge terminations), raw material flaws (generally leading to problematic terminations), and fractures. When the reduction potential is considered with the raw material type of the cores, it shows that most of the BIF, goethitised shale, and martite-goethite cores were considered to be viable. The quartz cores showed a slightly lower frequency of viable specimens (61.29%), and both chert and shale cores had nearly equal numbers of viable and exhausted cores. Once again, this suggests that chert and shale cores were more intensely reduced than coarser-grained materials. The fact that all but one of the BIF cores was considered viable suggests that they were not intensely reduced. While the BIF cores may have been able to produce a large number of flakes, their larger size meant that they did not reach the threshold of core exhaustion.

Table 5-8 Qualitative attributes for cores by analytical unit, Jundaru rockshelter

Core Type*	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Alternate	1	5.26	1	2.78	0	0.00	0	0.00	1	5.88	0	0.00	0	0.00	1	10.00	4	2.90
Bidirectional	2	10.53	2	5.56	1	7.14	1	5.56	0	0.00	2	11.76	0	0.00	0	0.00	8	5.80
Bipolar	0	0.00	1	2.78	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	10.00	2	1.45
Rotated	6	31.58	19	52.78	5	35.71	7	38.89	7	41.18	10	58.82	2	28.57	3	30.00	59	42.75
Unidirectional	9	47.37	13	36.11	8	57.14	10	55.56	9	52.94	4	23.53	5	71.43	5	50.00	63	45.65
Indeterminate	1	5.26	0	0.00	0	0.00	0	0.00	0	0.00	1	5.88	0	0.00	0	0.00	2	1.45
Total	**19**	**100**	**36**	**100**	**14**	**100**	**18**	**100**	**17**	**100**	**17**	**100**	**7**	**100**	**10**	**100**	**138**	**100**
Platform Type	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cortex	6	50.00	6	27.27	5	45.45	5	38.46	10	58.82	4	28.57	1	20.00	5	55.56	42	40.78
Plain	5	41.67	15	68.18	6	54.55	7	53.85	6	35.29	10	71.43	4	80.00	4	44.44	57	55.34
Other	1	8.33	1	4.55	0	0.00	1	7.69	1	5.88	0	0.00	0	0.00	0	0.00	4	3.88
Total	**12**	**100**	**22**	**100**	**11**	**100**	**13**	**100**	**17**	**100**	**14**	**100**	**5**	**100**	**9**	**100**	**103**	**100**
Scar Type	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Flake	12	100	22	100	11	100	13	100	17	100	14	100	5	100	9	100	103	100
Total	**12**	**100**	**22**	**100**	**11**	**100**	**13**	**100**	**17**	**100**	**14**	**100**	**5**	**100**	**9**	**100**	**103**	**100**
Avg. No. Scars	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg
BIF	2	4.50	4	10.75	2	8.00	3	5.33	9	6.11	5	12.00	2	6.50	5	5.60	32	7.50
Chert	2	11.00	5	8.00	2	11.00	1	3.00	2	9.50	1	1.00	0	0.00	0	0.00	13	8.23
Goethitised Shale	0	0.00	0	0.00	2	3.50	3	4.33	0	0.00	1	5.00	0	0.00	2	5.50	8	4.50
Martite-Goethite	0	0.00	0	0.00	3	2.67	1	10.00	3	6.00	2	2.00	1	1.00	0	0.00	10	4.10
Quartz	7	4.29	8	4.38	2	1.50	5	4.00	3	6.33	3	8.00	1	5.00	2	13.00	31	5.23
Shale	1	5.00	5	6.40	0	0.00	0	0.00	0	0.00	2	13.50	1	1.00	0	0.00	9	7.22
Total	**12**	**5.50**	**22**	**6.82**	**11**	**5.09**	**13**	**4.77**	**17**	**6.53**	**14**	**8.64**	**5**	**4.00**	**9**	**7.22**	**103**	**6.32**
Reduction Potential	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Exhausted	4	33.33	10	45.45	2	18.18	4	30.77	2	11.76	3	21.43	0	0.00	0	0.00	25	24.27
Viable	8	66.67	12	54.55	9	81.82	9	69.23	15	88.24	11	78.57	5	100	9	100	78	75.73
Total	**12**	**100**	**22**	**100**	**11**	**100**	**13**	**100**	**17**	**100**	**14**	**100**	**5**	**100**	**9**	**100**	**103**	**100**

* Note: core type is presented for all cores, while all other attributes are presented for complete cores

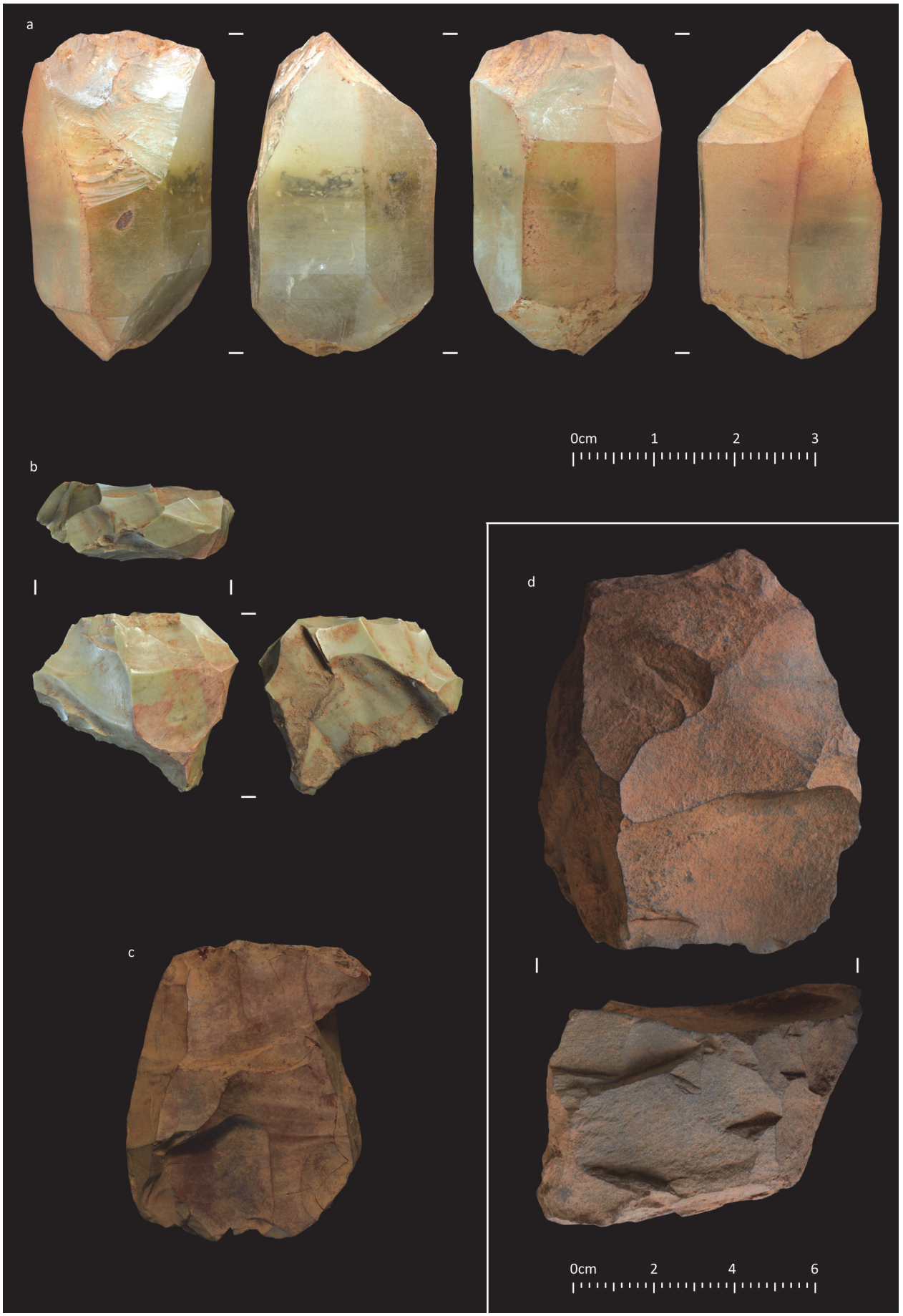

Figure 5-22 Cores from Jundaru rockshelter: a) bipolar core from AU8 (Artefact 26,132), b) rotated core from AU2 (Artefact 15,932), c) bidirectional core from AU1 (Artefact 3396), and d) rotated core from AU3 (Artefact 17,519)

Table 5-9 Quantitative attributes for complete cores by analytical unit, Jundaru rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	12	28.35	43.85	16.46	9.80
	2	22	29.89	63.51	13.06	14.16
	3	11	41.32	84.29	18.73	21.66
	4	13	37.39	82.67	11.45	20.21
	5	17	40.50	74.93	11.79	21.44
	6	14	32.72	53.73	14.13	12.79
	7	5	24.81	37.48	12.91	9.05
	8	9	42.02	100.23	16.27	25.23
B. Max Width (mm)	1	12	27.71	45.38	14.12	8.72
	2	22	36.06	73.73	13.25	15.96
	3	11	37.39	67.62	18.53	14.54
	4	13	33.62	67.43	16.88	14.26
	5	17	45.08	83.37	13.18	20.83
	6	14	36.56	61.6	17.03	12.65
	7	5	42.66	60.21	29.32	15.09
	8	9	50.63	92.44	21.31	25.39
C. Max Thickness (mm)	1	12	18.86	28.34	9.73	5.96
	2	22	21.84	52.66	9.38	12.61
	3	11	28.00	52	11.37	12.98
	4	13	22.24	35.43	10.71	8.26
	5	17	32.13	70.85	8.64	15.94
	6	14	35.60	88.68	11.3	23.15
	7	5	24.96	49.58	12.29	14.40
	8	9	41.58	70.64	22.39	14.26
D. Mass (g)	1	12	16.74	40.28	4.97	12.12
	2	22	40.82	269.54	3.7	62.59
	3	11	96.66	478	6.47	139.66
	4	13	43.28	126.16	2.53	39.83
	5	17	97.40	272.36	3.86	95.82
	6	14	70.56	282.04	4.66	79.94
	7	5	40.53	106.4	8.03	38.02
	8	9	138.72	597.3	20.1	187.74
Measurement	**AU**	**Count**	**Average Length**	**SD**	**Average Width**	**SD**
E. Average Maximum Negative Scar Dimensions	1	12	19.09	8.80	17.05	6.72
	2	22	20.75	11.09	19.42	12.05
	3	11	21.25	10.67	22.55	12.12
	4	13	17.15	9.03	18.49	6.53
	5	17	22.23	10.73	22.73	12.39
	6	14	23.39	10.81	24.87	10.57
	7	5	20.33	7.93	23.84	9.01
	8	9	25.01	14.40	23.66	12.49
F. Average Minimum Negative Scar Dimensions	1	12	11.23	6.32	10.76	4.59
	2	22	12.10	5.96	11.99	6.13
	3	11	16.23	10.48	18.73	16.03
	4	13	9.35	6.70	10.09	5.54
	5	17	12.38	4.45	13.21	5.19
	6	14	11.03	6.29	15.66	6.31
	7	5	15.98	6.33	16.05	8.16
	8	9	12.67	8.71	13.12	6.01

Quantitative Core Attributes

The quantitative attributes for the complete cores in AU1 through AU8 are presented in Table 5-9, including the maximum dimensions, mass, and average minimum and maximum negative scar dimensions. The average dimension of all cores in the assemblage is 36.89mm long (SD=22.11), 39.31mm wide (SD=19.13), and 28.38mm thick (SD=16.18). Over time there is a moderate amount of variation in the size of the cores; however, when this is considered against the high standard deviations, the variation is not significant. The smallest core in the assemblage is an exhausted, rotated core that was produced on a quartz crystal and measures 11.45-x-16.88-x-10.71mm (Artefact 4855; AU4). Similarly-sized cores are present in most analytical units and this may represent the minimum threshold in core size for effective reduction. The largest specimen is from AU8 and is a unidirectional BIF core (100.23-x-92.44-x-44.38mm). These two cores highlight the considerable range in the core sizes. When the maximum length is examined by quartiles, the first quartile is 21.77mm and the third quartile is 43.27mm, which demonstrates that 50% of the cores have lengths between these two values and 75% of the cores measure less than 43.27mm in length. This suggests that the high standard deviation values are due to a relatively small number of large and very small cores that skew the data. On the whole, most cores are relatively small.

When core dimensions are considered by raw material types, BIF and martite-goethite cores have the largest average size, followed by goethitised-shale and shale cores. Through the

sequence, the BIF cores are much smaller in AU7, AU2, and AU1. Chert cores are amongst the smallest and are only surpassed by quartz cores. Most of the cores in the assemblage are viable and retain cortex, with only 12 cores exhibiting no cortex, so this data confirms the theory that the local coarser-grained materials were generally obtained as larger pieces, while chert cobbles were typically smaller. The size of the quartz that was sourced for cores also appears to have been considerably smaller than other material types.

While the average minimum and maximum negative scar dimensions appear to be very consistent over time, there are also considerable standard deviations. The high standard deviations indicate that there is a high degree of variation within the sample. The maximum sizes of the scars do show that despite considerable differences in the core dimensions, larger cores do not necessarily equate to larger flakes. Smaller cores will limit the size of the flakes that are produced, and the quartz cores have the smallest average maximum scar dimensions. The average minimum scar length is consistent for BIF, chert, goethitised shale, and shale cores, while it is greater for martite-goethite cores and less for quartz cores.

Flakes

Flakes and flake fragments are the primary component of Jundaru's artefact assemblage, accounting for 83.24% of the artefacts from the eight analytical units. In most assemblages there are a large number of broken flakes, and it is important to identify these specimens so as to avoid misrepresenting the assemblage size. A total of 8908 complete flakes are present in the assemblage in addition to 12,859 specimens that are in various states of fragmentation (Table 5-10). Basic attributes were recorded for the 8420 flake fragments that were subject to sampling, which included their state of completion (longitudinal fragmentation and transverse fragmentation), which makes it possible to estimate the minimum number of flakes for the entire assemblage as opposed to only the proportion of the assemblage that was not subject to sampling.

Flake Fragmentation

Using the calculation MNF = C + T + CL + BL (see Hiscock 2002), it is estimated that the 21,767 flakes and flake fragments represent at least 15,073 complete flakes (MNF = 8908 + 4528 + 1192 + 445). When the types of flake fragmentation are considered, the data shows that the number of longitudinal flake fragments is much lower than the number of transverse flake fragments. The assemblage includes a much higher proportion of distal than proximal flake fragments, and this is a recurring pattern amongst the excavated assemblages. As noted previously, distal flake fragments were also found to be more commonly represented in an experimental study of flake fragmentation amongst conjoin sets (Hiscock 2002: 255).

The calculated MNF also makes it possible to estimate the percentage of broken flakes in the assemblage, which is calculated to be 40.90% (percentage of broken flakes = (MNF – complete flakes) / MNF x 100). Flakes fragmentation can be the result of numerous different processes. They can be broken during manufacture, and these breaks tend to be longitudinal, while transverse fragmentation is more likely to occur as the result of trampling (Hiscock 1985: 87). Other post-depositional process may also affect the rate of flake fragmentation, and the site formation processes should be taken into account. In rockshelters such as Jundaru, the impact of roof collapse may also contribute to high proportions of broken flakes. The estimated percentage of broken flakes is slightly higher than at Djadjiling (Law and Cropper 2012), on par with that at HD07-3A-03, and slightly lower that at HD07-3A-PAD13. The proportion of broken flakes is considerably higher at HS-A1, where it is estimated to be 56.19% (this discrepancy may be related to the different site formation processes at HS-A1).

Table 5-10 Flake fragmentation, Jundaru rockshelter

Longitudinal Fragmentation	Transverse Fragmentation				
	Complete	Distal	Prox.	Medial	Total
Complete	8908	4528	2177	1102	16,715
Left + Left LCS	1192	445	305	384	2326
Right + Right LCS	1165	429	262	324	2180
Medial	62	170	60	254	546
Total	**11,327**	**5572**	**2804**	**2064**	**21,767**

When the fragmentation rates are compared amongst the analytical units, the data indicates that the deeper layers have a considerably higher percentage of broken flakes than the upper layers. This is the opposite pattern to the intensity of site occupation, so other factors must be considered. The highest estimated proportion of broken flakes occurs in AU8 (48%). Between AU7 and AU2 there is a general decline in fragmentation rates (AU7: 43.8%; AU6: 43.8%; AU5: 45.1%; AU4: 40.9%; AU3: 39.6%; and AU2: 39.0%), which increases again slightly in AU1 (42.0%). The most plausible explanation for this pattern of flake fragmentation is that flakes were broken as the result of roof collapse. In the lower layers of the site (*i.e.*, below 100cmbd; AU8 to AU5), roof collapse would have caused a higher degree of flake fragmentation. In the layers immediately beneath the large block of roof collapse that covered most of Unit 10, there were numerous artefacts that were found *in situ* during the excavation that had been broken. For example, Artefact 25,922 was found *in situ* during the excavation of U10-L27, and the green shale flake was found broken into seven separate pieces, each with clear points of impact on the surface oriented towards the shelter roof (Note: as the artefact was clearly broken by roof collapse, it was refitted and recorded in the database as a single I artefact). There were numerous other such examples from the same excavation layer.

The increase in flake fragmentation for AU1 does not conform to the pattern observed for the assemblage. In AU1 there was no significant roof collapse, nor does there appear to have been a greater occupational intensity during this phase (*i.e.*, increasing breakage due to treadage). AU1 accounts for arbitrary excavation layers from the surface down to 40cmbd, and it is possible that modern site visitation may have caused some flake breakage. Apart from the numerous brief visits to the site since its initial discovery there have been three potential sources for increased activity (*i.e.*, treadage) at the site: the MHA excavation, the subsequent ground penetrating radar survey, and the installation of safety equipment prior to the ACHM excavation. While the analysts were not specifically looking for evidence of recent breaks, several fresh breaks and evidence of recent edge damage were noted in AU1. Fresh breaks were also observed in lower analytical units so this theory remains untested due to the lack of quantifiable data.

Flake Subtypes

A small proportion of the flakes in the assemblage exhibit characteristics that identify them as having been produced by a particular reduction method (*e.g.*, spall) or as a flake sub-type (*e.g.*, blade). Flake sub-types typically were only assigned for complete specimens. In a small number of instances, a flake may have attributes of more than one flake type. By far, the most common flake sub-category is blades, with 431 complete flakes having lengths at least twice their widths. There are also

an additional 40 specimens that have the dimensions of blades, but also have characteristics of another flake type (34 spalls, 1 bipolar flake, 2 ridge flakes, and 3 platform rejuvenation flakes). Most blades appear simply to be elongated flakes rather than blades produced through a specific blade-focused reduction technology.

The 431 specimens that have attributes of other flake types account for 4.84% of the complete flakes and there is minor variation through the analytical units. The greatest relative proportion of blades is in AU8 (6.46%), but this drops in AU7 to 2.90%. Blade frequency increases through to AU5 (4.53%), drops in AU4 (3.39%) then rises again through to AU1 (4.79%). There is a peak in both blade numbers and frequency in AU2, where the 195 blades account for 5.45% of the complete flakes. There is no evidence to suggest that blade manufacture was done purposefully or that there was a different reduction strategy focused on their production; hence, blades occurred fortuitously. The numbers of blades do increase in the analytical units with backed artefacts, but blade frequency during this time remains proportional to flakes with only a slight rise.

Blades occur on both fine-grained and coarse-grained raw materials, including chert (40.14%), brown shale (18.56%), BIF (21.81%), ironstone (2.32%). Other materials (*e.g.*, quartz, 11.83%; goethitised shale, 3.94%; and green shale, 1.39%) are also documented in the sample. When compared to the averages for the assemblage as a whole, there is a slight over-representation of chert blades, but this is very minor and the patterns closely follow the raw material patterns of flakes. This distribution and range of raw materials also provides evidence that these artefacts were produced during typical expedient flake-based reduction strategies.

The second most prevalent flake sub-category is one that was not defined in the analysis methodology, retouching flakes (n=202). The complete retouching flakes in the assemblage are short and wide, averaging 4.3mm long, 8.1mm wide, and 2.19mm thick. The flakes appear to be the result of retouching the edge of a steeply retouched artefact. Retouching flakes were distinguished from other small flakes by the presence of a facetted overhang and their overall form (squat often with a prominent concave profile). This 131aceting appears to be retouch that was subsequently removed by the flake, possibly during the maintenance of tools such as tulas. One of the retouching flakes appears to have been produced through bipolar reduction and one retouching flake has blade proportions.

The assemblage includes 51 burin spalls, with their occurrence being concentrated in AU2 (n=33) and AU1 (n=13). Only isolated examples were identified in the lower analytical units, with the lowermost specimen recovered from AU7 (U1-L22). The deepest burin recovered from the site was in AU6 (U6-L18). The distribution of both spalls and burins demonstrates that this retouching technique only became established in the late Holocene. Eight burin spalls were submitted for usewear analysis, and the results consistently show that that the burin technique was I to sharpen or rejuvenate a worn edge of a tool typically bearing signs of use for woodworking (Fullagar 2013). The spalls themselves show no evidence of having been used after being detached from the flake or tool (Fullagar 2013).

Evidence of core rejuvenation is rare in the assemblage, as rotation appears to have been used to extend the use-life of a core. Thirty-five platform rejuvenation flakes were identified in the assemblage, accounting for 0.16% of the flakes. Specimens were found in each of the eight analytical units, but the greatest number (albeit proportional) is in AU2 (n=13) and AU1 (n=10). Platform rejuvenation flakes were used to remove part or all of a problematic platform and are typically removed perpendicular to the knapping axis. By rejuvenating the platform, the knapper would have been able to continue reduction using the same core orientation. Because rotated cores are so common in the assemblage, it is possible that some of the platform rejuvenation flakes may have been inadvertently created as the knapper rotated the core and began the reduction from a new striking platform perpendicular to a previous platform.

Twelve bipolar flakes are present in the assemblage, including one specimen that is believed to be a retouching flake. Bipolar flakes occur in each analytical unit, with the exception of AU7 and AU3. The majority of the bipolar flakes were produced from quartz (n=7), but chert, shale, BIF, and goethitised shale specimens were also identified. The bipolar flakes are small with an average length of 13.81mm and a range between 4.6mm and 29.76mm. The small size of these artefacts may indicate that bipolar reduction was I to reduce small cores (or retouched flakes) when hand-held reduction methods became impractical.

The final and least common flake sub-type in the assemblage is ridge flakes. Nine ridge flakes were identified, with most specimens being from the late Holocene layers (AU2, n=3 and AU1, n=4). AU5 and AU4 also have one specimen each. Ridge flakes are often associated with blade manufacture and are a means of preparing a core to facilitate the subsequent removal of long straight blades. While blades do not appear to have been systematically produced at Jundaru, this reduction technique was known but not commonly I. In one instance (Artefact 25,336) it looks as though the ridge blade was used to correct a knapping error. A large step termination occurred on the core face and was subsequently removed by the ridge flake. Some of the smaller examples in the late Holocene layers bear a strong resemblance to steeply retouched and backed flakes; however, they are clearly distinguished from these retouched artefacts by the fact that the scars along the dorsal surface were struck from an arris prior to the detachment of the ridge blade.

Quantitative Flake Attributes

The quantitative flake attributes are presented in Table 5-11 by analytical unit and include the maximum dimensions, axis dimension, mass, elongation index, and parallel index for complete flakes. The table also includes the platform dimensions and exterior platform angle for all complete flakes and all proximal flake fragments (longitudinally complete) that were not subject to sampling.

The maximum dimensions of the complete flakes in the assemblage show a slight trend towards smaller specimens in the later phase of the site's occupation. Throughout the analytical units, there is a considerable range in the size of flakes; however, both the maximum and minimum dimensions are relatively similar. The standard deviation values are relatively high and this is a good indication that there are concentrations of flakes in some size classes. When the data is examined by quartiles, it shows that three-quarters of the flakes have lengths of 11.83mm or less, yet the average length for the entire assemblage is 9.58mm. A quarter of the complete flakes have lengths greater than 11.83mm and reaching a maximum of 67.21mm.

Table 5-11 Quantitative flake attributes by analytical unit, Jundaru rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	1525	9.59	50.36	1.8	6.98
	2	3578	8.79	67.56	1.57	6.92
	3	1005	12.54	63.15	2.22	9.50
	4	946	12.72	61.75	2.23	8.84
	5	662	11.80	65.67	2.14	8.33
	6	523	13.01	66.68	2.63	9.89
	7	344	12.52	59.77	1.68	9.15
	8	325	11.32	51.31	2.39	7.52
B. Max Width (mm)	1	1525	9.62	69.44	0.61	6.46
	2	3578	9.02	59.98	1.10	6.25
	3	1005	13.25	62.52	1.71	9.37
	4	946	13.47	57.67	0.92	8.69
	5	662	11.94	56.14	1.47	7.94
	6	523	13.91	69.43	3.38	10.09
	7	344	13.38	45.62	3.29	8.37
	8	325	11.46	43.88	2.87	7.85
C. Max Thickness (mm)	1	1525	2.59	18.43	0.33	2.39
	2	3578	2.37	34.48	0.23	2.39
	3	1005	3.59	32.06	0.29	3.21
	4	946	3.86	24.70	0.48	3.13
	5	662	3.52	34.81	0.51	3.01
	6	523	4.14	26.16	0.26	3.67
	7	344	4.05	24.88	0.41	3.67
	8	325	3.38	28.93	0.51	2.93
D. Axis Length (mm)	1	1525	8.83	48.75	1.33	6.59
	2	3578	8.05	67.21	1.42	6.47
	3	1005	11.44	62.59	1.67	8.83
	4	946	11.62	62.00	1.93	8.57
	5	662	10.58	58.66	1.88	7.64
	6	523	11.84	59.42	2.10	9.05
	7	344	11.16	49.44	1.66	8.42
	8	325	10.17	44.79	2.22	6.94
E. Axis Width (mm)	1	1525	8.38	48.45	0.39	5.57
	2	3578	7.89	57.47	0.72	5.57
	3	1005	11.52	61.57	2.40	8.27
	4	946	11.72	53.12	1.61	7.64
	5	662	10.40	48.61	2.01	6.95
	6	523	11.94	56.93	2.85	8.48
	7	344	11.48	43.78	2.80	7.27
	8	325	9.81	40.71	2.54	6.45
F. Axis Thickness (mm)	1	1525	2.23	18.26	0.16	2.08
	2	3578	1.98	34.31	0.20	2.01
	3	1005	3.15	82.00	0.23	3.74
	4	946	3.24	24.60	0.44	2.68
	5	662	3.05	29.74	0.35	2.71
	6	523	3.51	20.62	0.23	3.12
	7	344	3.34	20.31	0.47	2.82
	8	325	2.86	29.31	0.33	2.63
G. Mass (g)	1	1525	0.69	30.58	0.01	2.38
	2	3578	0.65	78.24	0.01	3.31
	3	1005	1.85	59.78	0.01	5.22
	4	946	1.77	92.84	0.01	5.22
	5	662	1.38	72.09	0.01	4.65
	6	523	2.27	61.44	0.01	6.46
	7	344	1.69	26.11	0.01	3.86
	8	325	1.26	40.00	0.01	3.97
H. Elongation Index	1	1525	1.08	7.49	0.28	0.59
	2	3578	1.05	7.35	0.24	0.62
	3	1005	1.02	3.60	0.25	0.49
	4	946	1.02	5.52	0.25	0.52
	5	662	1.07	5.12	0.30	0.54
	6	523	1.03	5.76	0.27	0.53
	7	344	0.98	3.31	0.20	0.45
	8	325	1.09	3.39	0.25	0.51

Measurement	AU	Count	Average	Max	Min	SD
I. Parallel Index	1	1525	1.74	17.91	0.15	1.08
	2	3578	1.70	13.27	0.27	0.97
	3	1005	1.60	7.74	0.05	0.89
	4	946	1.54	8.91	0.43	0.85
	5	662	1.63	18.70	0.61	1.13
	6	523	1.56	13.58	0.59	1.03
	7	344	1.62	11.59	0.62	1.02
	8	325	1.62	6.12	0.51	0.78
J. Platform Width (mm)	1	1668	5.89	45.43	0.44	4.60
	2	3829	5.63	48.89	0.45	4.57
	3	1093	8.29	59.39	0.52	6.54
	4	1027	8.85	47.71	0.81	6.27
	5	697	7.54	33.18	0.77	5.37
	6	556	9.04	55.45	0.88	7.30
	7	368	8.53	34.05	0.44	6.20
	8	344	6.90	35.87	1.35	5.14
K. Platform Thickness (mm)	1	1668	1.91	19.34	0.12	1.91
	2	3829	1.73	18.14	0.02	1.77
	3	1093	2.68	32.84	0.17	2.63
	4	1027	2.94	18.48	0.18	2.49
	5	697	2.56	33.48	0.23	2.35
	6	556	3.11	17.19	0.22	2.88
	7	368	2.87	15.77	0.26	2.48
	8	344	2.48	27.05	0.26	2.40
L. Platform Angle (°)	1	1668	76.11	130.00	31.00	13.95
	2	3829	76.83	128.00	23.00	13.69
	3	1093	74.63	127.00	25.00	14.72
	4	1027	72.83	130.00	27.00	15.67
	5	697	75.29	123.00	20.00	15.22
	6	557	73.36	117.00	30.00	15.48
	7	368	71.98	116.00	27.00	15.53
	8	344	73.38	110.00	30.00	14.98

Note: Measurements A-I are for complete flakes. Platform measurements (J-L) include all complete flakes and all proximal flakes that are longitudinally complete.

When flake size is considered by raw material type, chert flakes have the smallest average length (7.97mm), followed closely by quartz (9.21mm), vitreous goethite (9.28mm), shale (10.17mm), and goethitised shale (10.98mm). The coarser-grained materials are larger, with BIF and martite-goethite flakes having an average length of 14.50 and 21.56mm respectively. The coarser-grained materials (BIF, martite-goethite, and limonite) also have the greatest standard deviation values, while the finer-grained materials (quartz, chert, and vitreous goethite) have much lower standard deviations. This indicates that there is a greater consistency in the size of the flakes produced from finer-grained materials. It has been previously established that chert and quartz cores are the smallest in the assemblage, and this was clearly a contributing factor that limited the maximum size of flakes produced. The reverse is true for BIF and martite-goethite cores, with their large size enabling the production of large flakes resulting in a higher degree of size variation.

The shape of flakes can also be explored through the elongation index (Table 6-11: H) and the parallel index (Table 5-11: I). The elongation index shows the tendency towards flake elongation through a calculation of the maximum width to the maximum length. There is relative consistency throughout all of the analytical units, with the index showing that flake length is generally only slightly greater than the flake width. AU7 has the lowest elongation index value, indicating that flakes were slightly squatter in this phase. AU8 has the highest value (followed closely by AU1), indicating that there is a minor trend for slightly elongated flakes. As is discussed above, only 471 flakes meet the metrical requirements to be called blades, which comprise 5.29% of the complete flakes.

The parallel index is a metric evaluation of flake form that compares the platform width to the axis width. This ratio provides information regarding the shape of the flake from its platform to its midpoint with values greater than one indicating that the flake expands from the platform to its midpoint. Values less than one indicate the flake has a contracting form from its platform to midpoint. The average data in each analytical unit show that most flakes expand away from the platform towards the midpoint, and 80.48% of complete flakes fall into this category (rounded to two decimal places). Contracting forms were identified in 18.61% of the sample. There are 81 flakes that have parallel forms with a value of one, as well as numerous others that are very close.

The platform dimensions provided in the table below include all complete flakes and all longitudinally complete proximal flakes that were not subject to sampling with a total sample size of 9582 artefacts. Through the analytical units there is a trend towards smaller platforms in the later analytical units; however, this pattern appears to largely be related to the flake size. Because experimental research has shown that striking platform attributes, such as exterior striking platform angle and platform dimensions, are related to flake morphology and size (Dibble and Rezek 2009; Pelcin 1997b), it is important to understand the variability in these attributes independent of flake size. When the averages of platform width or thickness are simply compared, it is difficult to discern any patterns as there is a great deal of variation due to the size range of the flakes (*i.e.*, large flakes will naturally have larger platforms than small flakes). In order to mitigate this variable, platform dimensions can be explored through ratios.

A ratio of the striking platform width to the maximum flake width is used here to explore patterns of platform width variation that are independent of flake size. Amongst the complete flakes, the average ratios are consistent with an

average value of 1.92. Throughout the analytical units, AU2 (1.97) and AU1 (2.01) have the greatest values and AU4 (1.78) has the lowest value followed closely by AU6 (1.83). The higher values indicate slightly narrower striking platforms, but high standard deviation values indicate that there is considerable variation within the sample. When the data is compared by platform type, dihedral platforms are the widest (1.37), followed by winged (1.50), facetted (1.57), and cortical platforms (1.63). Linear platforms are the narrowest with a value of 2.76, but cortical (2.74) are equally narrow. Plain platforms occur in the middle of the range with a value of 1.87. There is also variation amongst the various raw material types, with quartz (1.74) and BIF (1.76) having the widest platforms. Chert flakes occur in the middle of the range (2.04) and limonite (2.52) and flakes of indeterminate materials (2.60) have the narrowest platforms.

Similarly, platform thickness can be evaluated by a ratio (maximum thickness/platform thickness) to allow comparison of the data amongst flakes of various sizes. Lower values indicate thicker platforms and higher numbers equate to thinner platforms. Throughout occupation, the average platform thickness ratios remain relatively uniform with a range of 1.57 (AU7) to 1.70 (AU2). Other assemblages (*e.g.*, HD07-3A-03, HD07-3A-PAD13, and HS-A1) show much greater degree of variation. Perhaps the variation shown in some of the smaller assemblages is due to the small sample size. There is slightly greater variation amongst the different raw material types, with quartz having the lowest average value (1.56) and limonite having the highest value (2.04), representing thick and thin platforms respectively. Chert (1.65), BIF (1.66), and shale (1.72) flakes have values that are much closer to the averages for the assemblage and indicate moderately thick platforms.

The exterior striking platform angles remain relatively consistent over the course of the occupation, with a range between 71.98° and 76.83° (Table 5-11: L). There is a slight trend towards higher exterior platform angles in the late Holocene analytical units. High angles are generally believed to result in the production of larger flakes (Dibble 1997; Pelcin 1997a). Through the entire assemblage, BIF flakes had the lowest average platform angles (72.03°), followed by shale (75.05°), quartz (76.73°), and chert (76.82°). Goethitised shale, martite-goethite, vitreous goethite, and limonite had higher average exterior platform angles. In AU3 and AU2 there is a considerable difference between BIF and chert flakes (6 and 5° respectively), but in the earlier analytical units the angles are more similar. This may be due to the increased use of chert in these layers and the need to maximize the resource.

Qualitative Flake Attributes

The qualitative attributes recorded for complete and proximal flakes are presented in Table 5-12: A-D and include platform type, overhang removal, lipping, and bulb of percussion type. These attributes were recorded for the 8908 complete flakes in the assemblage as well as the 674 longitudinally complete proximal flake fragments that were not subject to sampling, resulting in a total sample size of 9582 artefacts.

Over the course of the occupation and within each analytical unit, plain striking platforms are predominant (Table 5-12: A). Both chert and BIF flakes have very similar proportions of plain striking platforms. Linear platforms, which are a variation of plain platforms, are second in abundance for the assemblage. Their occurrence tends to be low over much of the sequence, but their frequency begins to rise beginning in AU3 and peaking in AU2. Linear platforms are more common on chert and shale flakes. Cortical striking platforms are much more common earlier in the sequence, particularly in AU7 and AU6, but they become increasingly infrequent. The analysis of the cores showed similar proportions of cortical platforms through the sequence. The disparity between the cores and flakes may be due to the lack of chert cores in the assemblage, particularly as the lowest incidence of cortical platforms occurs at the peak of chert use. Cortical striking platforms are rare on chert and shale flakes, particularly in AU2. Other platform types (*e.g.*, winged, facetted, or dihedral) are rare and were not a regular aspect of the reduction strategy; however, they are slightly more frequent amongst chert and shale flakes. There was also a small number of flakes that have had their platforms crushed as they were removed.

Overhang modification is rare, particularly up to the mid-Holocene (*i.e.*, AU3; Table 5-12: B). Facetted overhangs become slightly more common from AU3 onwards and particularly during AU2 where they account for 13.74% of the sample. Four abraded overhangs were observed in the entire sample. Crushed overhangs are also uncommon, and like crushed platforms, they do not represent a deliberate modification but are knapping errors. Crushing can occur if the overhang is too acute or if the platform is struck too close to its edge. The vast majority of the flakes in the assemblage shows no modification or crushing of the overhang.

Lipping and diffuse bulbs of percussion were once believed to be characteristic attributes of soft-hammer percussion, but through experimental research it has been demonstrated that these characteristics can occur on flakes produced through both hard-hammer and soft-hammer techniques (Pelcin 1997a). Other factors such as the angle of force and thickness of the platform are believed to contribute to the appearance of these attributes (Pelcin 1997a). At Jundaru lipping only occurs on 6.19% of the sample, with slightly higher frequencies in AU4 and AU1 (Table 5-12: C). As indicated by striking platform thickness to maximum thickness ratios, the data show that flakes with lipping (1.33) consistently have much thicker platforms than flakes without lipping (1.68). It is likely that the platform thickness affects the formation of lipping, and it is also possible that occasionally, low angles of force were used to detach flakes (which often cause lipping).

There is a relatively even division between diffuse and prominent bulbs, with the latter being slightly more common (Table 5-12: D). There is a slightly greater frequency of diffuse bulbs earlier in the sequence, followed by a transition to a greater frequency of prominent bulbs, particularly in AU2. This pattern reversal is due to the increased use of chert, which generally had much higher frequencies of prominent than diffuse bulbs throughout the entire sequence. Some raw material types show varied patterns amongst the analytical units. Shale flakes show a considerable increase in the proportion of prominent bulbs in AU3 and AU2, whereas in the other analytical units, the number of prominent bulbs only slightly exceeds that of diffuse bulbs. While most analytical units show a similar proportion of BIF flakes with diffuse and prominent bulbs, AU8 and AU6 have much higher frequencies of diffuse bulbs. The data does not indicate that platform thickness has affected the development of diffuse or prominent bulbs, with little variation between the striking platform thickness to maximum thickness ratios. However, the average exterior striking platform angle is higher (76.95°) for flakes with prominent bulbs than those with diffuse bulbs (73.42°). This data suggests that the formation of the bulb is influenced by both raw material type and the exterior platform angle. It is also likely that the angle of force has an impact on this attribute.

Table 5-12 Qualitative flake attributes by analytical unit, Jundaru rockshelter

A. Platform Type [cp]	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cortical	137	8.21	228	5.95	116	10.58	108	10.55	78	11.19	99	17.81	59	16.03	38	11.05	863	9.01
Crushed	36	2.16	68	1.78	7	0.64	8	0.78	7	1.00	2	0.36	0	0.00	2	0.58	130	1.36
Dihedral	57	3.42	117	3.06	21	1.92	28	2.73	15	2.15	21	3.78	10	2.72	8	2.33	277	2.89
Facetted	42	2.52	125	3.26	14	1.28	13	1.27	3	0.43	3	0.54	3	0.82	1	0.29	204	2.13
Linear	188	11.27	501	13.08	105	9.58	63	6.15	56	8.03	37	6.65	17	4.62	23	6.69	990	10.33
Plain	1182	70.86	2691	70.28	819	74.73	791	77.25	530	76.04	391	70.32	275	74.73	268	77.91	6947	72.50
Winged	26	1.56	99	2.59	14	1.28	13	1.27	8	1.15	3	0.54	4	1.09	4	1.16	171	1.78
Total	**1668**	**100**	**3829**	**100**	**1096**	**100**	**1024**	**100**	**697**	**100**	**556**	**100**	**368**	**100**	**344**	**100**	**9582**	**100**
B. Overhang Removal [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Abraded	0	0.00	2	0.05	0	0.00	1	0.10	1	0.14	0	0.00	0	0.00	0	0.00	4	0.04
Crushed	57	3.42	75	1.96	14	1.28	10	0.98	10	1.43	4	0.72	3	0.82	2	0.58	175	1.83
Facetted	160	9.59	526	13.74	82	7.48	49	4.79	21	3.01	15	2.70	7	1.90	7	2.03	867	9.05
None	1451	86.99	3226	84.25	1000	91.24	964	94.14	665	95.41	537	96.58	358	97.28	335	97.38	8536	89.08
Total	**1668**	**100**	**3829**	**100**	**1096**	**100**	**1024**	**100**	**697**	**100**	**556**	**100**	**368**	**100**	**344**	**100**	**9582**	**100**
C. Lipping [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
No	1524	91.37	3625	94.67	1037	94.62	950	92.77	659	94.55	523	94.06	350	95.11	321	93.31	8989	93.81
Yes	144	8.63	204	5.33	6059	5.38	74	7.23	38	5.45	33	5.94	18	4.89	23	6.69	593	6.19
Total	**1668**	**100**	**3829**	**100**	**1096**	**100**	**1024**	**100**	**697**	**100**	**556**	**100**	**368**	**100**	**344**	**100**	**9582**	**100**
D. Bulb of Perc. [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diffuse	821	49.22	1354	35.36	446	40.69	508	49.61	374	53.66	323	58.09	183	49.73	196	56.98	4205	43.88
Prominent	847	50.78	2469	64.48	650	59.31	515	50.29	323	46.34	232	41.73	185	50.27	148	43.02	5369	56.03
Missing	0	0.00	6	0.16	0	0.00	1	0.10	0	0.00	1	0.18	0	0.00	0	0.00	8	0.08
Total	**1668**	**100**	**3829**	**100**	**1096**	**100**	**1024**	**100**	**697**	**100**	**556**	**100**	**368**	**100**	**344**	**100**	**9582**	**100**
E. Dorsal Cortex [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
None	1220	80.00	3018	84.35	722	71.84	716	75.69	493	74.47	363	69.41	260	75.58	232	71.38	7024	78.85
1-32%	153	10.03	325	9.08	156	15.52	103	10.89	78	11.78	79	15.11	43	12.50	39	12.00	976	10.96
33-65%	36	2.36	82	2.29	35	3.48	31	3.28	35	5.29	22	4.21	15	4.36	15	4.62	271	3.04
66-99%	35	2.30	49	1.37	29	2.89	29	3.07	17	2.57	15	2.87	7	2.03	12	3.69	193	2.17
100%	81	5.31	104	2.91	63	6.27	67	7.08	39	5.89	44	8.41	19	5.52	27	8.31	444	4.98
Total	**1525**	**100**	**3578**	**100**	**1005**	**100**	**946**	**100**	**662**	**100**	**523**	**100**	**344**	**100**	**325**	**100**	**8908**	**100**
F. Dorsal Scars [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0	81	5.31	104	2.91	63	6.27	67	7.08	39	5.89	44	8.41	19	5.52	27	8.31	444	4.98
1	295	19.34	699	19.54	217	21.59	222	23.47	149	22.51	125	23.90	79	22.97	66	20.31	1852	20.79
2	479	31.41	1251	34.96	353	35.12	320	33.83	245	37.01	190	36.33	134	38.95	131	40.31	3103	34.83
3	416	27.28	971	27.14	231	22.99	216	22.83	140	21.15	110	21.03	68	19.77	57	17.54	2209	24.80
4	156	10.23	380	10.62	79	7.86	89	9.41	52	7.85	29	5.54	26	7.56	23	7.08	834	9.36
5	61	4.00	112	3.13	40	3.98	20	2.11	17	2.57	14	2.68	10	2.91	14	4.31	288	3.23
6	19	1.25	42	1.17	11	1.09	6	0.63	11	1.66	6	1.15	6	1.74	6	1.85	107	1.20
7	15	0.98	8	0.22	6	0.60	2	0.21	5	0.76	3	0.57	1	0.29	1	0.31	41	0.46
8	1	0.07	7	0.20	4	0.40	3	0.32	2	0.30	0	0.00	0	0.00	0	0.00	17	0.19
9	1	0.07	1	0.03	1	0.10	1	0.11	2	0.30	1	0.19	1	0.29	0	0.00	8	0.09
10	0	0.00	2	0.06	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.02
11	1	0.07	0	0.00	0	0.00	0	0.00	0	0.00	1	0.19	0	0.00	0	0.00	2	0.02
12	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01
Total	**1525**	**100**	**3578**	**100**	**1005**	**100**	**946**	**100**	**662**	**100**	**523**	**100**	**344**	**100**	**325**	**100**	**8908**	**100**
G. Scar Orient. [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Unidirect.	945	61.97	2152	60.15	629	62.59	539	56.98	422	63.75	289	55.26	190	55.23	204	62.77	5370	60.28
Bidirect.	19	1.25	31	0.87	4	0.40	7	0.74	12	1.81	9	1.72	2	0.58	3	0.92	87	0.98
Rotated	233	15.28	686	19.17	120	11.94	115	12.16	57	8.61	61	11.66	38	11.05	19	5.85	1329	14.92
NA	81	5.31	104	2.91	189	18.81	218	23.04	39	5.89	44	8.41	19	5.52	27	8.31	444	4.98
Ind.	247	16.20	605	16.91	63	6.27	67	7.08	132	19.94	120	22.94	95	27.62	72	22.15	1678	18.84
Total	**1525**	**100**	**3578**	**100**	**1005**	**100**	**946**	**100**	**662**	**100**	**523**	**100**	**344**	**100**	**325**	**100**	**8908**	**100**
H. Form [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Contracting	349	22.89	910	25.43	275	27.36	269	28.44	181	27.34	156	29.83	101	29.36	86	26.46	2327	26.12
Expanding	883	57.90	2113	59.06	580	57.71	548	57.93	369	55.74	285	54.49	189	54.94	172	52.92	5139	57.69
Leaf	98	6.43	154	4.30	52	5.17	35	3.70	46	6.95	29	5.54	29	8.43	33	10.15	476	5.34
Parallel	40	2.62	108	3.02	22	2.19	27	2.85	11	1.66	15	2.87	3	0.87	5	1.54	231	2.59
Sub-Parallel	154	10.10	292	8.16	76	7.56	67	7.08	55	8.31	38	7.27	22	6.40	29	8.92	733	8.23
Irregular	1	0.07	1	0.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.02
Total	**1525**	**100**	**3578**	**100**	**1005**	**100**	**946**	**100**	**662**	**100**	**523**	**100**	**344**	**100**	**325**	**100**	**8908**	**100**

I. Profile [c]	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Concave	428	28.07	852	23.81	232	23.08	160	16.91	140	21.15	104	19.89	75	21.80	86	26.46	2077	23.32
Convex	225	14.75	482	13.47	196	19.50	198	20.93	125	18.88	91	17.40	99	28.78	79	24.31	1495	16.78
Straight	781	51.21	2030	56.74	508	50.55	539	56.98	359	54.23	300	57.36	150	43.60	138	42.46	4805	53.94
Twisted	91	5.97	212	5.93	69	6.87	49	5.18	38	5.74	28	5.35	20	5.81	22	6.77	529	5.94
Irregular	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01
Ind.	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01
Total	**1525**	**100**	**3578**	**100**	**1005**	**100**	**946**	**100**	**662**	**100**	**523**	**100**	**344**	**100**	**325**	**100**	**8908**	**100**
J. Cross-Section [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Left Triangle	249	16.33	556	15.54	165	16.42	144	15.22	118	17.82	100	19.12	84	24.42	71	21.85	1487	16.69
Right Triangle	238	15.61	498	13.92	146	14.53	142	15.01	111	16.77	66	12.62	62	18.02	66	20.31	1329	14.92
Plano-convex	315	20.66	719	20.10	239	23.78	256	27.06	168	25.38	134	25.62	82	23.84	71	21.85	1984	22.27
Symmetric Triangle	201	13.18	534	14.92	169	16.82	149	15.75	93	14.05	82	15.68	44	12.79	44	13.54	1316	14.77
Trapezoid	291	19.08	557	15.57	159	15.82	144	15.22	109	16.47	80	15.30	47	13.66	65	20.00	1452	16.30
Irregular	231	15.15	714	19.96	127	12.64	111	11.73	63	9.52	61	11.66	25	7.27	8	2.46	1340	15.04
Total	**1525**	**100**	**3578**	**100**	**1005**	**100**	**946**	**100**	**662**	**100**	**523**	**100**	**344**	**100**	**325**	**100**	**8908**	**100**
K. Term. [cd]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**AU7**		**AU8**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Axial	24	1.37	50	1.21	16	1.34	13	1.19	8	0.99	11	1.65	8	1.69	8	1.86	138	1.31
Cortical Axial	7	0.40	19	0.46	13	1.09	5	0.46	8	0.99	9	1.35	3	0.63	6	1.39	70	0.66
Feather	1207	68.89	3060	73.86	812	67.89	719	65.60	565	69.67	475	71.21	299	63.08	286	66.36	7423	70.23
Hinge	260	14.84	535	12.91	132	11.04	131	11.95	81	9.99	62	9.30	55	11.60	44	10.21	1300	12.30
Inflexed	21	1.20	36	0.87	20	1.67	13	1.19	8	0.99	9	1.35	13	2.74	3	0.70	123	1.16
Plunge	48	2.74	84	2.03	25	2.09	12	1.09	16	1.97	6	0.90	10	2.11	9	2.09	210	1.99
Step	185	10.56	359	8.67	178	14.88	203	18.52	125	15.41	95	14.24	86	18.14	75	17.40	1306	12.36
Total	**1752**	**100**	**4143**	**100**	**1196**	**100**	**1096**	**100**	**811**	**100**	**667**	**100**	**474**	**100**	**431**	**100**	**10570**	**100**

Key: cp - complete and proximal flakes not subject to sampling; c – complete flakes; cd - complete and distal flakes not subject to sampling

A flake's dorsal surface retains a number of attributes that can help reconstruct the knapping methods utilised by the knappers in its production, including the proportion of dorsal cortex (Table 5-12: E), the number of dorsal scars (Table 5-12: F), and the scar orientation (Table 5-12: G). These attributes were only recorded for complete flakes in the assemblage. There are five classes of dorsal cortex that include completely cortical flakes (primary flakes), a range of partially cortical flakes (secondary flakes), and non-cortical or tertiary flakes. The pattern remains uniform over time with a slightly higher proportion of non-cortical flakes in AU2, which may indicate a period of greater reduction intensity. When this attribute is examined by raw material types, it shows a clear division between chert and shale flakes and the other raw material types. Chert and shale flakes have the highest percentage of non-cortical flakes (n=3157, 88.56% and n=1295, 85.09% respectively). In AU2, this reaches a peak with 90.10% of the chert flakes exhibiting no cortex on the dorsal surface. The frequency of primary and secondary chert and shale flakes is very low suggesting that these two raw material types were more intensely reduced than other material types. This finding correlates well with the lower incidence of cortical platforms on chert and shale flakes. The presence of primary and secondary chert and shale flakes provides evidence that some cores were initially reduced at the site; however, the low numbers of these flake classes considered with the high number of chert varieties is a good indication that some previously-knapped cores also were brought to the site for further reduction. Nearly a fifth of the martite-goethite flakes are completely cortical (n=33, 19.76%). There are also fairly high proportions of goethitised shale, BIF, quartz, and vitreous goethite primary flakes. The higher frequency of primary and secondary flakes of these coarser-grained and widely available raw material types suggests that they were not intensely reduced and that all stages of core reduction would have generally taken place on-site.

For all complete flakes, the number of dorsal scars was counted. In the sample, there is a range from zero (for completely cortical flakes) to 12 dorsal scars. Most flakes in the assemblage have between one and three scars, and flakes with four or more scars become increasingly infrequent. Earlier in the sequence, there is a higher proportion of flakes with one to two scars, and in AU2 and AU1 there is a considerably higher frequency of flakes with three scars. In the late Holocene layers, there is a higher abundance of chert and shale flakes with three and four dorsal scars as compared with the other material types. This suggests that there was greater reduction intensity during the later stages of occupation.

The orientation of the negative flake scars provides an additional means of evaluating how cores were reduced. There is a predominance of unidirectional flake scars, demonstrating that knappers generally preferred to remove flakes from one platform using the same orientation. Rotated cores account for nearly half of the assemblage; yet, flakes with rotated scars account for under 15% of the assemblage and there are higher frequencies in AU2 and AU1. This suggests that even when knappers rotated their cores, they typically reduced only a single core face at time in a unidirectional manner. As such, only the initial flakes would have yielded rotated scars if the new core face intersected a previously knapped surface. For nearly a fifth of the flakes, the orientation could not be determined with certainty and the orientation was recorded as indeterminate. These specimens occurred within each raw material type.

While quantitative attributes can be used to explore patterns of flake form, a range of qualitative attributes were also recorded in order to characterise the morphology of complete flakes (Table 5-12: H-J). As was indicated by the parallel index, the flake form attribute shows that most flakes in the assemblage expand away from the platform and 26.12% contract from the platform. This remains relatively constant throughout the sequence, with a slightly lower frequency of contracting flakes in the late Holocene layers, complemented by a slight increase in sub-parallel forms. Other flake forms, such as sub-parallel, parallel, or leaf-shaped, occur relatively infrequently in the sample. Amongst the raw material types, chert has a slightly higher frequency of distally expanding flakes and a lower

proportion of distally contracting flakes; although, chert flakes still follow the general trend for the assemblage. Quartz flakes have the highest incidence of distally contracting forms (30.04%, n=408). Sub-parallel flakes occur in all raw material types (apart from vitreous goethite) and there are similar proportions (7-8%) in BIF, chert, goethitised shale, and shale. Quartz and martite-goethite have a slightly raised frequency of sub-parallel flakes (11.84% and 10.18% respectively).

Over half of the complete flakes exhibit straight profiles and there is only minor variation over time, with slightly lower frequencies in AU8 and AU7 and a peak in AU6. Concave profiles are second in abundance, followed by flakes with convex profiles. Twisted profiles are rare. Amongst the raw material types, martite-goethite flakes have a slightly higher incidence of straight profiles and goethitised shale has a greater frequency of convex profiles than the averages for the assemblage. These differences may relate to these specific raw material types and how they fracture.

There is a high degree of variation in flake cross-section, with a relatively similar proportion of flakes in each category. Over time, the distribution remains relatively consistent. When the data is examined for blades, there is a higher frequency of specimens with a symmetric triangle cross-section (36.66%), followed by trapezoidal cross-sections (22.51%). When cross-sections are compared by platform type, winged platforms show different patterns than all other platform types in the assemblage, which are dominated by triangular cross-sections. Flakes with winged platforms have the highest frequency of trapezoidal cross-sections (26.58%) and lowest proportion of triangular cross-sections (22.15%). Plano-convex cross-sections are also most common amongst flakes with winged platforms (37.97%). Half of the complete spalls have symmetric cross-section, with the majority of the remainder having trapezoidal cross-sections (41.18%). Cross-section shape is useful for investigating blank selection among blade and spall-rich assemblages (*e.g.*, see Cropper 2011a), but in this flake-based assemblage it reveals little about the technological strategies.

The termination was assessed for 8908 complete flakes and 1662 distal flakes that are longitudinally complete and not subject to sampling, yielding a total sample size of 10,570 artefacts. Feather terminations are predominant and account for between 63.08% and 73.86% of the sample in each analytical unit. There are a remarkably similar number of hinge and step terminations in the assemblage. Early in the sequence there is a greater frequency of step terminations, and this decreases considerably in AU2 and AU1. AU1 has the greatest frequency of hinge terminations, and this reduces slightly in the preceding phases of occupation. Plunge terminations are infrequent and there are fairly constant proportions over time. This is also true of axial and cortical axial terminations. Axial and cortical axial terminations are slightly more common amongst quartz flakes, while they are less commonly found on shale and chert flakes. Axial terminations are often associated with bipolar reduction and this technique may have been useful for reducing small quartz cobbles. Plunge terminations are least common on coarser-grained materials, such as BIF and martite-goethite. This may also be due to the fact that BIF and martite-goethite cores were generally larger and there would have been less likelihood of an accidental plunge termination. Amongst the BIF and martite-goethite flakes, step terminations occur at a higher frequency and this is also likely related to the knapping qualities of these materials. Complete flakes with plunge, axial, and cortical axial terminations have higher average external platform angles (*ca.* 81-83°) than flakes with hinge, feather, inflexed, and stepped terminations (*ca.* 74-75°). This may indicate that there is a greater chance of plunge or axial terminations if higher external platform angles are utilised.

Retouched and Utilised Artefacts

The Jundaru assemblage includes a large number of retouched and utilised artefacts, and the distribution of the various subtypes is presented in Table 5-13 below. The 1018 artefacts recovered from the excavation comprise 3.89% of the assemblage (excluding surface artefacts). The proportion of retouched artefacts varies through the sequence and is at its peak during the initial occupation in AU8 (6.8%). From AU8 there is a minor decline in AU7 (5.96%) followed by a sharp fall in AU6 (2.96%) that continues to AU4 (1.62%) with a slight rise in AU3 (2.16%). The proportion of retouched artefacts increases considerably in AU2 (4.25%) from AU3, continuing into AU1 (5.45%). One possible factor that may have affected the data was that excavation of Units 8, 10, and 11 was not continuous, and artefacts were only recovered from the top of the sequence for Unit 8 and the bottom of the sequence for Units 10 and 11. When the artefacts from these excavation units were filtered from the data, the same pattern was found, but it was even more exaggerated with the proportion of retouched artefacts reaching 8.63% in AU8 and remaining largely unchanged in the uppermost analytical units due to the larger number of artefacts. This data indicates that retouched artefacts were an important and constant part of the flaked stone assemblage, and there was not a proportional increase of retouched artefacts when formalised implements, such as backed artefacts and tulas, were introduced.

By absolute count, the majority of retouched and utilised artefacts are from the late Holocene layers of the site, but there remain small samples in each of the analytical units. The retouched artefacts from the initial half of the occupation are particularly important because few sites have significant numbers of retouched artefacts dating to the Pleistocene and this data will help gain a better understanding of the manufacture and use of retouched artefacts during this time. The following section discuss patterns of formalised tool manufacture and chronology as well as the broader edge modification analysis of both formal and non-formal retouched and utilised artefacts.

Formalised Retouched Artefacts

Formalised retouched artefacts include specimens that can be further classified based on specific retouching technologies used in their manufacture (*e.g.*, backing and burination) or according to distinctive and repeated forms (*e.g.*, tulas, endscrapers, burrens, and backed artefacts). With few exceptions, formalised retouched artefacts only begin to appear during the mid-Holocene (AU3) at Jundaru. The formalised tool types included backed artefacts, tulas, burrens, eloueras, scrapers, and burins. The timing of the first appearance of many of these formalised implements, particularly backed artefacts, tulas, and burrens, and eloueras, is an ongoing focus of Australian archaeology. The provenance of the artefacts indicates that backed artefacts became an integral part of the tool-kit in the mid-Holocene, possibly around 5,000 years ago. The occurrence of scrapers appears to be concomitant with backed artefacts; however, tulas, burrens, eloueras, and burins appear considerably later, by no earlier than 1000 years ago.

Table 5-13 Distribution of retouched and utilised artefacts by analytical unit, Jundaru rockshelter

Ret. Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
Subtype	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*108*	*39.27*	*194*	*44.50*	*38*	*64.41*	*29*	*64.44*	*26*	*78.79*	*25*	*56.82*	*37*	*66.07*	*39*	*55.71*	*496*	*48.72*
Alternate Edge	2	0.73	3	0.69	1	1.69	1	2.22	3	9.09	0	0.00	1	1.79	1	1.43	12	1.18
Alternating	15	5.45	26	5.96	2	3.39	3	6.67	5	15.15	3	6.82	4	7.14	4	5.71	62	6.09
Bifacial	0	0.00	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.43	2	0.20
Unifacial	91	33.09	164	37.61	35	59.32	25	55.56	18	54.55	22	50.00	32	57.14	33	47.14	420	41.26
Utilised Artefact	*100*	*36.36*	*130*	*29.82*	*11*	*18.64*	*16*	*35.56*	*7*	*21.21*	*18*	*40.91*	*19*	*33.93*	*31*	*44.29*	*332*	*32.61*
Alternate Edge	2	0.73	2	0.46	0	0.00	0	0.00	0	0.00	2	4.55	1	1.79	2	2.86	9	0.88
Alternating	55	20.00	87	19.95	9	15.25	7	15.56	4	12.12	8	18.18	10	17.86	19	27.14	199	19.55
Unifacial	43	15.64	41	9.40	2	3.39	9	20.00	3	9.09	8	18.18	8	14.29	10	14.29	124	12.18
Asym. Backed Art. (Bondi)	*0*	*0.00*	*6*	*1.38*	*1*	*1.69*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*7*	*0.69*
Symm. Backed Art.	*29*	*10.55*	*42*	*9.63*	*8*	*13.56*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*79*	*7.76*
Crescent	7	2.55	13	2.98	3	5.08	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	23	2.26
Crescent – E	4	1.45	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.49
Trapeze	1	0.36	7	1.61	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8	0.79
Trapeze - NLB	14	5.09	12	2.75	3	5.08	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	29	2.85
Triangle	3	1.09	9	2.06	2	3.39	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	14	1.38
Backed Artefact (Ind)	*20*	*7.27*	*37*	*8.49*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*57*	*5.60*
Burin	*8*	*2.91*	*15*	*3.44*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*2.27*	*0*	*0.00*	*0*	*0.00*	*24*	*2.36*
Double	1	0.36	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Multiple Mixed	0	0.00	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Opposed	0	0.00	5	1.15	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.49
Simple	4	1.45	4	0.92	0	0.00	0	0.00	0	0.00	1	2.27	0	0.00	0	0.00	9	0.88
Transverse	1	0.36	4	0.92	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.49
Truncation	1	0.36	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Indeterminate	1	0.36	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.20
Tula	*7*	*2.55*	*2*	*0.46*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*9*	*0.88*
Functional	1	0.36	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Slug	6	2.18	2	0.46	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8	0.79
Burren	*1*	*0.36*	*1*	*0.23*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.20*
Elouera	*0*	*0.00*	*3*	*0.69*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*0.29*
Scraper	*2*	*0.73*	*6*	*1.38*	*1*	*1.69*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*9*	*0.88*
Endscraper	1	0.36	4	0.92	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.49
Side Scraper	1	0.36	2	0.46	1	1.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.39
Total	**275**	**100**	**436**	**100**	**59**	**100**	**45**	**100**	**33**	**100**	**44**	**100**	**56**	**100**	**70**	**100**	**1018**	**100**

Backed Artefacts – Artefacts exhibiting backing were recovered in AU3 through to AU1, and specimens were also recovered from the surface of the shelter (a Bondi point, a crescent, a trapeze with no lateral backing, and a backed artefact fragment). The greatest proportion of backed artefacts was in AU2 and AU1, with nine backed artefacts recovered from AU3. The lowermost specimens were both recovered from between 60 to 65cmbd and include a bondi point (Artefact 4522; U1-L07) and a trapeze (Artefact 13,216; U3-L08) that was collected *in situ* at 60.5cmbd. There is no radiocarbon date for these contexts, but a charcoal sample collected from 56cmbd within Feature 10 was dated to 3899±45 cal BP. The depth of these artefacts indicates that they are between four and nine centimetres deeper than the charcoal sample; therefore, they pre-date Feature 10. Previously, PAD 3 provided the earliest evidence of backed artefacts at Hope Downs 1 with four backed artefacts recovered from Feature 1, which was dated to 4686±78 cal BP. One additional backed artefact was also found in the sediment below Feature 1 at PAD 3. The age-depth curve suggests that the backed artefacts at Jundaru are of a similar antiquity or even slightly older, possibly pre-dating 5000 cal BP. This age estimate should be viewed cautiously due to the lack of chronological resolution. The backed artefacts identified on the surface of the rockshelter provide evidence that these tools continued to be manufactured until the recent past, as a radiocarbon date from Feature 1 (U4-L1.1; 8cmbs) yielded a date of 176±86 cal BP.

There are seven Bondi points in the excavated assemblage (Figure 5-23: a-b), as well as one specimen that was recovered from the surface of the rockshelter (Artefact 26,168). The artefacts from the excavation are all from AU2 with the exception of Artefact 4522, which is from AU3. The complete Bondi points in the assemblage generally have quite elongated forms (Figure 5-24); although, Artefact 547 trends towards a more squat form, measuring 17.86-x-7.29mm. There is overlap between the forms of Bondi points and elongated crescents, with the latter being narrower. In each instance, the backing has created a pointed tip and an asymmetrical form. There is a comparatively even distribution between artefacts with backing on the right (n=3) and left (n=5) margins. Most of the backing was created through dorsal retouch; although, bifacial and alternating backing is also present in the sample.

The five complete Bondi points were submitted for usewear analysis, and only Artefact 22,255 provided any evidence (although not conclusive) of possibly having being used as a tip for a projectile or similar implement (Fullagar 2013). The presence of such artefacts at the rockshelter suggests that maintenance and repair of projectiles occurred at the site. Some of the artefacts had poorly-developed usewear (*e.g.*, Artefact 547) and while function was found to be uncertain, Fullagar (2013) suggested that it may have been used for cutting or piercing soft tissue, such as skin. Similarly, Artefact 24,019 has usewear that appears to have derived from cutting soft tissue; this artefact was likely hafted (Fullagar 2013). In contrast, Artefact 19,454 was found to have usewear on the distal tip that is typical of use as a graver, and the chord exhibits usewear indicative of wood scraping (Fullagar 2013).



Figure 5-23 Bondi points from Jundaru rockshelter: a) Artefact 22,255 and b) Artefact 15,343; elongated crescents: c) Artefact 15,463, and d) Artefact 10,039; crescents: e) Artefact 22,512 and f) Artefact 10,524; trapezes: g) Artefact 24,666 and h) Artefact 24,356; trapezes with no lateral backing: i) Artefact 6095 and j) Artefact 10,072; triangles: k) Artefact 11,076 and l) Artefact 21,631

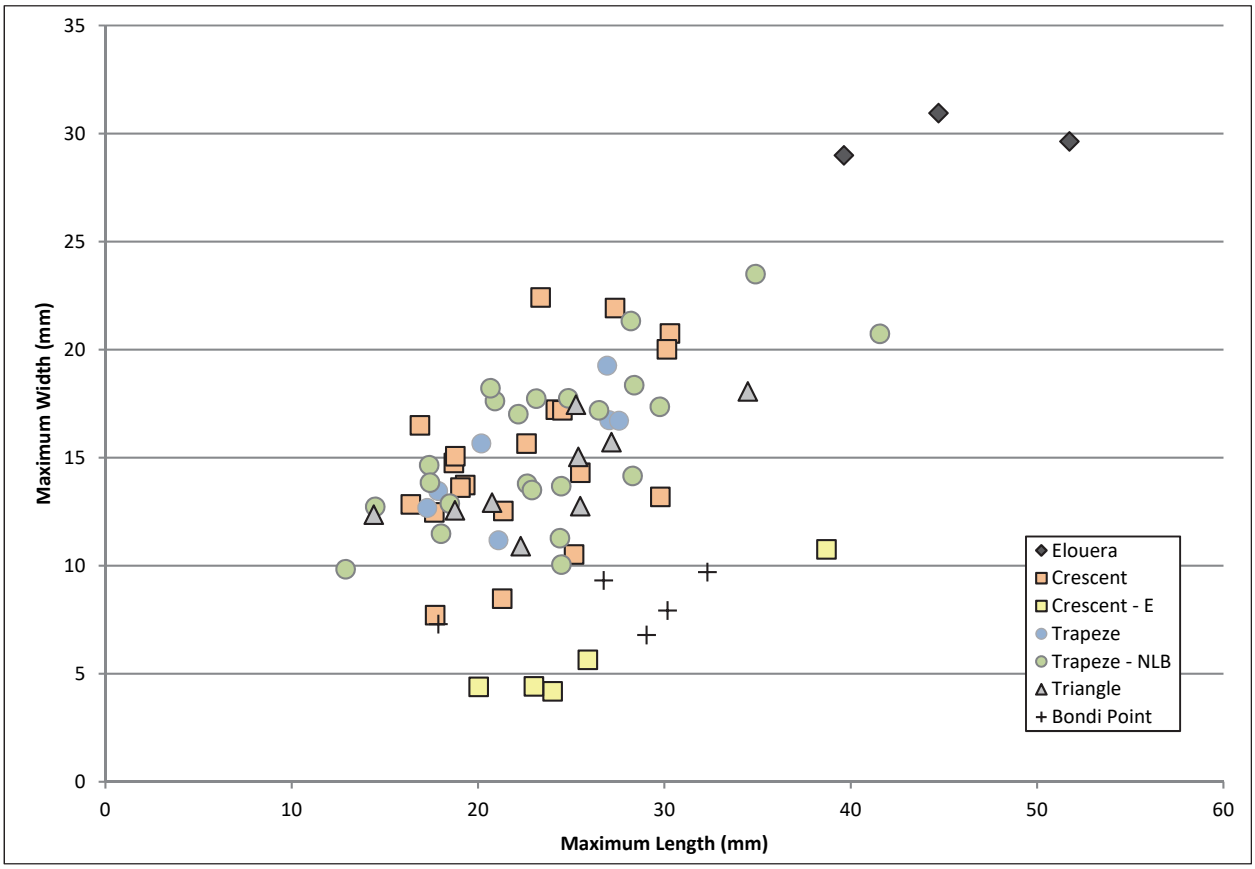

Figure 5-24 Size distribution of complete backed artefacts and eloueras from Jundaru rockshelter

There are five elongated crescents in the assemblage (Figure 5-23: c-d), and all occur within AU1 except for Artefact 15,463, which is in the upper layer of AU2. What differentiate these specimens from the typical crescents are their elongated forms. All of the specimens are long and narrow, and when their length and width are plotted against that of crescents, they form a distinct population (see Figure 5-24). The shape and angle of the pointed ends of elongated crescents bear much more similarity to Bondi points than to crescents; however, their symmetrical form differentiates them from Bondi points. In the sample plotted in Figure 5-24 there is one outlier, Artefact 10,214, which has a slightly lower elongation ratio (maximum length/maximum width). This artefact has a ratio with a value of 3.6 whereas the other elongated crescents have values between 4.6 and 5.7. The crescents have much lower values, ranging between 1.0 and 2.3. This artefact is still clearly more elongated than the crescents; hence, it is still reasonable to classify this artefact as an elongated crescent. Four of the five artefacts have backed edges on the right margin and it is continuous along its entire length. Artefact 14,392 is the only elongated crescent to have been backed along the left margin. This artefact is unusual in that the knapper selected a flake with a twisted profile as its blank (most other flakes are very straight).

All of the elongated crescents were submitted for usewear analysis and they all show evidence of the tips having been used (Fullagar 2013). Artefacts 10,039, 10,214, 14,392, 15,463 were suggested to have been used as an awl or other tool for piercing soft tissue, while Artefact 10,287 has usewear that indicates it was used in a drilling or graving motion (Fullagar 2013). Fullagar (2013) also suggests that Artefact 15,463 may have been used as a projectile or an awl.

There are 23 crescents in the assemblage and they are the second most abundant symmetrical backed artefact type (Figure 5-23: e-f). While all the artefacts in this group are crescent-shaped, there still remains a fair amount of variability and some have slight asymmetry. As in Figure 5-24 illustrates, the complete crescents have quite a similar range of lengths; however, there is greater variation in their widths. Four of the crescents have widths greater than 20mm, and they form a discrete group within Figure 5-24. Two narrow crescents, with widths less than 10mm, also are outliers and fall between the main group of crescents and elongated crescents. These two artefacts are considerably shorter than the elongated crescents; therefore, they have been classified as crescents. Despite their narrow width, they also are relatively short causing their elongation ratios also fall within the upper range of the other crescents.

On the 20 complete crescents, there is a nearly even split between those backed on the left margin (n=11) and those backed on the right margin (n=9). However, when the broken specimens are also included, there is a much higher proportion with backing on the left (n=14) than right (n=9) margin. The backing is principally dorsal, with three instances of bifacial backing, one instance of ventral backing, and one area of alternating backing. Where the curved backed edge meets the unmodified straight lateral edge (or chord), tips are created. On some artefacts the tips are rounded over through retouch (*e.g.*, Artefact 7297), whereas the retouch has formed extremely sharp, delicate tips on other specimens (*e.g.*, Artefact 10,524). Artefact 10,662 may provide a clue as to the variation in the shape of some of the crescents. The distal tip of this artefact is sharply-pointed with an angle of approximately 50°, while the proximal end is slightly obtuse (*ca.* 100°). This slightly asymmetrical artefact appears to have been repaired, with the proximal end having been broken at some point, and having been reworked to a more obtuse angle. This artefact could have been a crescent originally, but it is also possible that it could

have been another form of symmetrical backed artefact, such as a trapeze, and its original shape has been obscured by later retouch. Where both ends had received damage, the tips would have a more rounded appearance and the artefact would be less elongated.

The 20 complete crescents were submitted for usewear and all show evidence of use on the chord (Fullagar 2013). Most specimens also exhibit usewear on the tips, and several specimens show possible impact fractures, including burination (*e.g.*, Artefacts 12,389, 14,164, 14,762, 22,512, and 23,849; Fullagar, this volume). Fullagar (2013) suggests that four of the specimens may have been hafted as the tip of a projectile or a thrusting implement, and that two specimens may have been hafted as a barb on a projectile. He suggested that both a projectile tip and barb were possible uses for Artefact 22,512, while Artefact 14,164 is unlikely to have served such a function (Fullagar 2013). The latter crescent has burin facets along the chord, and the usewear is indicative of woodworking (Fullagar 2013). It is possible that this artefact could have been recycled after it was de-hafted.

The most numerous symmetrical backed artefact type is the trapeze with no lateral backing (trapeze – NLB; Figure 5-23: i-j), with 29 specimens identified in the excavated assemblage as well as one artefact recovered from the surface of the rockshelter. These backed artefacts typically have distal and proximal oblique truncations, giving them a trapezoidal form. However, as their name suggests, they lack of backing along the short lateral margin opposite the chord, which is what differentiates them from a standard trapeze. As a group, the trapezes with no lateral backing are fairly standardised both in size and form. Most complete specimens range in length between 17.37 and 29.75mm, but there are two outliers on either side of this range with a minimum length of 12.89mm and a maximum length of 41.56mm. The width shows a consistent increase from the minimum value (9.83mm) to the maximum value (23.49mm), with an average of 15.47mm. This range overlaps with that for trapezes and crescents, which have average widths of 15.00mm and 15.04mm. The similarity in the average widths of these three backed artefact types may indicate that this was an important attribute to the knapper. It is possible that the trapezes with no lateral backing were not backed on the lateral margin because doing so would reduce their width beyond what was deemed acceptable. Triangles are slightly narrower, with an average width of 14.19mm.

The trapezes with no lateral backing include three artefacts that are only backed at either the distal (Artefact 7855) or proximal end (Artefacts 364 and 12,312). Both Artefacts 364 and 12,312 have unmodified hinge terminations at the distal end, and it is possible that this was considered a suitable edge and that backing was not required. There are also five proximal or distal fragments that bear an oblique truncation and no lateral backing; hence, they were included in this backed artefact subtype. It is not clear if these artefacts were used as they are, were discarded or lost in a partially completed state, or are broken. Artefacts 7855 and 9492 show some usewear, suggesting that at least these two artefacts were utilised (although they were not submitted for formal usewear analysis). Once again, the dorsal backing dominates the sample, with rare instances of alternating, bifacial, and ventral backing. The backing on these artefacts is essentially oblique truncations, and in most cases it is rectilinear. There are occasional specimens that have backed edges that are concave, convex, or even nosed. There is a higher proportion of complete artefacts with backing on the right margin (n=13) than the left margin (n=9), which goes against the general trend for backed artefacts where left backing is slightly more common.

Twenty-three trapezes with no lateral backing were submitted for usewear analysis, and most specimens exhibited usewear on the chord and on at least one tip (Fullagar 2013). Six of the artefacts had minor tip damage and three had usewear indicative of their likely use as barbs (Fullagar 2013). In general, this group of symmetrical backed artefacts shows a distinctly different pattern of usewear traces than the crescents, which had a much higher incidence of usewear typical of projectile tips or barbs.

Trapezes with backing along the entire margin opposite the chord are less common, and there are nine examples in the assemblage, including one specimen collected from the surface of the rockshelter (Figure 5-23: g-h). There is some continuity between trapezes and crescents, and perhaps there is a retouch continuum between the various backed artefact forms. Some of the specimens show quite sharp angles between the distal and proximal oblique truncations and the lateral backing, whereas it is slightly rounded on others. Where this rounding occurs, it has been noted that these artefacts may be transitional between crescents and trapezes (*e.g.*, Artefact 15,102 and 15,670). Two of the complete specimens are asymmetrical, with a straight truncation at one end, and an oblique truncation at the other end. Similar artefacts were observed amongst the crescents, but these artefacts retain some angularity; hence, they have been classified as trapezes. While they have asymmetrical forms, they do not bear resemblance to Bondi points, but share more similarities with other symmetrical backed artefacts. Of the six complete specimens, four exhibit left lateral backing and two have right lateral backing. The backing is predominantly dorsal, but there are four edge modification areas with bifacial backing, and one with ventral backing. Most of the backing is rectilinear, but there is some variation with concave, convex, and denticulate delineation.

Usewear analysis of six complete trapezes shows that three specimens exhibit usewear on the chord and tip, while the other three specimens have minor tip damage (Fullagar, this volume). This pattern repeats that for trapezes with no lateral backing, suggesting that these artefact types were used in a similar manner.

There are 14 triangles in the assemblage (Figure 5-23: k-l), including nine complete specimens, three distal fragments, one proximal fragment, and one left fragment. All of the broken artefacts only have small breaks allowing their classification as triangles. The complete artefacts have tight distribution of both length and width (Figure 5-24) with the exception of one slightly larger specimen (Artefact 6457). Triangles have backing forming two oblique truncations at the distal and proximal ends, meeting at an apex. Typically the triangles are symmetrical, but some specimens are slightly asymmetrical. Most of the specimens have a very straight chord, but several specimens show that the knapper selected flakes that have a sinusoidal edge, with either a concavity (*e.g.*, Artefacts 6457 and 11,911) or convexity (*e.g.*, Artefact 15,344) at the midpoint. There is an unusually high proportion of left backing amongst the complete triangles (n=8) with one specimen exhibiting backing along the right margin. When the incomplete specimens are also considered the pattern is less extreme as there are ten artefacts with left backing and four with right backing.

Artefact 14,148 is atypical and possibly should not be included amongst the triangles; yet, it clearly has a triangular shape that was created through backing so it is included here. The distal right and left edges were each backed, creating a sharp pointed tip at the distal end. The proximal end is roughly broken, and according to Fullagar (2013), this complex break may have occurred while in the haft. Unusually, it is the sharp tip created

by the backing that appears to have been utilised, while the opposite end appears to have been hafted. The ventral surface shows a distinct line across the artefact where residues are adhering to the artefact, and this may delimit the extent of haft. The tip of the artefact exhibited usewear indicative of drilling or graving of wood (Fullagar 2013).

Usewear analysis of the other complete triangles indicates that two specimens were likely used as barbs (Artefacts 6457 and 11,076) and Artefact 21,631 may have been a projectile tip (Fullagar 2013). Three other triangles (Artefacts 809, 4375, and 22,507) exhibit minor tip damage, while the remaining three specimens (Artefacts 10,774, 11,911, and 15,344) have minor usewear on the chord and tip (Fullagar 2013). Apart from Artefact 14,148, the triangles have quite similar usewear patterns to the crescents.

Eloueras – All three eloueras occur in AU2, with Artefact 6680 recovered from Unit 2 (*in situ* 41.5cmbd) and Artefacts 12,306 (*in situ* 46cmbd; Figure 5-26: a) and 12,308 from Unit 3 (*in situ* 46cmbd). The context of these artefacts suggests that they were discarded no earlier than 1000 years ago. Once again, the initial occurrence of eloueras is similar to tulas and burrens, but slightly later than backed artefacts (*ca.* 5,000 years ago). All three eloueras are complete; although, Artefact 6680 has a small fragment missing from the apex of its backed edge. This break may be due to damage while the artefact was hafted (Fullagar 2013). This brown shale specimen has backing along the right lateral edge and it is assumed to have had a crescent shape. The backing is bifacial along the proximal portion, but along the distal portion of the backing it is only dorsal. Artefact 12,306 was produced on a BIF flake and has backing along the distal and proximal left edges, forming a crescent shape. The artefact also has alternating retouch along the right lateral edge. Artefact 12,308 was produced on the proximal fragment of a brown shale flake. Perhaps due to its natural shape, backing only occurs on the distal left edge and it characterised as dorsal stepped and scaled SAR. As Figure 5-24 illustrates, there is a clear differentiation in the size of eloueras and backed artefacts. The eloueras were submitted for usewear analysis, and Fullagar (2013) found that they exhibited usewear consistent with woodworking. Fullagar (2013) suggests that Artefact 12,308 may not have been hafted but used as a hand-held scraper. Both Artefacts 6680 and 12,306 show traces of resin that indicate they were utilised within hafts.

Tulas – Nine tulas were identified in the excavation, with seven specimens recovered from AU1 and two specimens from AU2. In AU2, Artefact 14,937 was recovered *in situ* at a depth of 42cmbd (U4-L04) and Artefact 20,138 was recovered from between 40 and 45cmbd (U5-L04). The initial appearance of tulas is much later than backed artefacts, and based on the age-depth relationship of the ACHM radiocarbon series, it is estimated that they only occurred in the archaeological record within the last millennium. This corresponds to the chronology of tulas at HD07-3A-03, where they were only present during the last 600 years of the occupation.

Eight of the tulas in the assemblage were classified as having slug or exhausted forms (Figure 5-26: c-d), including one incomplete specimen (complete length, right fragment). There sample also contains one much larger artefact that is considered to be a tula in the early stage of reduction rather than a tula slug. Artefact 10,140 is a functional tula that was produced from a large pink and green banded chert flake (Figure 5-26: b). The artefact is large (38.04-x-43.34-x-16.36mm) and it retains its broad and thick plain platform (32.05mm wide and 13.99mm thick) and prominent bulb of percussion. The artefact has only been marginally reduced with continuous retouch along the right lateral edge, distal edge, and left lateral edge. While the artefact is much larger than the tula slugs (Figure 5-25), based on its prominent bulb of percussion and the continuous convex dorsal retouch, the artefact was considered to be a tula in the early stage of reduction (*i.e.*, a functional tula). There appear to be at least two stages of retouch, with the most recent retouch scars showing no patination. Unlike the tula slugs in the assemblage, the retouch along the working edge on Artefact 10,140 is not stepped. Fullagar (2013) studied the artefact for evidence of usewear and found that the second stage of retouch may have removed most of the more developed usewear; however, there remained enough usewear to provide evidence that this artefact had likely been hafted and used to adze or scrape wood.

The tula slugs show some variation in the morphology with their working edges generally either retouched to an oblique angle or straight across the width of the tula. Artefacts 101, 10,356, 14,937, and 18,973 have had one side retouched further than the other, creating an angled working edge in relation to the platform. Artefacts 9789, 14,368, and 21,732 have retouch that extends straight across the distal margin. The working edge of the tulas varies from concave (Artefacts 101, and 10,356) to convex (Artefacts 10,140, 14,937, and 21,732), but rectilinear delineation (Artefacts 9789, 14,368, 18,973, and 20, 138) is slightly more common. All of the slugs have steep stepped and scaled retouch. Artefact 21,732 is the exception as it does not exhibit stepped retouch on its working edge, but has regular scaled retouch. This specimen is slightly smaller than the other tulas, and it appears as though it could have been further reduced. As Figure 5-25 illustrates, when the maximum width and length of Artefact 31,732 are plotted against the other tulas in the assemblage, it occurs within the cluster of tula slugs; therefore, this specimen was classified as a tula slug.

For all complete tulas, the average PRI is 0.45 with a range between 0.35 and 0.59. The PRI values for tulas are not particularly high because of the large unretouched proximal margin. Amongst the tulas where the striking platform has been preserved in its entirety, there is a fairly wide range in platform dimensions. Platform width ranges from 18.04 to 32.48mm, and platform thickness ranges between 3.29 and 13.99mm. The maximum width of the tulas has a similar range to the platform width, with values falling between 18.20 and 43.34mm (Figure 5-25).

Burrens – There are two burrens in the assemblage: Artefact 3388 and 3590. Artefact 3388 was identified in lower AU1 (35-40cmbd) and Artefact 3590 was found in AU2 (40-45cmbd); hence, the first appearance of burrens at Jundaru is simultaneous with tulas. Both of the burrens are incomplete. Only the very distal tip of Artefact 3388 is missing and this specimen is nearly complete. The burren was formed by invasive stepped and scaled SAR on both the right (dorsal) and left (alternating) lateral edges. The retouch on the left edge appears to be more recent (not patinated) and forms five notches (*i.e.*, denticulate delineation). Some of the retouch scars on the right edge are patinated (at locations 6 and 7), while the scars towards the distal end are not patinated (at location 8). This suggests that there were at least two stages of reduction for this artefact. While this artefact is technically not complete, its perimeter and retouch length was still measured and it has a PRI of 0.74. The GIUR of the retouch on the left lateral edge is 1.00. The second burren in the assemblage, Artefact 3590, is a medial fragment that is longitudinally complete. The specimen exhibits long stepped alternating SAR along both the right and left lateral margins, and in both instances it is interrupted by transverse breaks at the proximal and distal ends of the artefact.

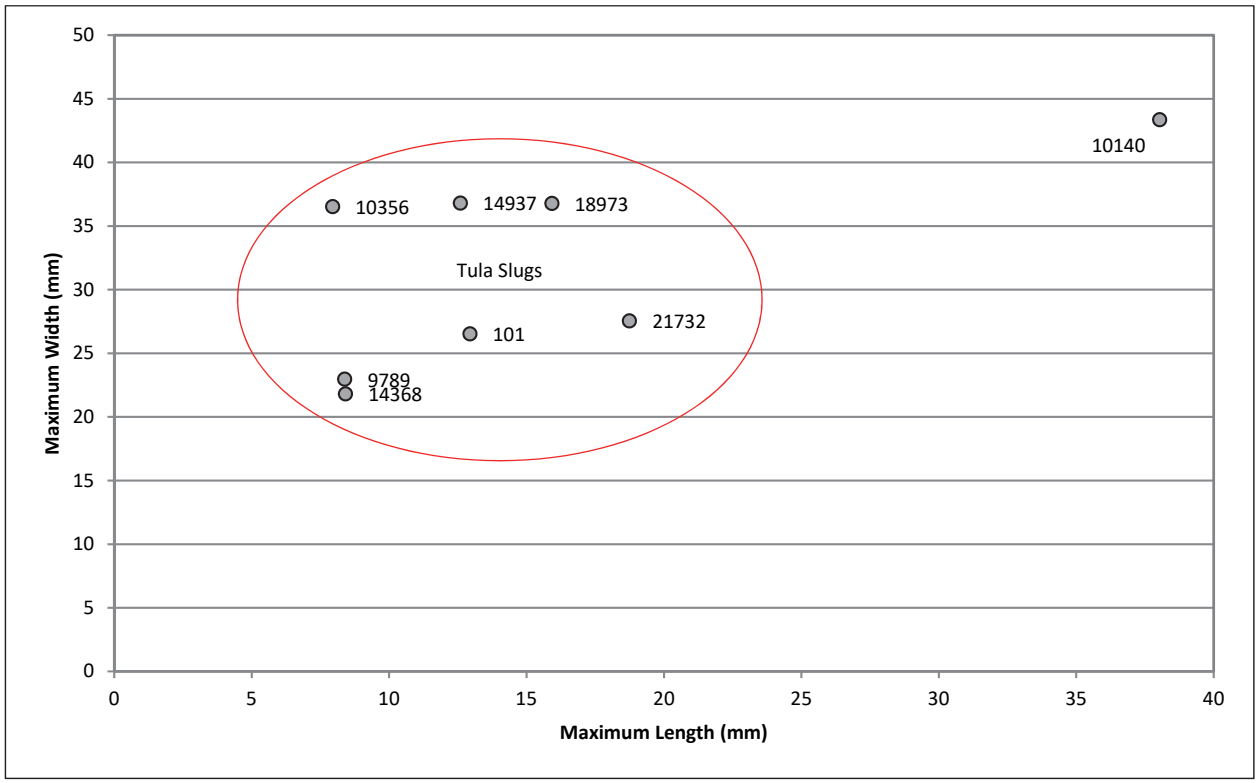

Figure 5-25 Maximum length and width of complete tulas from Jundaru rockshelter; note the cluster of tula slugs and the outlier of the functional tula (Artefact 10,140)

Burins – There are 24 burins in the assemblage and they occur predominantly in AU1 and AU2 with one outlier identified in AU6. In AU2, there are eight specimens recovered from various excavation units at depths between 45 and 50cmbd, and burins continue up throughout the sequence. While burins appear slightly earlier, their chronological distribution generally parallels that of tulas, burrens, and eloueras. The distribution of burin types is presented in Table 5-13, which demonstrates that simple burins are most common, followed by transverse burins. Two burins were classified as having an indeterminate type as the facet initiation was not preserved. In both cases, the facets occurred along the left lateral edge of the flake.

There are nine simple burins in the assemblage, in which the knapper has used an unprepared plain surface on either the distal or proximal margin from which to remove the spall along either the left or right lateral edge. The burins have between one and three facets, with most exhibiting only a single facet (n=5). Most of the facets were initiated from the distal end of the flake; two were initiated from the proximal end. Artefact 6097 is a double burin that has two simple burin edges on the distal right and left margins. At least four spalls were removed from this burin.

Transverse burins are the second most abundant type in the sample, with five specimens identified. Unlike most of the burins in the assemblage, transverse burins have had spalls removed from across either the distal or proximal margin. All of the transverse burins have facets on the distal margin, and all have only one facet with the exception of Artefact 7223, which has two facets. Four of the five transverse burins have retouch along the lateral edge just prior to the initiation of the spall. Depending on how the burins were used, this retouch may be either preparation of the striking platform or it may be a used edge and the facet may simply have been used as a means of rejuvenating or resharpening the edge.

Opposed burins have had spalls initiated from both the distal and proximal margins; therefore, they have a minimum of two burin edges. The opposed burins include a variety of forms. Artefact 6455 is an opposed burin with a double straight truncation burin at the proximal end. Spalls were also struck from the distal right margin, but the initiation has not been preserved so it is not possible to determine the burin type. The burin is highly reduced and at least six spalls were removed from the lateral margins, and two flakes were struck from the truncation along the dorsal surface. Artefact 6920 is an opposed transverse burin, with single facets on each the distal and proximal margins. Like the transverse burins discussed above, the lateral margins of this retouch were retouched prior to the removal of the spalls. Artefact 10,616 is an opposed simple burin (proximal) and oblique truncation burin (distal). This excellent specimen has three facets. Artefact 12,302 also combines a transverse burin (proximal) and a straight truncation burin (distal), each with multiple step-terminated facets. This artefact has red streaks on both the dorsal and ventral surface. The artefact appears to be reddened and crazed through heat-exposure, and one spall appears to have been removed after the heating (demonstrated by a lack of reddening). Artefact 22,104 also includes a transverse burin (distal) and it has a simple burin initiated from the proximal right margin. The transverse burin was initiated from an area of retouch on the left lateral edge.

Artefacts 823 is an interesting specimen and is classified as a multiple mixed burin as it has a dihedral burin at the proximal end and a simple burin on the right edge (Figure 5-27: c). Unusually, the knapper used the natural shape of the flake (diamond-shaped) to remove another spall from the right lateral edge. The apex of the angled edge was used as the striking platform, and the knapper removed the spall without any preparation. The spalls removed from this flake crated two burin edges or bits.

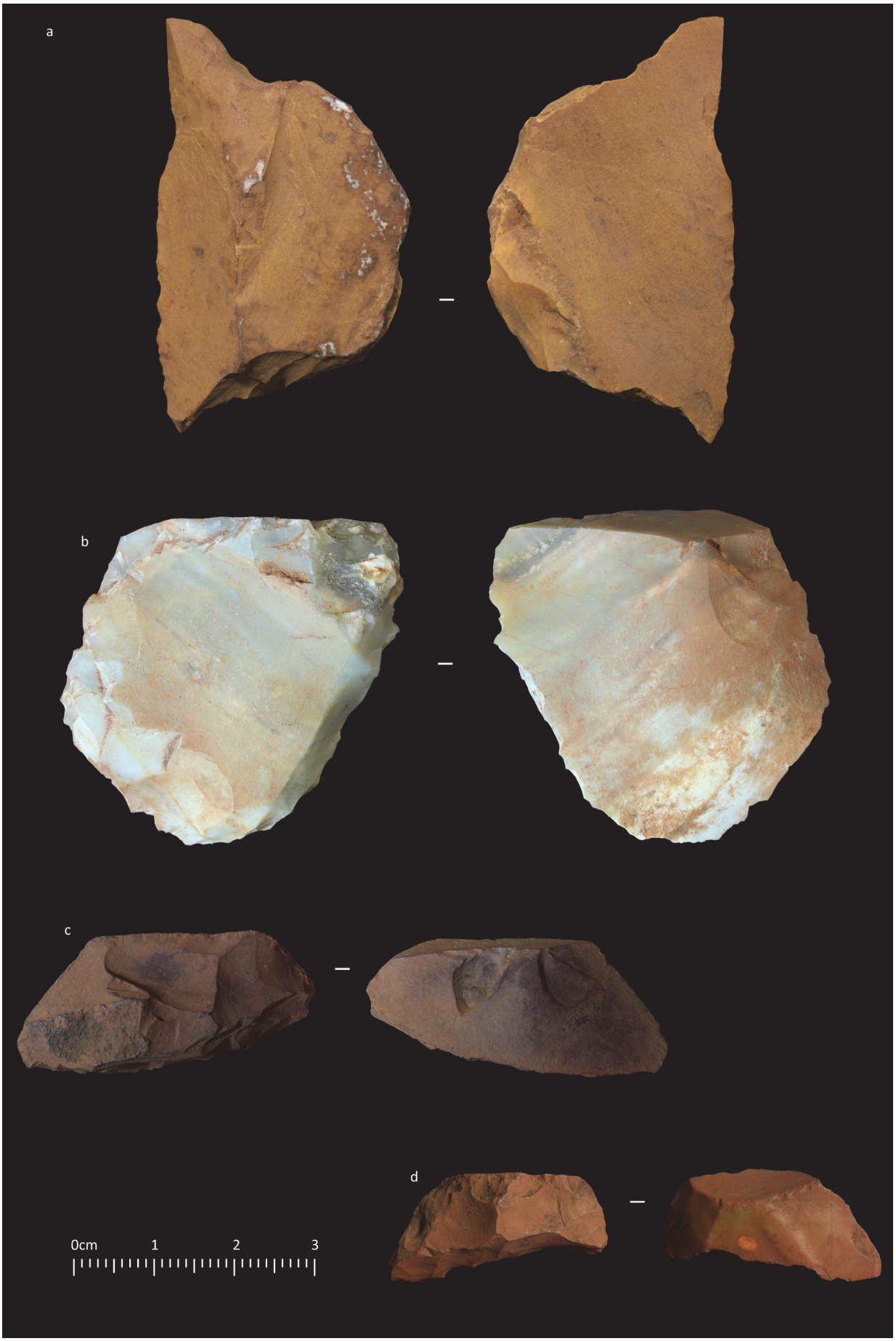

Figure 5-26 Retouched artefacts from Jundaru rockshelter: a) elouera (Artefact 12,306), b) functional tula (Artefact 10,140), c) tula slug (Artefact 18,973), and d) tula slug (Artefact 101)



Figure 5-27 Retouched artefacts from Jundaru rockshelter: a) truncation burin (Artefact 9784), b) endscraper (Artefact 12,876), c) multiple mixed burin (Artefact 823), d) side scraper (Artefact 8039), and e) side scraper (Artefact 23,854)

There is one burin on truncation (Artefact 9784), which has two facets that were initiated from the distal right margin (Figure 5-27: a). One facet runs the entire length of the flake, while the other terminates half way down with a large hinge termination. The oblique truncation was created on the distal margin and the acute angle was used as the striking platform for the burin. The proximal end has also been snapped, but this specimen has been recorded as complete as there is usewear along the snapped edge.

Fullagar (2013) analysed 12 burins and most artefacts exhibited usewear consistent with wood scraping activities, and in many instances the burin blow appears to have been used to rejuvenate the working edge. A different pattern of usewear was found on Artefact 823, which showed evidence that the two bits had been utilised, possibly for graving hard material such as wood or bone (Fullagar 2013). The use of burins as engraving tools has long been established in other countries, as has their use as cutting and scraping tools (see Barton *et al.* 1996; Stafford 1977; Tomášková 2005). Eight burin spalls were also submitted for usewear analysis and all appear to have been detached to resharpen a tool that had been used for wood scraping. Two spalls provide good evidence for their use after detachment. One specimen (Artefact 14,730) shows evidence of having been used after it was detached, and Artefact 22,505 (plunging spall) appears to have been hafted after it was detached as it has residue on its ventral surface (possibly resin).

Scrapers – There are nine scrapers in the assemblage, including five endscrapers and four side scrapers. The scrapers also predominantly occur within AU2 and AU1 with one side scraper also being identified in AU3 (Artefact 8039; *in situ* 64cmbd). The lowermost specimen extends the chronology of scrapers so that it is equal to that of backed artefacts. Seven of the scrapers are complete, but one endscraper is broken (longitudinally complete distal fragment) as is one side scraper (longitudinally complete medial fragment). Amongst the formalised retouched artefacts, scrapers are one of the least well-defined artefact types and this is largely due to the fact that there can be a continuum between retouched flakes and scrapers and it can be difficult to clearly define the two artefact types.

The endscrapers in the assemblage are a varied group, ranging in maximum length from 12.6mm (Artefact 4196) to 47.22mm (Artefact 12,876), with an average length of 24.74mm. The maximum widths are more uniform, with the exception of Artefact 12,876, which is particularly narrow (14.78mm). The three other specimens have maximum widths between 21.02 and 23.44mm. The working edge occurs on both the distal and proximal ends and with either convex or rectilinear delineations. In all but one instance (Artefact 4196, proximal edge) the retouch is dorsal and steep. Both scaled and stepped retouch was observed amongst the artefacts. Fullagar (2013) examined two of the endscrapers and found that blade-like Artefact 12,876 may have been used to scrape a resinous wood, while the small Artefact 10,530 exhibited striations and polish. Distinct residues are present on the proximal end of Artefact 12,876 (Figure 5-27: b), and they are likely the result of working resinous wood rather than residues from hafting (Fullagar 2013).

The three complete side scrapers vary in size (Artefact 8039, 37.21-x-33.08-x-10.44mm; Artefact 10,286, 27.33-x-11.83-x-4.4mm; Artefact 23,854, 21.15-x-20.29-x-5.98mm). Artefacts 8039 and 23,854 have retouched edges on the left lateral margin, and both edges have slightly concave delineations (Figure 5-27: d-e). In both instances, the retouch is long SAR with Artefact 8039 having scaled retouch and Artefact 23,854 having stepped and scaled retouch. The other two side scrapers, Artefacts 10,286 and 24,482 have slightly convex working edges that occur on the right lateral margin. Both artefacts have dorsal stepped and scaled SAR. Artefacts 8039 and 10,286 were submitted for usewear analysis, which has suggested that they were utilised for wood scraping (Fullagar 2013). Usewear on Artefact 23,854 also suggests it was used for scraping; however, Fullagar (2013) found that the retouched edge was hafted and the usewear indicative of scraping is on the opposite margin (right).

Edge Modification Analysis

The 481 complete retouched and utilised artefacts in the assemblage provide the opportunity to consider the patterns of edge modification and the techniques used in the production of retouched artefacts in particular. Table 5-14 documents the number of edge modification areas for each of the retouched or utilised artefact subtype, with a combined total of 966 edge modification areas.

Amongst the retouched and utilised artefact types, burins have the highest average number of edge modification areas, with an average of 3.55 edge modification areas per artefact. Symmetrical backed artefacts have the second greatest number of edge modification areas followed closely by eloueras. A small number of alternate edge retouched artefacts, which occur earlier in the sequence (AU5 and AU8) rival these formal tools with an average of four edge modification areas. Utilised artefacts have the lowest average number of edge modification areas.

Table 5-15 presents the edge modification types for the various retouched artefact types over time. Amongst the non-formalised retouched artefacts, regular retouch accounts for nearly two-thirds of the edge modification areas (63.36%) and usewear comprises the majority of the other edge modification areas (31.34%). Other types of retouch are rare on non-formal retouched artefacts, but include notches, retouched notches, and truncations. These patterns remain relatively consistent through the sequence. Two of the retouched artefacts have straight truncations, with one occurring at the distal end (Artefact 9790) and the other along the proximal margin (Artefact 24,476). The truncations exhibit steep retouch, but it was not characteristic of backing. Backing is the predominant edge modification type for both symmetrical and asymmetrical backed artefacts. In the assemblage backing was only identified on backed artefacts and eloueras, and it only occurs in the assemblage beginning in AU3. Backed artefacts also show a high proportion of usewear, while other forms of retouch are relatively uncommon. Apart from burins, backed artefacts are the only retouched artefact types to exhibit burin facets. It is possible that some of the facets are the result of impact fractures (see Fullagar 2013, this volume; Lombard 2005; Epstein 1963; Dockall 1997).

The burins in the assemblage show a mixture retouch types, with burination being the most common. Four instances of truncation retouch were identified, and often truncations were used to prepare an edge before removing a spall. Regular retouch is almost as common amongst the burins as burination, and this attests to the complex nature of these artefacts. Fullagar (2013) found the burins at Jundaru were used for woodworking, and it is believed that spalls were removed to rejuvenate the worn working edges, which were retouched in some cases.

Table 5-14 Number of edge modification areas on complete artefacts by analytical unit, Jundaru rockshelter

Retouched Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
Subtype	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM
Retouched Artefact	*36*	*69*	*54*	*111*	*23*	*36*	*18*	*30*	*13*	*36*	*15*	*39*	*21*	*47*	*28*	*66*	*208*	*434*
Alternate Edge	0	0	0	0	0	0	0	0	2	9	0	0	0	0	1	3	3	12
Alternating	4	11	6	20	2	6	2	2	4	9	2	10	2	6	4	14	26	78
Bifacial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	2
Unifacial	32	58	48	91	21	30	16	28	7	18	13	29	19	41	22	47	178	342
Utilised Artefact	*43*	*64*	*66*	*106*	*6*	*11*	*10*	*12*	*5*	*6*	*13*	*19*	*15*	*21*	*19*	*32*	*177*	*271*
Alternate Edge	1	3	2	2	0	0	0	0	0	0	2	7	1	2	0	0	6	14
Alternating	19	34	42	75	5	10	5	7	2	3	4	4	7	10	12	21	96	164
Unifacial	23	27	22	29	1	1	5	5	3	3	7	8	7	9	7	11	75	93
Asym. Backed Art. (Bondi)	*0*	*0*	*5*	*11*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*5*	*11*
Symm. Backed Art.	*24*	*70*	*30*	*77*	*8*	*21*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*62*	*168*
Crescent	7	18	10	21	3	7	0	0	0	0	0	0	0	0	0	0	20	46
Crescent – E	4	6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	7
Trapeze	1	3	5	20	0	0	0	0	0	0	0	0	0	0	0	0	6	23
Trapeze - NLB	11	40	8	17	3	7	0	0	0	0	0	0	0	0	0	0	22	64
Triangle	1	3	6	18	2	7	0	0	0	0	0	0	0	0	0	0	9	28
Burin	*2*	*8*	*9*	*31*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*11*	*39*
Multiple Mixed	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	1	6
Opposed	0	0	4	18	0	0	0	0	0	0	0	0	0	0	0	0	4	18
Simple	1	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0	4	9
Transverse	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Truncation	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Tula	*7*	*17*	*1*	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*8*	*19*
Functional	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Slug	6	13	1	2	0	0	0	0	0	0	0	0	0	0	0	0	7	15
Elouera	*0*	*0*	*3*	*8*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*8*
Scraper	*2*	*3*	*4*	*9*	*1*	*4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*7*	*16*
Endscraper	1	1	3	8	0	0	0	0	0	0	0	0	0	0	0	0	4	9
Side Scraper	1	2	1	1	1	4	0	0	0	0	0	0	0	0	0	0	3	7
Total	**114**	**231**	**172**	**355**	**38**	**72**	**28**	**42**	**18**	**42**	**28**	**58**	**36**	**68**	**47**	**98**	**481**	**966**

Key: n – number of complete retouched or utilised artefacts; EM – number of edge modification areas

When the edge modification types are examined without considering the retouched artefact types, there are clear patterns through the sequence. Macroscopic usewear remains a consistently high edge modification type over time, with the exception of a minor dip in AU3. When the various retouch types are considered independent of usewear, it is clear that regular retouch is overwhelmingly dominant from AU8 to AU4. Beginning in AU3 there is a slight decline with the introduction of backing, and this pattern continues to intensify. In the last two analytical units the proportion of regular retouch is further diminished by the increase of backing as well as the introduction of burination and the increase in truncations.

The attribute 'position' records whether the edge modification area occurs on the dorsal or ventral surface. Two other edge modifications positions also were often utilised: alternating (if the scars alternate between the two surfaces in a continuous area) and bifacial (if the area that exhibits scars initiated from both the dorsal and ventral surfaces).

Table 5-16 presents the distribution of retouch and usewear position by edge modification type over time. Throughout the entire sequence, dorsal edge modification is predominant and accounts for an average of 48.76% of the sample. Usewear shows a slightly different pattern to retouch, with approximately two-thirds of the usewear being alternating. There are only 15 (26.79%) instances of dorsal usewear and four (7.14%) instances of ventral usewear. When the patterns are examined for various types of retouch independent of usewear, dorsal retouch is dominant (63.77%), distantly followed by ventral retouch (21.86%). Alternating retouch (7.69%), burin edge (4.45%), and bifacial retouch (2.23%) are rare. Backing is almost exclusively dorsal, with bifacial (n=9), alternating (n=6), and ventral backing (n=3) being very rare. Each of the ten notches occurs on the dorsal surface, as do 12 of the 13 retouched notches. There is also one ventral retouched notch. Likewise, truncations are predominantly dorsal, with one exception being on the ventral surface.

Table 5-17 provides the data for the edge modification angle by retouch type (or usewear) and by analytical unit. When usewear is included in the sample, AAR is predominant and accounts for nearly three-quarters of the edge modification areas on average with a range of 63.94% to 94.12% amongst the analytical units. Usewear is predominantly acute, with 94.70% being classified as AAR and 5.30% being SAR. Six of the usewear instances classified as SAR also exhibit edge rounding. When usewear is removed from the sample, the patterns for retouch angle show that there is a much closer distribution between AAR (53.85%) and SAR (41.70%), with the burin edges being classified as not applicable due to their different retouch technique. SAR includes all backing and truncations (with one exception). Notches are predominantly acute with only one instance of a steep notch, while retouched notches are more commonly steep than acute. Acute regular retouch is by far more prevalent than steep retouch.

Edge modification extent is a qualitative attribute that considers how far the area of retouch or usewear extends towards the midpoint of the artefact, ranging from less than 1mm (for all usewear) to covering. As Table 5-18 reveals, the majority of edge modification remains close to the margins of the artefact. By definition, all usewear extends no further than 1mm from the edge of the artefact. As usewear accounts for nearly half of the sample, this category also comprises under half of all edge modification areas. Over three-quarters of all retouched areas were classified as having short extents (with usewear excluded from the sample). Long and invasive retouch are uncommon,

and covering retouch is extremely rare with two instances recorded. Most backing dramatically changes the shape of a flake, but the retouch remains close to the edge of the artefact, as the scars are very steep. As a result, all but one instance of backing has been classified as short. One elongated crescent (Artefact 10,039) has a slightly less steep backed margin allowing the flake scars to extend further towards the midline; the backing on this artefact was classified as long.

Delineation is used to characterise how the edge modification has altered the shape of an edge, with the exception of regular delineation where there edge modification follows the natural shape of the flake edge. In most cases, regular delineation occurs when the edge modification is minimal, such as in usewear and in regular retouch and this is the pattern demonstrated at Jundaru (Table 5-19). While it is not typical that usewear alone will modify the shape of a flake's edge, a small number of artefacts have utilised edges with usewear classified with delineations other than regular. In several cases, the utilised edges occurred on formalised tools, such as backed artefacts, tulas, and scrapers and the area of usewear may have occurred on a retouched edge. When usewear is removed from the sample, the patterns for areas of retouch can be explored further. The vast majority of retouch areas have regular delineations, indicating that the retouch has not changed the shape of the edge. Concave delineations are second in abundance, but they only comprise 9.79% of the sample. The frequency of regular retouch is slightly higher earlier in the sequence, but in AU2 and AU1 there is a minor drop. While concave and denticulate retouch always have been present in the assemblage, rectilinear, convex, and sinusoidal only emerge in from AU3 to AU2. Backing is predominantly rectilinear, followed by convex delineations. There are also a number of backed retouched areas with concave delineations, and those with the exceptional nosed or denticulate delineations. By definition notches and retouched notches have concave delineations.

The location of each edge modification area was assigned using a location map, making it possible to determine if there are any patterns as to where retouch and usewear occurs. Table 5-20 presents a summary of the location data by edge modification type through the sequence. Edge modification of the lateral margins alone is predominant, and over the entire assemblage, there are virtually indistinguishable frequencies between the left and right margins. Occasionally, the lateral retouch extends to either the distal or proximal edge, and this is slightly more common when the retouch is on the left rather than right edge. Distal edge modification is much more common than on the proximal edge, and only on rare instances does the retouch extend from one lateral margin, over either the distal or proximal end, and onto the other lateral margin.

Table 5-15 Edge modification types for complete specimens by analytical unit, Jundaru rockshelter

Retouched Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*69*	*29.8*	*111*	*31.2*	*36*	*50.0*	*30*	*71.4*	*36*	*85.7*	*39*	*67.2*	*47*	*69.1*	*66*	*67.3*	*434*	*44.9*
Notch	1	0.43	2	0.56	1	1.39	1	2.38	0	0.00	0	0.00	3	4.41	0	0.00	8	0.83
Retouch	42	18.1	69	19.4	28	38.8	21	50.0	23	54.7	25	43.1	26	38.2	41	41.8	275	28.4
Retouched Notch	0	0.00	4	1.13	0	0.00	3	7.14	1	2.38	2	3.45	2	2.94	1	1.02	13	1.35
Truncation	1	0.43	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Usewear	25	10.8	35	9.86	7	9.72	5	11.9	12	28.5	12	20.6	16	23.5	24	24.4	136	14.0
Utilised Artefact	*64*	*27.7*	*106*	*29.8*	*11*	*15.2*	*12*	*28.5*	*6*	*14.2*	*19*	*32.7*	*21*	*30.8*	*32*	*32.6*	*271*	*28.0*
Usewear	64	27.7	106	29.8	11	15.2	12	28.5	6	14.2	19	32.7	21	30.8	32	32.6	271	28.0
Asym. Backed Art.	*0*	*0.00*	*11*	*3.10*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*11*	*1.14*
Backing	0	0.00	5	1.41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Retouch	0	0.00	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Truncation	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Usewear	0	0.00	3	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.31
Sym. Backed Art.	*70*	*30.3*	*77*	*21.6*	*21*	*29.1*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*168*	*17.3*
Backing	38	16.4	53	14.9	14	19.4	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	105	10.8
Burin	3	1.30	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.41
Notch	1	0.43	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Retouch	6	2.60	5	1.41	1	1.39	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	12	1.24
Usewear	22	9.52	17	4.79	6	8.33	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	45	4.66
Burin	*8*	*3.46*	*31*	*8.73*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*39*	*4.04*
Burin	2	0.87	16	4.51	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	18	1.86
Retouch	4	1.73	8	2.25	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	12	1.24
Truncation	1	0.43	3	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.41
Usewear	1	0.43	4	1.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Tula	*17*	*7.36*	*2*	*0.56*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*19*	*1.97*
Retouch	13	5.63	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	14	1.45
Usewear	4	1.73	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Elouera	*0*	*0.00*	*8*	*2.25*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*8*	*0.83*
Backing	0	0.00	5	1.41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Retouch	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Usewear	0	0.00	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Scraper	*3*	*1.30*	*9*	*2.54*	*4*	*5.56*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*16*	*1.66*
Retouch	2	0.87	6	1.69	3	4.17	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	11	1.14
Usewear	1	0.43	3	0.85	1	1.39	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Total	**231**	**100**	**355**	**100**	**72**	**100**	**42**	**100**	**42**	**100**	**58**	**100**	**68**	**100**	**98**	**100**	**966**	**100**

Table 5-16 Retouch and/or usewear position and modification type by analytical unit, Jundaru rockshelter

Scar Position	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Alternating	*70*	*30.30*	*122*	*34.37*	*21*	*29.17*	*12*	*28.57*	*13*	*30.95*	*14*	*24.14*	*20*	*29.41*	*40*	*40.82*	*312*	*32.30*
Backing	3	1.30	3	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	6	0.62
Retouch	7	3.03	8	2.25	3	4.17	3	7.14	3	7.14	4	6.90	1	1.47	3	3.06	32	3.31
Usewear	60	25.97	111	31.27	18	25.00	9	21.43	10	23.81	10	17.24	19	27.94	37	37.76	274	28.36
Dorsal	*126*	*54.55*	*164*	*46.20*	*34*	*47.22*	*20*	*47.62*	*21*	*50.00*	*29*	*50.00*	*36*	*52.94*	*41*	*41.84*	*471*	*48.76*
Backing	35	15.15	48	13.52	14	19.44	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	97	10.04
Notch	2	0.87	3	0.85	1	1.39	1	2.38	0	0.00	0	0.00	3	4.41	0	0.00	10	1.04
Retouch	41	17.75	54	15.21	15	20.83	10	23.81	14	33.33	12	20.69	19	27.94	25	25.51	190	19.67
Ret. Notch	0	0.00	4	1.13	0	0.00	2	4.76	1	2.38	2	3.45	2	2.94	1	1.02	12	1.24
Truncation	2	0.87	4	1.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	6	0.62
Usewear	46	19.91	51	14.37	4	5.56	7	16.67	6	14.29	15	25.86	12	17.65	15	15.31	156	16.15
Ventral	*29*	*12.55*	*43*	*12.11*	*17*	*23.61*	*10*	*23.81*	*8*	*19.05*	*15*	*25.86*	*12*	*17.65*	*16*	*16.33*	*150*	*15.53*
Backing	0	0.00	3	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.31
Retouch	18	7.79	30	8.45	14	19.44	8	19.05	6	14.29	9	15.52	6	8.82	12	12.24	103	10.66
Ret. Notch	0	0.00	0	0.00	0	0.00	1	2.38	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Truncation	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Usewear	11	4.76	9	2.54	3	4.17	1	2.38	2	4.76	6	10.34	6	8.82	4	4.08	42	4.35
Bifacial	*1*	*0.43*	*9*	*2.54*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.02*	*11*	*1.14*
Backing	0	0.00	9	2.54	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	9	0.93
Retouch	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.02	2	0.21
Burin Edge	*5*	*2.16*	*17*	*4.79*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*22*	*2.28*
Burin	5	2.16	17	4.79	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	22	2.28
Total	**231**	**100**	**355**	**100**	**72**	**100**	**42**	**100**	**42**	**100**	**58**	**100**	**68**	**100**	**98**	**100**	**966**	**100**

Table 5-17 Incidence of acute angle retouch (AAR) and steep angle retouch (SAR) by analytical unit, Jundaru rockshelter

Retouch Angle	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AAR (<60°)	*154*	*66.67*	*227*	*63.94*	*54*	*75.00*	*37*	*88.10*	*38*	*90.48*	*51*	*87.93*	*64*	*94.12*	*88*	*89.80*	*713*	*73.8*
Notch	1	0.43	3	0.85	1	1.39	1	2.38	0	0.00	0	0.00	3	4.41	0	0.00	9	0.93
Retouch	46	19.91	65	18.31	28	38.89	19	45.24	19	45.24	19	32.76	22	32.35	33	33.67	251	25.9
Ret. Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	2.38	2	3.45	2	2.94	0	0.00	5	0.52
Truncation	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Usewear	106	45.89	159	44.79	25	34.72	17	40.48	18	42.86	30	51.72	37	54.41	55	56.12	447	46.2
SAR (>60°)	*72*	*31.17*	*111*	*31.27*	*18*	*25.00*	*5*	*11.90*	*4*	*9.52*	*7*	*12.07*	*4*	*5.88*	*10*	*10.20*	*231*	*23.9*
Backing	38	16.45	63	17.75	14	19.44	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	115	11.9
Notch	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Retouch	21	9.09	27	7.61	4	5.56	2	4.76	4	9.52	6	10.34	4	5.88	8	8.16	76	7.87
Ret. Notch	0	0.00	4	1.13	0	0.00	3	7.14	0	0.00	0	0.00	0	0.00	1	1.02	8	0.83
Truncation	1	0.43	5	1.41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	6	0.62
Usewear	11	4.76	12	3.38	0	0.00	0	0.00	0	0.00	1	1.72	0	0.00	1	1.02	25	2.59
NA	*5*	*2.16*	*17*	*4.79*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*22*	*2.28*
Burin	5	2.16	17	4.79	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	22	2.28
Total	**231**	**100**	**355**	**100**	**72**	**100**	**42**	**100**	**42**	**100**	**58**	**100**	**68**	**100**	**98**	**100**	**966**	**100**

Amongst the various edge modification types, there are some patterns in the location data; although, some types show no location preferences. Standard retouch shows relatively even proportions of right and left edge modification, accounting for approximately a third of the sample each. Distal retouch comprises another quarter of the sample, indicating that retouch on other areas, including the proximal edge, is uncommon. Usewear on the right lateral edge is marginally more common than usewear on the left margin, and there is a much lower incidence of distal usewear as compared with distal retouch. Burin facets on the right are marginally more numerous than those on the left margin, with both having been initiated from either the distal or proximal edge. Both notches and retouched notches are relatively evenly distributed between the left and right margins. Truncations were created in similar proportions on the distal and proximal margins.

Backing accounts for a significant proportion of the lateral retouch that continues either to the proximal or distal end. The data shows that 64.35% of the backing is on the left lateral edge, continuing onto the distal and (or) proximal margins. An additional 5.22% occurs only on the left edge; hence, nearly 70% of all backing is on the left margin. This is even more pronounced in the earliest stage of backed artefact manufacture, in AU3 where 85.71% of the backed areas were on the left margin. By AU1 there was an increased proportion of backing on the right margin. While this data seems to suggest that there was a strong preference for backing on the left margin, it is important to point out that these patterns reflect individual retouch areas, and often several areas of backing were carried out on each backed artefacts. When the data is compiled to compare the frequency of left or right backing for the entire backed artefact, the proportions are much closer with a slightly higher number of complete specimens with backing on the left margin (n=36) over the right margin (n=31).

Table 5-18 Edge modification extent analytical unit, Jundaru rockshelter

Retouch Extent	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
<1mm	*117*	*50.65*	*171*	*48.17*	*25*	*34.72*	*17*	*40.48*	*18*	*42.86*	*31*	*53.45*	*37*	*54.41*	*56*	*57.14*	*472*	*48.86*
Usewear	117	50.65	171	48.17	25	34.72	17	40.48	18	42.86	31	53.45	37	54.41	56	57.14	472	48.86
Short	*89*	*38.53*	*147*	*41.41*	*37*	*51.39*	*13*	*30.95*	*20*	*47.62*	*17*	*29.31*	*27*	*39.71*	*33*	*33.67*	*383*	*39.65*
Backing	37	16.02	63	17.75	14	19.44	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	114	11.80
Notch	2	0.87	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	2	2.94	0	0.00	5	0.52
Retouch	50	21.65	76	21.41	23	31.94	12	28.57	20	47.62	17	29.31	23	33.82	32	32.65	253	26.19
Ret. Notch	0	0.00	3	0.85	0	0.00	1	2.38	0	0.00	0	0.00	2	2.94	1	1.02	7	0.72
Truncation	0	0.00	4	1.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.41
Long	*14*	*6.06*	*15*	*4.23*	*9*	*12.50*	*9*	*21.43*	*2*	*4.76*	*8*	*13.79*	*3*	*4.41*	*5*	*5.10*	*65*	*6.73*
Backing	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Notch	0	0.00	1	0.28	1	1.39	1	2.38	0	0.00	0	0.00	1	1.47	0	0.00	4	0.41
Retouch	11	4.76	12	3.38	8	11.11	6	14.29	1	2.38	7	12.07	2	2.94	5	5.10	52	5.38
Ret. Notch	0	0.00	1	0.28	0	0.00	2	4.76	1	2.38	1	1.72	0	0.00	0	0.00	5	0.52
Truncation	2	0.87	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.31
Invasive	*5*	*2.16*	*4*	*1.13*	*1*	*1.39*	*3*	*7.14*	*2*	*4.76*	*2*	*3.45*	*1*	*1.47*	*4*	*4.08*	*22*	*2.28*
Notch	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Retouch	5	2.16	3	0.85	1	1.39	3	7.14	2	4.76	1	1.72	1	1.47	4	4.08	20	2.07
Ret. Notch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.72	0	0.00	0	0.00	1	0.10
Covering	*1*	*0.43*	*1*	*0.28*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.21*
Retouch	1	0.43	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
NA	*5*	*2.16*	*17*	*4.79*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*22*	*2.28*
Burin	5	2.16	17	4.79	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	22	2.28
Total	**231**	**100**	**355**	**100**	**72**	**100**	**42**	**100**	**42**	**100**	**58**	**100**	**68**	**100**	**98**	**100**	**966**	**100**

Table 5-19 Delineation of edge modification by analytical unit, Jundaru rockshelter

Delineation	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Regular	*151*	*65.37*	*229*	*64.51*	*49*	*68.06*	*33*	*78.57*	*37*	*88.10*	*54*	*93.10*	*52*	*76.47*	*89*	*90.82*	*694*	*71.84*
Retouch	41	17.75	66	18.59	24	33.33	16	38.10	19	45.24	23	39.66	18	26.47	33	33.67	240	24.84
Usewear	110	47.62	163	45.92	25	34.72	17	40.48	18	42.86	31	53.45	34	50.00	56	57.14	454	47.00
Rectilinear	*34*	*14.72*	*50*	*14.08*	*8*	*11.11*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*2.04*	*94*	*9.73*
Backing	23	9.96	40	11.27	8	11.11	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	71	7.35
Retouch	6	2.60	5	1.41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	2.04	13	1.35
Truncation	2	0.87	3	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Usewear	3	1.30	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	0.52
Concave	*11*	*4.76*	*27*	*7.61*	*6*	*8.33*	*5*	*11.90*	*3*	*7.14*	*3*	*5.17*	*12*	*17.65*	*2*	*2.04*	*69*	*7.14*
Backing	2	0.87	7	1.97	2	2.78	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	11	1.14
Notch	2	0.87	3	0.85	1	1.39	1	2.38	0	0.00	0	0.00	3	4.41	0	0.00	10	1.04
Retouch	7	3.03	12	3.38	3	4.17	1	2.38	2	4.76	1	1.72	5	7.35	1	1.02	32	3.31
Ret. Notch	0	0.00	4	1.13	0	0.00	3	7.14	1	2.38	2	3.45	2	2.94	1	1.02	13	1.35
Usewear	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	2	2.94	0	0.00	3	0.31
Convex	*23*	*9.96*	*25*	*7.04*	*4*	*5.56*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.47*	*1*	*1.02*	*54*	*5.59*
Backing	12	5.19	14	3.94	4	5.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	30	3.11
Retouch	7	3.03	4	1.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.02	12	1.24
Truncation	0	0.00	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Usewear	4	1.73	5	1.41	0	0.00	0	0.00	0	0.00	0	0.00	1	1.47	0	0.00	10	1.04
Sinusoidal	*5*	*2.16*	*0*	*0.00*	*3*	*4.17*	*2*	*4.76*	*1*	*2.38*	*1*	*1.72*	*1*	*1.47*	*0*	*0.00*	*13*	*1.35*
Retouch	5	2.16	0	0.00	3	4.17	2	4.76	1	2.38	1	1.72	1	1.47	0	0.00	13	1.35
Nosed	*1*	*0.43*	*0*	*0.00*	*1*	*1.39*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.21*
Backing	1	0.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Retouch	0	0.00	0	0.00	1	1.39	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Denticulate	*1*	*0.43*	*5*	*1.41*	*1*	*1.39*	*2*	*4.76*	*1*	*2.38*	*0*	*0.00*	*2*	*2.94*	*4*	*4.08*	*16*	*1.66*
Backing	0	0.00	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Retouch	1	0.43	3	0.85	1	1.39	2	4.76	1	2.38	0	0.00	2	2.94	4	4.08	14	1.45
Irregular	*0*	*0.00*	*2*	*0.56*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.21*
Retouch	0	0.00	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
NA	*5*	*2.16*	*17*	*4.79*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*22*	*2.28*
Burin	5	2.16	17	4.79	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	22	2.28
Total	**231**	**100**	**355**	**100**	**72**	**100**	**42**	**100**	**42**	**100**	**58**	**100**	**68**	**100**	**98**	**100**	**966**	**100**

Table 5-20 Location and type of edge modification for complete retouched and utilised flakes from Jundaru rockshelter

Location	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
RLE	*63*	*27.27*	*117*	*32.96*	*17*	*23.61*	*13*	*30.95*	*16*	*38.10*	*20*	*34.48*	*25*	*36.76*	*44*	*44.90*	*315*	*32.61*
Backing	1	0.43	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.31
Burin	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Notch	1	0.43	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	1	1.47	0	0.00	4	0.41
Retouch	18	7.79	30	8.45	7	9.72	7	16.67	8	19.05	6	10.34	12	17.65	15	15.31	103	10.66
Ret. Notch	0	0.00	2	0.56	0	0.00	0	0.00	0	0.00	2	3.45	0	0.00	1	1.02	5	0.52
Usewear	43	18.61	80	22.54	10	13.89	6	14.29	8	19.05	12	20.69	12	17.65	28	28.57	199	20.60
LLE	*64*	*27.71*	*102*	*28.73*	*23*	*31.94*	*13*	*30.95*	*11*	*26.19*	*25*	*43.10*	*29*	*42.65*	*38*	*38.78*	*305*	*31.57*
Backing	0	0.00	6	1.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	6	0.62
Notch	1	0.43	1	0.28	0	0.00	1	2.38	0	0.00	0	0.00	2	2.94	0	0.00	5	0.52
Retouch	22	9.52	30	8.45	11	15.28	5	11.90	6	14.29	11	18.97	9	13.24	17	17.35	111	11.49
Ret. Notch	0	0.00	2	0.56	0	0.00	1	2.38	1	2.38	0	0.00	1	1.47	0	0.00	5	0.52
Usewear	41	17.75	63	17.75	12	16.67	6	14.29	4	9.52	14	24.14	17	25.00	21	21.43	178	18.43
LLE + DE or PE	*29*	*12.55*	*54*	*15.21*	*13*	*18.06*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*2.94*	*2*	*2.04*	*100*	*10.35*
Backing	23	9.96	39	10.99	12	16.67	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	74	7.66
Burin	3	1.30	5	1.41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8	0.83
Retouch	0	0.00	4	1.13	1	1.39	0	0.00	0	0.00	0	0.00	0	0.00	1	1.02	6	0.62
Usewear	3	1.30	6	1.69	0	0.00	0	0.00	0	0.00	0	0.00	2	2.94	1	1.02	12	1.24
RLE + DE or PE	*20*	*8.66*	*23*	*6.48*	*2*	*2.78*	*1*	*2.38*	*0*	*0.00*	*0*	*0.00*	*2*	*2.94*	*0*	*0.00*	*48*	*4.97*
Backing	13	5.63	14	3.94	2	2.78	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	29	3.00
Burin	2	0.87	9	2.54	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	11	1.14
Retouch	2	0.87	0	0.00	0	0.00	1	2.38	0	0.00	0	0.00	1	1.47	0	0.00	4	0.41
Usewear	3	1.30	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.47	0	0.00	4	0.41
DE	*47*	*20.35*	*38*	*10.70*	*15*	*20.83*	*12*	*28.57*	*14*	*33.33*	*13*	*22.41*	*10*	*14.71*	*10*	*10.20*	*159*	*16.46*
Notch	0	0.00	0	0.00	1	1.39	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Retouch	22	9.52	19	5.35	11	15.28	5	11.90	9	21.43	8	13.79	4	5.88	5	5.10	83	8.59
Ret. Notch	0	0.00	0	0.00	0	0.00	2	4.76	0	0.00	0	0.00	1	1.47	0	0.00	3	0.31
Truncation	2	0.87	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.41
Usewear	23	9.96	17	4.79	3	4.17	5	11.90	5	11.90	5	8.62	5	7.35	5	5.10	68	7.04
PE	*7*	*3.03*	*14*	*3.94*	*2*	*2.78*	*2*	*4.76*	*1*	*2.38*	*0*	*0.00*	*0*	*0.00*	*3*	*3.06*	*29*	*3.00*
Backing	1	0.43	2	0.56	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.31
Retouch	3	1.30	8	2.25	2	2.78	2	4.76	0	0.00	0	0.00	0	0.00	3	3.06	18	1.86
Truncation	0	0.00	3	0.85	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.31
Usewear	3	1.30	1	0.28	0	0.00	0	0.00	1	2.38	0	0.00	0	0.00	0	0.00	5	0.52
DE + LLE + RLE	*1*	*0.43*	*6*	*1.69*	*0*	*0.00*	*1*	*2.38*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.02*	*9*	*0.93*
Burin	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Retouch	0	0.00	1	0.28	0	0.00	1	2.38	0	0.00	0	0.00	0	0.00	0	0.00	2	0.21
Usewear	1	0.43	4	1.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.02	6	0.62
PE + LLE + RLE	*0*	*0.00*	*1*	*0.28*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.10*
Burin	0	0.00	1	0.28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.10
Total	**231**	**100**	**355**	**100**	**72**	**100**	**42**	**100**	**42**	**100**	**58**	**100**	**68**	**100**	**98**	**100**	**966**	**100**

Key: LLE – Left Lateral Edge, RRL – Right Lateral Edge, DE – Distal Edge, PE – Proximal Edge

The quantitative retouch statistics are presented in Table 5-21, which includes the average retouch length, GIUR, and PRI. The data is presented by analytical unit, and Jundaru is one of the few sites that has a large enough sample to explore changes through time. The average retouch length was determined for 456 edge modification areas. All instances of usewear were excluded from this calculation, as many of the usewear scars were created through the use of the artefact rather than from deliberate edge modification. Burins were also excluded from the sample, as they were produced using a different retouch technique that is not suited to the same types of measurements as retouch that is perpendicular to the flake edge. The greatest average length of retouched areas occurs in AU4, and the lowest is in AU5. The sample shows that the average length of the retouch areas is higher in the Holocene analytical units (AU4-AU1) than in the Pleistocene occupation (AU8-AU5). Throughout the sequence there is considerable variation between the minimum and maximum length of the retouch areas, resulting in high standard deviation values. This is particularly true in AU4, where the maximum length is 112.43mm and the minimum length is 1.84mm. Artefact 4899 exhibits the maximum retouch length for AU4, and this specimen is not typical. The large flakes that were removed from the distal edge, continuing along the right and left margins, do not exhibit the patinated appearance of the rest of the flake. It is more likely that this flake was collected elsewhere and re-used as core. Without this unusual artefact, the average length of the retouch areas in AU4 is reduced to 20.02mm (SD=12.87), which is still the highest of all eight analytical units.

The GIUR is a method of exploring the degree of dorsal lateral edge retouch through a ratio of the retouch thickness to the flake thickness. Because the GIUR is limited to dorsal, lateral retouch, there are 172 areas of retouch suitable for this index. The average GIUR values show fluctuations through the sequence, with the lowest average value in AU5 and the greatest value in AU3. The average GIUR values increase over time, with lower values in AU8 through AU4 and higher values from AU3. The higher GIUR values coincide with the appearance of formalised retouched artefacts, and this suggests that artefacts were more intensely retouched from the mid-Holocene onwards.

Table 5-21 Summary statistics for the retouch length, GIUR, and PRI, Jundaru rockshelter

Measurement	AU	Average	Min	Max	SD	n
A. Retouch Length (mm) by AU	1	14.90	1.11	78	11.59	104
	2	15.81	1.94	77.98	12.83	156
	3	17.95	1.01	78.55	15.60	47
	4	23.71	1.84	112.43	22.37	25
	5	10.39	2.33	34.07	8.34	24
	6	13.27	2.08	46.53	10.08	27
	7	12.14	1.76	48	10.63	31
	8	12.85	1.18	33.62	8.42	42
	Total	**15.30**	**1.01**	**12.97**	**112.43**	**456**
B. GIUR Statistics by AU	1	0.56	0.16	1.00	0.26	33
	2	0.58	0.11	1.00	0.27	63
	3	0.68	0.20	1.00	0.26	10
	4	0.39	0.15	0.65	0.20	6
	5	0.34	0.10	0.64	0.18	13
	6	0.51	0.34	1.00	0.21	10
	7	0.40	0.09	0.77	0.20	17
	8	0.39	0.10	0.83	0.21	20
	Total	**0.51**	**0.09**	**1.00**	**0.26**	**172**
C. PRI Statistics by AU	1	0.33	0.02	1.00	0.21	69
	2	0.34	0.02	1.00	0.24	97
	3	0.29	0.03	0.72	0.20	32
	4	0.25	0.03	0.63	0.16	18
	5	0.17	0.02	0.48	0.13	13
	6	0.18	0.02	0.43	0.15	15
	7	0.18	0.02	0.59	0.13	21
	8	0.20	0.05	0.57	0.16	28
	Total	**0.28**	**0.02**	**1.00**	**0.21**	**293**
Measurement	**RM**	**Average**	**Min**	**Max**	**SD**	**n**
D. PRI Statistics by Raw Material	BIF	0.18	0.02	0.68	0.15	59
	Chert	0.35	0.02	1.00	0.23	137
	Goethitised Shale	0.15	0.03	0.43	0.12	16
	Martite-Goethite	0.10	0.04	0.20	0.07	6
	Quartz	0.20	0.06	0.38	0.10	9
	Shale	0.29	0.02	0.80	0.19	66
	Total	**0.28**	**0.02**	**1.00**	**0.21**	**293**
Measurement	**AU**	**Average Length**	**SD Length**	**Average Width**	**SD Width**	**n**
E. Average Retouched Artefact Size (Excluding Utilised Artefacts)	1	22.85	9.41	19.00	8.74	71
	2	26.76	11.47	19.88	10.29	106
	3	31.95	15.98	29.52	14.84	32
	4	35.94	13.71	32.90	11.96	18
	5	35.93	14.45	33.64	13.13	13
	6	39.74	15.42	35.62	16.20	15
	7	30.15	9.61	29.42	10.26	21
	8	28.27	11.96	22.53	7.57	28
	Total	**28.34**	**12.75**	**23.73**	**12.19**	**304**

The PRI is a measure of how much of an artefact's perimeter has been retouched, and it compares the combined length of the retouch areas to the perimeter length of the artefact. The PRI index was calculated for 293 complete retouched artefacts (excluding burins and utilised artefacts), and through the sequence there is an increase in the average PRI. From the initial occupation through to AU5, the PRI indicates that most artefacts had retouch along less than a fifth of their perimeter. In AU4, the amount of retouch increases and this continues through to AU1. Throughout the sample, the standard deviation values are high and this suggests that there are numerous specimens clustered at the minimum and maximum extremes. Between AU8 and AU4, there are few artefacts that have a PRI of 0.5 or greater. AU8 and AU4 have two specimens with retouch along more than half of the perimeter, there is one such specimen in AU7, and there are none in AU6 and AU5. The proportion of artefacts with retouch along at least half of the perimeter increases from the mid-Holocene (22.88% in AU3, 31.96% in AU2, and 24.64% in AU1).

As with the GIUR, the PRI increases with the proliferation of formalised artefacts into the assemblage. When the PRI is considered by retouched artefact type, the formalised retouched artefact types have consistently higher PRI values than non-formalised retouched artefacts. The average PRI is greatest for symmetrical backed artefacts (0.54), but tulas (0.45), asymmetrical backed artefacts (0.43), eloueras (0.40), and scrapers (0.38) all have much higher average values than non-formalised retouched artefacts. Through the sequence, the PRI of non-formalised retouched artefacts remains fairly constant with a range between 0.17 (in AU1 and AU5) and 0.25 (in AU4). Most analytical units have average PRI values of either 0.20 (AU8, AU3, and AU2) or 0.18 (AU7 and AU5). This data shows that these artefacts remain relatively uniform through time, and that the variation in PRI is primarily due to the influence of formalised tools from AU3 onwards. The higher average PRI value in AU4 is interesting, as this relates only to non-formalised retouched artefacts. It is possible that this represents an initial intensification of retouched artefacts

leading up to the introduction of formalised retouched artefact types.

In addition to variation through time, there is also variation in the PRI values amongst artefacts produced from different raw material types. Chert and shale artefacts have the highest average PRI values. Chert artefacts have the greatest PRI values throughout most of the sequence, particularly in from AU3 to AU1. The data shows that there is a deviation from this pattern in AU7 and AU6 where there are very low PRI values for chert (0.17 and 0.04 respectively). In AU8 there are comparable shale and chert PRI values (0.26 and 0.25 respectively), and in AU4 the single shale artefact has a much higher PRI value than the four chert artefacts (0.63 and 0.26 respectively). BIF, goethitised shale, martite-goethite, and quartz artefacts consistently show much lower PRI values through the sequence. The PRI data reiterates the findings of the raw material analysis, which indicate that chert and shale were targeted for the manufacture of retouched artefacts over lower-quality materials.

Over the course of the occupation of Jundaru, the average size of retouched artefacts changes. There is a general increase in the average size from AU8 (28.27mm long, 22.53mm wide) that peaks in AU6 (39.74mm long, 35.62mm wide) and then consistently drops for the remainder of the sequence. The average size of retouched artefacts is at its lowest in AU1, where the average dimensions are 22.85mm long and 19.00mm wide. The size of retouched artefacts in the assemblage shows a relationship with the utilisation of chert. In periods when chert use is low, the average size of retouched artefacts is greater, and when chert use increases, the average size of retouched artefacts declines.

Grindstones and Artefacts with Use Polish

Twenty-seven artefacts with evidence of grinding or polish were recovered from Jundaru, including one large lower grindstone that was collected from the surface of the shelter. This group includes a diverse array of artefacts that exhibit ground or polished surfaces, including grindstones, utilised pebbles, and one utilised quartz crystal (Table 5-22). The antiquity of seed grinding is a persistent question in arid-zone research; hence, it was deemed important to distinguish between specimens that possibly could have been used in processing seeds and those that are unlikely to have functioned in this way (*e.g.*, utilised pebbles and the utilised quartz crystal).

Table 5-22 Distribution of grindstone and artefacts with use polish by analytical unit, Jundaru rockshelter

AU	Grindstone	Utilised Pebble	Utilised Crystal	Total	
	n	n	n	n	%
Surface	1	0	0	1	3.70
AU1	6	0	0	6	22.22
AU2	5	2	0	7	25.93
AU3	6	2	0	8	29.63
AU4	2	0	0	2	7.41
AU5	0	1	0	1	3.70
AU6	0	0	1	1	3.70
AU7	0	0	0	0	0.00
AU8	0	1	0	1	3.70
Total	**20** **74.07%**	**6** **22.22%**	**1** **3.7%**	**27** **100%**	**100** -

Grindstones – Twenty grindstones were identified in the Jundaru assemblage. The majority of the grindstones are believed to have been used as lower grindstones, given their size and shape (n=18). There are two specimens that were likely used as mullers (in AU3 and AU2). As Table 5-22 demonstrates, grindstones are present from AU4 onwards. The lowermost grindstones were recovered *in situ* between 73cmbd (Artefacts 17,795) and 72.5cmbd (Artefact 25,052) from two different areas of the excavation trench (U4-L10 and U8-L09 respectively). The depth of these two specimens indicates that they were discarded at the site slightly earlier than 7686±34 cal BP. The large surface specimen (Artefact 26,150) indicates that grindstones continued to be utilised at Jundaru up to the recent past.

The grindstones are generally amorphous and have varied appearances and sizes, which may be due to the selection of raw materials that were utilised (Figure 5-28: a-e). Eight of the 20 grindstones were produced from thin slabs of BIF that have horizontal laminae (referred to here as tabular BIF). These slabs of rock have fractures that run parallel with the natural bedding plains of the rock. The tabular BIF has fractured into large thin slabs, possibly as result of different rates of weathering of some bands. Tabular BIF makes ideal blanks for grindstones because as they have large flat surfaces and are thin, so that they remain light enough to be transportable. No source of this material has been observed on the Hope Downs 1 lease, but it is known to be available within the local region. The exact source is yet to be identified. Abraded river cobbles were utilised for six of the grindstones, and they are distinguished by their weathered surfaces. The remaining specimens were produced from larger, blockier fragments of BIF or martite-goethite. This material was likely collected locally as it weathered from the bedrock exposures. These artefacts do not show signs of transport batterings typical of river cobbles.

All of the grindstones were submitted for usewear analysis, with the exception of Artefacts 26,150 and 17,795. All of the grindstones exhibited usewear, such as smoothing, polish, alignments, and striations, and many had residues (Fullagar 2013). A detailed study of the residues was not carried out, but would be useful for identifying what materials were processed on these grindstones. Only one grindstone (Artefact 8060) was found that showed evidence of possible ochre grinding (Fullagar 2013). Some of the grindstones may have been used for seed grinding, but this requires further research to determine.

Two grindstones were recovered from AU4, Artefacts 25,052 and 17,795. Artefact 25,052 was produced on a pentagonal-shaped fragment of tabular BIF (Figure 5-28: a). The rounded edges suggest the artefact is complete. There is clear evidence of grinding on one surface, as well as a grey ashy residue. The opposite side is very fragile and small fragments continue to exfoliate from the specimen. No usewear was observed on the lower surface, and perhaps this is due to weathering. Artefact 17,795 is a fragment of a grindstone that was produced on a BIF fragment (Figure 5-28: c). While the artefact is thin, it does not have the banding typical of tabular BIF. The artefact has negative flake scars along one short margin. The flaking was possibly done to shape the artefact. The ground surface is opposite to the surface used as the striking platform. The edge where the flake terminations intersect with the ground surface is rounded over, which demonstrates that the artefact was shaped prior to grinding. A similar artefact was found at HD07-3A-03 (Artefact 6262), and trimmed or dressed grindstones have been identified throughout Australia (*e.g.*, Smith *et al.* 2010; McCarthy 1976: 59).

There are six grindstones in AU3, including specimens produced on BIF river cobbles, blocky fragments, and tabular fragments. Artefact 8060 is a fragment of a lower grindstone that was produced on tabular BIF. This small triangular fragment has clearly broken off of a much larger grindstone.

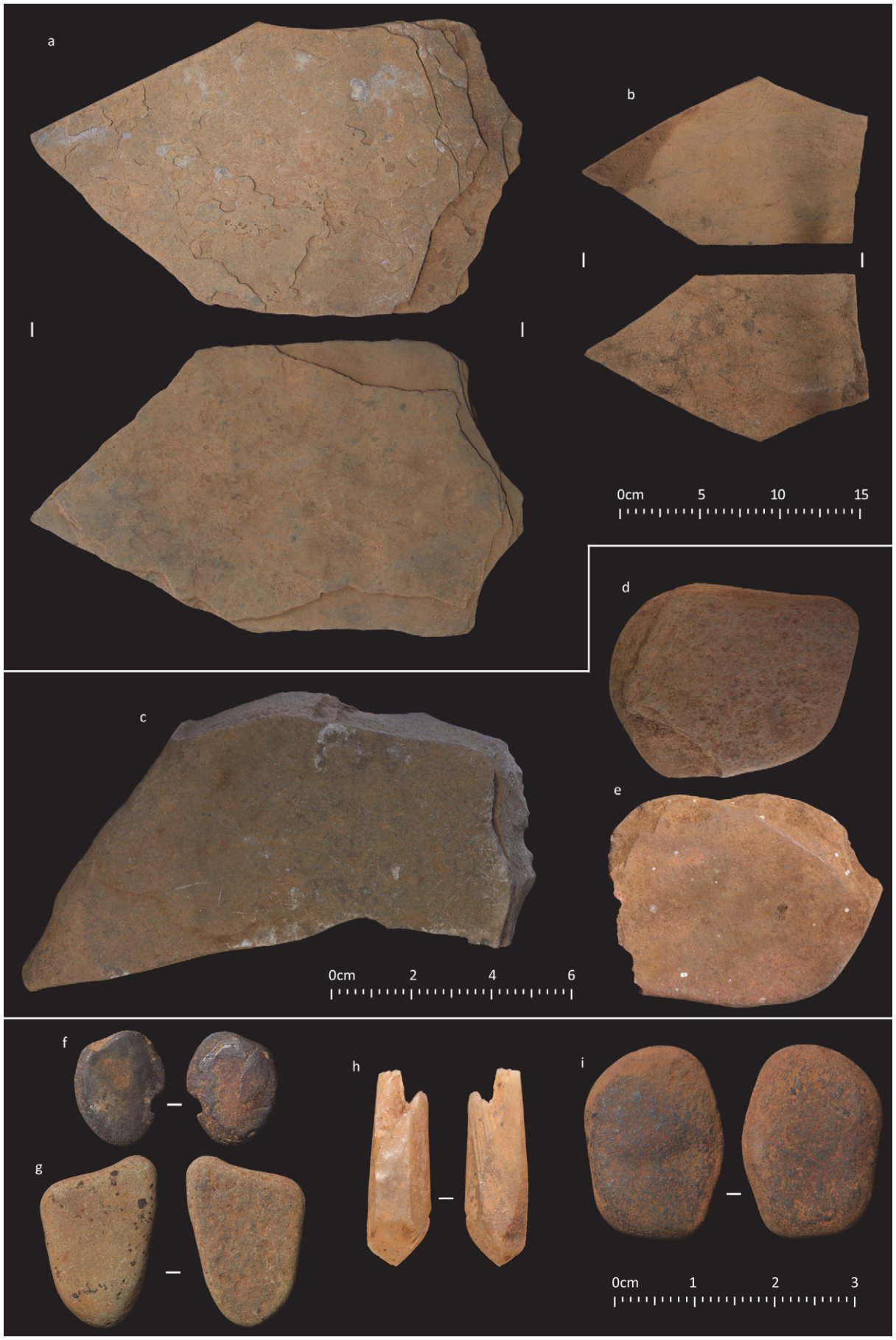

Figure 5-28 Grindstones from Jundaru rockshelter: a) Artefact 25,052 from AU4, b) Artefact 211 from AU1, c) Artefact 17,795, d) Artefact 10,382 from AU2, and e) Artefact 4073 from AU2; utilised pebbles: f) Artefact 26,040 from AU8, g) Artefact 22,576 from AU2, and i) Artefact 22,791 from AU3; utilised quartz crystal: h) Artefact 9284 from AU6

Two of the edges are rounded over and appear intact, while the third shorter edge appears to be a more recent break. This specimen did not conjoin with any of the grindstones in the assemblage. The specimen has one ground surface, while the opposite surface is rough. Artefact 4557 was produced on a broken BIF river cobble, and it is possible that it was used as a muller as the ground surface has a convex profile. One surface is smoothed and has striations. The cobble is broken on two edges as well as on the surface opposite the grinding; however, the grinding appears to continue over the breaks on the edges, suggesting that the artefact was used in its current form. Artefact 1516 is a lower grindstone made on a thin tabular fragment of BIF. The fragment has an asymmetrical trapezoidal shape (right trapezoid) and the ground surface is slightly rippled. One surface exhibits grinding, which extends to the margins of the fragment. It is possible that this grindstone is not complete as one edge does not have the developed rounding that is present on the other edges. Artefact 1477 appears to be a small lower grindstone that was produced on a weathered blocky fragment of BIF. All surfaces exhibit the same weathering and patina, so it may be a complete specimen. One surface exhibits grinding. Artefact 1476 is a small fragment of a lower grindstone that was made on a flat river cobble. The rectangular artefact has three broken edges, while the fourth edge is rounded over. There is grinding on one surface. This artefact has a strikingly similar appearance to Artefact 22,575, but the two pieces do not conjoin. Artefact 1398 is a lower grindstone that has grinding on one surface. The artefact was produced on a trapezoidal piece of tabular BIF and has fractured along natural faults running parallel to the grinding surface (the artefact is now in four thin pieces). These fractures appear to have occurred after the artefact was deposited, as it has remained intact. Near the centre of the grinding surface there are two depressions, possibly as the result of use and natural fracture. One of the depressions has a white substance adhering to it. While it has fractures along the natural bedding, it appears to be nearly complete.

Five grindstones were recovered from AU2. Artefact 22,575 is a small fragment of a lower grindstone that was made on a flat river cobble. The rectangular artefact has three broken edges, while the fourth edge is rounded over. The grindstone exhibits grinding on both surfaces, but it is more pronounced on one side. This artefact is similar in appearance to Artefact 1476, but the specimens do not conjoin. The artefacts have different provenances and Artefact 1476 does not have grinding on both surfaces; therefore, it is coincidental that these artefacts look alike. Artefact 10,382 is presumed to have been used as a muller due to its rounded shape, which makes use of the rounded cross-section of the BIF river cobble (Figure 5-28: d). The specimen has grinding on both the upper and lower surfaces. Artefact 7760 is a lower grindstone on a broken BIF river cobble. The lower surface appears to have a natural fracture, and another straight break on the margin gives the specimen a crescent shape. Some grinding is evident on one surface and there is possible residue. The break on the lower surface appears to be natural and may have occurred prior to the collection of the cobble, but it is possible that the break on the margin occurred during the use-life of the specimen. Artefact 4073 is an excellent example of a lower grindstone on a BIF cobble that was likely sourced from a nearby gully, as suggested by the weathering (Figure 5-28: e). Most of the cobble is intact, with the exception of two areas where the edge has been roughly flaked. Both surfaces have clear evidence of grinding, and there are two small glossy areas that may have residue. Artefact 1240 is a lower grindstone on a thin tabular fragment of BIF that is roughly D-shaped. The artefact has very light grinding on one surface, and there is also white substance adhering to this surface. This artefact is possibly complete.

There are six grindstones in AU1 and all appear to have been used as lower grindstones. Artefact 21,460 was produced from a thin fragment of BIF. While this fragment is very thin, it does not exhibit the characteristics of tabular BIF. One surface has areas that are ground, and on the opposite surface, there are a few flake scars (slightly abraded). Rounding on all edges suggests that this is a complete specimen; although, there is some recent edge damage along one margin. Artefact 10,071 was made on a thin tabular BIF fragment with a hexagonal (irregular) shape. One of the surfaces shows evidence of grinding. Some edges exhibit slight rounding (less clear on other edges), and it is possible that this artefact may be complete. Also produced from a tabular fragment of BIF, Artefact 538 has one ground surface that also has a black ashy residue. The artefact has a trapezoidal shape and may be complete, as there is some minor flaking around the perimeter and the edges appear to be slightly rounded. Artefact 537 utilises a cobble with a naturally concave surface, which has been ground. The breaks along the edges appear to be rounded, suggesting this specimen is complete. Artefact 211 is an excellent example of a lower grindstone, which was produced on a pentagonal fragment of tabular BIF (Figure 5-28: b). The grindstone is very thin and uniform and exhibits grinding on both surfaces, both of which are very flat. The edges of the grindstone appear slightly rounded, suggesting that this is a complete specimen. Artefact 210 is a lower grindstone on a blocky BIF fragment. There is grinding on one surface with a small area that is highly polished with possible residue. The grinding continues right up to the edges of the surface and the edges appear to be rounded over, suggesting this is a complete specimen.

One grindstone was recovered from the surface of the rockshelter southwest of the excavation trench and near to the roof collapse (Artefact 26,150; see Figure 5-5). This specimen was produced on a very large block of weathered martite-goethite, which has had all of its edges rounded. This weathering suggests that it may have been sourced from a gully and considering its considerable weight (28kg), the rock was likely obtained from near the rockshelter. This artefact is complete and exhibits grinding on two surfaces. One surface has a natural concavity, and this surface has more developed usewear than on the other side.

Utilised Pebbles – Six small rounded pebbles were recovered from AU8, AU5, AU3, and AU2 (Table 5-22; Figure 5-28: f-g, and i). The pebbles were initially believed to be manuports, possibly collected from the gully below and brought up to the rockshelter. Closer inspection of the artefacts revealed that all exhibited usewear, generally polishing, and some had residue adhering to their surface. While the artefacts were found throughout the sequence, they are quite uniform in size. The maximum length ranges between 14.8 and 24.61mm, with an average of 21.03mm. The average maximum width is 13.81mm and the average thickness is 5.42mm.

Five of the pebbles were submitted for usewear analysis to confirm that they had been used and were not simply manuports, but utilised artefacts. Fullagar (2013) confirmed that usewear was present on the artefacts. Artefact 22,576 from AU2 exhibited only possible patches of grinding, but it also had residue similar to resin on one surface (Fullagar 2013). Artefacts 22,791, 24,408, 24,888, and 26,040 had abrasive smoothing over their entire surface, and Fullagar (2013) suggests that these artefacts had been rubbed or smoothed. Artefact 22,791 (AU3; Figure 5-28: i) also had black residue on the upper and lower surfaces, and Fullagar (2013) indicates that it could be ‘a remnant of some hafting adhesive and the pebble may have been a polished ornament of some kind’. Some of the

artefacts also exhibited possible traces of ochre (Fullagar 2013). The function of these artefacts remains uncertain, but they may have been used as smoothing or polishing stones, possibly for finishing wooden or bone artefacts.

Utilised Quartz Crystal – One utilised quartz crystal was recovered from AU6. A quartz crystal core was identified in AU8, but it does not exhibit use polish. Quartz crystals are not a common component of artefact assemblages at Hope Downs 1, but flaked specimens have been identified at Hope 1-17 and HS-A1.

Artefact 9284 is a highly worn quartz crystal that was found in AU6 (U2-L16, 105-110cmbd; Figure 5-28: i). The quartz crystal has six crystal faces, with macroscopic usewear evident along two of the faces. The crystal is well-formed at the top (proximal), while the distal end is rough and is the base from which the crystal grew. On the crystal faces opposite the usewear there are some dark patches (possible residue), and they only occur along the distal half of the crystal.

Fullagar (2013) analysed the artefact and confirmed that the quartz crystal was utilised with the usewear consistent with rubbing soft tissue. Fullagar (2013) found usewear along all of the ridges, with some faces having more developed wear than others; the usewear was predominantly along the proximal half of the artefact. The black residue on the distal portion of the artefact is suggested to be resin, possibly indicating that the artefact was hafted (Fullagar 2013).

A much larger quartz crystal was recovered from AU8 (U1-L28) and was used as a bipolar core. Artefact 26,132 was also submitted for usewear analysis and it had minor usewear along one edge of the platform; however, it did not exhibit any evidence that the crystal faces were used in a rubbing motion like Artefact 9284 (Fullagar 2013).

It is not possible to determine exactly how these artefacts were utilised. It is unknown if they were utilitarian objects or if they had some other meaning. Crystals (often quartz crystals) have often been associated with medicine men across Australia, with the crystals acting as magic stones (see Elkin 1993). Elkin (1993) makes numerous mention of quartz crystals being rubbed by the medicine man to bring effect. Similarly, McCarthy (1976: 65-66, 78 Figure 56) notes that quartz crystals are 'associated with rain-making, hunting, sorcery, causing and curing sickness, as charms against sickness and danger, and for other purposes.'

Manuports

Three manuports were also identified in the assemblage, including two specimens from AU3 (Artefacts 21,180 and 24,887) and Artefact 4897 from the top of AU4. Artefacts 4897 and 21,180 are BIF river cobble, neither of which bear macroscopic signs of use. Artefact 4897 has ashy sediment adhering to one end, and this artefact may possibly be associated with overlying Feature 18. Artefact 24,887 is a small (10.51-x-9.25-x-2.79mm) brown shale river pebble. Unlike the utilised pebbles described above, this artefact did not exhibit any clear usewear. It is also considerably smaller than the other artefacts; however, it is possible that it was utilised in a similar way. Usewear analysis could confirm this hypothesis.

Artefact Analysis Summary

The large artefact assemblage from Jundaru provides an unparalleled opportunity to study the flaked stone artefact technologies over the 36,000 years of occupation. In total, 26,151 artefacts were recovered from ACHM's excavations, with an additional 30 artefacts recovered from other contexts. Diagnostic artefacts comprise nearly 88% of the excavated assemblage, with non-diagnostic artefacts (flaked pieces, heat shatter, and manuports) accounting for 12.24% of the assemblage.

As was discussed previously, MHA conducted an analysis of artefacts from one quadrant of Unit 11 (Edwards *et al.* 2001: 69). It was reported that 4577 artefacts were recovered from this quadrant, and they used this figure to estimate that 30,000 and 40,000 artefacts were found during their test excavations (Edwards *et al.* 2001: 69). This estimate does not correspond with the results of the current artefact analysis. When the MHA data is examined, there is an extremely high proportion of flaked pieces that account for 76.21% of the assemblage (Edwards *et al.* 2001: 71). ACHM's assessment of these flaked pieces is that the vast majority are naturally exfoliated rock fragments. This misidentification of the natural rock fragments as artefacts led to the over-estimation of artefact numbers at Jundaru. Nevertheless, the data produced here demonstrates that Jundaru continues to have the largest reported assemblage of any rockshelter in the inland Pilbara.

The data from Jundaru excavations show that beginning by approximately 36,000 years ago there was intermittent occupation of the site. The current analysis illustrates how artefact numbers increase mid-way through AU8 and then drop slightly in the beginning of AU7 and remain in modest proportions through to the middle of AU6. This suggests that that the site was repeatedly occupied from 36,000 until approximately 19,000 years ago, but site use was likely brief and intermittent. Artefact density begins to increase again in the middle of AU6 (*ca.* 19,000 years ago) through to the peak in late Holocene. Artefact density peaks in AU2 and AU1, and this is evidence for the intensification of site use during the late Holocene. This phase begins by 3899±45 cal BP and continues through to the beginning of AU1 with a subsequent decline in artefact density. It is reassuring that the same pattern is expressed amongst the diagnostic artefacts from the MHA excavation (Figure 5-29) with the greatest number of artefacts found between Spits 6 and 3.

The analysis has demonstrated that there were shifts in the types of raw material that were procured over time. BIF, chert, and quartz show the most considerable changes in abundance through the sequence. BIF was most heavily utilised in AU7, AU6, AU4, and AU3, while chert was used in moderate proportions early in the sequence (AU8-AU7), before its use declined from AU6 through AU4. Beginning in AU4, the proportion of chert rose; although, BIF remained the predominant raw material type. From AU2 through AU1, chert was overwhelmingly dominant and there was a simultaneous decline in BIF artefacts. On average, quartz only accounts for a modest proportion of the assemblage (14.42%), but in AU5 quartz use peaked, with over a third of artefacts produced from quartz, while chert was at its lowest frequency. The frequency of quartz declined between AU4 to AU2, but rose again in AU1.

The data from Jundaru indicates that knappers preferentially selected chert and fine-grained brown shale over other raw material types for the production of both formalised retouched artefacts and non-formalised retouched and utilised artefacts. This supports similar findings at HS-A1 and PAD 3, while Djadjiling showed high use of chert for retouched/utilised artefacts throughout the sequence.

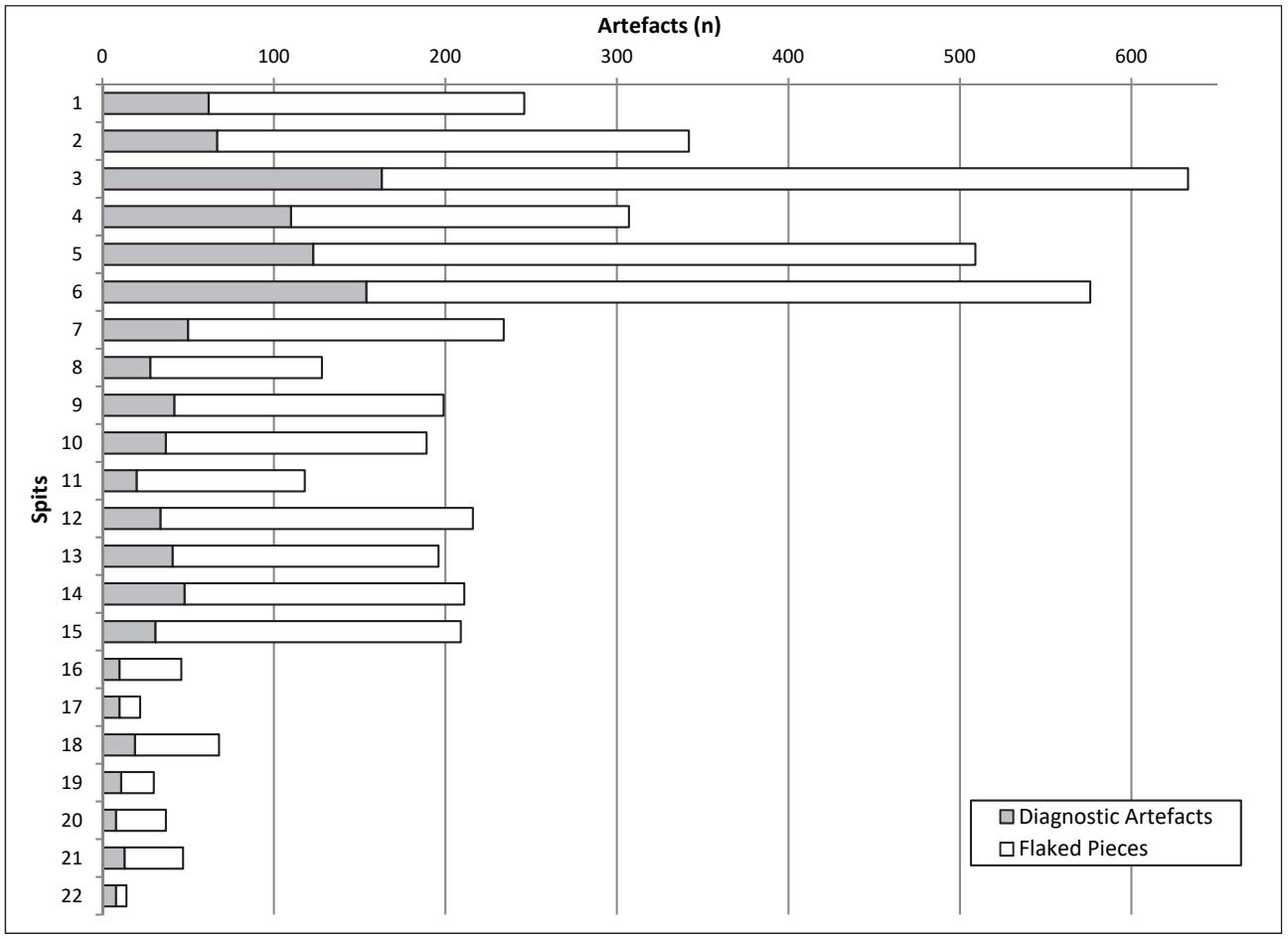

Figure 5-29 Distribution of diagnostic artefacts and flaked pieces by spit from the MHA excavation at Jundaru rockshelter (after Edwards *et al.* 2001: 71)

A large number of cores and core fragments were recovered from the excavated assemblage. Through the sequence, cores comprise less than one percent of the assemblage, with the exception of AU5 where the 17 cores account for 1.14% of the artefacts. The proportion of cores is lowest in AU2 and AU1. A comparison of the core raw material types with the assemblage averages suggests that chert and shale cores are under-represented in the assemblage. In contrast, there is a greater abundance of cores produced from coarser-grained materials or materials not suited for formalised retouched artefact manufacture. The most plausible theory to explain this discrepancy is that cores of high-quality materials were removed from the site. It is possible that this may affect the results of the core analysis.

Unidirectional and rotated cores are predominant, and their proportions vary through time. Unidirectional cores are most common through the sequence, with the exception of AU6 and AU2 when there are greater proportions of rotated reduction strategies. Unidirectional strategies peak in AU7; however, this analytical unit also has the smallest sample size, which may bias the results. Other core types, such as bipolar, alternate, or bidirectional, are rare and comprise only a negligible proportion of the assemblage. Most of the cores have either plain or cortical striking platforms, and there are some minor changes over time. Plain striking platforms are more abundant in in AU7, AU6, and AU2, while cortical platforms are more frequent in AU8, AU5, AU4, AU3, and AU1.

BIF and martite-goethite cores have the largest average size, while chert and quartz cores are consistently amongst the smallest. Most of the BIF, goethitised shale, and martite-goethite cores were considered viable, while there was a greater proportion of exhausted chert and quartz cores. This variation may be largely due to the size of the raw material that was available, with chert and quartz cobbles being much smaller than BIF and martite-goethite cobbles.

Flakes and flake fragments are the largest component of the assemblage, accounting for 83.24% of the excavated assemblage. It is estimated that the 21,767 flakes and flake fragments represent at least 15,073 complete flakes (MNF index). This indicates that the percentage of broken flakes for the assemblage is 40.90%, which is broadly comparable to Djadjiling, HD07-3A-03, and HD07-3A-PAD13, while HS-A1 has a considerably higher rate of flake fragmentation. At Jundaru, the lower layers have greater proportions of broken flakes and it is suggested this may be related to a large roof collapse event.

Flake size slightly decreases through the sequence and this corresponds with the increased use of chert. The average size of flakes by raw material corresponds well with the size trends observed for the cores. Chert flakes consistently are the smallest of all raw material types (followed by quartz), while BIF and martite-goethite are the largest. In AU8 and AU1 the flakes are slightly more elongated than in the other analytical units, as determined by the elongation index. In AU2 and AU1 the complete flakes have slightly narrower platforms, while platform thickness is relatively consistent through time. The late Holocene layers have slightly higher exterior platform angles, and this is largely due to the greater proportion of chert flakes

that have the high average angles. Early in the occupation, BIF and chert have similar exterior platform angles, but beginning in AU3 there is a divergence (lower angles for BIF flakes and higher for chert flakes). The higher angles amongst the chert flakes may have helped produce larger flakes off of the small cores. Plain platforms are predominant through the sequence, and thinner linear platforms become more abundant from AU3, particularly on chert flakes. In contrast, there is a greater abundance of cortical striking platforms early in the sequence, but they decline over time. Cortical striking platforms are more frequent amongst BIF flakes, while they are relatively uncommon for chert and shale flakes. Modification of the overhang is rare at the beginning of the sequence, but from AU3 onwards it becomes more common amongst chert and shale flakes.

Retouched and utilised artefacts account for 3.89% of the excavated assemblage, and there is variation in their frequency over time. Surprisingly, the greatest proportion of retouched and utilised artefacts occurs in AU8. The proportion of retouched artefacts falls consistently until AU4, rising again slowly from AU3 to AU1. All of the formalised retouched artefacts were recovered from the mid-Holocene (AU3) onwards, with the exception of one burin that was identified in AU6. Backed artefacts were utilised much earlier (*ca.* 5000 years ago) than burrens, tulas, scrapers, and burins. Crescents and trapezes with no lateral backing are the most abundant backed artefact types. The assemblage also includes a range of other backed artefact types, including seven Bondi points and five elongated crescents (that have a similar appearance to Bondi points). The edge modification patterns for non-formalised retouched artefacts indicate that they were generally produced using short dorsal regular AAR on the lateral edges. It is only when formalised retouched artefacts are introduced that there is greater variation in how knappers retouched artefacts; however, the production of non-formalised retouched artefacts remains consistent through the sequence.

5.7 SPECIALIST STUDIES

Numerous specialist studies were commissioned to provide further context to the archaeological patterns at Jundaru, including artefact usewear and residue analysis (Fullagar 2013), macrobotanical analysis (Fairbairn 2013), archaeomagnetic analysis (Herries 2013), palynological analysis (Haberle *et al.*, this volume), phytolith analysis (Wallis, this volume), faunal analysis (McDowell, this volume), and mineralogical analysis of cemented sediment samples (Gilkes and Yusihami 2013). The results of the studies are summarised below, with the exception of the analysis of the cemented sediment as it has been discussed elsewhere (see Section 5.3). The results of these studies are considered below in relation to the archaeological materials and chronology, details that were not provided to these analysts.

Artefact Usewear and Residue Analysis

In total, 163 artefacts were submitted to Dr Richard Fullagar for usewear and residue analysis. The artefacts were selected from throughout the sequence; however, the vast proportion of artefacts is from AU2 and AU1 and primarily includes formalised retouched artefacts. In addition to the identification of usewear and residue on the artefacts, the researchers sought a greater understanding of the function of backed artefacts and aimed to improve our depiction of past Aboriginal subsistence. The following paragraphs summarise Fullagar's results (2013; see also Fullagar, this volume) and consider the broader archaeological context of the findings.

Seventy-one backed artefacts were examined for usewear and residues, including 65 symmetrical backed artefacts, five Bondi points, and one fragmentary backed artefact. A summary of the usewear and interpreted function is presented in Table 5-23. The analysis indicates that 53.52% of backed artefacts exhibit minor usewear on the chord and tip, and minor tip damage is second in abundance, accounting for 21.13% of the sample. Most of these artefacts have only minor tip damage, but Fullagar (2013) found that 14 of the 74 backed artefacts analysed were likely used as barbs or tips (18.92%). Fullagar (2013) notes that this is a 'high rate of damage compared with some experimental studies'. There is a higher frequency of crescents (35%, n=7) and triangles (30%, n=3) that may have functioned barbs or projectile tips, and this is much lower for Bondi points (20%, n=1) and trapezes with no lateral backing (13.04%, n=3). Fullagar (2013) did not find that any of the elongated crescents or trapezes had usewear that suggested they functioned in this manner. It is possible that backed artefacts were utilised in numerous ways, and at least four specimens were probably not projectile elements (Fullagar 2013). Many of the backed artefacts showed evidence of cutting or possible cutting (n=16), as well as cutting with projectile (n=1), awling (n=1), impact (n=8), piercing (n=12), scraping (n=5), slicing (n=1) (Fullagar, this volume). The sample also showed a range of other modes of use, including graving/drilling (n=2), awling/possible awling (n=4), possible awl/projectile (n=2), scraping (n=4), scraping/impact (n=1), scraping/graving (n=1), slicing/scraping (n=1), and uncertain (n=2) (Fullagar, this volume). Hafting traces were found on 42 backed artefacts (Fullagar, this volume). The material worked was uncertain for 47 artefacts, and soft tissue was the most common worked material (n=12) (Fullagar, this volume). Fullagar (this volume) also found that some backed artefacts were used on wood (n=3) and plants (n=1).

Three eloueras were submitted for analysis, and unlike the backed artefacts, Fullagar (2013) found that they exhibited usewear consistent with woodworking. One specimen appears to have been used to work both skin and wood. The usewear and residues indicate that two of the specimens were hafted, while the third may have been hand-held (Fullagar 2013).

Each of the eight tulas analysed exhibited usewear and residues characteristic of tulas; however, some areas of polish were more grainy than found amongst experimental specimens (Fullagar 2013). Fullagar (2013) considers the grainy appearance to possibly indicate that the artefacts were utilised for many tasks, rather than only scraping or adzing wood.

Five scrapers were submitted for analysis, including two endscrapers and three side scrapers. Fullagar (2013) examined two of the endscrapers and found that blade-like Artefact 14,173 may have been used to scrape a resinous wood, while Artefact 10,530 exhibited striations and polish, and was also used to work wood. Two of the side scrapers have usewear suggesting they were utilised for wood scraping (Fullagar 2013). The third side scraper (Artefact 23,854) was hafted along the backed margin, while the unretouched right lateral margin was used for scraping (Fullagar 2013). The material worked by this artefact is uncertain.

Table 5-23 Summary of backed artefact usewear (after Fullagar 2013), Jundaru rockshelter

Backed Artefact Type	Minor Usewear on Chord and Tip		Minor Tip Damage Present		Barb Likely		Tip Impact Likely		Tip and Barb Likely		Probably Not a Projectile Element		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n
Bondi	3	60.00	1	20.00	0	0.00	1	20.00	0	0.00	0	0.00	5
Crescent - E	4	80.00	0	0.00	0	0.00	0	0.00	0	0.00	1	20.00	5
Crescent	11	52.38	2	9.52	2	9.52	4	19.05	1	4.76	1	4.76	21
Trapeze	7	57.14	3	42.86	0	0.00	0	0.00	0	0.00	0	0.00	7
Trapeze - NLB	14	60.87	6	26.09	3	13.04	0	0.00	0	0.00	0	0.00	23
Triangle	3	30.00	3	30.00	2	20.00	1	10.00	0	0.00	1	10.00	10
Indeterminate	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	100	1
Total	**38**	**53.52**	**15**	**21.13**	**7**	**9.86**	**6**	**8.45**	**1**	**1.41**	**4**	**5.63**	**71**

Twelve burins were examined and Fullagar (2013) found that burination was utilised as a resharpening technique. The artefacts were primarily used to work wood (n=8) or wood/bone (n=1), while the material worked by three specimens could not be determined (Fullagar 2013: Table E-2). The mode of use was generally scraping (n=8) and one specimen likely functioned as a graver (Fullagar 2013: Table E-2). None of the burins exhibited hafting traces (Fullagar 2013: Table E-2). The spalls provide further confirmation that burination was used to resharpen artefacts, and two spalls were also utilised after they were detached (Fullagar 2013).

Twenty-eight retouched or utilised artefacts were studied and the usewear traces indicate they were used for a variety of tasks, but predominantly for scraping and cutting/sawing (Fullagar 2013). Most artefacts did not have well-preserved residues. Three artefacts that had been identified as retouching flakes were also examined, and Fullagar (2013) confirmed that these flakes were created during sharpening or use.

Fullagar (2013) examined 18 grindstones and five utilised pebbles. All of the grindstones exhibited usewear, such as smoothing, polish, alignments, and striations, and many had residues (Fullagar 2013). Only one grindstone (Artefact 8060) was found that showed evidence of possible ochre grinding (Fullagar 2013). While analysis of the residues was not carried out, it is assumed that the remaining grindstones were used for seed grinding. Some grindstones also show ochre on the surface, and may have been used to process this mineral. The small ground or polished pebbles showed evidence of usewear, with most specimens having abrasive smoothing over the entire surface, suggesting they were rubbed or smoothed (Fullagar 2013). On artefact had black residue on two surfaces, and Fullagar (2013) suggests that it could be 'a remnant of some hafting adhesive and the pebble may have been a polished ornament of some kind'.

An utilised quartz crystal and a quartz crystal core were also submitted for usewear analysis. Fullagar (2013) found that the utilised quartz crystal (Artefact 9284) was possibly hafted and has usewear consistent with rubbing soft tissue. The presence of a haft bears similarity to the magic stones described by McCarthy (1976: 65, 78). The quartz crystal core had minor usewear along one edge of the platform, but had evidence that the crystal faces were used in a rubbing motion like Artefact 9284 (Fullagar 2013).

Macrobotanical Analysis

Fifty-four samples were submitted to Dr Andrew Fairbairn at the University of Queensland for macrobotanical analysis in order to determine what woody plant species were used as fuel in hearths throughout the occupation at Jundaru (Fairbairn 2013). The study also considered if the macrobotanical evidence could provide information regarding environmental change through time and if the plant remains could yield any information on past subsistence strategies. The following paragraphs summarise the findings within the broader archaeological patterns for the site.

In a preliminary assessment, Fairbairn identified wood charcoal samples from 14 combustion features that were suitable for macrobotanical analysis (Features 1, 2, 4, 5, 6, 11, 13, 14, 15, 16, 17, 18, 21, and 24). Ten features did not have sufficient samples for the analysis. The samples were submitted without provenance data and were assigned random sample numbers to avoid any inadvertent bias in the interpretation of the data. Once the analysis was completed, a key to the provenance of the samples was provided to the specialist.

The results of the study show the wood charcoals are dominated by *Eucalyptus* and Myrtaceae, along with a significant proportion of *Acacia* (Fairbairn 2013). Through the sequence, the proportion of *Acacia* varies. Features 24 through 11 have fairly high proportions, but the late Holocene features (Features 6-1) show a marked decline in the abundance of *Acacia* and this pattern continues to Feature 1 (Fairbairn 2013). Fairbairn (2011; 2013) notes that the wood charcoals from HS-A1 and PAD 3 also show a decline in *Acacia* at this time, while Djadjiling shows the opposite pattern. Fairbairn (2013) suggests that the lower frequency of *Acacia* wood charcoals at these sites may reflect broad climate changes (*e.g.*, reduced precipitation) that altered the woodland surrounding these sites.

Other macrofossils were rare amongst the samples; however, blackened fragments of spinifex resin were identified in Feature 7 (Fairbairn 2013). Amongst the 56 flaked stone artefacts in Feature 7 is one retouched artefact (Artefact 16,306). The analyst suggested that while most of distal margin was removed by large potlid, the artefact was potentially a tula. It is possible that the resin is related to the de-hafting of this artefact. Both Feature 1 and Feature 7 also contained unidentifiable seed fragments (Fairbairn 2013).

Archaeomagnetic Analysis

Dr Andrew Herries was contracted to perform archaeomagnetic analysis of sediment samples from Jundaru. The focus of this research was to identify any changes in site use and the local environment through time. The following section summarises the results of Herries' work and considers the results along with the archaeological patterns. The full report is available elsewhere (see Herries 2013).

Seventy-four sediment samples were submitted from Jundaru, including a continuous column of 32 samples from Unit 1 (Quad A) with samples from Layers 1 through 32. Samples from each of the 24 combustion features were also submitted,

with multiple samples submitted from some features. Sediment samples were also selected from four arbitrary layers in Unit 4 (Layers 11-14), which are adjacent to Features 17, 19, and 20, in order to determine if it was possible to distinguish between combustion features and the surrounding sediment. The samples were assigned random numbers prior to their submission in order to avoid inadvertent bias. Once the samples were processed, a provenance key was provided so that the results could be interpreted accordingly.

The samples from Jundaru exhibited high magnetic susceptibility values as the result of the naturally high iron content in the sediment and through the heating of the sediment by past human occupants (Herries 2013). The data shows that the magnetic susceptibility values generally increase towards the top of the sequence, with low values found below 170cmbd and slightly higher values through to 120cmbd (Herries 2013). Beginning at 120cmbd, the values rise considerably and this trend continues through to 100cmbd (Herries 2013). This correlates to a period of slight increasing artefact abundance (particularly from 110cmbd) that occurred towards the end of peak LGM conditions. Above 100cmbd, the magnetic susceptibility values fluctuate (Herries 2013). Based on the magnetic susceptibility values and the frequency dependence of magnetic susceptibility, Herries (2013) suggests that the signal above 100cmbd is largely affected by anthropogenic alteration. The distribution of artefacts through the sequence shows a large increase in artefact numbers from 95cmbd. The lower deposits, particularly below 155 to 170cmbd are less altered, and this corresponds well with the initial occupation in AU8. Artefacts below 170cmbd are infrequent.

The data indicates that there was considerable mixing of burned sediment from combustion features with the surrounding background sediment between 95 and 75cmbd (Herries 2013). Several combustion features were identified between these depths, including two large pit-like hearths, Features 17 and 20. The edges of these features were difficult to delineate and had mottling with brown background sediment. The archaeomagnetic data supports the interpretation of the excavators that there had been some disturbance to the features and as a result, ashy sediment was distributed throughout the site. The upper layers show less anthropogenic alteration and Herries (2013) suggests that this is perhaps due to a decline in use of the north part of the site where the samples were collected. As the rockshelter roof is very low over Unit 1 (particularly over Quad A) this seems to be a reasonable theory; however, the artefact numbers in the first two layers of Unit 1 are higher than in any of the other excavation units. It is possible that artefacts were discarded in the less frequently used areas of the site in this late stage of the occupation.

Analysis of the feature sediment samples shows that almost all have high magnetic susceptibility values as is expected for combustion features, but there are a small number that have slightly lower values. Feature 20 has only slightly higher magnetic susceptibility values than the surrounding background sediment, and this may be due to mixing of burned sediment with background sediment (Herries 2013). This feature was interpreted to be a cooking pit, which could explain mixing of the sediment. Features 21 and 23 have the lowest magnetic susceptibility values of the hearths, and Herries (2013) suggests that these hearths may have not been intensively used. This interpretation correlates well with ephemeral nature and lack of cultural material in Feature 23; however, Feature 21 is very large and a large assemblage of artefacts and faunal remains were recovered from its matrix. Features with thick deposits of ash have the greatest magnetic susceptibility values (Herries 2013); however, ashy sediment was not identified in either feature. Instead both had concentrations of charcoal with reddened sediment beneath. The lack of ash may be due to the preservation of the features, as both are amongst the oldest identified at the site. Herries (2013) also notes that the lower anthropogenic signal may be caused if the features were constructed during glacial conditions. Feature 23 dates to 19,820±172 cal BP during the height of the LGM, so climate could be a factor affecting its archaeomagnetic signal.

In addition to being able to identify the initiation and intensity of human occupations, archaeomagnetic analysis can reveal changes in the climatic conditions through the sequence. The basal deposits show evidence of climatic conditions that were either cooler or extremely arid (Herries 2013). Herries (2013) found that sediments below 130 show evidence of having been deposited during a glacial period, and the transition to warmer conditions occurs between 130 and 100cmbd. Sediment above 60cmbd was deposited during a warmer interglacial period. Between these zones, there was intense anthropogenic alteration of the sediment so that the climatic signal is no longer clear, but he suggests that the transition from glacial to interglacial conditions may have occurred at approximately 80cmbd (Herries 2013). Herries' interpretation of the climatic changes fits well with the radiocarbon chronology.

Sedimentary, Charcoal and Palynological Analysis

A series of sediment samples were submitted to PalaeoWorks for sedimentary, micro-charcoal, and palynological analysis. PalaeoWorks is the consulting arm of the Department of Archaeology and Natural History at the Australian National University. The analysis was carried out by Simon Haberle, Feli Hopf, and Phil Roberts, and their results are presented as Chapter 13 (see also Haberle *et al.* 2013). The following paragraphs summarise their results and correlate them with the archaeological patterns and chronology for the site.

A continuous column of 32 samples from each arbitrary layer in Unit 1 (Layers 1-32; Quad A) were submitted for analysis. Four sediment samples from the surface of the rockshelter (samples taken from the northwest, northeast, east, and southeast of the excavation trench) were also submitted. As with all of the specialist studies, the samples were submitted without provenance data and were assigned random sample numbers to avoid any inadvertent bias in the interpretation of the data. Once the analysis had been completed, the sample provenance key was provided to the specialist..

The results show that there is a gradual increase in the loss on ignition (LOI) values from the base to the surface (Haberle *et al.*, this volume). The data indicates that the proportion of organic matter in the sediment increases in the upper layers. There is a small peak in LOI in Layer 24 (145-150cmbd), and there are also slightly higher LOI values between Layer 19 (120-125cmbd) and Layer 16 (105-110cmbd). There is no clear archaeological pattern associated with the peak in Layer 24, but between Layers 19 and 16 artefact numbers begin to slowly increase and the earliest hearth was identified in this depth range (Feature 24). From this point onwards, LOI slowly increases and this parallels the increase in artefact numbers. The final peak is in Layer 3 (40-45cmbd), which occurs during one of the highest periods of artefact discard and several features were identified at this depth.

Macroscopic charcoal (>125µm) is most abundant between Layer 20 (125-130cmbd) and Layer 3 (40-45cmbd) and reaches a peak between 65 to 70cmbd in Layer 8 (Haberle *et al.*, this volume). When the macro-charcoal abundance data is overlaid

with the distribution of artefacts, there is a striking correlation up to Layer 13 (90-95cmbd). Beginning at 95cmbd there is a sharp rise in the number of artefacts and this continues throughout the rest of the sequence. In contrast, there is a small dip in the abundance of macro-charcoal in Layer 12 and the abundance of macro-charcoal remains at moderate proportions until Layer 3, despite the increased frequency of combustion features.
Haberle *et al.* (this volume) found that microscopic charcoal (<63µm) is only abundant between Layer 25 (150-155cmbd) and Layer 22 (135-140cmbd), as well as in the samples from the surface around the excavation trench. Burned grass phytoliths are abundant in Layer 31 (180-185), Layer 22 (135-140cmbd) and Layer 8 (Haberle *et al.*, this volume). Haberle *et al.* (this volume) suggest that regional fires contribute a portion of the burned phytoliths and micro-charcoal in the assemblage, and localised fires (either in the rockshelter or within several metres) are only recognisable between Layer 20 and Layer 3.

Like all of the Hope Downs 1 sites that were subject to pollen analysis, significant concentrations of pollen were only found in the upper deposit. In Layer 4 (45-50cmbd), *Corymbia* sp. and *Eucalyptus* sp. have a similar abundance and comprise the predominant tree component with an understorey of grasses and daisies (Asteraceae; Haberle *et al.*, this volume). The three surface samples that were analysed show some variation with *Corymbia* sp. predominant in one sample (ui-1935), while *Eucalyptus* sp. is more frequent in the other two samples and particularly dominant in the sample taken from the southeast of the trench (Haberle *et al.*, this volume). Similarly, the surface samples show that there was an understorey of grasses and daisies (Haberle *et al.*, this volume).

Dung fungi were identified in Layer 4 and Haberle *et al.* (this volume) suggest that this may reflect a greater abundance of larger fauna and may possibly indicate the presence of dingo at the site. The radiocarbon chronology indicates Layer 4 occurred during the late Holocene, with deposition occurring by approximately 2500 years ago (as indicated by the age-depth trend line), which is well-within the estimated timing for the arrival of the dingo in Australia (Savolainen *et al.* 2004; Oskarsson *et al.* 2011; McNiven 2004).

Phytolith Analysis

Dr Lynley Wallis was engaged to conduct phytolith analysis of sediment samples from Jundaru with the aim of determining if phytoliths were present in samples and the range of plant species represented in each sample (Wallis 2013; see also Wallis, this volume). The research considered if there were changes in the local flora through time and if phytolith analysis could provide any information regarding past subsistence strategies. The results of the phytolith analysis are summarised here with correlations to the chronology and archaeological patterns at Jundaru.

Thirty-six sediment samples were submitted for analysis, including samples from each of the 32 arbitrary layers of Unit 1 (Layer 1-32; Quad A). Four surface sediment samples were also submitted for analysis, and these were collected from surrounding the excavation trench. The sediment was placed into a sieve with 1mm mesh and sieved onto a dustpan before being placed into a resealable plastic bag. The samples were assigned random numbers prior to submission to ensure that the results are not a product of sequential lab processing or that there was any bias in the interpretation of the results. A provenance key was provided after the analysis was carried out, and the samples were interpreted in the order of their real stratigraphic association.

LOI analysis was also carried out by Wallis, and her results correspond well with the LOI values from Haberle *et al.* (this volume) with a few minor variations. The data indicates a general trend to lower LOI values in the earliest part of the sequence and higher values in the surface layers (Wallis, this volume). There is good correlation between the LOI values and the number of artefacts in each layer with just a few exceptions. In Layer 19 (120-125cmbd), the LOI values peak, while there is only a small increase in the proportion of artefacts from the previous layer. In Layer 11 (60-65cmbd), there is a sharp rise in the artefact numbers, but the LOI remains consistent from the previous layer. The LOI values are at their highest between Layer 5 (50-55cmbd) and the surface, and this corresponds with the intensification of site occupation in the late Holocene. Additionally, there is a small peak in LOI values in Layer 28 (165-170cmbd), and this layer shows a considerable rise in artefact numbers over the previous layer. This perhaps represents the first significant phase of site use.

Wallis (this volume) found that phytoliths were well-preserved and range in abundance from 2.46 (Layer 25) to 10.76% (Layer 27), with an average of approximately 7%. The average abundance of phytoliths is higher than at Djadjiling (Wallis, this volume), and this may be due to the greater intensity of occupation at Jundaru. When the phytolith abundance is compared with the distribution of artefacts at the site, there is fairly good correlation from Layer 24 upwards. The high phytolith abundance between Layer 32 and 27 occurs during the initial occupation of the site when site use appears to be low. Wallis (this volume) has suggested that the high phytolith levels in this early phase may either indicate background levels (*e.g.*, through the decay of macropod scat, *etc.*) or may indicate that human occupation began with the earliest level at the site. The latter theory is certainly true at Jundaru, with the lowermost artefacts recovered from between 185 and 190cmbd (equivalent to U1-L32). Based on the number of artefacts, it appears that the initial occupation was very limited, with only 15 artefacts recovered between 190 and 175cmbd. If the phytoliths in these layers represent a background, then it is particularly high and with phytolith abundance greater or equivalent to the phase of the most intense occupation in the late Holocene layers. In Unit 1, cemented sediment was identified from Layer 20 through to the base of the excavation. It is possible that the cemented sediment may have affected the results in these layers. Wallis (this volume) identified five samples with over-estimates of phytolith abundance, as the pre-treatments did not remove all of the non-phytolith material from these samples. It is possible that this may also have occurred in other layers, but it was not as obvious. The two most considerable over-estimates are from Layers 26 and 28 and are well-within the zone of cemented sediment. The over-estimates from higher in the sequence would not have been affected by cemented sediment, but they each occur in arbitrary layers that have close association to combustion features. For example, Layer 14 is adjacent to Feature 21, Layer 9 is adjacent to Features 15 and 18, and Layer 6 is near to features in Unit 2 (Features 11 and 9). Additionally, the proportion of phytoliths is somewhat lower than expected in the late Holocene layers, and this could be due to higher sedimentation rates during this time.

Wallis (this volume) divides the sequence into three phytolith zones. Zone 1 (including 1a, 1b, and 1c) includes Layers 32 (190-195cmbd) through 20 (125-130cmbd; Zone 1a, Layer 32; Zone 1b, Layers 31-25; and Zone 1c, Layers 24-20), Zone 2 comprises Layer 19 (120-125cmbd) to 4 (45-50cmbd), and Zone 3 includes Layers 3 (40-45cmbd) to 1 (surface to 35cmbd;

Wallis, this volume). Zone 1 correlates precisely to with AU8 and AU7, and Wallis (this volume) suggests that it represents the onset of the LGM. Unlike Zones 1b and 1c, there is a minor peak in tree phytoliths in Zone 1a (Wallis, this volume). Without being privy to the radiocarbon chronology, Wallis (this volume) identifies that there was a different floral signal in Zone 1a, and she suggests that it may be more appropriate to separate it from Zones 1b and 1c due to the higher incidence of tree phytoliths and high frequency of phytoliths from Panicoid grasses as well as Chloridoid and Pooideae grasses in Zone 1a. This data, together with the radiocarbon results, shows that this initial phase occurred during the late marine isotope stage (MIS) 3, prior to 35,000 years ago; hence, it should be considered a separate zone. Zone 1b and 1c represent the beginning of the glacial period through to the onset peak LGM conditions at approximately 23,000 years ago (based on the age-depth trend line for the ACHM date series).

The commencement of Zone 2 coincides with the first layer of AU6 and it continues midway through AU2. Through this zone there is an increase in the frequency of tree/shrub phytoliths, suggesting a greater amount of effective precipitation during this time (Wallis, this volume). The phytolith morphologies in the assemblage show that from Layer 20 and upwards there is a greater proportion of tree/shrub phytoliths, a re-emergence of Panicoid grasses, and a decline in Pooideae grasses in comparison with Zone 1 (Wallis, this volume). Wallis (this volume) interprets the sequence as representative of the onset of the Holocene with the establishment of modern vegetation patterns. When the phytolith data is considered with the radiocarbon chronology, it reveals that Zone 2 begins with the onset of hyperarid conditions during the peak LGM.

The data shows a low peak in the abundance of tree/shrub phytoliths at the beginning of Zone 2 (Layer 19; Wallis, this volume), which is dated to approximately 23,000 cal BP. More favourable conditions are generally believed to have only returned by 14,000 years ago with the re-initiation of the summer monsoon cycle across northern Australia (Wyrwoll and Miller 2001: 127). Based on the age-depth trend, this likely occurred during the deposition of Layer 13 in Unit 1. Between Layers 19 and 15 there are two small peaks in the abundance of tree/shrub phytoliths, followed by troughs that reach similar proportions as in Zones 1b and 1c (Wallis, this volume). In Layer 14 there is a large peak in tree/shrub phytoliths, and above this layer there is a fairly high proportion of tree/shrub phytoliths, albeit with fluctuations (Wallis, this volume). The artefact distribution suggests a slow but steady increase in site utilisation beginning in Layer 19, and it is possible that there was a much greater input of phytoliths as the result of the occupation. For example, in Quad A of Layer 19, a small ashy lens was identified and perhaps this influenced the abundance of tree/shrub phytoliths in this layer. The low peak in Layers 15 and 16 also may be related to ashy deposits encountered during excavation. Similarly, Layer 14 shows a large peak in tree/shrub phytoliths; however, the sample was taken next to a hearth (Feature 21).

Two troughs in tree/shrub phytolith abundance occur in Layers 8 and 6 (Wallis, this volume). These layers correspond with the extent of AU3 (*ca.* 7700 to 3800 cal BP). Between 5400 and 3700 cal BP, there is a period of increased aridity due to the cessation of the annual monsoonal cycle along the northwest coast of Western Australia (Nott 2011). Additionally, research has shown that climatic fluctuations may be related to El Niño/Southern Oscillation (ENSO) variability (Williams *et al.* 2008). It is possible that these broader environmental changes caused fluctuations in the vegetation surrounding the site. However, artefact densities continued to increase steadily through this phase, and human activity at Jundaru likely contributed to the phytolith assemblage as numerous ash lenses and two hearths were identified in AU3. In the uppermost zone, Zone 3, the abundance of tree/shrub and Panicoid grass phytoliths decrease slightly with an increase of Pooideae phytoliths (Wallis, this volume). This last phase occurs in the late Holocene, beginning midway in AU2 through to the end of AU1. AU2 and the beginning of AU1 represent the most intense phase of site use, as is indicated by the high number of flaked stone artefacts. Combustion features are common in AU2, but two hearths were identified in AU1. While it is possible that the fluctuations in the frequency of tree/shrub phytoliths in Zone 3 represent changes related to human activity, climatic variation may have been the critical factor.

Faunal Analysis

All faunal remains recovered from the Jundaru excavations were submitted to Matthew McDowell for analysis, and the results can be found in Chapter 14 of, this volume. In the following paragraphs, the results of the faunal analysis will be summarised in relation to the archaeological patterns. This section also considers the significance of emu eggshell fragments, which may provide rare evidence for the seasonality of the occupations.

McDowell (this volume) identified 3533 specimens that he determined to represent at least 2611 individuals and 22 species. Kangaroo was most frequently represented in the analytical units, but numerous other mammals were identified, including quoll (*Dasyurus* spp.), bandicoot (*Isoodon* spp. and *Permaelidae* spp.), bilby (*Macrotis lagotis*), possum (*Trichosurus vulpecula*), bettong (*Bettongia* spp.), rock-wallaby (*Petrogale* sp.), bat (*Chiroptera* gen. sp.), mice (*Leggadina lakedownensis* and *Pseudomys desertor*), and rat (Zyzomys argurus and *Rattus* sp.)(McDowell, this volume). The remains of reptiles, birds, frogs, and a snail were also included in the assemblage (McDowell, this volume). The diversity of species is greatest in AU3, while the minimum number of individuals is greatest in AU4 (McDowell, this volume). Two large hearths were identified in AU4, which have been interpreted as possible roasting or cooking pits. The high number of faunal remains associated with these features supports this interpretation. A number of combustion features were identified in AU3, including four ash lenses and a hearth.

The faunal remains were found to be well-preserved with little weathering; however, they were highly fragmented (McDowell, this volume). The primary cause of the fragmentation was suggested to be treadage and deliberate breakage, but McDowell (this volume) also indicates that some breakage could be related to overall maintenance or cleaning of the site. There is a high frequency of spiral fractures in the assemblage (McDowell, this volume), which provides good evidence for the accumulation of the assemblage as the result of the human occupation as these fractures occur on green bone at or near the time of death. Over half of the bones were burned, and the proportion of calcined bones increases with increasing depth (McDowell, this volume). While modification of the bones is not common in the assemblage, there is a slight increase in the upper analytical units (McDowell, this volume; see Figure 5-30). McDowell (this volume) assessed most of the assemblage as having been deposited through cultural means. This interpretation is supported by the high proportion of burned specimens, many of which were burned at temperatures only achievable in a hearth (McDowell, this volume).

The faunal analysis identified emu shell fragments from 49 contexts at Jundaru (with some contexts having more than one fragment; Figure 5-31). Assuming that the emu eggshell fragments represent consumed eggs, they provide important information regarding seasonality. It is acknowledged that some eggs may have had secondary uses, such as containers, but none of the emu eggshell fragments exhibit signs of modification (*e.g.*, carving or drilling). Additionally, the identification of shell fragments within the matrix of combustion features provides compelling evidence for their use as a food item.

Emus lay eggs on a seasonal basis in autumn and winter, generally beginning in early April and extending through to early September, with a peak in June (Western Australia Department of Environment and Conservation 2009; Malecki and Martin 2002: 167). While most shell fragments were recovered from arbitrary excavation layers, shell fragments were also found within Features 12, 13, and 20. This suggests that these features were created during the autumn or winter. Emu eggshell fragments were most prevalent in AU3 or between 7686±34 cal BP and just prior to 3899±45 cal BP, but there were also a number of fragments in AU2 and AU4. The presence of these faunal remains in the assemblage provides evidence that Aboriginal people occupied the shelter during the cooler months; however, it does not discount the possibility that the site was also visited in the summer and spring.



Figure 5-30 Modified faunal remains from Jundaru rockshelter: a) *Macropus* distal fibula fragment with cut marks (faunal ID 1178; AU4), b) Macropus long bone fragment with cut mark (faunal ID 1913; AU4), and c) bone flake ejected by percussion (faunal ID 1687; AU2)



Figure 5-31 Emu eggshell fragments from Jundaru rockshelter: a) faunal ID 1084 (AU5), b) faunal ID 2668 (AU3), c) faunal ID 2078 (AU4), and d) faunal ID 3010 (AU4)

Three emu eggshell fragments were recovered from AU1 and only one fragment was recovered from AU5 (U2; 85-90cmbd); no eggshell fragments were found below 90cmbd. The absence of shell fragments below 90cmbd corresponds with the findings of the MHA excavation (Edwards *et al.* 2001: 95-96). This roughly correlates to the transition from sediment that is slightly alkaline to increasingly acidic layers, and the acidity in the sediment may have affected the preservation of the eggshell. This data therefore does not suggest that the site was utilised during the autumn and winter in the Holocene and in the spring or summer in the Pleistocene. Instead, it reflects a lack of data from the initial occupation to Pleistocene/Holocene transition.

5.8 DISCUSSION

Despite its inconspicuous appearance, Jundaru has proven to be one of the most significant rockshelter sites investigated at Hope Downs 1 and perhaps in the Hamersley Range. The initial test excavations conducted by MHA first pointed to the site's archaeological potential, and their work uncovered a large assemblage of material remains and suggested that the site was initially occupied as early as 24,314 cal BP (Edwards *et al.* 2001: 68). Due to the position of the site in the proposed Hope North mine pit, the DAA granted a Section 18 permit to impact the site, prompting a mitigative rockshelter salvage program. ACHM's excavations recovered the largest stone assemblage reported thus far for any rockshelter in the inland Pilbara and have extended the initial occupation of the site over 10,000 years to 35,978±653 cal BP. Jundaru may not have been occupied as early as Djadjiling, HS-A1, or HD07-3A-PAD13, but its archaeological and cultural importance lies in the rich assemblage of cultural remains and well-preserved combustion features that are unrivalled by the other sites at Hope Downs 1. A summary of the results for Jundaru is presented in Table 5-24.

The salvage excavations identified 24 combustion features, recovered 26,181 artefacts and 3502 faunal specimens, plotted 330 charcoal samples for radiocarbon dating, and collected 239 sediment samples and nearly 700 macrobotanic samples. The large assemblage of material remains from Jundaru provided the opportunity to carry out a wide range of specialist studies, including artefact usewear analysis, macrobotanical analysis, archaeomagnetic analysis, palynological analysis (Haberle *et al.*, this volume), phytolith analysis, faunal analysis, and mineralogical analysis in addition to the technological analysis of the artefact assemblage. The results of these specialist studies have proven to be instrumental, as they provide contextual information for the archaeological remains.

The radiocarbon chronology for Jundaru places it amongst the four other Pleistocene sites identified at Hope Downs 1 (Djadjiling, HD07-3A-PAD13, HS-A1, and Hope 1-41), which have now established demonstrably that there is a repeated pattern of early occupation of the inland Pilbara. This is further confirmed by Pleistocene occupations at other sites in the inland Pilbara, including Newman Rockshelter (30,897±372 cal BP, SUA-1510; Brown 1987), Mesa J24 Rockshelter (28,317±415 cal BP, Wk-2514; Hughes *et al.* 2011), and Juukan-1 (37,504±373 cal BP; Beta 249759; Slack *et al.* 2009). The dates for the initial occupation of the inland Pilbara correspond well with other parts of the arid zone. Nearby in the Little Sandy Desert, a Pleistocene occupation at Serpent's Glen rockshelter occurs slightly before 28,300±186 cal BP (23,550±140 BP; ANSTO-0ZB582; O'Connor *et al.* 1998). Evidence from the margin of the Great Sandy Desert suggests that the occupation of the shoreline of Lake Gregory may have occurred as early as 45,000 to 50,000 years ago (Veth *et al.* 2009). Radiocarbon dates from Puritjarra and Kulpi Mara rockshelters suggest that the central Australian ranges were occupied between 35,730±481 cal BP (31,140±470 BP; ANU10013; Smith *et al.* 1997) and 34,178±343 cal BP (29,510±230 BP; Beta-98034; Thorley 1998; Thorley *et al.* 2011).

The 14 radiocarbon dates for Jundaru provide a high level of chronological resolution for the archaeological sequence, and there is good agreement between the ACHM series and the MHA series. The deepest charcoal sample (173cmbd) yielded a date of 35,978±653 cal BP for the onset of site occupation. A small number of artefacts were identified below this charcoal sample, suggesting that the site may have been occupied slightly earlier. In comparison to the other Pleistocene sites at Hope Downs 1, the artefact density at Jundaru is substantially higher throughout the sequence. This is particularly valuable for gaining a better understanding of the technological reduction and retouching strategies that were utilised during both the Pleistocene and Holocene. The large assemblage of artefacts from the Pleistocene occupation is particularly valuable, as most other contemporary sites have only small assemblages.

The artefact densities suggest that Jundaru was repeatedly occupied from approximately 36,000 years ago. During the initial site use, it is possible that the site was only occupied briefly, as suggested by the lower artefact densities and the weak signal for anthropogenic alteration of the sediment (see Herries, this volume). Like the other Pleistocene sites, Jundaru was visited throughout the cooler and more arid conditions of the glacial period. The frequency of artefacts increased slightly during peak LGM conditions. It is believed that the use of the site during the LGM was a continuation of existing land-use patterns. A total of 3456 artefacts was recovered from the initial occupation through to the end of the LGM and transition to warmer conditions (AU8-AU6), an estimated span of 20,000 years. Over this time, an average of 17 artefacts were discarded every century. While the artefact densities through this period are ten times that identified at Djadjiling, the artefact density suggests the site was utilised only ephemerally.

A rapid rise in artefact density begins in mid-AU5 and this roughly correlates with the re-initiation of the summer monsoon (see Wyrwoll and Miller 2001: 127). A local response to this regional climate change may be shown by the large peak in tree phytoliths at the beginning of AU5 and a general increase in the incidence of tree and shrub phytoliths (Wallis, this volume). The distribution of faunal remains also shows a considerable rise in the number of specimens beginning in AU5. There is a peak at the beginning of AU4 with a corresponding rise in artefact numbers, which is contemporary with Features 20 and 19. While the abundance of artefacts drops to previous levels following this peak and rise slowly to AU2, the faunal remains show a trough between 80 and 75cmbd, followed by a second larger peak at the end of AU4. This peak is associated with the occurrence of Feature 17. AU4 also marks a significant increase in the number of combustion features at the site, and this trend continues through to AU1. From AU3 there is a gradual decline in the number of faunal remains through to the surface. It is surprising that the abundance of faunal remains does not increase during the late Holocene (as does the artefact density).

Table 5-24 Summary of results, Jundaru rockshelter

AU	Depth (cmbd)	Features with Max Depth Range	Dates (cal BP)	Art. Count	Artefact Notes	Palynological Analysis [1]	Macrobot. Analysis [2]	Archaeomag. Analysis [3]	Phytolith Analysis [4]
1	000-030			1207					
	030-035	F1 (30-32.5cmbd) F2 (32-39cmbd)	176±86 (31cmbd)	1134					
	035-040			2702					
2	040-045	F3 (40-45cmbd) F4 (40-44cmbd) F5 (41.5-47cmbd)		3646	→ tula → burren				Zone 3; ↓ tree/shrub & Panicoid grasses; ↑ Pooideae grasses
	045-050	F6 (47-51cmbd) F7 (44-57cmbd) F8 (45-49cmbd)		4093	→ most burins → eloueras	→Dung fungi (dingo?)	↓ *Acacia* (F6)		
	050-055	F9 (50.5-53.5) F10 (51-57cmbd) F11 (53.5-59.5cmbd) F12 (51.5-62cmbd)		2531					
3	055-060		3899±45 (56cmbd)	1038				→ warmer	∇ tree/shrub
	060-065	F13 (61-67.5cmbd) F14 (62.5-66cmbd)		889	→ backed art. → scrapers				
	065-070	F15 (67.5-72.5cmbd) F16 (68.5-75cmbd)		806		Burned grass phytoliths			∇ tree/shrub
4	070-075	F17 (73-89cmbd) F18 (70.5-77cmbd)	7686±34 (72cmbd)	881	→ trimmed GS → tabular GS				
	075-080			700					
	080-085	F19 (23-93cmbd) F20 (83-100.5cmbd)		1200					
5	085-090		10,774±135 (88cmbd)	695					
	090-095			771					→ higher incidence of tree/shrub
	095-100	F21 (95-103cmbd)		402				→ high anthro. signal	Δ tree (large)
6	100-105	F22 (101-105cmbd) F23 (100-103.5cmbd)	19,820±172 (101cmbd)	373					
	105-110	F24 (105-110cmbd)		379	Util. quartz crystal		Gum and *Acacia*		
	110-115			255	One burin				
	115-120			279					
	120-125		18,659±74 (123cmbd)	202					Zone 2; ↑ tree/shrub & Panicoid grasses; ↓ Pooideae grasses
7	125-130			169		→ localised fires		→ transition to warmer	
	130-135			203					
	135-140		26,793±369 (139cmbd)	216		Burned grass phytoliths			
	140-145			176					
	145-150			175					
8	150-155		33,255±651 (154cmbd)	213		→ micro. charcoal			Zone 1c; ↑ Panicoid grass
	155-160			266					
	160-165			263	Quartz crystal core				
	165-170			202	→ util. pebble			→ low anthro. alteration; glacial	
	170-175		35,978±653 (173cmbd)	70					
	175-180			9					
	180-185			5		Burned grass phytoliths			
	185-190			1					Zone 1b; ↓ tree; ↓ Panicoid grasses; ↑ Pooideae grasses
9	190-195			0				→alteration due to climate; glacial cond.	Zone 1a; Δ tree (low)
	195-200			0					

Key: → first instance/beginning of; ↑ general increase; ↓ general decrease; Δ peak; ∇ trough
Source: 1 (Haberle *et al.*, this volume), 2 (Fairbairn 2013), 3 (Herries 2013), and 4 (Wallis, this volume)

Through the Holocene there was greater occupational intensity, as indicated by low peak in artefact density at the beginning of AU4. Following the low peak, artefact numbers rise through to the beginning of AU2 where densities increase dramatically. The distribution of artefacts suggests that occupational intensity was greatest from AU2 and the beginning of AU1, which accounts for the last 4,000 years of site use. A corresponding increase in site use during the mid-Holocene has also been identified at HS-A1, HD07-3A-PAD13, HD07-3A-03, PAD 3, and PAD 4 (Cropper 2011b). During AU2, the phytolith and macrobotanical analyses suggest that there was a local response to climate change, perhaps as a response to lower rainfall. Feature 6 shows the first marked decline in *Acacia* wood charcoals (Fairbairn 2013), and from 45cmbd there is a decline in the abundance of wood and shrub phytoliths.

The large artefact assemblage from Jundaru provides an excellent dataset for exploring the timing of the appearance of formalised retouched artefacts and grindstones. The data shows that retouched artefacts were an important component of the assemblage throughout the sequence. Even with the introduction of formalised retouched artefacts, the proportion of non-formalised retouched artefacts remains greater (as do the proportions of utilised artefacts). While backed artefacts were introduced in the mid-Holocene, followed by burins, eloueras, burrens, and tulas in the late Holocene, they were a complement to a successful tradition of non-formalised retouched artefacts that continued through the occupation.

In the assemblage, backed artefacts occur earlier than other formalised retouched artefacts. The lowermost backed artefacts were recovered below Feature 10, which was dated to 3899±45 cal BP. The age-depth trend line of the ACHM radiocarbon series suggests that they may have first been utilised at the site prior to 5000 years ago. This chronology is consistent with previous findings at PAD 3 where they were found to at least 4686±78 cal BP and possibly earlier. Eloueras, tulas, burrens, and burins appear considerably later than backed artefacts, possibly only within the last thousand years. Eloueras, tulas, and burrens appear concurrently in the sequence between 40 and 46cmbd, while the burins were found up to 45 to 50cmbd. This finding corresponds with the initial appearance of tulas at HD07-1A-07 (Cropper and Law 2012b) and the occurrence of tulas, burrens, and burins at HD07-3A-03. At Jundaru, the appearance of these specialised woodworking tools (*e.g.*, tulas, burrens, and burins) occurs during a period of intense site use and is concomitant with a decline in tree/shrub phytoliths (Wallis, this volume). The macrobotanical analysis of the wood charcoals also indicates that there was likely less *Acacia* surrounding the site, and this may be due to a climatic change (Fairbairn 2013). More research is required to determine if such climatic changes are related to the use of specialised woodworking tools. Alternatively, it may imply that there was a greater emphasis on the production or decoration of wooden artefacts.

While small utilised pebbles occur in the earliest phase of occupation, large flat grindstones that may have been used for seed processing first appear between 70 and 75cmbd. Artefact 25,052 was found immediately below Feature 16 and it appears that the hearth was constructed atop the grindstone. The grindstone was angled and its base continued below the feature and into the next arbitrary excavation layer with a basal depth of 72.5cmbd. The grindstone was only removed with the subsequent arbitrary excavation layer; however, it appears to be directly associated with the feature. Feature 16 is argued to be contemporary with Feature 15, suggesting that the grindstone was used approximately 7700 years ago. While grindstones produced from river cobbles have been found earlier at HD07-3A-PAD13, the recovery of Artefact 25,052 represents the earliest occurrence of a tabular grindstone amongst the Hope Downs 1 sites. The second grindstone at this level is Artefact 17,795, which is a fragment of a lower grindstone that was trimmed along one side. This specimen was recovered from Unit 4 (73cmbd), slightly above Feature 17.

Twenty-four combustion features were identified at Jundaru, including hearths, ash lenses, and charcoal lenses; these features vary considerably in size, shape, and possibly function. Half of the features were identified as either charcoal or ash lenses, and these features show no evidence of *in situ* burning (*e.g.*, reddened sediment beneath the lens). Feature 1 is the only hearth to have a distinct layered appearance, and it is the youngest feature at Jundaru (176±86 cal BP). Other hearths show a mottled appearance with patches of light ash amongst the predominantly dark grey matrix that overlies reddened sediment. The lack of layering in most features may indicate that there was some post-depositional disturbance, perhaps during the contemporary occupation or as the result of subsequent human or animal activity. Two large pit-like hearths occur at the site (Features 20 and 17), and these features show considerable mixing of the sediment. This was determined through their mottled appearances and confirmed through archaeomagnetic analysis (see Herries 2013). The mixed sediment could be a result of hearth maintenance as well as inserting and removing the food item. Similar features were identified at Djadjiling and HS-A1.

There are six combustion features that are attributed to the Pleistocene occupation, ranging in age between 19,820±172 cal BP (Feature 23) and 10,774±135 cal BP (Feature 19). A charcoal lens was found just below Feature 23, indicating that it is slightly older. Features 24 through 21 were created at the site during the height of the LGM, providing unequivocal evidence of site use during this colder and more arid period. The archaeomagnetic signal indicated glacial conditions from 130 to 100cmbd (Herries 2013), which corresponds with the peak LGM. Features 20 and 19 were utilised at the end of the Pleistocene, and there is a contemporary low peak in artefact numbers suggesting a more intense phase of site use. The considerable size and depth of Feature 20 suggest that this feature may have been an ash or charcoal cooking pit. This interpretation is supported by the large assemblage of faunal remains that was recovered from the feature matrix, which included many burned specimens as well as one bone fragment with two deep parallel cuts (Faunal ID 1099). An even greater number of faunal remains was recovered from the arbitrary excavation layers surrounding Features 19 and 20. The lowermost emu eggshell fragments were recovered from the arbitrary layer around Features 19 and 20 (80-85cmbd), and one fragment was also found in the Feature 20 matrix. One of the fragments was calcined, suggesting that it is associated with these combustion events (burning was indeterminate on the other two fragments). If the eggs were collected for consumption, this could indicate an autumn or winter occupation as emus lay eggs on a seasonal basis (Western Australia Department of Environment and Conservation 2009; Malecki and Martin 2002: 167). However, it is possible that the eggshell had been previously collected and utilised for other purposes (*e.g.*, water container, *etc.*) then discarded at the site. The large assemblage of faunal remains from Feature 20 and its surrounds is good evidence in support that the emu egg was a food item.

Four early Holocene features were identified, including another large pit-like hearth (Feature 17) and three ash lenses. The hearth was identified slightly above Feature 20, but its provenance indicates that it is younger. All of the early

Holocene features are believed to be contemporaneous, and Feature 15 was dated to 7686±34 cal BP. Faunal remains were recovered from the matrix of each feature, including many burned bones. A large assemblage of faunal remains was recovered from the arbitrary layers surrounding the features, including burned emu eggshell fragments, two emu bones, and macropod and mammal bones with cut marks.

There are 14 combustion features that were created in the middle and late Holocene, including eight hearths, four ash lenses, and two charcoal lenses. In comparison to the large pit-like hearths, much smaller assemblages were recovered from these combustion features. Additionally, there is a lower incidence of faunal remains recovered from the feature matrix. Emu eggshell fragments were also found in Features 12 and 13.

The different patterns between the abundance of artefacts and faunal remains may indicate that the site was utilised differently over time. Pit-like hearths only occur in AU4 and they were presumably used for cooking large food items. Lower grindstones also appear in the assemblage at this time. The combustion features in other phases of site use are much more ephemeral, and perhaps large food items were prepared and consumed elsewhere.

The investigations at Jundaru also help to build upon our knowledge of site selection by the past Aboriginal peoples and site formation processes. As archaeologists we often have preconceived notions as to which rockshelters would have been utilised by Aboriginal people in the past. Jundaru is a good example of a rockshelter that was intensively used that has both a limited area with a flat surface and only a small overhang. In contrast, HN-A7 is a very large cave located immediately across from Jundaru, but it was only ephemerally utilised (Cropper 2013b). Jundaru also highlights the fact that rockshelters are not static, but can change dramatically through time. Significant roof collapse events occurred through the sequence, and this would have dramatically reduced the size of the rockshelter's overhang. Importantly, the expanse of boulders resulting from the roof collapse created a sheltered area for sediment to accumulate, and this feature may have been critical in aiding site preservation. Numerous rockshelters surrounding Jundaru show evidence of ephemeral usage, likely by the people who also occupied Jundaru. There are several walled features surrounding the site, and it is possible that they were created as storage places by people knowing that they would return to Jundaru.

The Jundaru faunal assemblage provides many unique insights into the past Aboriginal diet. Burned and broken bone fragments demonstrate that the people who visited the site hunted a wide range of animals, but macropods were a staple in their diet. Kangaroos appear to have been the dominant prey animal throughout the occupation (McDowell, this volume). The people who occupied the site also collected emu eggs, and their association with hearths may even suggest that some eggs were roasted. The presence of egg shell in the assemblage also provides good evidence that Jundaru was often occupied in the autumn or winter, as this is when emu eggs could have been collected. While people presumably stalked emus in order to find their eggs, emus do not appear to have been commonly hunted. There are only two emu bones in the assemblage and both were recovered from the same elevation (65-70cmbd), albeit from different excavation units (Unit 4 and Unit 1). Lower grindstones appear in the assemblage slightly before 7686±34 cal BP, and it is possible that they were utilised for food processing. The macrobotanical remains provide no evidence as to what plants may have been collected and processed at the site.

Around 5000 years ago, people began utilising backed artefacts at Jundaru. Many of these artefacts exhibit hafting traces and resin, indicating that they were composite tools. The usewear analysis of artefacts from Djadjiling suggests that composite tools have been present in the assemblage since people first occupied the region. The reason why backed artefacts appear at this time remains unclear, but at Jundaru they appear in the archaeological record during a period when there may have been climatic variability, as is indicated by troughs in tree/shrub phytoliths both prior to and after their introduction (see Wallis, this volume). While artefacts used for woodworking occur in the earliest phases of site use (AU8), specialised woodworking tools (*e.g.,* tulas, burrens, and burins) only appear after 1000 years ago. At this time there is also evidence to suggest a reduction of trees and shrubs in the local area. These tools appear at the height of site use and could indicate that the cultural significance of wooden artefacts and their decoration had changed. Tools associated with wood graving could suggest that wooden artefacts were decorated to a greater degree, perhaps due to a need to distinguish either personal or cultural identities.

Thus far, the earliest evidence for the use of resin at Jundaru is in the mid-Holocene. While there are numerous known uses of spinifex resin (Pitman and Wallis 2012; Pitman 2010), its appearance at Jundaru is concomitant with the appearance of backed artefacts. Numerous artefacts analysed by Fullagar (2013) show residue traces consistent with spinifex resin, including backed artefacts, tulas, an elouera, and retouched artefacts. Two utilised pebbles also exhibit these residues (Fullagar 2013). Some of the artefacts that have resin on them also exhibit signs of thermal alteration. It is possible that these artefacts were warmed in fires to soften the resin, allowing for de-hafting and replacement. A blackened fragment of resin was identified in Feature 7. There are numerous retouching flakes in the assemblage, indicating that retouched artefacts were produced and resharpened at the site, further supporting this interpretation.

Jundaru is a site that demonstrates repeated use, while most sites in the project area show only fleeting use, with low artefact densities and ephemeral lenses of ashy sediment. Jundaru has extremely high artefact densities, numerous hearth features (including some large and complex hearths), and a large faunal assemblage. Moreover, the archaeomagnetic signal is extremely high following the LGM and throughout the Holocene (Herries 2013). This data indicates that Jundaru was likely occupied for longer durations of time than other sites. Jundaru consistently has higher artefact densities than other sites, and the assemblage size is nearly double the combined number of artefacts recovered from the other 30 rockshelters excavated during the Hope Downs 1 Mitigative Project. This alone suggests that Jundaru was a focal point for people using the region, whereby people returned year after year even through periods of climatic and environmental change.

While Jundaru is highly significant to both the Traditional Owners and archaeological community, a Section 18 permit was granted in 2002, allowing use of the land for mining activities—subject to mitigative salvage excavations. In conjunction with MIB and IB representatives, ACHM conducted a salvage program at Jundaru under Section 16 Permit 428 over a period of four months. The excavation fulfilled the proponent's requirement under the Section 18 permit, and the gully in which the site was located was in-filled for the construction of a haul road for the Hope North mine pit. While the site may no longer exist, a detailed record of the site's occupation has been recorded through the efforts of the excavation team and the numerous specialists who have contributed to this chapter. A

large assemblage of carefully archived artefacts, faunal remains, and samples will allow for continued research.

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Chapter 6

Excavations at HD07-3A-PAD13 Rockshelter

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HD07-3A-PAD13 is a small rockshelter in Hope South (Figure 6-2) with an occupation sequence extending back over 40,000 years. Between November 2008 and September 2010, ACHM carried out an excavations at HD07-3A-PAD13 as part of the Hope Downs 1 Mitigative Salvage Program (MIB40; under Section 16 permit 423). The optically stimulated luminescence (OSL) technique was used to date the rockshelter sediments and has provided evidence that this site was utilised intermittently over the last 47.1±4.8 ka years. HD07-3A-PAD13 is regarded as having high archaeological significance not only for its demonstrated antiquity, but also for its unique site formation processes. There are few documented sites of this antiquity in the Pilbara, and many sites have limited archaeological assemblages associated with the initial occupation. For these reasons, sites such as HD07-3A-PAD13 are invaluable to help reconstruct Aboriginal technological strategies, settlement patterns, and subsistence practices during this early period. The site is located at the proposed edge of the Hope South mine pit and was not intended to be directly affected by the mine.

6.1 SITE SETTING AND DESCRIPTION

HD07-3A-PAD13 is located in a broad valley of the Newman land system, surrounded by the iron-rich ranges along the western margin of Hope South (Figure 6-2). Several ephemeral creeks merge within the valley and there are archaeological sites along each of the tributaries. The high number of occupied rockshelters within the valley suggests that it was an area of repeated use. Immediately across the ephemeral creek to the northeast is HD07-3A-03, which has evidence of repeated occupation through the mid-Holocene to the last two centuries. HS-A2 is slightly further south along the same creek and was utilised concurrently with HD07-3A-03. Approximately 160m to the north, a large range forms the north border of the valley and there are numerous rockshelter sites along the creekline that runs from the west to the east along at the base of the range. On the south face of the range, there is a large exposure of goethitised shale that was utilised in the past (HS-A3).

One of the distinguishing characteristics of the rockshelters within this valley is that they are low-lying, and this is particularly true of HD07-3A-PAD13. The rockshelter is situated at the base of a low hill that is abutted by an alluvial terrace (Figure 6-3) and has a small ephemeral creek nearby. The geomorphic context of the site was evaluated by Professor Martin Williams (this volume), who concluded that the rockshelter deposit is part of a floodplain that has since been incised by erosional flood events, forming a small terrace. The terrace appears to have been stable for at least the last several centuries, based on the presence of the large trees growing upon it and the well-developed desert pavement (on the opposite side of the channel, near HD07-3A-03; M. Williams, this volume). A second lower (*ca.* 40cm above the channel base) and more recent terrace was also observed.



Figure 6-1 Photograph of HD07-3A-PAD13 rockshelter (facing west-southwest)

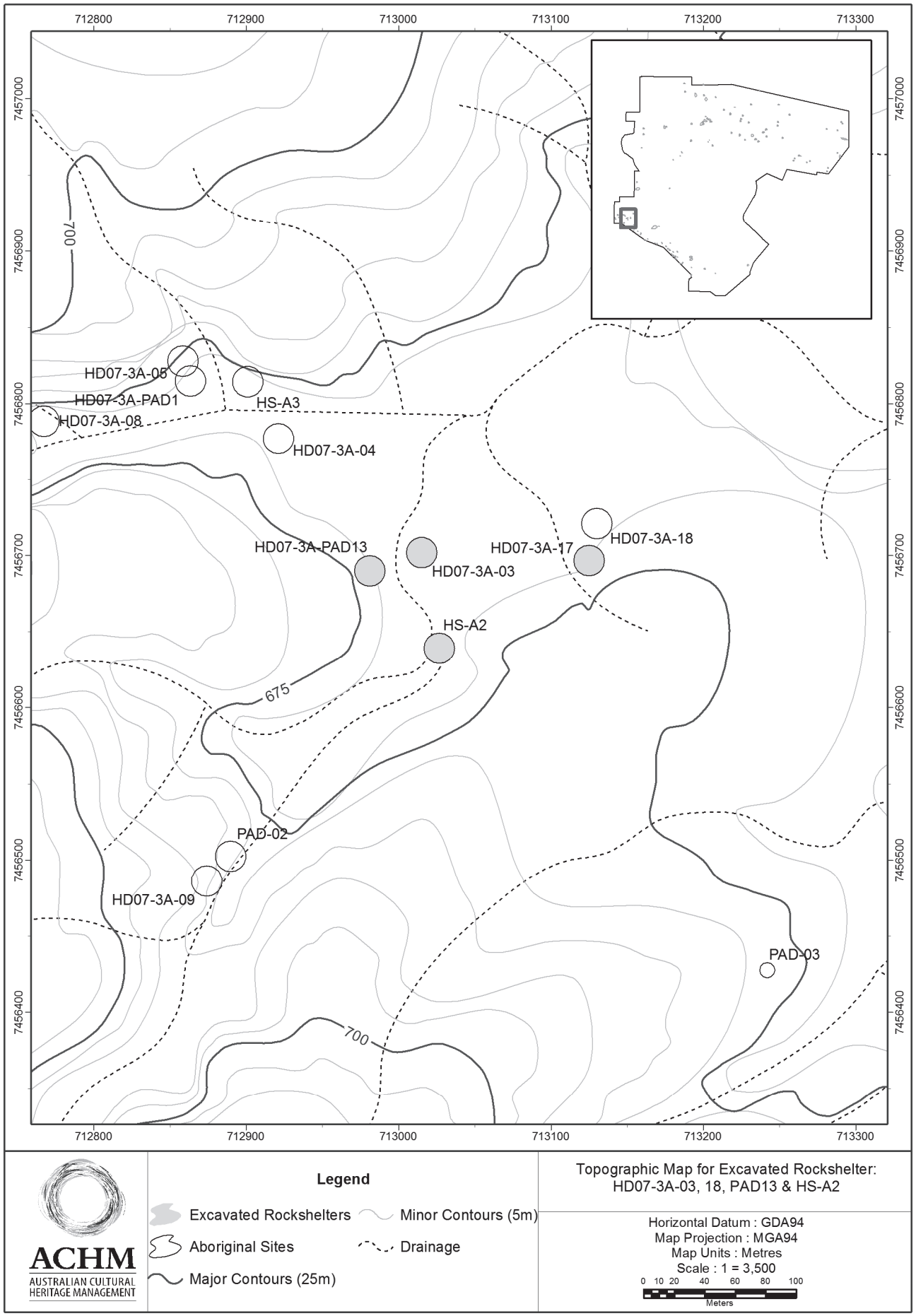

Figure 6-2 Topographic map for HD07-3A-PAD13 rockshelter

The rockshelter is very small, and its maximum dimensions are slightly deceptive as they do not truly reflect the useable ground space within the shelter as it appears today because of the sloping roof (Figure 6-4; Figure 6-5). The rockshelter has a maximum depth of 6m from the dripline to the back of the shelter, and the maximum width is along the entrance where it is 5.5m wide. The roof peaks at 1.7m (at the entrance on the south side of the shelter) and slopes down from the south side to the north side following the bedding of the bedrock. As a result, the south half of the shelter has a higher roof that extends along the entire east-west axis, and there is approximately seven square metres of useable ground space behind the dripline in this area of the rockshelter. This area was selected for the placement of the excavation trench.

On the north side of the shelter, there is a large area that has a very low roof height, which is less than 0.25m in many areas. Mapping this area was only possible using a laser distance meter. While this area of the shelter is presently unusable, it suggests that the rockshelter would have been much larger in the past when there was less accumulated sediment. In front of this low-roofed area, there is a strip approximately one metre in depth along the dripline that may have been utilised. However, just beyond the entrance, the roof slopes down considerably (see cross section A-B in Figure 6-4). This area could have only been utilised when there was less accumulated sediment.

The powdery floor surface of the rockshelter is level, and the sediment is unlike any other rockshelter excavated in Hope Downs 1 due to the virtual lack of exfoliated rock fragments. Most rockshelters show considerably weathering of the bedrock, with numerous cracks and fissures, but the walls and roof of HD07-3A-PAD13 appear to be very stable. This may indicate that the rockshelter formed under different conditions.

The shelter exhibited evidence of recent occupation by fauna. During the first excavation trip, bats were found in small crevice near the back of the shelter, but they did not appear to be continuously occupying the shelter or that our presence had caused them to relocate. Tracks in the powdery sediment indicate that a goanna and macropods also utilised the shelter. Antlions (doodlebugs) were present, and kangaroo ticks were particularly prevalent.

The vegetation survey carried out by Mattiske Consulting Pty Ltd (2009) classifies the vegetation within the valley as being tall acacia shrubland (C3 community; see Table 1-2), while hummock grasslands (S1 community) occupy the surrounding uplands. The upper terrace in the valley supports more established vegetation, including mature eucalypts and acacias, while the lower terrace is vegetated by young shrubs (M. Williams, this volume). This suggests that the incision of the lower terrace is a relatively recent erosional event. In the general area around the rockshelter and along the banks of the stream in front of the shelter, a wide range of plants were observed, including *Eucalyptus leucophloia* (snappy gum), *Cymbopogon ambiguous* (lemon grass), *Senna venusta, Gossypium robinsonii, Ptilotus calostachyus* (weeping mulla-mulla), and *Cassia* sp. Spinifex is predominant on the hillslope above the shelter and there are emergent *Eucalyptus leucophloia* surrounding the site.



Figure 6-3 HD07-3A-PAD13 (facing west); note the ephemeral creek in front of the rockshelter (entrance under the green-striped gazebo)

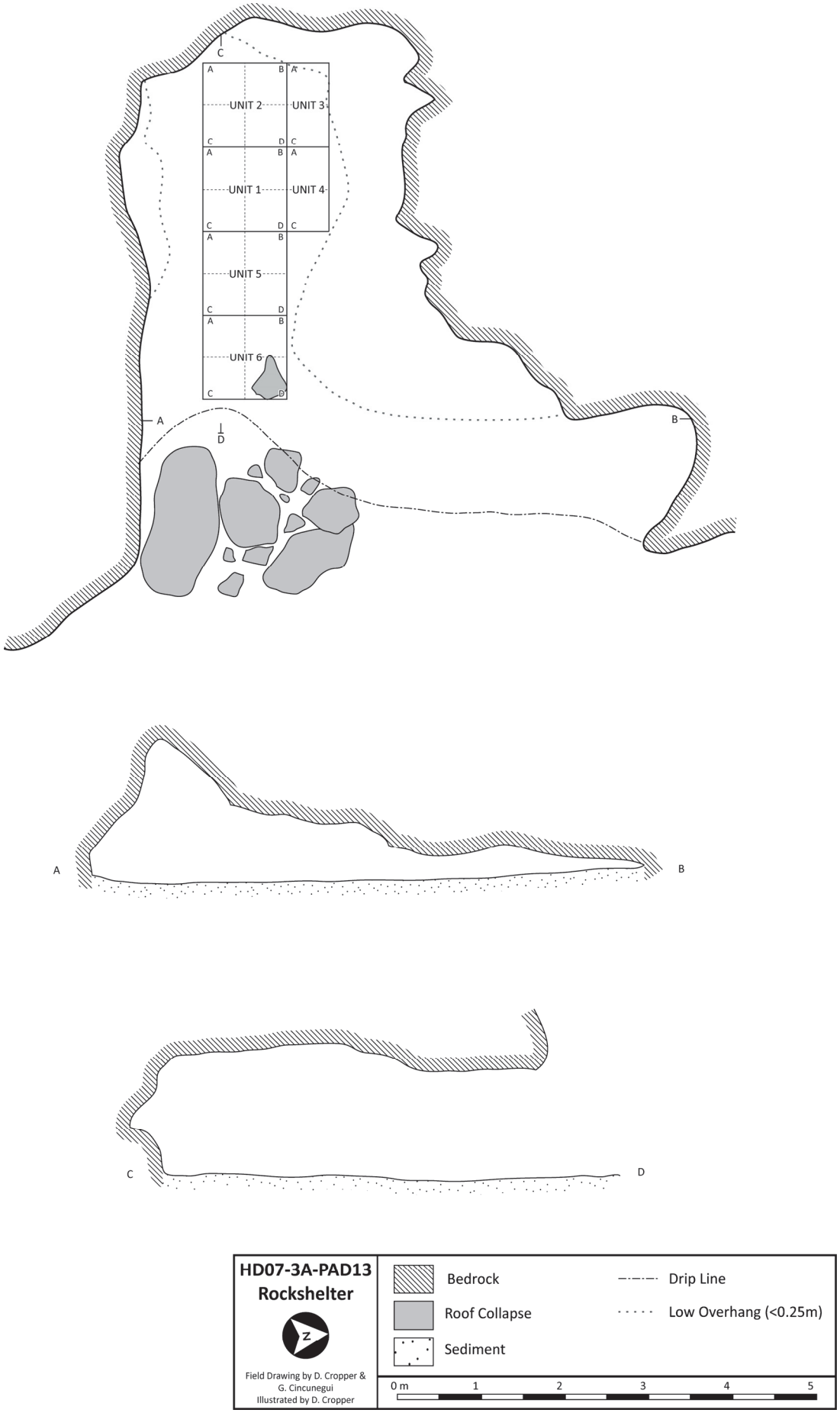

Figure 6-4 HD07-3A-PAD13 rockshelter plan and cross-sections



Figure 6-5 HD07-3A-PAD13 showing scale of the rockshelter; D. Cropper pictured



Figure 6-6 Interior of the south side of HD07-3A-PAD13 with backfill of Unit 1 removed and Units 2 to 6 prepared for excavation

6.2 SUMMARY OF FIELD INVESTIGATIONS

The salvage of HD07-3A-PAD13 was conducted over a series of four field trips between November 2008 and September 2010. Over the course of the site investigations, six excavation units were investigated, a program of OSL dating was carried out, and the site was stabilised for future research. A summary of each field trip is provided below. All excavated sediment was weighed and sieved, and during the final field trip, floatation and sorting of the coarse rock fraction was conducted at the site during the excavation. The fine rock fraction was collected and stored at the Hope Downs 1 Laboratory until it was processed in March 2009. On the subsequent field trips, a sorting work station was set up at the site, enabling the team to float and sort both the fine and coarse rock fraction. The team recovered a large assemblage of artefacts and collected numerous charcoal, sediment samples, and other samples. All of the material recovered from the site has been archived.

Test excavations began in early November 2008. A 1-x-1m excavation unit (Unit 1) was placed near the back of the rockshelter, in an area where the deposit was well-protected from the elements (Figure 6-4). The surface elevations of the unit varied between 23cmbd (in the south) and 27cmbd (in the northwest) and the first arbitrary layer was excavated to a depth of 30cmbd. In total, 32 arbitrary layers (5cm) were excavated

during this initial trip, reaching a maximum depth 180cmbd or approximately 160cm below the surface. While there was clearly deeper sediment below this depth, excavation of Unit 1 was halted at this point due to occupational health and safety concerns.

With the experience of Pleistocene deposits at sites such as Jundaru and Djadjiling, the considerable depth of artefacts at this site was believed to indicate a possible Pleistocene occupation; although, the site formation processes at HD07-3A-PAD13 were unlike any of the other rockshelters excavated by ACHM within the Hope Downs 1 Lease. The primary mode of sediment deposition was interpreted to be fluvial, with sediment accumulating as the result of low-energy flood events. In contrast, most other rockshelter sites have deposits comprised of exfoliated bedrock and with the silt component derived through aeolian deposition and chemical weathering of the bedrock and rock fragments. The different deposition modes make age-depth comparisons very difficult, as the sediment could have accumulated at different rates through time.

Charcoal was only recovered from the upper layers of the deposit; therefore, standard radiometric methods could not be used to provide an age estimate of the cultural materials. This was recognised in the field, and an alternative dating method was required. OSL was determined to be the best technique to provide an age estimate for the sediments, and from this we could gain a better understanding of the site's occupational history. The OSL technique calculates the time that has elapsed since particular grains of sediment (*e.g.*, quartz or feldspar) were last exposed to sunlight, and this could provide a chronological framework for the associated artefacts. The field team collected five OSL samples at depths ranging from 15 to 124cm below the surface. The samples were submitted to the Centre for Environmental Luminescence at the University of Adelaide for analysis (see F. Williams, this volume).

In May 2009, ACHM received the preliminary OSL results (Williams 2009), which indicated a Pleistocene Aboriginal occupation at HD07-3A-PAD13 (Cropper and Law 2009). These results were confirmed by the final OSL report (Cropper and Law 2010a), and further investigation of the site was recommended.

The excavation of HD07-3A-PAD13 resumed in mid-June 2010, and the area of excavation was extended to cover a total area of five square metres (Figure 6-4). Due to the depth of the deposit and the confined nature of this rockshelter, a large excavation area needed to be opened in order to provide safe working conditions. Bedrock was exposed across the entire trench, with the exception of the excavation unit nearest to the rockshelter entrance (Unit 6; excavated to 75cmbd or *ca.* 50cmbs), which was used as a step to safely enter and exit the excavation trench. Geocloth was placed over the surface of Unit 6 in order to protect the deposit for future excavation. The deepest *in situ* artefact recovered during this final stage of excavation was a quartz flake (204cmbd), and numerous artefacts were recovered during the sieving of the coarse and fine-fraction. The excavations revealed undulating bedrock across the trench that slopes down to the northeast, reaching a maximum depth of 239cmbd. The condition of the bedrock varied depending on the lithology, but in general the bedrock was extremely friable and weathered.

Two senior scientists from the University of Adelaide, Frances Williams and Professor Martin Williams, were contracted to carry out *in situ* collection of OSL samples in order to establish the onset of human occupation at the site (see F. Williams, this volume). Four OSL samples were collected from Unit 5 (Quads C and D) at depths between 156.5cmbd and 193.5cmbd. Each OSL sample measured approximately nine centimetres in diameter and was dug into the trench section to a depth of 30cm to 40cm. After each sample was collected, a portable gamma spectrometer was inserted into the opening in order to measure the gamma radiation. This is particularly important, as the gamma radiation can be affected by the proximity to bedrock and large rocks.

It was recommended that the proponent avoid directly impacting HD07-3A-PAD13 because of its high scientific value and unique site formation processes (Cropper and Law 2010b; Law and Cropper 2010). Accordingly, the excavation trench was backfilled in order to stabilise it and protect the deposit for future research. Once the trench was completely backfilled, a layer of geo-cloth was placed over the trench to add further protection.

6.3 STRATIGRAPHY

Excavation at HD07-3A-PAD13 revealed an accumulated deposit with a maximum depth of over two metres (Figure 6-7; Figure 6-8). Five stratigraphic layers were identified at the site (SL1-SL5) based in subtle differences in the composition. Throughout the entire sequence, the colour of the sediment was consistently yellowish red (5YR 4/6) with little variation, indicating that there was a consistent source for the sediment. The two layers were differences were identified were the basal layer, which had a much higher proportion of degrading bedrock, and SL2, which comprised a deposit of densely-packed mud wasp brood chambers.

No combustion features were identified during the excavation of HD07-3A-PAD13, and even diffuse ash lenses were not encountered. It is possible that floodwaters may have transported the charcoal out of the rockshelter, but is expected that some trace of a hearth would remain. The archaeomagnetic analysis did not identify any evidence of combustion features (Herries 2013).

Stratigraphic Layer 5 - SL5 occurred just above the bedrock and had the highest proportion of rock of any of the stratigraphic layers in the deposit (45% soil, 15% fine rock, 10% small rock, 10% coarse rock, and 10% large rock). The rock in the layer originated from the degrading bedrock and it ranged from fine rock (less than 1cm) to large rocks (greater than 10cm). Some of the fine sediment fraction had a mineralised appearance, indicating that there had been *in situ* chemical weathering or decay of the bedrock and rock fragments. The chemical weathering of the bedrock was the result of water seeping through and causing breakdown of the rock through processes such as oxidisation or hydration. Fine roots extended through the deposit into SL5 and they also appeared to have contributed to the breakdown of the bedrock. Roots were matted against the bedrock in areas and also continued into the many fissures and cracks in the degrading bedrock surface. This suggests that more moisture is present near the bedrock, which added to its breakdown. As this layer essentially reflects the weathering of the bedrock, it followed the contour of the bedrock. As such, it is more predominant in areas where there are large exposures of bedrock.

Stratigraphic Layer 4 - SL4 was a fine yellowish red silty loam with occasional fragments of exfoliated roof collapse and degrading bedrock (75% soil, 5% fine rock, 5% small rock, and 5% coarse rock). The fine silt fraction of this layer accumulated as the result of large flood events when the overbank floodwater carrying a suspended load of fine silt entered into the

rockshelter and deposited the sediment. No rounded river gravels were observed in the layer and there is a very low proportion of sand (as above), which attests to the low energy of the overbank floodwater. This interpretation of the site formation processes was confirmed by M. Williams (this volume). The composition of the silty loam was approximately 10 to 15% clay, 70% silt, and 15% very fine sand (M. Williams, this volume). Sub-rounded to sub-angular sand grains were present in the deposit, and similar-sized dark minerals and ironstone were abundant (M. Williams, this volume). The low energy of the floodwaters would not have caused significant displacement to artefacts present on the shelter floor, but it is possible that some tiny flakes may have shifted during flood events. Organic material on the surface of the shelter may have floated and been redistributed in the deposit, and this may have affected the preservation of hearth features at the site. None of the original stratification remains visible in the deposit (M. Williams, this volume). The fine-grained deposit was observed to become very powdery when dry, any occupation of the rockshelter, either by fauna or humans, would have destroyed the original structure of the deposit. Throughout this layer, there were a number of large blocks of roof collapse. SL4 was differentiated from SL3 by its higher proportion of angular rock, which was derived from the weathering of the rockshelter. The greater proportion of angular rock in this layer indicates that there was greater weathering of the rockshelter walls and ceiling during the deposition of this layer, perhaps due to repeated wetting and drying of the bedrock.

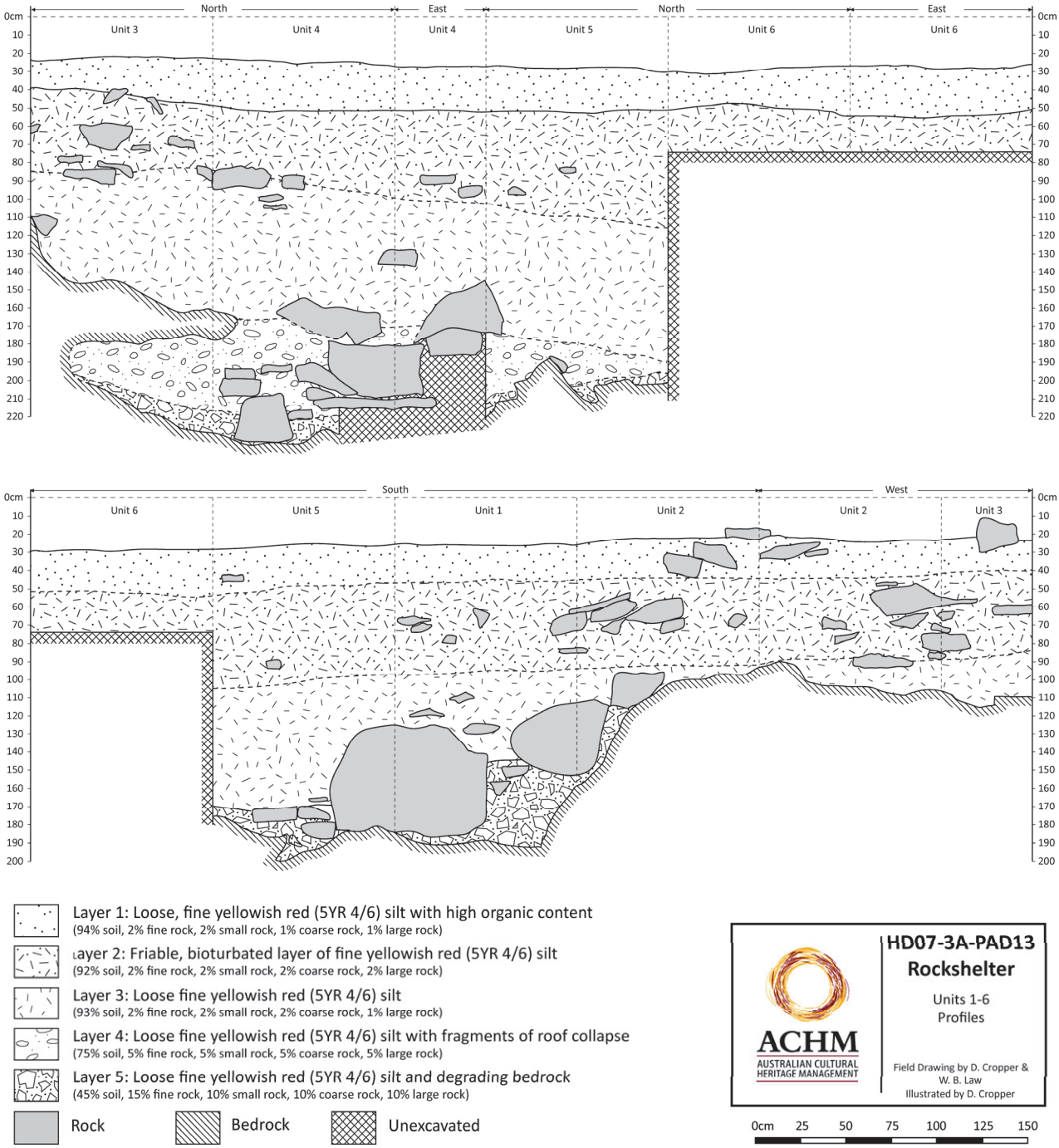

Figure 6-7 Unit 1 to Unit 6 profile for HD07-3A-PAD13 rockshelter

Stratigraphic Layer 3 - SL3 was identified on the basis of a significant reduction in the rock component, with the deposit largely comprised of yellowish red silty loam (93% soil, 2% fine rock, 2% small rock, and 1% coarse rock). As with the previous layer, the silty loam component accumulated through fluvial deposition, and there are no visible structures. The fact that artefacts are dispersed throughout the layer suggests that there were numerous flood events around this period, resulting in their rapid burial and the quick accumulation of sediment as opposed to one or two events that deposited large quantities of silt; although, it is possible that there may have been limited vertical movement of artefacts due to sediment disturbance. No rounded river gravels were observed, but there was a small proportion of angular fragments of exfoliated bedrock. Throughout the lower half of this layer, there were occasional large blocks of angular rock that have fallen from the rockshelter roof. Tiny fragments of charcoal were observed, which may represent a background assemblage that was washed into the flooded creek and deposited in the rockshelter along with the alluvium. It is possible that some of the very small fragments may have even blown into the shelter. Mud wasp brood chambers were identified in the layer, but they occur rarely. The upper limit of the layer was defined by the limits of the densely-packed mud wasp brood chambers of SL2, which appears to interrupt a relatively continuous mode of deposition (Figure 6-8).

Stratigraphic Layer 2 – The sediment of SL2 was also comprised primarily of silty loam, with occasional fragments of exfoliated bedrock (92% soil, 2% fine rock, 2% small rock, and 2% coarse rock).; however, it was distinguished from the underlying and overlying strata by the high density of mud wasp brood chambers. The layer was approximately 50cm thick and the density of brood chambers was greatest in the east half of the rockshelter, and they became more diffuse towards the back of the shelter. During this period, sediment continued to be deposited through fluvial processes; however, the deposit was altered by the accumulation of mud wasp brood chambers. In Unit 6, there was some evidence for slightly higher-energy fluvial deposition at the top of the layer (*ca.* 50-65cmbd) as very small rounded pebbles were identified; however, this was restricted to the deposit near the entrance of the rockshelter as pebbles were not identified further back.

The layer was characterised by tightly packed oval-shaped mud structures, approximately three centimetres long and up to a centimetre in diameter (Figure 6-9). Most of the structures were observed to have a hole at one end and some contained a dried disk-shaped organic object. Numerous specialists were consulted to determine if the structures represented insects that burrowed through the deposit (causing potential disturbance). Nadine Guthrie, a Research Scientist in the Science Division of the Department of Environment and Conservation (WA), identified the structures as being mud wasp brood chambers based on photographic evidence (N. Guthrie 2012, pers. com., 9 Feb.). Each brood chamber would have contained an egg and food for the offspring as it progresses through the larval and pupal stages (N. Guthrie 2012, pers. com., 9 Feb.). The mud wasps would have constructed nests on the shelter ceiling, and they subsequently fell to the ground. This finding demonstrates that the brood chambers represent a different mode of sediment accumulation, rather than bioturbation. The holes in the brood chambers are emergence holes where the adult broke through the chamber (Smith 1979: 183), and the disk-shape objects found in some of the chambers are believed to be the dried remains of dead larva or pupa (N. Guthrie 2012, pers. com., 9 Feb.). The chambers may have fallen off the shelter ceiling due to their weight or if environmental conditions changed stages (N. Guthrie 2012, pers. com., 9 Feb.). Samples of the brood chambers were collected and have been archived for future research (ui-464, ui-705, and ui-726). Occasionally the thin papery cocoon, which is spun inside the chamber during the pupal stage, was also found.

Occasional brood chambers have been observed at other rockshelters at Hope Downs 1 (*e.g.*, Jundaru and HS-A2), but no other sites had densities comparable to HD07-3A-PAD13. The abundance of brood chambers at this site is almost certainly related to the fine silty loam on the surface of the shelter, which would have been ideal for nest building, and the availability of water. In contrast, the floor surface of most other rockshelters is covered with rock fragments. It is presumed here that the mud wasps collected the sediment for their nests directly from the rockshelter, as there is an ample supply of silty sediment. However, it has been noted elsewhere that they may range up to 50m to collect the necessary materials (Ian Naumann in Wallis 2002). Smith (1979: 183) notes that nests are generally only found near a reliable source of water. No rockholes or permanent water supplies were identified immediately surrounding the site; however, it is possible that there would have been rockholes in the numerous creeklines near the site in the past that would have provided an ephemeral water source after rain. At HD07-3A-PAD13, no mud wasp nests were identified on the rockshelter walls or roof, suggesting that environmental conditions are no longer suitable.

The fact that the brood chambers fell to the ground is significant, as it means that insects were not burrowing into or out of the deposit, possibly displacing artefacts and other associated materials. Any artefacts that were discarded on the surface of the rockshelter during this phase of site use would have been covered by the brood chambers that fell from the roof. In other archaeological contexts, mud wasp nests have been argued to be a 'valuable tool in archaeological and palaeoclimatic research' (Roberts *et al.* 1997) and have been used to provide dating evidence for rock art (Roberts *et al.* 1997) and reconstructing past environmental conditions (Wallis 2002).

Based on the number of chambers at the site, it is likely that they accumulated over a considerable period of time. The nest building appears to have occurred during a phase when there was little sediment accumulation at the site, as flood events on the scale seen in SL3 would have successively buried the brood chambers as they fell to the ground. Instead, SL2 is comprised of tightly-packed chambers with no evidence of alluvium separating them. There is a large gap in the dates from the base of the layer and the top of the layer, spanning nearly 30,000 years. This indicates that there was extremely low aggradation of the deposit during this period, which extends from the onset of more arid conditions approximately 30,000 years ago, through the LGM and into the Holocene.



Figure 6-8 Left: stratigraphic profile in unit 4 (northeast corner). note the brood chambers of SL2 separating SL3 and SL1; right: bedrock exposed at the back of the excavation trench in Units 2 and 3 at HD07-3A-PAD13 rockshelter

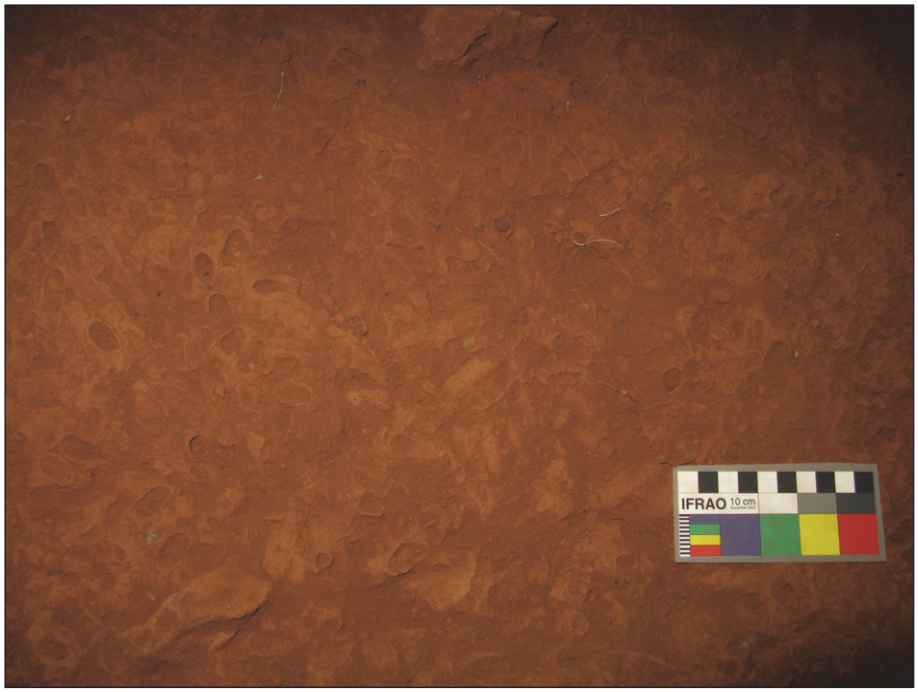

Figure 6-9 Detail of the mud wasp brood chambers identified in Unit 1, Layer 7 at HD07-3A-PAD13 rockshelter

The upper limit of SL2 was between 50 and 40cmbd, with the lower elevations occurring near the entrance of the rockshelter. It is possible that fewer brood chambers were constructed near to the rockshelter entrance, which may account for lower elevations near the entrance and higher elevations near the rear of the shelter. Smith (1979: 183) indicates that mud wasps preferred dimly-lit areas. Alternatively, it is possible that the when the floodwaters once again entered the rockshelter that the brood chambers closer to the entrance suffered erosion from the floodwaters.

Stratigraphic Layer 1 – The lower boundary of SL1 was between 50 and 40cmbd and was marked by a decrease in the density of the mud wasp brood chambers; although, the matrix composition remained nearly identical (94% soil, 2% fine rock, 1% small rock, and 1% coarse rock). With the exception of the excavation Layer 1, brood chambers were observed throughout the deposit, but their occurrence was patchy. This suggests that sediment was once again deposited in the shelter, burying the mud wasp nests as they fell to the ground. Some of the chambers appear to have since degraded, as isolated papery

cocoons were also identified. The sediment was consistent with that in SL3, suggesting that the mode of deposition continued to be fluvial. SL1 had a greater proportion of organic matter towards the top of the deposit, including macropod scats, seeds, grass heads, leaves, and pieces of wood. The deposit was also loose and powdery in the upper 10cm, presumably due to the lack of compression and because it was drier than the remainder of the deposit.

6.4 OSL AND RADIOCARBON DATES

Two dating methods have been used to provide chronological context to the archaeological sequence at HD07-3A-PAD13, AMS radiocarbon dating and OSL dating. The challenge of this site was that no combustion features were identified during the excavation, so it was not possible to date individual occupations at the site. Because charcoal was very infrequent throughout the majority of the deposit, radiocarbon dating was only used to date the upper deposit. Alternative dating methods were required to provide chronological context for most of the archaeological sequence at HD07-3A-PAD13. The OSL technique measures the last moment a quartz grain was exposed to sunlight before it was buried by sediment. The OSL method dates when the sediment was deposited, and the age of the sediment provides an estimate of the age of the associated cultural material. The sediment in HD07-3A-PAD13 was deposited during extreme flood events, and as the slackwater receded, sediment was deposited over large areas of the valley, including inside HD07-3A-PAD13. It is during these flood events that the sediment would have last been exposed to sunlight.

OSL dating was conducted in two separate rounds in 2009 (AdBL09004 to AdBL09007) and 2010 (AdBL10011 to AdBL10014) by Frances Williams at the Luminescence Dating Laboratory at the University of Adelaide (now the Centre for Environmental Luminescence). The OSL results are presented in Table 6-1 and the full OSL report is presented as Chapter 16. Unpublished reports were also submitted to ACHM documenting the provisional and final results of the 2009 dates (Williams 2009; Williams 2010). As the results of these reports are superseded by those presented in, this volume, they have not been included in this report.

The first series of OSL samples were collected by the salvage team. PVC tubes (3cm diameter and 10cm long) were hammered into the north wall of Unit 1 at various depths (40, 93, 119, 148.5, and 149cmbd). The ends of the tubes were packed with foam and sealed with black cloth duct tape. Bulk sediment samples were collected from around each sample location, and all of the material was placed into sealed black bags and then transported back to Adelaide. In addition to the luminescence measurements of the samples, the environmental dose rate of each sample needs to be determined in order to calculate the age. To determine the environmental dose rate three series of measurements are needed: 1) the water content of the sample, 2) the cosmic ray contribution (dependent on the density and thickness of the rockshelter roof and hillslope above it), and 3) the concentrations of uranium, thorium, and potassium and their gamma ray contribution (F. Williams, this volume). For the 2009 round of dating, this was determined using bulk sediment samples provided to the analyst.

Provisional results for the first series of dates were first reported in May 2009 (Williams 2009). The results were considered provisional as Williams was awaiting the dosimetry results from the Australian Nuclear Science and Technology Organisation (ANSTO). The sample collected from 40cmbd did not have sufficient material for analysis (Williams 2009). The final report was submitted in April 2010 after receiving the dosimetry results from Genalysis Laboratory Services (Williams 2010) and were then reported to Karijini Development Pty Ltd and to RTIO (Cropper and Law 2010a; Cropper and Law 2009).

Due to the antiquity of the site, the project managers believed that it was important for a team of specialists to visit the site in order to collect the samples and perform *in situ* dosimetry measurements. In September 2010, Frances Williams, assisted by Martin Williams, visited HD07-3A-PAD13, collecting OSL samples and carrying out *in situ* dosimetry. The four sediment samples were collected at depths ranging from 157m to 194cmbd. The samples were collected from an area approximately 9cm in diameter.

After visiting the site, Williams noted that the thickness of the rockshelter had not been taken into account when determining the cosmic ray contribution of the 2009 dates. Additionally, the potassium concentrations in the earlier samples were considerably different to those measured *in situ* (F. Williams, this volume). The differences in the dose rates in the two series are believed to be due to the disparate methods used in their measurement (*i.e.*, the bulk samples are less representative of the actual deposit; F. Williams, this volume). As a result, the dose rates, equivalent doses, and ages were re-calculated for the 2009 series, which altered the ages of the samples. The results of the 2010 series and the revised 2009 series of dates are presented in Table 6-1.

The deepest sample yielded an age of 63.1±8.4 ka, and this age is interpreted by the project managers as being anomalous. F. Williams (this volume) noted that there appears to be two groups of grains in the sample: an older group with higher equivalent dose rates (not fully bleached) and a younger group with lower equivalent dose rates. The younger grains are believed to be completely bleached, thus providing 'the youngest possible age for the deposition of this horizon' (F. Williams, this volume). There are interpretive issues with this sample and based on the antiquity of the other sites at Hope Downs 1 as well as throughout the arid zone, this age appears too early for the date of the initial occupation of the site. It is possible that the grains were not fully bleached, or that there was re-working of some of the sediments. Artefacts were found up to 26cm below the sample (at its midpoint) that yielded the 63.1±8.4 ka date. There is a great deal of scepticism of sites with cultural material suggested to be greater than 50,000 years old (see O'Connell and Allen 2004).

Currently, the earliest occupation of the Pilbara appears to be around 43,000 years ago and this is demonstrated at Djadjiling (Law *et al.* 2010; Law and Cropper 2012) and HS-A1. Similar, but slightly later, dates are demonstrated for Jundaru and Juukan 1 (Slack *et al.* 2009). Nearby in the Little Sandy Desert, a Pleistocene occupation at Serpent's Glen rockshelter occurs slightly before 28,300±186 cal BP (23,550±140 BP; ANSTO-0ZB582; O'Connor *et al.* 1998). Radiocarbon dates from Puritjarra and Kulpi Mara rockshelters suggest that the central Australian ranges were occupied between 35,730±481 cal BP (31,140±470 BP; ANU10013; Smith *et al.* 1997) and 34,178±343 cal BP (29,510±230 BP; Beta-98034; Thorley 1998; Thorley *et al.* 2011). More recently, evidence from the margin of the Great Sandy Desert suggests that the occupation of the shoreline of Lake Gregory may have occurred as early as 45,000 to 50,000 years ago (Veth *et al.* 2009). Based on the timing of Aboriginal occupation elsewhere in the arid zone, the date of 63.1±8.4 ka from HD07-3A-PAD13 appears to be too early to represent the initial occupation of the site and should be regarded as anomalous.

Table 6-1 OSL results, HD07-3A-PAD13 rockshelter

Lab Code	Sample No*	Strat Layer	Depth (cmbd)^	Dose Rate (Gy/Ka)	Err	D_e (Gy)	Err	Age (ka)
AdBL09004	c-006 (DC131)	3	93 (91.5-94.5)	1.37	0.04	42.5	4.3	31.0±3.1
AdBL09005	c-007 (DC132)	3	119 (117.5-120.5)	1.84	0.06	53.3	5.3	29.0±2.9
AdBL09006	c-008 (DC133)	3	148.5 (147-150)	1.42	0.04	51.1	5.1	36.0±3.6
AdBL09007	c-009 (DC134)	3	149 (147.5-150.5)	1.46	0.05	49.2	4.9	33.7±3.4
AdBL10011	c-035 (HD10/3)	3	157 (152.5-161.5)	1.57	0.03	43.4	3.8	27.6±2.5
AdBL10012	c-034 (HD10/2)	3	168 (163.5-172.5)	1.52	0.03	51.7	3.73	33.9±2.5
AdBL10013	c-033 (HD10/1)	4	177 (172.5-181.5)	0.87	0.02	41.0	4	47.1±4.8
AdBL10014	c-036 (HD10/4)	5	194 (189.5-198.5)	0.56	0.02	35.4	4.7	63.1±8.4

* For the sample numbers, the number in the brackets was used by the Luminescence Laboratory, while the number at the beginning is the ACHM code.

^ For the sample depth, the midpoint and range is given to reflect the diameter of the sample collection area.

Table 6-2 AMS radiocarbon results, HD07-3A-PAD13 rockshelter

Lab Code	Sample No.	Material	Context	Strat. Layer	Depth (cmbd)	Depth (cmbs)	$\delta^{13}C$	^{14}C Age (BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-26727	c-01	Charcoal	U1-L01-QC	1	28	~3.5	-23.7±0.2	840±30	893 to 686	747±39
Wk-26728	c-03	Charcoal	U1-L03-QC	1	38	~13.5	-24.0±0.2	235±30	422 to -4	280±101
Wk-26729	c-04	Charcoal	U1-L05-QC	1	47	~22.5	-23.9±0.2	1559±30	1526 to 1385	1462±41

The sample collected at 177cmbd provides a better indicator of when people first began to use the site. The sediment within this sample was deposited 47.1±4.8 ka. In contrast to radiocarbon determinations, OSL dates have a much larger error; hence, this date has a range from 51.9 ka to 42.3 ka. The younger age range is consistent with the calibrated radiocarbon chronology for the early occupation of other sites at Hope Downs 1, such as Djadjiling and HS-A1 (Jundaru was occupied slightly more recently). Therefore, the project managers view the OSL results cautiously and suggest that the site was occupied during the younger range of this OSL date.

The OSL dates between 168 and 93cmbd document the rapid deposition of sediment in SL3 over the course of several millennia from approximate 33.9±2.5 ka to 31.0±3.1 ka. While the dates within this depth range show minor inversions, these are not statistically significant considering the error range. This phase of sedimentation occurred during a phase of warmer and wetter conditions prior to the onset of arid conditions, approximately 30,000 years ago (Magee *et al.* 2004; Johnson *et al.* 1999). After 31.0±3.1 ka, sedimentation rates decreased dramatically.

As charcoal was present in the upper portion of the deposit, AMS radiocarbon dating was used to provide chronological context to the site stratigraphy and archaeological sequence. The charcoal selected for dating was collected *in situ*, but there is no certainty that it is associated with the past human occupation of the site. There are a number of natural processes that may account for charcoal in the deposit. It is possible that the charcoal may have been blown into the site, or it may have been washed into the shelter during flood events. It is also possible that it may be cultural, but the combustion feature that it originated from was not uncovered during the excavation.

Despite the fine-grained sediment comprising the HD07-3A-PAD13 deposit and careful excavation, only 27 charcoal samples were recovered. In some instances the charcoal samples consisted of a single fragment of charcoal, while other samples included multiple fragments from the same position (this was noted in the field records). After the initial field trip during which Unit 1 was excavated, three samples from Unit 1 were selected to date the upper portion of the deposit between 28 and 47cmbd (Table 6-2). Even after excavating Units 2 through 6, only 15 samples were recovered below the lowermost radiocarbon date, and all of the charcoal samples were very small (the 15 samples have a combined weight of 11.91g). At this time, the samples in SL2 were viewed as possibly having been affected by bioturbation and were not submitted for analysis. This is now known not to be the case, and these samples may provide greater chronological resolution for this period of low sedimentation. The elevation of the samples was recorded in relation to the datum; however, the approximate depth below the surface has also been presented in the table below using the average surface elevations for each excavation unit.

The charcoal samples were submitted to the Radiocarbon Dating Laboratory at the University of Waikato and the results are presented in Table 6-2. The age and depth of sample Wk-26729 is in good agreement with the neighbouring site, HD07-3A-03. This sample occurred near the transition between stratigraphic Levels 2 and 1, and may indicate onset of flood events resumed by 1462±41 cal BP after a long hiatus. While the charcoal samples were carefully selected from good contexts, the radiometric dates show an inversion between Wk-26728 and Wk-26727. Both samples were collected *in situ* and there was no reason to suspect that the samples may be compromised. Because the sediment is extremely powdery, it is reasonable to assume that there may have been some disturbance when both animals (particularly macropods) and humans have occupied the site. Alternatively, it is possible that during flood events, older charcoal may have been introduced into the site.

6.5 ARTEFACT ANALYSIS

A moderate-sized assemblage of 1718 artefacts was recovered from the excavation at HD07-3A-PAD13. Each artefact in the assemblage was subject to a full technological analysis according to the methodology outlined in Chapter 4. The artefact analysis was performed by Dawn Cropper. The results of the analysis are presented in the following sections, including a discussion of the division of analytical units and the distribution of artefacts through the sequence.

Division of Analytical Units

In order to interpret the results of the artefact analysis accurately, it is necessary to divide the assemblage into smaller analytical units. The division of analytical units used here is

largely reliant on the site's chronostratigraphy. SL2 was particularly difficult to divide into analytical units, as there are no dates within this layer. Because a high number of artefacts were recovered from this layer, which comprises a great deal of the site's occupation history, it was deemed necessary to divide the layer based on the patterns of artefact densities (AU4 through AU2).

Analytical Unit 7 – AU7 is the lowermost analytical unit and is archaeologically sterile. The layer includes arbitrary excavation Layers 42 through 40. The chronology for the accumulation of this deposit has not been established.

Analytical Unit 6 – AU6 encompasses arbitrary excavation Layers 39 to 30 in all excavation units (220-170cmbd). The lowermost boundary of this analytical unit is defined by the deepest artefacts, which were recovered from Layer 39. An OSL sample was taken at a depth of 177cmbd (for the centre of the sample), and it was determined that the age of the sediment is 47.1±4.8 ka; hence, this provides an age estimate for the early occupation of the site. While artefacts were found at depths up to 43cm below this OSL sample, it is likely that there was a period of rapid sediment deposition, not unlike that in SL3. A second OSL sample was taken from this analytical unit, but as discussed above, the results of this sample are considered to be erroneous. The upper boundary of the analytical unit generally corresponds to the transition between SL4 and SL3. An OSL date for a sediment sample collected just above this transition (168cmbd), suggests that this period of site use continued until approximately 33.9±2.5 ka.

Analytical Unit 5 – AU5 generally correlates to SL3, including arbitrary excavation Layers 29 to 14 (170-90cmbd). While this represents 80cm of the site's depositional history, the OSL dates indicate that this layer accumulated over a relatively short period of time between approximately 33.9±2.5 and 31.0±3.1 ka.

Analytical Unit 4 – AU4 marks the transition between SL3 and SL2, approximately 31.0±3.1 ka. This analytical unit includes only two arbitrary excavation layers (Layers 13 to 12; 90-80cmbd). Both of these layers show very consistent, low artefact discard rates, while there is a sharp rise in artefact numbers in the overlying excavation layer. There are no dates for this analytical unit, but it is presumed to date to the height of the LGM. This interpretation is based on the decline in sedimentation rates and Herries' (this volume) interpretation of the archaeomagnetic data that indicates a cool climate ending by overlying Layer 11 (75-80cmbd). During this phase of site use, most of the accumulated sediment is due to mud wasp brood chambers falling from the rockshelter roof.

Analytical Unit 3 – Within SL2, the artefact densities peak between arbitrary excavation Layers 11 to 8 (80-60cmbd); therefore, these layers have been grouped together as AU3. Archaeomagnetic analysis shows that these layers were deposited under warm conditions (Herries 2013), possibly after the LGM or into the early to mid-Holocene. Mud wasp brood chambers continue to be the major contributor to the accumulation of sediment in the site.

Analytical Unit 2 – AU2 represents the upper portion of SL2, and it includes arbitrary excavation Layers 7 to 6 (60-50cmbd). After AU3, there is a sharp decline in the artefact numbers for Layers 7 and 6, followed by a rise in Layer 5. An AMS radiocarbon date of 1462±41 cal BP was determined for a charcoal sample collected slightly above the upper boundary of AU2. Haberle *et al.* (this volume) identified a peak in burned grass phytoliths in Layer 7, which is interpreted to be a localised fire event. A similar event was observed in excavation Layer 8 at HD07-3A-03 (Haberle *et al.*, this volume), and a charcoal sample from the layer dates to (3241±52 cal BP). Given that the sites are located opposite each other and have similar site formation processes, it is possible that the burned grass phytoliths mark the same localised fire event, approximately 3200 years ago; however, this needs to be confirmed through additional radiocarbon dating. It is possible that AU2 represents a phase of low site use from the mid-Holocene to 1500 years ago.

Analytical Unit 1 – AU1 is the uppermost analytical unit, encompassing arbitrary excavation Layers 5 to the surface (50-28.5/21cmbd). An AMS determination from the base of this analytical unit indicates that it represents the last 1500 years of the site's occupation history (1462±41 cal BP; 47cmbd). AU1 was a period of more intense site use with increased sediment deposition rates.

Artefact Distribution

An assemblage of 1718 artefacts was recovered during the excavation at HD07-3A-PAD13, including three retouched flakes and one flake from the surface of the shelter. The distribution of artefacts presented in Table 6-3 is divided into two groups: diagnostic and non-diagnostic artefacts. Diagnostic artefacts include all specimens that were undoubtedly produced through deliberate human actions, including cores, flakes, retouched (and utilised) flakes, and grindstones. Flakes are the largest component of the diagnostic artefacts, comprising 93% of this group. Other diagnostic artefacts only occur occasionally, and retouched and utilised flakes are infrequent in this assemblage. The low occurrence of retouched artefacts may suggest that tasks were typically not carried out within the confines of this particular rockshelter.

Non-diagnostic artefacts include flaked pieces, heat shatter (and potlids), and manuports. In the HD07-3A-PAD13 assemblage the proportion of non-diagnostic elements is low, particularly in comparison to Djadjiling. Similar proportions of non-diagnostic artefacts were found in the Jundaru assemblage, while HS-A1 had an even lower proportion of non-diagnostic artefacts.

The distribution of artefacts over the occupation sequence indicates that there was generally only intermittent use of the rockshelter, and this is documented by analytical unit in Table 6-3 and by arbitrary excavation layer in Figure 6-10. The figure also identified artefacts that were recovered from the excavation that continued to bedrock (Units 1 to 5, shown in dark grey) and those from Unit 6 (shown in light grey), which was terminated at75cmbd and did not continue to bedrock. Without identifying the artefacts in Unit 6, the densities in arbitrary excavation Layers 1 to 10 are not clearly represented.

During the initial occupation of the site in AU6, few artefacts were discarded, particularly in arbitrary excavation Layers 39 through 37, from which five artefacts were recovered. There was a slight rise in discard rates in Layer 33; however, site use appears to have been low during this time. In AU5, the artefact numbers per layer are consistently low, but their distribution shows that there were multiple occupations during this short period. While AU5 comprises 16 arbitrary excavation layers, the OSL dates demonstrate that this deposit accumulated rapidly between 33.9±2.5 and 31.0±3.1 ka. After approximately 31 ka, site use declined as did the rate of sedimentation. In AU4, 73 artefacts were recovered. Due to the lack of dates for the upper limit of this analytical unit, it can only be postulated that these artefacts were deposited during the height of the LGM.

Table 6-3 Artefact distribution by analytical unit, HD07-3A-PAD13 rockshelter

Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diagnostic Artefacts	*4*	*100*	*462*	*92.40*	*111*	*94.87*	*429*	*84.12*	*67*	*91.78*	*305*	*84.72*	*134*	*87.01*	*1512*	*88.01*
Core	0	0.00	7	1.40	1	0.85	11	2.16	2	2.74	13	3.61	9	5.84	43	2.50
Flake	1	25.00	436	87.20	108	92.31	408	80.00	61	83.56	277	76.94	119	77.27	1410	82.07
Retouched / Utilised Flake	3	75.00	17	3.40	1	0.85	10	1.96	3	4.11	9	2.50	5	3.25	48	2.79
Grindstone	0	0.00	2	0.40	1	0.85	0	0.00	1	1.37	6	1.67	1	0.65	11	0.64
Non-Diagnostic Artefacts	*0*	*0.00*	*38*	*7.60*	*6*	*5.13*	*81*	*15.88*	*6*	*8.22*	*55*	*15.28*	*20*	*12.99*	*206*	*11.99*
Flaked Piece	0	0.00	17	3.40	4	3.42	24	4.71	4	5.48	15	4.17	10	6.49	74	4.31
Heat Shatter & Potlid	0	0.00	21	4.20	2	1.71	57	11.18	2	2.74	37	10.28	7	4.55	126	7.33
Manuport	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.83	3	1.95	6	0.35
Total	**4**	**100**	**500**	**100**	**117**	**100**	**510**	**100**	**73**	**100**	**360**	**100**	**154**	**100**	**1718**	**100**

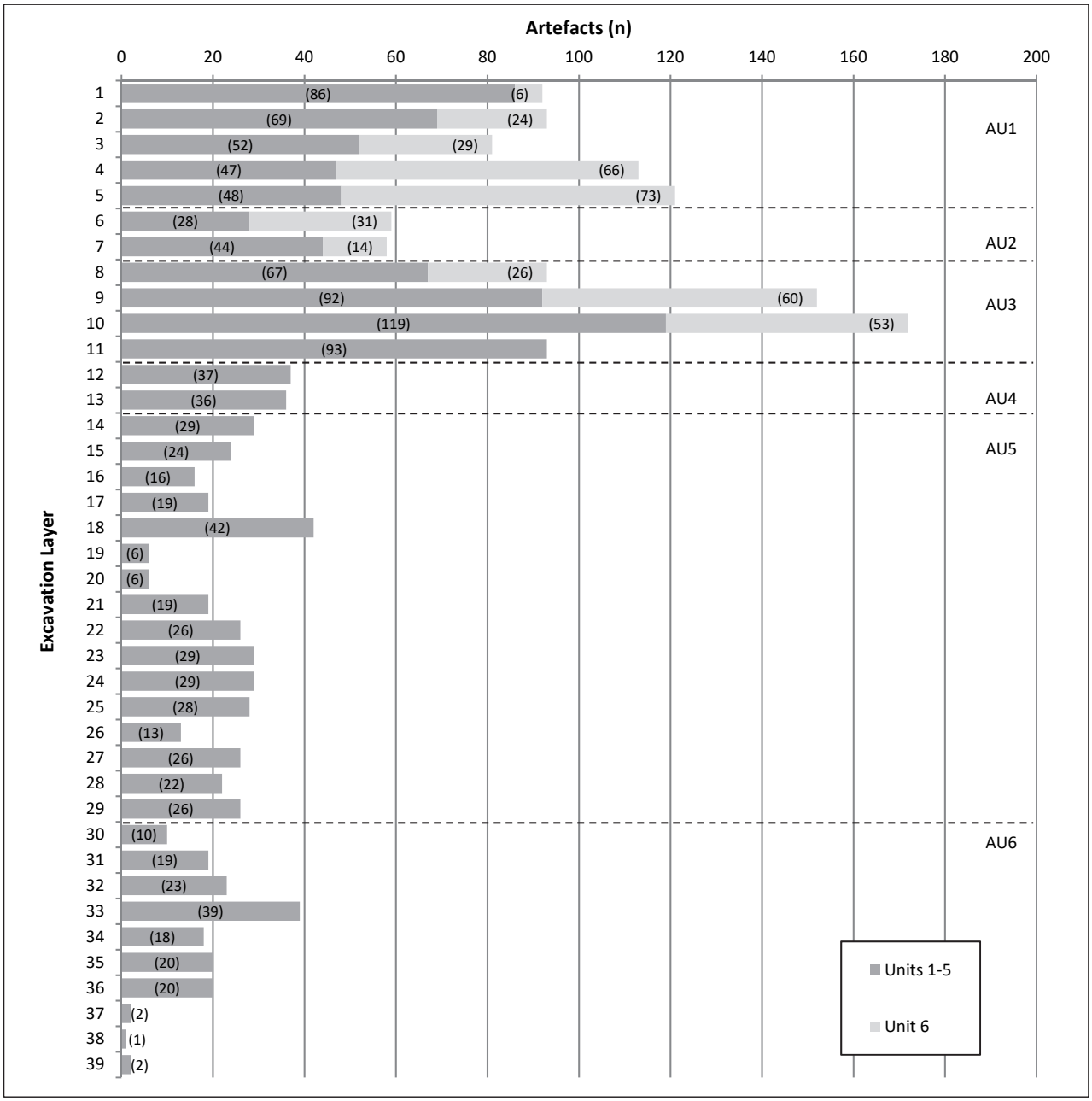

Figure 6-10 Distribution of artefacts by arbitrary excavation layer and excavation unit for HD07-3A-PAD13 rockshelter

AU3 is believed to represent the terminal Pleistocene and early Holocene occupation; although, it is acknowledged that there are no dates for this period. There is a sharp rise in the number of artefacts at the beginning of AU3. Excavation Layers 10 and 9 have the highest density of artefacts per excavation layer; however, it should also be noted that the proportion of artefacts in Layers 10 through 1 will naturally be higher as it also includes the artefacts from Unit 6, which was not excavated to bedrock. Regardless of the artefacts from Unit 6, there remains

a clear pattern of increased artefact numbers during this phase of site use.

There is a subsequent decline in site use during AU2 that persisted until approximately 1500 years ago. The phase comprises two excavation layers that were deposited during the first half of the late Holocene. Throughout AU1 there is a noticeable increase in artefact numbers, suggesting more frequent site use or perhaps longer occupations. Even in the most recent phase of site use, the proportion of artefacts remains low, particularly when compared with HD07-3A-03. This suggests that the site was only ephemerally occupied for short periods of time. A conjoining core and flake was identified in Layer 4 of Unit 6.

While refitting was not carried out systematically as part of the artefact analysis, 11 conjoin sets were identified in the assemblage (Table 6-4; Figure 6-11). In most instances, the conjoin sets were recovered from the same excavation layer, but there are three instances where artefacts were conjoined from different layers. The conjoin sets consist of two artefacts, with the exception of Sets 4 and 8, which each have four artefacts. The conjoin sets in AU5 include a heat-affected flake and a potlid, which strongly suggests *in situ* heating of the artefact despite the fact that no combustion features were identified in the deposit. The conjoin sets indicate the deposit is well-preserved, and the presence of refitted flakes suggest knapping occurred within the rockshelter. This is particularly well-illustrated by the refitted flake with longitudinal cone splits and by the conjoined cores and flakes.

Raw Materials

The raw material of each artefact was classified according to the types described in Chapter 4. The distribution of raw materials in the HD07-3A-PAD13 assemblage is presented by count in Table 6-6 and by weight in Table 6-5. In the following section, the results of the raw material analysis are discussed in terms of their absolute and relative frequency rather than by weight, as there are considerable differences in the weight of each raw material type. Iron-rich raw materials, such as BIF and martite-goethite, are much heavier than siliceous materials like quartz and chert; therefore, the data is skewed towards the heavier materials. The weights of each material type have been included below in the event that it may be useful for inter-site or regional comparisons. The four surface artefacts have not been included in the table below.

Over the course of the occupation of HD07-3A-PAD13, there are clear changes in the raw material procurement strategies; however, the cortical surfaces on the cores and flakes demonstrates that the knappers primarily obtained river cobbles for their raw material, possibly from the ephemeral creeks near the site(see Figure 6-12). There is a general trend towards increasing proportions of finer-grained raw materials in the younger analytical units. In the earliest phases of occupation, the artefacts were predominantly produced from BIF, with BIF accounting for 57.79% and 43.61% of the artefacts in AU6 and AU5 respectively. In AU6, quartz, shale, and chert artefacts comprise the majority of the remaining specimens, while other raw material types are very rare. In AU5, the proportion of BIF drops slightly and there is simultaneous increase in the proportion of chert, goethitised shale, and shale artefacts. The frequency of chert use increases nearly 10% between these two analytical units.

In AU4, the transition away from coarse-grained material begins and this continues throughout the rest of the occupation sequence. The frequency of chert use remains consistent between AU5 and AU4, but there is an increased proportion of both shale and goethitised shale. AU4 also has the lowest occurrence of quartz artefacts; although, quartz was only a minor component of the raw materials used throughout the course of the site's occupation. The patterns in AU3 show a continuation from AU4, but there is a higher proportion of chert artefacts and lower proportion of shale artefacts. The trend towards increased chert use is firmly established by AU2, where over half of the artefacts were manufactured from chert. As chert use intensified through AU2 and into AU1, the frequency of BIF artefacts declined.

Coarser-grained raw materials, such as BIF, martite-goethite, shale, and goethitised shale, are abundant in the area immediately surrounding the site, while chert was a much more scarce resource. The occupants of HD07-3A-PAD13 utilised large proportions of chert from the late Holocene onwards. This suggests that there was a deliberate procurement strategy focused on obtaining this less abundant and therefore more costly resource. Despite the increased abundance of chert artefacts, only two chert cores were identified in the assemblage, including one in AU5 and one in AU1. Greater use of chert in the late Holocene has also been identified at other sites such as HD07-3A-03 and HD07-1A-07. Djadjiling shows a dissimilar pattern with considerable use of chert throughout the occupation and unusually high proportions of chert artefacts between AU4 and AU3 or between approximately 30,000 and 16,500 cal BP (Law and Cropper 2012: 158).

Table 6-4 Conjoin sets, HD07-3A-PAD13 rockshelter

Conjoin Set	Description	AU	Unit-Layer Key
1	Artefacts 315 (core fragment) and 429 (core fragment; 2 fragments)	2/3	U2-L07/ U3-L08
2	Artefacts 335 (potlid) and 337 (heat-affected flake)	5	U2-L15
3	Artefacts 387 (flake) and 390 (flake)	6	U2-L31/ U2-L32
4	Artefacts 451 (core), 452 (distal flake; 2 fragments, glued), 453 (flake), and 454 (right flake - off same flake as 452, but there is a gap between fragments)	5	U3-L23
5	Artefacts 467 (flake) and 470 (flake)	5	U3-L29
6	Artefacts 468 (flake) and 469 (flake; 2 fragments)	5	U3-L29
7	Artefacts 475 (flake) and 476 (distal flake - exfoliated off of the dorsal surface and took of the distal end)	6	U3-L31
8	Artefacts 594 (right LCS) and 588 (left LCS), 589 (flake - right LCS), 587 (flake - left LCS)	5	U4-L28/L27
9	Artefacts 1193 (core) and 1194 (flake)	6	U5-L30
10	Artefacts 1301 (flake; 3 fragments) and 1306 (éraillure flake)	6	U5-L35
11	Artefacts 1419 (core) and 1421 (flake). Several flakes were taken off the core after Artefact 1421.	1	U6-L04

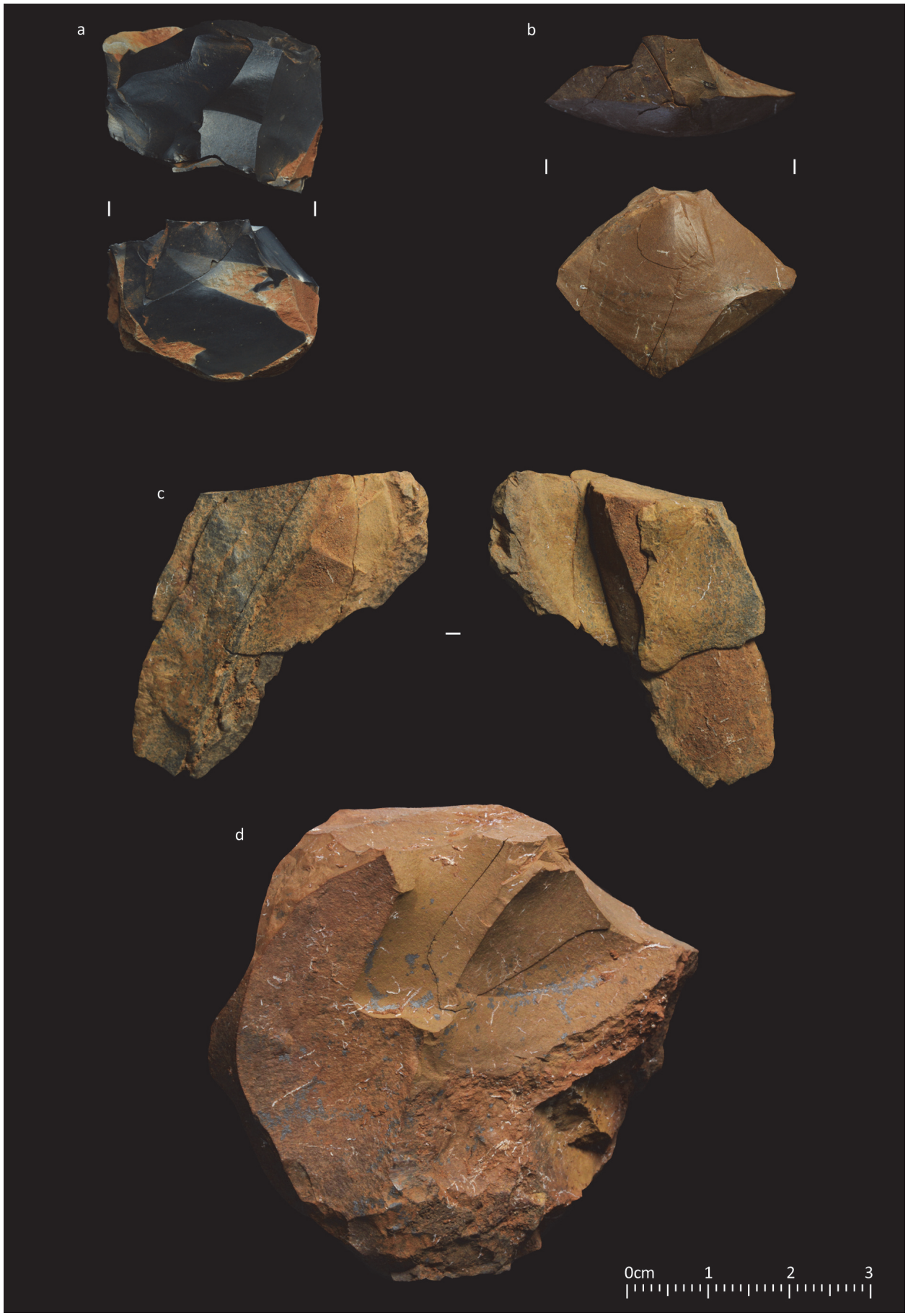

Figure 6-11 Conjoin sets from HD07-3A-PAD13 rockshelter: a) Artefacts 1419 (core) and 1421 (flake) from AU1, b) Artefacts 1301 (3 fragments) and 1306 (éraillure flake) from AU6, c) Artefacts 588 (front – right LCS), 594 (front - left LCS), 589 (centre – right LCS), 587 (back - left LCS) from AU5, and d) Artefacts 1193 (core) and 1194 (flake) from AU6

Table 6-5 Distribution of raw material types by weight and analytical unit, HD07-3A-PAD13 rockshelter

Raw Material	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Type	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%
BIF	*1345.53*	*58.51*	*110.58*	*54.22*	*1359.1*	*62.65*	*1762.9*	*94.28*	*6719.4*	*75.08*	*2291.4*	*88.44*	*13588.98*	*75.15*
Homogenous BIF	1345.53	58.51	110.58	54.22	1106.4	51.00	1762.9	94.28	6719.4	75.08	2291.4	88.44	13336.29	73.75
Laminate BIF	0	0.00	0	0.00	252.69	11.65	0	0.00	0	0.00	0	0.00	252.69	1.40
Chert	*124.52*	*1.60*	*23.39*	*11.47*	*66.04*	*3.04*	*35*	*1.88*	*127*	*1.42*	*49*	*1.91*	*425.67*	*1.80*
Creamy Grey	0.02	0.00	0	0.00	0	0.00	0	0.00	0.23	0.00	0	0.00	0.25	0.00
Dark Grey	29.25	1.27	8.67	4.25	6.97	0.32	4.74	0.25	21.08	0.24	3.25	0.13	73.96	0.41
Dashed Black	0	0.00	0	0.00	1.64	0.08	0	0.00	0.22	0.00	0	0.00	1.86	0.01
Greyish Brown	7.17	0.31	4.75	2.33	11.23	0.52	1.62	0.09	0.16	0.00	40.27	1.55	65.2	0.36
Light Green-Grey	6.2	0.27	0.07	0.03	0.14	0.01	0.13	0.01	0.88	0.01	0	0.00	7.42	0.04
Moss Agate	0.04	0.00	0	0.00	0	0.00	0	0.00	17.84	0.20	0	0.00	17.88	0.10
Olive	36.18	1.57	1.72	0.84	10.22	0.47	0.02	0.00	23.05	0.26	0.14	0.01	71.33	0.39
Pink and Green	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.39	0.02	0.39	0.00
Red	3.77	0.16	2.46	1.21	0.74	0.03	1.62	0.09	0.28	0.00	1.77	0.07	10.64	0.06
Speckled Black	0.67	0.03	0	0.00	0	0.00	0	0.00	0.84	0.01	0	0.00	1.51	0.01
Sugar	0.39	0.02	0	0.00	10.11	0.47	26.69	1.43	0	0.00	3.56	0.14	40.75	0.23
Thylo	2.42	0.11	0.08	0.04	0	0.00	0	0.00	0.37	0.00	0	0.00	2.87	0.02
Trans. Dark Grey	0.43	0.02	0.17	0.08	0.73	0.03	0	0.00	0	0.00	0	0.00	1.33	0.01
Trans. Green	6.43	0.28	0.25	0.12	10.94	0.50	0	0.00	0.93	0.01	0	0.00	18.55	0.10
White & Trans.	8.98	0.39	5.17	2.54	13.24	0.61	0.33	0.02	61.31	0.69	0	0.00	89.03	0.49
Yellow Trans.	22.57	0.98	0.05	0.02	0.08	0.00	0	0.00	0	0.00	0	0.00	22.7	0.13
Goethitised Shale	*1.45*	*0.06*	*26.47*	*12.98*	*64.03*	*2.95*	*8.06*	*0.43*	*431.19*	*4.82*	*2.75*	*0.11*	*533.95*	*2.95*
Martite-Goethite	*0.88*	*0.04*	*15.06*	*7.38*	*156.59*	*7.22*	*0*	*0.00*	*599.43*	*6.70*	*160.39*	*6.19*	*932.35*	*5.16*
Quartz	*45.67*	*1.99*	*2.21*	*1.08*	*151*	*6.96*	*0.3*	*0.02*	*830.44*	*9.28*	*41.81*	*1.61*	*1071.43*	*5.93*
Quartz	45.32	1.97	2.21	1.08	151	6.96	0.3	0.02	830.44	9.28	41.81	1.61	1071.08	5.92
Quartz Crystal	0.35	0.02	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.35	0.00
Shale	*776.9*	*33.78*	*24.65*	*12.09*	*351.68*	*16.21*	*63.54*	*3.40*	*240.12*	*2.68*	*45.25*	*1.75*	*1502.14*	*8.31*
Brown Shale	98.88	4.30	11.59	5.68	314.64	14.50	63.54	3.40	119.71	1.34	37.46	1.45	645.82	3.57
Green Shale	678.02	29.48	13.06	6.40	37.04	1.71	0	0.00	120.41	1.35	7.79	0.30	856.32	4.74
Vitreous Goethite	*4.84*	*0.21*	*1.58*	*0.77*	*20.91*	*0.96*	*0*	*0.00*	*1.33*	*0.01*	*0*	*0.00*	*28.66*	*0.16*
Total	**2299.79**	**100**	**203.94**	**100**	**2169.4**	**100**	**1869.9**	**100**	**8949.1**	**100**	**2590.9**	**100**	**18083.18**	**100**

Table 6-6 Distribution of raw material types by count and analytical unit, HD07-3A-PAD13 rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
BIF	*75*	*15.00*	*25*	*21.37*	*201*	*39.41*	*25*	*34.25*	*157*	*43.61*	*89*	*57.79*	*572*	*33.37*
Homogenous BIF	75	15.00	25	21.37	200	39.22	25	34.25	157	43.61	89	57.79	571	33.31
Laminate BIF	0	0.00	0	0.00	1	0.20	0	0.00	0	0.00	0	0.00	1	0.06
Chert	*254*	*50.80*	*61*	*52.14*	*116*	*22.75*	*12*	*16.44*	*62*	*17.22*	*11*	*7.14*	*516*	*30.11*
Creamy Grey	1	0.20	0	0.00	0	0.00	0	0.00	1	0.28	0	0.00	2	0.12
Dark Grey	43	8.60	10	8.55	10	1.96	2	2.74	10	2.78	2	1.30	77	4.49
Dashed Black	0	0.00	0	0.00	1	0.20	0	0.00	2	0.56	0	0.00	3	0.18
Greyish Brown	33	6.60	16	13.68	16	3.14	2	2.74	2	0.56	3	1.95	72	4.20
Light Green-Grey	7	1.40	2	1.71	2	0.39	3	4.11	5	1.39	0	0.00	19	1.11
Moss Agate	1	0.20	0	0.00	0	0.00	0	0.00	1	0.28	0	0.00	2	0.12
Olive	58	11.60	8	6.84	24	4.71	1	1.37	29	8.06	1	0.65	121	7.06
Pink and Green	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.65	1	0.06
Red	31	6.20	3	2.56	9	1.76	1	1.37	4	1.11	2	1.30	50	2.92
Speckled Black	2	0.40	0	0.00	0	0.00	0	0.00	1	0.28	0	0.00	3	0.18
Sugar	3	0.60	0	0.00	1	0.20	1	1.37	0	0.00	2	1.30	7	0.41
Thylo	2	0.40	1	0.85	0	0.00	0	0.00	1	0.28	0	0.00	4	0.23
Trans. Dark Grey	4	0.80	2	1.71	1	0.20	0	0.00	0	0.00	0	0.00	7	0.41
Trans. Green	20	4.00	2	1.71	24	4.71	0	0.00	5	1.39	0	0.00	51	2.98
White & Trans.	43	8.60	16	13.68	26	5.10	2	2.74	1	0.28	0	0.00	88	5.13
Yellow Trans.	6	1.20	1	0.85	2	0.39	0	0.00	0	0.00	0	0.00	9	0.53
Goethitised Shale	*7*	*1.40*	*5*	*4.27*	*32*	*6.27*	*10*	*13.70*	*26*	*7.22*	*2*	*1.30*	*82*	*4.78*
Martite-Goethite	*2*	*0.40*	*1*	*0.85*	*8*	*1.57*	*0*	*0.00*	*6*	*1.67*	*3*	*1.95*	*20*	*1.17*
Quartz	*58*	*11.60*	*9*	*7.69*	*51*	*10.00*	*4*	*5.48*	*26*	*7.22*	*21*	*13.64*	*169*	*9.86*
Quartz	55	11.00	9	7.69	51	10.00	4	5.48	26	7.22	21	13.64	166	9.68
Quartz Crystal	3	0.60	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.18
Shale	*90*	*18.00*	*15*	*12.82*	*97*	*19.02*	*22*	*30.14*	*82*	*22.78*	*28*	*18.18*	*334*	*19.49*
Brown Shale	77	15.40	12	10.26	79	15.49	22	30.14	77	21.39	26	16.88	293	17.09
Green Shale	13	2.60	3	2.56	18	3.53	0	0.00	5	1.39	2	1.30	41	2.39
Vitreous Goethite	*14*	*2.80*	*1*	*0.85*	*5*	*0.98*	*0*	*0.00*	*1*	*0.28*	*0*	*0.00*	*21*	*1.23*
Total	**500**	**100**	**117**	**100**	**510**	**100**	**73**	**100**	**360**	**100**	**154**	**100**	**1714**	**100**

There are 16 varieties of chert in the assemblage, and each type is differentiated on the basis of unique colours, patterns, or textures. Throughout the analytical units, the range of chert in the assemblage demonstrates that the artefacts were produced from numerous cores. AU5 has the highest concentration of a single chert type, with olive chert accounting for 47.54% of the chert artefacts. In other analytical units, there is much greater diversity with one variety rarely accounting for over a quarter of the chert artefacts. Olive chert, greyish brown chert, and white and translucent chert are fairly common throughout the occupation of the site. The predominance of dark grey chert seen in the Djadjiling assemblage is certainly not repeated in this assemblage. There may have been different availability of the chert varieties throughout Hope Downs 1, or it is possible that some groups favoured particular varieties.

The lack of goethitised shale artefacts in the assemblage is noteworthy, as HS-A3 is 150m north of the site. HS-A3 has been identified as a quarry, but there is also a large proportion of naturally exfoliated flakes at the site (Law *et al.* 2009: 338). Goethitised shale has abundant flaws within the matrix and it is fairly brittle, and perhaps this is why the occupants of HD07-3A-PAD13 did not utilise this resource to a greater degree. Similarly, quartz cobbles are readily available in the creeklines surrounding the site, and while their availability in the past is unknown, it is presumed that they would have had a similar distribution. The low use of quartz suggests that knappers did not favour quartz for artefact manufacture.

Table 6-7 provides a breakdown of the raw material trends amongst the main diagnostic artefact types: cores, flakes, and retouched (or utilised) flakes. This table helps to identify if any raw materials are under- or over-represented amongst the three artefact types; however, the low proportion of retouched (or utilised) artefacts and cores in the assemblage means that one or two artefacts can have a significant effect on the relative proportion of each raw material type. As flakes comprise the bulk of the assemblage, their proportions mirror distribution of raw material types for the assemblage as a whole.

While there are few cores for such a long occupation sequence, the data suggests that there is an under-representation of chert specimens as the proportion of chert flakes (28.67%) is much higher than the proportion of chert cores (4.65%). BIF cores account for 60.47% of the sample, while BIF flakes are much less common. This is also true of quartz cores, albeit to a lesser degree. This suggests that BIF and quartz cores were disposable resources that could easily be replaced; hence, there was no real necessity for the knappers to take these cores with them when they left the site. In contrast, chert was a more valuable resource as it was less commonly available. It is likely that the occupants of the site took many of the chert cores with them when they left the site, leading to an imbalance in the proportion of chert cores and flakes. It is also possible that some of the chert flakes were manufactured elsewhere and brought into the site.

In terms of the raw material use for retouched artefacts, only AU1 shows any obvious patterns as it has a slightly greater abundance of specimens. Nearly two-thirds of the retouched artefacts in this analytical unit were produced from chert, which is slightly higher than the proportion of chert flakes. This suggests that chert flakes were preferentially selected for the manufacture of retouched flakes and for utilised flakes.

Evidence of thermal alteration was low in the assemblage, with 13.68% of the assemblage exhibiting attributes consistent with heating or burning. AU2 and AU4 have the lowest incidence of thermal alteration, while it is moderately higher in AU3 (15.88%), AU1 (14.6%) and AU5 (13.89%). The fact that many of the heated artefacts are crazed or have potlid fractures indicates that they were not heated in a controlled manner; hence, they were probably unintentionally burned. Combustion features were not identified during the excavation, but it is very unlikely that these artefacts were transported into the shelter with the floodwaters. The artefacts are too large and heavy to have been suspended in the sediment load of the low-energy floodwaters. This suggests that some artefacts may have been heated within the rockshelter. The refitted flake and potlid also support this theory (Conjoin Set 2). It is possible that the charcoal and ash from hearths inside the rockshelter floated when floodwaters entered the rockshelter and was distributed as dispersed charcoal. Artefacts could have been exposed to heat outside the rockshelter and then brought into the shelter.

Table 6-7 Raw material trends for cores, flakes, and retouched and utilised flakes, HD07-3A-PAD13 rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cores	*7*	*100*	*1*	*100*	*11*	*100*	*2*	*100*	*13*	*100*	*9*	*100*	*43*	*100*
BIF	2	28.57	1	100	6	54.55	1	50.00	8	61.54	8	88.89	26	60.47
Chert	1	14.29	0	0.00	0	0.00	0	0.00	1	7.69	0	0.00	2	4.65
Goethitised Shale	0	0.00	0	0.00	0	0.00	0	0.00	1	7.69	0	0.00	1	2.33
Martite-Goethite	0	0.00	0	0.00	2	18.18	0	0.00	1	7.69	0	0.00	3	6.98
Quartz	3	42.86	0	0.00	2	18.18	0	0.00	2	15.38	1	11.11	8	18.60
Shale	1	14.29	0	0.00	1	9.09	1	50.00	0	0.00	0	0.00	3	6.98
Flakes	*436*	*100*	*108*	*100*	*408*	*100*	*61*	*100*	*277*	*100*	*119*	*100*	*1409*	*100*
BIF	60	13.76	23	21.30	189	46.32	22	36.07	132	47.65	75	63.03	501	35.56
Chert	224	51.38	54	50.00	56	13.73	8	13.11	53	19.13	9	7.56	404	28.67
Goethitised Shale	5	1.15	5	4.63	29	7.11	9	14.75	20	7.22	1	0.84	69	4.90
Martite-Goethite	2	0.46	1	0.93	6	1.47	0	0.00	4	1.44	2	1.68	15	1.06
Quartz	52	11.93	9	8.33	44	10.78	3	4.92	21	7.58	16	13.45	145	10.29
Shale	81	18.58	15	13.89	79	19.36	19	31.15	46	16.61	16	13.45	256	18.17
Vitreous Goethite	12	2.75	1	0.93	5	1.23	0	0.00	1	0.36	0	0.00	19	1.35
Retouched/Utilised Flakes	*17*	*100*	*1*	*100*	*10*	*100*	*3*	*100*	*9*	*100*	*5*	*100*	*45*	*100*
BIF	2	11.76	0	0.00	5	50.00	1	33.33	4	44.44	2	40.00	14	31.11
Chert	11	64.71	1	100	2	20.00	1	33.33	1	11.11	1	20.00	17	37.78
Goethitised Shale	0	0.00	0	0.00	1	10.00	0	0.00	0	0.00	1	20.00	2	4.44
Quartz	2	11.76	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	4.44
Shale	1	5.88	0	0.00	2	20.00	1	33.33	4	44.44	1	20.00	9	20.00
Vitreous Goethite	1	5.88	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	2.22
Total	**460**	**-**	**110**	**-**	**429**	**-**	**66**	**-**	**299**	**-**	**133**	**-**	**1497**	**-**

Most artefacts do not show any other material alterations, but with increasing depth there is a greater incidence of artefacts with cemented sediment on at least one surface. For example, in AU1 through AU5, between 6.8% and 5.1% of artefacts exhibit this alteration, yet it increases considerably in the lower analytical units (AU4, 10.96%; AU5, 15.28%; AU6, 14.29%). When the cemented sediment occurs on the artefacts, it is typically only on one surface. This suggests that these artefacts sat on the surface of the rockshelter for some period of time during which the deposit became saturated, allowing for the deposition of the minerals on the underside of the artefacts (Figure 6-12: b; Figure 6-13: f-g). Many of the artefacts also have tiny rhizoliths, which are formed by localised cementation around roots (Figure 6-11: b-d).

Cores

Forty-three cores were recovered from HD07-3A-PAD13, including 38 complete specimens and five core fragments. Two of the core fragments conjoin; one fragment was recovered from Unit 2 (Layer 7, Artefact 315) and the other fragment was recovered from Unit 3 (Layer 8, Artefact 429). At least one additional fragment is missing from this core, but no other core fragments were recovered that conjoin to this set. It is presumed that the remaining piece(s) remain in unexcavated portions of the site. A representative sample of the cores from the site is pictured in Figure 6-12.

Cores were recovered in each of the analytical units, with the exception of AU2. Based on the high proportion of chert flakes at the site, it was anticipated that chert cores would be abundant. As is discussed above, chert cores are under-represented in the assemblage, which suggests that many of the chert cores were removed from the site. With this in mind, it is possible that the cores discarded at the site do not represent the full range of reduction methods employed by the knappers. While all of the Hope Downs 1 lithic analyses incorporate the technological information from cores and flakes, this assemblage highlights the necessity for considering the data from each source.

Qualitative Core Attributes

Qualitative attributes are reported in Table 6-8 for the 38 complete cores. Throughout the occupation sequence, rotated cores are predominant (*e.g.*, Figure 6-12: a-c), followed by unidirectional cores (*e.g.*, Figure 6-12: d). AU5 is the one exception, where this pattern is reversed. Only in the Pleistocene layers (AU6 and AU5) are bidirectional cores present, but only one specimen was recovered in each analytical unit. It is likely that the core rotation happened to make use of opposed platforms, rather than this being a distinct reduction strategy. Core rotation may have been used as a means of extending the use-life of a core, and there is little evidence to suggest that knappers alternated between striking platforms on rotated cores. It appears that when a core face or platform became problematic, the knapper rotated the core and made use of an alternative platform.

There is a fairly even distribution of cores with cortical and plain striking platforms (Table 6-8: B). Not surprisingly, cortical platforms are predominant in AU5, which has a high proportion of unidirectional cores. One specimen exhibits both cortical and plain platforms, as the rotated platform made use of a previously knapped surface. This is also the case for many of the rotated cores, which is why plain platforms are so common (*e.g.*, Figure 6-12: a-c). None of the platforms exhibit a facetted surface. While flakes with facetted platforms are not common, this may indicate that facetting occurs immediately prior to the removal of the flake.

The morphology of the negative flake scars shows that flake production was the norm (Table 6-8: C). There is one blade core in the assemblage and two specimens that exhibit both flake and blade scars. While approximately 7% of all complete flakes are blades, the blade cores present in the assemblage do not indicate that there was any technological strategy aimed at their production. Instead, blade production probably was an incidental outcome of knapping.

The number of scars on a core can provide an indicator of how intensely it was reduced, but it is acknowledged that this is a broad measure of reduction intensity as larger raw materials will be able to produce more flakes and highly reduced cores will only show the most recent removals. Within the analytical units, there are too few cores to consider patterns of negative scar numbers by raw material type as presented in Table 6-8: D. For the assemblage as a whole, the data indicates that martite-goethite, quartz, and BIF cores generally have fewer negative scars than chert, shale, or goethitised shale. In each of the raw material types with higher average numbers of negative scars, there is a small sample of cores that may skew the data. Only BIF and quartz (to a lesser degree) cores are common enough in the assemblage to provide an adequate sample, and both show low numbers of negative scars. The number of dorsal scars on a core can also indicate the minimum number of flakes produced by the cores present in the assemblage; however, the cores may have produced many more flakes as later scars obscure earlier ones. A total of 218 scars was observed on the 38 complete cores, which is considerably less than the minimum number of flakes estimated for the assemblage (MNF=1054; see the following section). This is further highlights the discrepancy between the number of flakes and cores at the site.

With the exception of one core (Artefact 1395) all of the cores were assessed as being viable (Table 6-8: E) and were left in a state where they could have easily been further reduced. Artefact 1395 is the exception. On this small quartz core (13.63-x-18.65-x-16.1mm, 4.51g) the main striking platform is completely crushed. Both its diminutive size and crushed platform may have led to its discard.

Quantitative Core Attributes

The quantitative statistics for complete cores are presented in Table 6-9, which includes the maximum dimensions, mass, and dimensions of the smallest and largest negative flake scars. There is a general average trend towards slightly smaller cores from the older to younger layers as demonstrated though their average maximum length, width, and thickness. The standard deviation values are relatively high, indicating that there are a number of specimens at the extreme size ranges and few near the average. The highest standard deviation value is in AU1, where there is a clear division between the small cores and large cores, with no specimens near the average dimensions. The small cores were produced on quartz and chert cobbles (*e.g.*, Figure 6-12: a), while the larger cores are shale and BIF. These raw material trends continue in the other analytical units, with one or two exceptions. The martite-goethite cores occur amongst the small group, while the other coarse-grained cores make up the group of large cores. This may suggest that in this particular area, martite-goethite does not commonly outcrop.

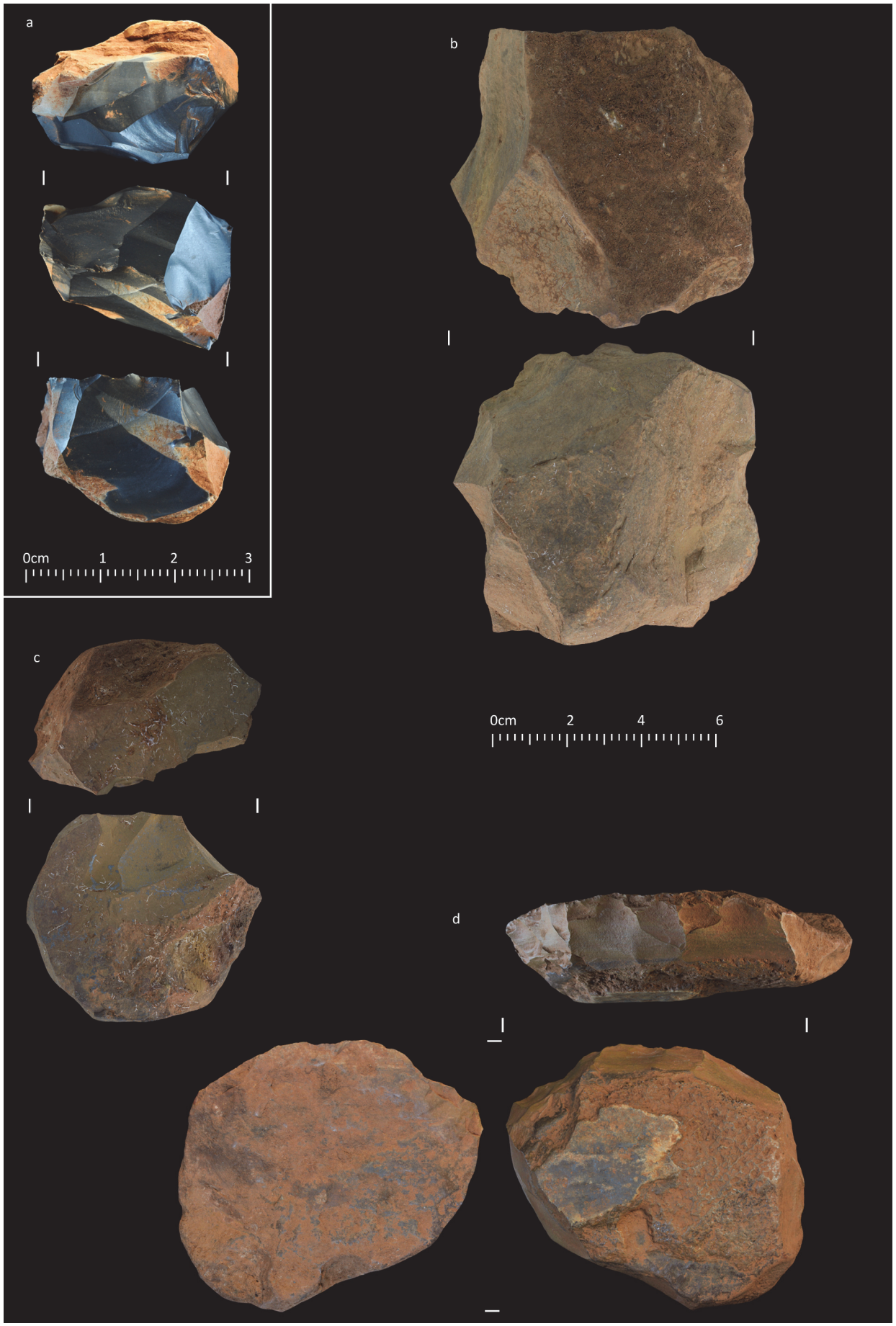

Figure 6-12 Cores from HD07-3A-PAD13 rockshelter: a) Artefact 1419 from AU1, b) Artefact 237 from AU6, c) Artefact 1193 from AU6, and d) Artefact 848 from AU3

Table 6-8 Qualitative attributes for cores by analytical unit, HD07-3A-PAD13 rockshelter

A. Core Type*	AU1		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Rotated	5	71.43	7	70.00	1	100	4	33.33	5	62.50	22	57.89
Unidirectional	2	28.57	3	30.00	0	0.00	7	58.33	2	25.00	14	36.84
Bidirectional	0	0.00	0	0.00	0	0.00	1	8.33	1	12.50	2	5.26
Total	**7**	**100**	**10**	**100**	**1**	**100**	**12**	**100**	**8**	**100**	**38**	**100**
B. Platform Type	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Cortex	4	57.14	4	40.00	0	0.00	8	66.67	3	37.50	19	50.00
Plain	3	42.86	6	60.00	1	100	4	33.33	4	50.00	18	47.37
Other	0	0.00	0	0.00	0	0.00	0	0.00	1	12.50	1	2.63
Total	**7**	**100**	**10**	**100**	**1**	**100**	**12**	**100**	**8**	**100**	**38**	**100**
C. Scar Type	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Flake	6	85.71	10	100	1	100	10	83.33	8	100	35	92.11
Blade	0	0.00	0	0.00	0	0.00	1	8.33	0	0.00	1	2.63
Mixed flake/blade	1	14.29	0	0.00	0	0.00	1	8.33	0	0.00	2	5.26
Total	**7**	**100**	**10**	**100**	**1**	**100**	**12**	**100**	**8**	**100**	**38**	**100**
D. Avg. No. Scars	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg
BIF	2	8.00	5	8.40	0	0.00	7	3.14	7	5.43	21	5.62
Chert	1	9.00	0	0.00	0	0.00	1	5.00	0	0.00	2	7.00
Goethitised Shale	0	0.00	0	0.00	0	0.00	1	14.00	0	0.00	1	14.00
Martite-Goethite	0	0.00	2	2.00	0	0.00	1	2.00	0	0.00	3	2.00
Quartz	3	6.00	2	4.00	0	0.00	2	3.00	1	7.00	8	4.88
Shale	1	3.00	1	13.00	1	7.00	0	0.00	0	0.00	3	7.67
Total	**7**	**6.57**	**10**	**6.70**	**1**	**7.00**	**12**	**4.08**	**8**	**5.63**	**38**	**5.63**
E. Reduction Potential	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Exhausted	1	14.29	0	0.00	0	0.00	0	0.00	0	0.00	1	2.63
Viable	6	85.71	10	100	1	100	12	100	8	100	37	97.37
Total	**7**	**100**	**10**	**100**	**1**	**100**	**12**	**100**	**8**	**100**	**38**	**100**

*Note: core type is presented for all cores, while all other attributes are presented for complete cores

Table 6-9 Quantitative attributes for complete cores by analytical unit, HD07-3A-PAD13 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	7	37.40	77.34	13.63	26.94
	3	10	34.54	51.63	20.94	12.60
	4	1	38.70	38.7	38.7	-
	5	12	50.88	89.14	22.1	18.43
	6	8	52.36	77.01	24.05	16.45
B. Max Width (mm)	1	7	44.45	95.82	16.41	32.27
	3	10	51.68	88.49	25.72	24.12
	4	1	32.50	32.5	32.5	-
	5	12	65.45	108.95	36.01	27.00
	6	8	57.40	84.35	26.89	21.31
C. Max Thickness (mm)	1	7	37.19	105.52	13.56	33.23
	3	10	46.54	74.96	29.21	14.92
	4	1	17.49	17.49	17.49	-
	5	12	57.83	117.6	29.41	23.03
	6	8	47.23	83.63	23.87	22.30
D. Mass (g)	1	7	221.89	746.9	4.51	308.60
	3	10	115.29	252.69	22.03	80.29
	4	1	24.58	24.58	24.58	-
	5	12	303.86	1100.6	38.29	304.34
	6	8	153.77	702.7	33.4	224.21

Measurement	AU	Count	Average Length (mm)	SD	Average Width (mm)	SD
E. Average Maximum Negative Scar Dimensions	1	7	23.41	12.99	23.95	14.71
	3	10	29.58	11.04	27.41	11.54
	4	1	31.89	-	32.40	-
	5	12	37.48	16.89	35.83	13.38
	6	8	37.58	15.73	35.95	9.26
F. Average Minimum Negative Scar Dimensions	1	7	14.68	15.43	11.59	4.95
	3	10	12.33	4.83	14.57	6.09
	4	1	31.48	-	20.15	-
	5	12	24.44	20.51	22.20	15.55
	6	8	20.26	9.32	19.27	8.22

Only five of the complete cores do not have cortex remaining; hence, the size and shape of the cores is largely dictated by the cobble that is sourced. Artefact 848 (Figure 6-12: d) is quite unusually shaped (flat oval), and it bears a lot of similarity to a grindstone that was unifacially trimmed at HD07-3A-03 (hence technologically a core; Artefact 6262, Figure 10-11: f). While the two artefacts look similar, Artefact 848 does not exhibit macroscopic evidence of grinding. It is likely that the knapper just selected a flat cobble for reduction. Usewear analysis of this artefact may help to determine if it was used as a grindstone.

The dimensions of the largest and smallest negative flake scars were recorded for each complete core to provide an estimate of the size range of flakes produced by the cores in the assemblage. The average maximum flake dimensions become progressively larger with increasing age (Table 6-9: E), mirroring the trends in the core size over time. There is greater variation in the minimum scar size than expected (Table 6-9: F), as there is generally a common threshold for the minimum size of flakes and perhaps this is a reflection of the low intensity of core reduction.

Flakes

In total, 1410 flakes and flake fragments were recovered from the site, comprising 82.07% of the artefact assemblage. There are 599 complete flakes in the assemblage, as well as 811 flakes that are in various states of fragmentation but are still clearly identifiable as a flake (Table 6-10). It is important to identify clearly the proportions of complete and broken flakes in an assemblage, as those with high proportions of broken flakes may appear to have higher artefact densities than those with lower flake fragmentation rates. The MNF index is a means of estimating the minimum number of flakes present in an assemblage (Hiscock 2002). Based on the calculation MNF = C + T + CL + BL, it is estimated that the 1410 flakes and flake fragments represent at least 1054 complete flakes (MNF = 599 + 318 + 105 + 32).

Table 6-10 Flake fragmentation, HD07-3A-PAD13 rockshelter

Longitudinal Fragmentation	Transverse Fragmentation				
	Complete	Distal	Prox.	Medial	Total
Complete	599	318	79	61	1057
Left + Left LCS	90	29	17	20	156
Right + Right LCS	105	32	15	20	172
Medial	4	9	6	6	25
Total	**798**	**388**	**117**	**107**	**1410**

Using the MNF it is possible to estimate the percentage of broken flakes in the assemblage, which is calculated to be 43.17% (percentage of broken flakes = (MNF - complete flakes) / MNF x 100). Considering the low artefact density through time, the proportion of broken flakes is very high. Due to the high percentage of flake fragmentation, the trends throughout the occupation history were also examined to try and determine if there were any periods that showed different results. The greatest percentages of broken flakes were in AU4 (47.5%), AU3 (47.59%), and AU2 (47.19%), while there are slightly lower estimated frequencies of broken flakes in AU6 (44.56%), AU2 (42.59%), and AU1 (40.74%). It is surprising that AU1 has a lower percentage of broken flakes given the higher artefact density suggests that there was greater use of the site during this phase of occupation. The higher rates of breakage in AU4 through AU2 may relate to the lower sediment deposition during this period. If artefacts are exposed for longer times, they are more susceptible to trampling and breakage.

Flakes can break both longitudinally (with left, medial, and right fragments) and transversely (with proximal, medial, and distal fragments), and flake fragmentation can be caused by a number of factors. They can be broken during flake production, and these breaks tend to be longitudinal, while transverse fragmentation is more likely to occur as the result of trampling (Hiscock 1985: 87). As Table 6-10 demonstrates, there are fairly even proportions of left and right fragments, while the proportion of distal and proximal flake fragments is disparate. There are four times the number of distal flake fragments in comparison to proximal flake fragments (that are longitudinally complete), and this is disparity is troublesome, however, Hiscock (2002: 255) found in his study of flake fragmentation amongst conjoin sets that distal flake fragments were also more commonly represented that proximal flake fragments. This pattern is certainly not restricted to this assemblage, but other excavated assemblages have far greater numbers of distal than proximal flakes (*e.g.*, Djadjiling and PAD 4). At HD07-3A-03 and PAD 3, there are much closer proportions, but distal flakes still outnumber proximal fragments. One concern is that naturally exfoliated fragments of BIF were mistaken as distal flake fragment; however, when the proportions of distal flakes were compared by raw material to complete flakes, distal BIF flakes were actually under-represented. Thus, naturally exfoliated BIF fragments are not being misidentified as distal flakes. The largest discrepancy between complete and distal flakes occurs amongst the quartz specimens (15.72% distal flakes versus 7.77% complete flakes), while there were slightly higher proportions of chert and goethitised shale distal flakes.

Flake Subtypes

Amongst the flakes, there is a small number of specimens that can be further classified into subtypes according to unique morphological features or because they were produced by particular reduction techniques. Blades are the most common flake subtype, and they are defined here as being at least twice as long as they are wide. There are only 42 complete flakes that meet the definitions of a blade, and five specimens also exhibit traits of other flake subtypes (4 burin spalls and one ridge flake). Of the 37 blades that do not have traits of other flake types, they are most numerous in AU1 (n=18), followed by AU5 (n=9) and AU3 (n=6). The shape of the blades varies, with most having distally contracting forms (n=15). There are only three parallel-sided blades and seven sub-parallel-sided blades. The low proportions of blades in the assemblage and the variation in the size and shape suggests that there was not a specific reduction technology for their production, and this supports the interpretation of the cores. Their presence in the assemblage appears to be fortuitous.

Four burin spalls were identified in the assemblage, with three specimens in AU1 and one in AU2. Spalls are the product of burin retouch. In some instances spalls are a desired product in this reduction strategy; however, evidence from other Hope Downs 1 sites suggests that burination was generally utilised to sharpen the burin edge (see Fullagar, this volume). No burins were identified amongst the retouched artefacts, but the presence of spalls indicates that burins were produced at the site. It is possible that the burins were either transported away from the site or remain in unexcavated areas. A small number of burins were found in contemporary levels at HD07-3A-03.

One squat and thick bipolar flake was identified in AU5. The quartz flake has a cortical striking platform and has a cortical axial termination. The distal end exhibits crushing, possibly as the result of the force directed through the core as it rested on an anvil. The quartz flakes has large flaws in the raw material, and the flake has cortex on up to two-thirds of the dorsal surface. It

appears that the knapper was trying to reduce a small quartz river cobble.

A sub-parallel ridge flake produced from dark grey chert was identified amongst the artefacts in AU1. Ridge flakes are typically associated with the preparation of blade cores. The knapper would have created a ridge on the core by removing a series of flakes, then the core was struck in line with the ridge and the force of the blow would have followed the ridge. The arrises of the negative scar on the core would then be used to guide subsequent removals. With one ridge flake present in the assemblage, it is possible that this specimen was inadvertently produced through core rotation; however, two ridge flakes were also identified at HD07-3A-03.

Additionally, four flakes from AU1 can clearly be identified as having been produced as the result of retouch. Three yellow translucent chert flakes were removed during the manufacture of a steeply retouched artefact. These artefacts were all found in close proximity to each other and likely originate from the same event; although, the retouched artefact has not been identified and may have been used and discarded elsewhere at the site. Artefact 1476, pictured in Figure 6-13 (d), exhibits numerous retouch scars on the dorsal surface, but the knapper accidentally struck this flake too far back from the edge and as a result, it has removed the distal portion of the retouched artefact. The fourth retouching flake removed the hinge termination from a brown shale flake.

Quantitative Flake Attributes

Table 6-11 presents the quantitative data for complete flakes in the assemblage, including the maximum and axis dimensions, mass, elongation index, and parallel index. The table also includes data for the platform dimensions and angle, which includes complete and proximal flakes that are longitudinally complete. There is a general decrease in artefact size from the older to younger analytical units as is demonstrated by the average maximum length, width, and thickness (Table 6-11: A-C). This pattern follows that observed amongst the cores, and it may reflect the increasing use of chert as it was typically only available as smaller cobbles. For each dimension, the standard deviation values are very high and are nearly equal to the average values. This indicates that the data is not normally distributed, but is divided between the small and large size extremes. The assemblage has far more small flakes than large flakes, but these large 'outliers' skew the data. For example, when the maximum length is examined by quartiles, half of the flakes are between 6.86 and 20.35mm (first to third quartile); therefore, three-quarters of the flakes have lengths less than 20.35mm. The axis dimensions show similar patters; albeit, with slightly smaller flake sizes.

The dimensions of the complete flakes can also be used to explore patterns of flake shape through the elongation index (Table 6-11: H) and the parallel index (Table 6-11: I). The elongation index is a measure that determines the tendency towards flake elongation through a calculation of the maximum width to the maximum length. The average elongation index values show that most flakes in the assemblage are slightly longer than they are wide. The flakes in AU6 are particularly squat, with the average elongation index value indicating that the flakes are wider than they are long. The flakes in AU1 show a slight trend towards elongation, and there are 22 flakes that reach blade proportions in this phase of occupation (18 blades, 3 spalls, and 1 ridge flake).

The parallel index is a metric evaluation of flake form that compares the platform width to the axis width. As such, it provides information regarding the shape of the flake from its platform to its midpoint. The average values in each analytical unit show that flakes generally expand towards their midpoint. A total of 115 flakes contracted from the platform towards the midpoint, with the greatest proportions in AU4 (28.57%), AU6 (27.45%), and AU3 (21.47%). This quantitative measure is an excellent complement to the qualitative observations of flake form, which are discussed below.

The striking platform is one of the key areas on a flake that can provide information regarding the methods that the knapper used in its manufacture. Quantitative attributes, such as the platform dimensions (Table 6-11: J-K) and the exterior striking platform angle (Table 6-11: L) have been show in experimental research to affect flake morphology and size (Dibble and Rezek 2009; Pelcin 1997b). Through the analytical units, width of the platforms steadily decreases and there is also a concomitant decrease in flake size; hence, this pattern likely reflects the changes in overall flake size. A ratio of the striking platform width to the maximum flake width removes the variable of the size. Amongst the complete flakes, the average ratios are consistent between AU6 (1.78) and AU2 (1.91). The average value for AU1 is slightly higher (2.13), indicating that the platforms were slightly narrower in AU1 as compared with those from AU6 through AU2.

A similar ratio can be determined for platform thickness (maximum thickness/platform thickness) to help overcome the variability of platform thickness due to the various flake sizes. The average ratios range from a low of 1.43 in AU6 to a high of 2.12 in AU3, but the remaining analytical units cluster around 1.60 (AU4) to 1.80 (AU1). Lower values indicate thicker platforms and higher numbers equate to narrower platforms. Therefore, the platforms are thickest in AU6 and narrowest in AU3. Platform thickness is one of the key factors affecting the size of flakes, with thicker platforms generally producing larger flakes (Dibble 1997; Pelcin 1997a). AU6 had the largest average flake size, but AU3 also had many small flakes.

The average exterior striking platform angle has a range from 77.05° in AU2 to 70.65° in AU6. There is a considerable degree of variation within the data. Other sites (*e.g.*, HD07-3A-03 and HD07-1A-07) have little variation amongst the analytical units; however, that may be due to their relatively short spans of occupation. The assemblage from Djadjiling also shows a fair range of exterior striking platform angles (10.46°; Law and Cropper 2012: 166). High striking platform angles are generally believed to result in the production of larger flakes (Dibble 1997; Pelcin 1997a); yet, the data does not conform to the theory with AU6 having the largest flakes.

Qualitative Flake Attributes

Amongst the complete and proximal flakes, plain striking platforms account for over three-quarters of the sample (Table 6-12). Flakes with cortical and linear platforms (a variation of plain platforms; see Chapter 4) comprise the majority of the remaining sample. Other types, such as dihedral, facetted, and crushed platforms, are rare in the assemblage. The cores show a slightly different pattern, with a much higher proportion of cortical platforms. There is a steady decline in the proportion of cortical platforms from AU6 through AU1, and this is believed to be due to the increased use of chert. Cortical platforms are particularly low amongst the chert flakes, with nine specimens identified. While few chert cores are present in the assemblage, this data supports the theory that chert cores are more highly reduced.

Table 6-11 Quantitative flake attributes by analytical unit, HD07-3A-PAD13 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	192	12.66	60.13	2.58	10.52
	2	47	13.53	40.9	4.26	10.51
	3	163	14.88	58.92	2.94	11.37
	4	21	17.83	42.48	2.1	10.49
	5	124	17.77	64.25	3.02	12.54
	6	51	16.56	75.98	2.9	14.88
B. Max Width (mm)	1	192	11.84	73.99	2.10	9.73
	2	47	12.90	45.45	3.06	9.30
	3	163	15.38	76.91	3.67	11.32
	4	21	16.18	32.29	6.41	7.16
	5	124	18.04	65.35	3.95	13.36
	6	51	19.62	77.47	5.47	16.76
C. Max Thickness (mm)	1	192	3.31	31.03	0.47	3.89
	2	47	3.53	14.37	0.48	3.04
	3	163	4.23	18.23	0.59	3.44
	4	21	5.61	12.74	1.36	3.44
	5	124	5.30	32.01	0.46	5.04
	6	51	6.54	42.94	0.84	8.74
D. Axis Length (mm)	1	192	11.74	57.21	2.26	9.87
	2	47	12.11	38.84	3.14	9.54
	3	163	13.52	58.77	2.53	10.75
	4	21	16.32	42.33	2.45	10.17
	5	124	16.12	57.75	2.42	11.68
	6	51	14.85	64.84	3.72	13.06
E. Axis Width (mm)	1	192	10.27	72.30	2.10	8.77
	2	47	11.24	36.50	2.32	7.80
	3	163	13.43	69.05	3.23	9.80
	4	21	14.25	27.42	4.76	6.20
	5	124	15.50	64.16	3.45	11.53
	6	51	16.89	70.28	1.14	15.18
F. Axis Thickness (mm)	1	192	2.76	31.76	0.40	3.58
	2	47	3.18	14.41	0.55	3.07
	3	163	3.62	17.72	0.51	3.15
	4	21	4.74	11.21	1.15	3.01
	5	124	4.54	29.55	0.49	4.55
	6	51	5.10	31.68	0.60	6.28
G. Mass (g)	1	192	2.07	102.56	0.01	9.16
	2	47	1.95	21.61	0.01	4.31
	3	163	2.75	35.26	0.01	5.69
	4	21	2.77	12.71	0.02	3.48
	5	124	5.71	141.43	0.01	16.10
	6	51	11.45	275.02	0.01	39.92
H. Elongation Index	1	192	1.21	5.93	0.37	0.83
	2	47	1.16	4.17	0.40	0.69
	3	163	1.02	2.81	0.31	0.48
	4	21	1.09	2.00	0.30	0.40
	5	124	1.08	3.01	0.34	0.50
	6	51	0.89	1.76	0.38	0.35
I. Parallel Index	1	192	1.82	12.56	0.62	1.20
	2	47	1.64	3.57	0.72	0.76
	3	163	1.58	5.51	0.54	0.83
	4	21	1.65	6.66	0.74	1.30
	5	124	1.63	4.56	0.52	0.71
	6	51	1.49	5.70	0.28	0.92
J. Platform Width (mm)	1	224	6.96	49.10	0.34	6.76
	2	56	7.25	29.65	1.14	5.62
	3	187	9.68	45.43	1.15	7.35
	4	24	11.52	24.56	1.81	6.99
	5	131	10.94	62.92	1.52	9.42
	6	55	12.91	56.10	2.43	12.21
K. Platform Thickness (mm)	1	224	2.23	21.93	0.23	2.79
	2	56	1.91	7.46	0.21	1.78
	3	187	2.94	18.15	0.28	2.49
	4	24	4.32	11.55	0.53	2.93
	5	131	3.84	24.59	0.34	3.80
	6	55	5.08	41.82	0.32	6.66

Measurement	AU	Count	Average	Max	Min	SD
L. Platform Angle (°)	1	224	74.85	125.00	23.00	13.79
	2	56	77.05	103.00	40.00	12.93
	3	187	70.70	105.00	18.00	14.25
	4	24	75.71	124.00	52.00	16.28
	5	131	72.76	124.00	29.00	15.23
	6	55	70.65	108.00	33.00	15.61

Note: Measurements A-I are for complete flakes. Platform measurements (J-L) include all complete flakes and all proximal flakes that are longitudinally complete.

Table 6-12 Qualitative flake attributes by analytical unit, HD07-3A-PAD13 rockshelter

A. Platform Type [cp]	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cortical	14	6.25	5	8.93	23	12.30	4	16.67	16	12.21	10	18.18	72	10.64
Crushed	2	0.89	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.30
Dihedral	7	3.13	2	3.57	4	2.14	1	4.17	3	2.29	0	0.00	17	2.51
Facetted	6	2.68	2	3.57	3	1.60	0	0.00	4	3.05	2	3.64	17	2.51
Linear	14	6.25	11	19.64	7	3.74	1	4.17	12	9.16	3	5.45	48	7.09
Plain	181	80.80	36	64.29	150	80.21	18	75.00	96	73.28	40	72.73	521	76.96
Total	**224**	**100**	**56**	**100**	**187**	**100**	**24**	**100**	**131**	**100**	**55**	**100**	**677**	**100**
B. Overhang Removal [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Abraded	0	0.00	0	0.00	1	0.53	0	0.00	0	0.00	0	0.00	1	0.15
Crushed	6	2.68	0	0.00	1	0.53	0	0.00	0	0.00	0	0.00	7	1.03
Facetted	8	3.57	2	3.57	0	0.00	0	0.00	2	1.53	0	0.00	12	1.77
None	210	93.75	54	96.43	185	98.93	24	100	129	98.47	55	100	657	97.05
Total	**224**	**100**	**56**	**100**	**187**	**100**	**24**	**100**	**131**	**100**	**55**	**100**	**677**	**100**
C. Lipping [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
No	197	87.95	52	92.86	165	88.24	21	87.50	118	90.08	49	89.09	602	88.92
Yes	27	12.05	4	7.14	22	11.76	3	12.50	13	9.92	6	10.91	75	11.08
Total	**224**	**100**	**56**	**100**	**187**	**100**	**24**	**100**	**131**	**100**	**55**	**100**	**677**	**100**
D. Bulb of Percussion [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diffuse	101	45.09	26	46.43	107	57.22	12	50.00	64	48.85	29	52.73	339	50.07
Prominent	122	54.46	30	53.57	80	42.78	12	50.00	66	50.38	26	47.27	336	49.63
Missing	1	0.45	0	0.00	0	0.00	0	0.00	1	0.76	0	0.00	2	0.30
Total	**224**	**100**	**56**	**100**	**187**	**100**	**24**	**100**	**131**	**100**	**55**	**100**	**677**	**100**
E. Dorsal Cortex [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
None	153	79.69	40	85.11	128	78.53	15	71.43	82	66.13	37	72.55	455	76.09
1-32%	28	14.58	6	12.77	18	11.04	6	28.57	23	18.55	5	9.80	86	14.38
33-65%	4	2.08	1	2.13	8	4.91	0	0.00	10	8.06	1	1.96	24	4.01
66-99%	2	1.04	0	0.00	2	1.23	0	0.00	1	0.81	2	3.92	7	1.17
100%	5	2.60	0	0.00	7	4.29	0	0.00	8	6.45	6	11.76	26	4.35
Total	**192**	**100**	**47**	**100**	**163**	**100**	**21**	**100**	**124**	**100**	**51**	**100**	**598**	**100**
F. Dorsal Scars [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0	5	2.60	0	0.00	7	4.29	0	0.00	8	6.45	6	11.76	26	4.35
1	18	9.38	9	19.15	36	22.09	3	14.29	20	16.13	9	17.65	95	15.89
2	63	32.81	15	31.91	45	27.61	10	47.62	43	34.68	20	39.22	196	32.78
3	58	30.21	14	29.79	49	30.06	6	28.57	28	22.58	9	17.65	164	27.42
4	28	14.58	4	8.51	16	9.82	2	9.52	12	9.68	5	9.80	67	11.20
5	15	7.81	1	2.13	6	3.68	0	0.00	10	8.06	1	1.96	33	5.52
6	2	1.04	0	0.00	2	1.23	0	0.00	2	1.61	0	0.00	6	1.00
7	3	1.56	3	6.38	0	0.00	0	0.00	0	0.00	1	1.96	7	1.17
8	0	0.00	0	0.00	1	0.61	0	0.00	0	0.00	0	0.00	1	0.17
9	0	0.00	1	2.13	0	0.00	0	0.00	1	0.81	0	0.00	2	0.33
10	0	0.00	0	0.00	1	0.61	0	0.00	0	0.00	0	0.00	1	0.17
Total	**192**	**100**	**47**	**100**	**163**	**100**	**21**	**100**	**124**	**100**	**51**	**100**	**598**	**100**
G. Scar Orientation [c] Orientation [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Unidirectional	161	83.85	37	78.72	127	77.91	19	90.48	99	79.84	34	66.67	477	79.77
Bidirectional	1	0.52	1	2.13	0	0.00	0	0.00	0	0.00	0	0.00	2	0.33
Rotated	18	9.38	2	4.26	6	3.68	2	9.52	8	6.45	2	3.92	38	6.35
NA	5	2.60	0	0.00	7	4.29	0	0.00	8	6.45	6	11.76	26	4.35
Indeterminate	7	3.65	7	14.89	23	14.11	0	0.00	9	7.26	9	17.65	55	9.20
Total	**192**	**100**	**47**	**100**	**163**	**100**	**21**	**100**	**124**	**100**	**51**	**100**	**598**	**100**

H. Form [c]	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Dist. Contracting	38	19.79	12	25.53	49	30.06	4	19.05	23	18.55	17	33.33	143	23.91
Dist. Expanding	126	65.63	28	59.57	92	56.44	12	57.14	81	65.32	30	58.82	369	61.71
Leaf	11	5.73	4	8.51	10	6.13	0	0.00	11	8.87	2	3.92	38	6.35
Parallel-Sided	4	2.08	1	2.13	2	1.23	0	0.00	0	0.00	0	0.00	7	1.17
Sub Parallel	13	6.77	2	4.26	10	6.13	5	23.81	9	7.26	2	3.92	41	6.86
Total	**192**	**100**	**47**	**100**	**163**	**100**	**21**	**100**	**124**	**100**	**51**	**100**	**598**	**100**
I. Profile [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Concave	64	33.33	14	29.79	34	20.86	3	14.29	37	29.84	10	19.61	162	27.09
Convex	31	16.15	14	29.79	51	31.29	10	47.62	28	22.58	13	25.49	147	24.58
Straight	85	44.27	15	31.91	73	44.79	7	33.33	53	42.74	26	50.98	259	43.31
Twisted	12	6.25	4	8.51	5	3.07	1	4.76	6	4.84	2	3.92	30	5.02
Total	**192**	**100**	**47**	**100**	**163**	**100**	**21**	**100**	**124**	**100**	**51**	**100**	**598**	**100**
J. Cross-section [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Left Triangle	49	25.52	8	17.02	36	22.09	6	28.57	22	17.74	10	19.61	131	21.91
Right Triangle	40	20.83	10	21.28	35	21.47	7	33.33	23	18.55	10	19.61	125	20.90
Plano-convex	17	8.85	8	17.02	40	24.54	1	4.76	23	18.55	12	23.53	101	16.89
Symmetric Triangle	25	13.02	6	12.77	15	9.20	1	4.76	20	16.13	6	11.76	73	12.21
Trapezoid	57	29.69	12	25.53	32	19.63	5	23.81	29	23.39	12	23.53	147	24.58
Irregular	4	2.08	3	6.38	5	3.07	1	4.76	7	5.65	1	1.96	21	3.51
Total	**192**	**100**	**47**	**100**	**163**	**100**	**21**	**100**	**124**	**100**	**51**	**100**	**598**	**100**
K. Termination [cd]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Axial	4	1.41	0	0.00	3	1.15	1	3.23	4	2.20	2	2.56	14	1.53
Cortical Axial	3	1.06	1	1.27	3	1.15	0	0.00	3	1.65	4	5.13	14	1.53
Feather	218	76.76	60	75.95	186	70.99	23	74.19	129	70.88	50	64.10	666	72.71
Hinge	37	13.03	6	7.59	38	14.50	2	6.45	25	13.74	12	15.38	120	13.10
Inflexed	7	2.46	2	2.53	2	0.76	0	0.00	2	1.10	1	1.28	14	1.53
Plunge	1	0.35	1	1.27	0	0.00	0	0.00	0	0.00	1	1.28	3	0.33
Step	14	4.93	9	11.39	30	11.45	5	16.13	19	10.44	8	10.26	85	9.28
Total	**284**	**100**	**79**	**100**	**262**	**100**	**31**	**100**	**182**	**100**	**78**	**100**	**916**	**100**

Key: cp - complete and proximal flakes; c - complete flakes; cd - complete and distal flakes

By facetting or grinding the thin overhang on a core, the edge of the core is strengthened, thereby decreasing the potential for knapping problems. The overhangs preserved on the flakes show little evidence that knappers routinely modified the overhang of a core prior to the detachment of a flake. Twelve flakes exhibit facetting and one has an abraded overhang, suggesting that this was only done in extremely rare circumstances. Crushed overhangs also appear amongst the sample, likely as the result of a thin and weak overhang. Overhang modification occurred more commonly amongst chert flakes (n=10), while two BIF flakes and one brown shale flake also had modified overhangs.

Lipping and diffuse bulbs of percussion were once believed to be traits of soft-hammer percussion, but more recent work has demonstrated that these characteristics can occur on flakes produced through both hard-hammer and soft-hammer techniques (Pelcin 1997a). Other factors such as the angle of force and thickness of the platform are believed to contribute to the appearance of these attributes (Pelcin 1997a). Over 11% of the flakes exhibit lipping on their ventral surface (Table 6-12: C). This suggests that occasionally flakes were struck with lower angles of force (Bonnichsen 1974: 165; Pelcin 1997a). The incidence of prominent and diffuse bulbs of percussion is evenly divided for the assemblage as a whole (Table 6-12: D); however, in from AU2 to AU1 prominent bulbs of percussion become slightly more common. The increase in prominent bulbs of percussion in the later stages of the occupation was initially believed to be related to the increase in chert artefacts in these analytical units; however, the data does not support this hypothesis. This variable appears to be independent of raw material in this assemblage.

The dorsal surface of a flake retains a number of attributes that can help reconstruct the knapping methods utilised by the knappers, including the proportion of dorsal cortex (Table 6-12: E), the number of dorsal scars (Table 6-12: F), and the scar orientation (Table 6-12: G). Within each analytical unit, non-cortical or tertiary flakes comprise the majority of the sample. In most phases of occupation, partially cortical and cortical flakes are present in the assemblage in small proportions. The presence of cortical flakes in the assemblage attests to the early stages of reduction at HD07-3A-PAD13. BIF flakes account for the vast majority of the completely cortical (n=43) and flakes with over a third cortex. Shale and quartz also occur in moderate frequencies throughout each category. In contrast, chert flakes only become numerous in the last category of cortical flakes (1-32% cortex), with 55 specimens recorded. There were eight chert flakes with more than a third dorsal cortex and only three completely cortical chert flakes. This data supports the hypothesis that partially reduced chert cores were brought to the site, flaked, and then viable cores were removed from the site, while BIF, shale, and quartz were sourced locally and reduced on-site and then discarded.

Completely cortical flakes typically are least numerous in an assemblage and the frequency of artefacts increases slightly with each decreasing category of cortex, ending with a spike in non-cortical flakes. The assemblage shows the spike in non-cortical flakes, but most analytical units have slightly higher numbers of completely cortical flakes than flakes with cortex over 66 to 99% of their dorsal surface. The reason for this pattern is not clear, but it may simply be due to how the cores were reduced.

The number of dorsal scars can provide a rough indication of the reduction stage as well as intensity of reduction; although, there can be a variation due to the size of the artefact and size of the scars. Up to ten negative flake scars were observed on one flake in the assemblage, but high negative scar counts are generally rare. Most flakes exhibit between one and four negative flake scars. With the exception of the BIF flakes, the majority of the flakes with more than five scars are quite small, suggesting that these raw materials were very highly reduced. The BIF flakes account for 19 of the 57 flakes with more than five negative scars, and these considerably larger flakes likely had a large surface area allowing for a greater number of negative flake scars. Goethitised shale (n=2), greyish brown chert (n=3), martite-goethite (n=1), brown shale (n=13), and green shale (n=1) are also larger than the average flake size, and they may also not be highly reduced.

The dorsal scars direction reveals how the knappers orientated the cores as they removed a sequence of flakes. The data demonstrates that a fifth of the flakes have unidirectional dorsal scars on average, with a peak in AU4 and a slight trough in AU6. The flakes show a different story than the cores in the assemblage, which were predominantly classified as rotated platform cores. The flakes show that even though the cores were rotated, the knappers generally removed flakes from one platform at a time in a unidirectional manner, resulting in a high proportion of flakes with unidirectional dorsal scars. Flakes with rotated scars only comprise a small proportion of the assemblage, and these flakes may have been produced when a core was rotated and there were two intersecting core faces. Two bidirectional cores were identified in the assemblage, and only two flakes with bidirectional scars were observed, suggesting that this was not a common reduction strategy. In a number of specimens the orientation could not be determined with certainty, and these were recorded as indeterminate.

The 598 complete flakes in the assemblage provide useful information regarding their morphology, and the qualitative attributes of flake form (Table 6-12: H), profile (Table 6-12: I), and cross-section (Table 6-12: J) are complements to the quantitative data discussed previously. The majority of flakes have a distally expanding form, with a slightly lower proportion than was recorded by the parallel index. This accounts for the identification of flakes with parallel, sub-parallel, and leaf-shaped forms. Less than a quarter of the flakes were described as having distally contracting forms. Over the course of the occupation sequence, the flake morphology remains fairly consistent with a slight rise in distally contracting flakes in AU6 and AU3. This variation is likely inconsequential. It may be coincidental, but these two analytical units also have the lowest average exterior platform angle. Research has found that expansion angle (the angle between the two flake edges) increased with decreasing platform thickness (Pelcin 1997a). Amongst the various flake forms, leaf-shaped flakes had the narrowest platforms, followed by sub-parallel flakes. Parallel-sided and distally contracting flakes had the thickest platforms. Distally expanding flakes fell into the middle of the range for platform thickness.

The majority of flakes were classified as having straight profiles, followed by concave and convex profiles. Twisted profiles were very rare. The cross-section of the flakes was distributed amongst the various categories and there is no clear patterning. This is also true of the blades, once again suggesting that they were not produced systematically or deliberately.

The termination is the final point at which the flake detaches from the core, and the termination type is affected by a number of factors. Throughout the sequence, feather terminations are dominant, but they are slightly less prevalent in AU5, AU6, and AU3. Feather terminations are generally considered to be ideal, as other types often make further reduction of the core problematic or may produce unsatisfactory flakes. Hinge terminations are relatively common in the assemblage, particularly in AU4, AU5, AU3, and AU1. Hinge terminations, as well as step terminations, which are slightly less common, often render core faces unworkable with one hinge or step termination leading to more. Hinge and step terminations occur amongst all of the major raw material types, with slightly higher frequencies amongst shale, goethitised shale, and BIF flakes. Cortical axial and axial terminations are essentially the same, with the former noting the presence of cortex on the base of the core. Axial terminations occur occasionally throughout the occupation, likely as the result of reducing small river cobbles. Axial terminations are often associated with bipolar reduction (Odell 2004: 58); although, they may also occur through hand-held reduction techniques. The axial and cortical axial flakes have the highest average exterior striking platform angles of all of the termination types (83.1° and 82.3° respectively). This was also observed in the HD07-3A-03 assemblage. Plunging terminations are infrequent, with three flakes with such terminations recorded in the assemblage. Like the axial terminations, the flakes with plunging terminations also have quite high exterior striking platform angles (80°).

Retouched and Utilised Artefacts

In total, 48 retouched and utilised artefacts were identified in the HD07-3A-PAD13 assemblage, including three retouched artefacts recovered from the surface of the shelter (one side scraper and two retouched artefacts). The artefacts from the excavation are listed in Table 6-13, which documents the retouched and utilised artefact type and subtype. Over the course of the occupation, retouched and utilised artefacts comprise only a small proportion of the artefact assemblage. The greatest numbers of retouched and utilised artefacts were recovered in AU1, AU3, and AU5.

The range of artefact types in the analytical units is limited and non-formal retouched artefacts comprise the majority of the sample. Formalised retouched artefacts are rare, including four backed artefacts and two scrapers. All but one of the formalised retouched artefacts was recovered from AU1. One endscraper was identified in AU4. In addition to the low proportion of retouched artefacts, utilised artefacts are surprisingly uncommon, with four specimens identified. The low diversity and number of retouched and utilised artefacts at HD07-3A-PAD13 may indicate that the rockshelter itself was not a focus of activities. In the following sections, the formalised retouched artefacts are briefly described before the general patterns of secondary edge modification are considered.

Formalised Retouched Artefacts

Four symmetrical backed artefacts were recovered from AU1, including two elongated crescents, a crescent, and a triangle. Artefact 137 (Figure 6-13: a) is an elongated crescent with a symmetrical form that was produced on an olive chert flake that exhibits some evidence of heating (reddening at proximal tip). The artefact has dorsal backing along the left lateral edge, which has been shaped into a convex form. The retouch gives the edge a slightly sinusoidal appearance. The right lateral edge has fine, alternating usewear along its entire length. The artefact has a thin coating of concretion adhering to the dorsal surface, which makes observation of residues and wear patterns difficult. On the ventral surface, there are some brown smears (possibly resin) near the proximal margin as well as two linear striations

that are approximately 45° to the working edge. Of the three backed artefacts, this specimen has the greatest amount of retouch with a PRI value of 0.63. Artefact 635 is a quartz crystal elongated crescent that was recovered from the surface layer of Unit 5 (Figure 6-13: c). The artefact is very small (15.49-x-4.35-x-3.16mm) and has a slight crescent shape. Due to its symmetrical form and lack of pointed tip, it has been classified as an elongated crescent as opposed to a Bondi point. The dorsal backing occurs on the distal right margin, while the proximal right margin remains unmodified. There is a small amount of usewear along the left lateral margin. On the ventral surface, there are numerous striations visible along the midline of the artefact (particularly in two concentrated areas). Reddish brown concretion occurs over many parts of the artefact, but it appears that there is also red residue along the proximal tip and along the backed margin. Due to the limited amount of retouch, the PRI for this artefact is low (PRI=0.28).

A crescent was identified in the surface layer of Unit 2, Artefact 249. This specimen is slightly larger than many backed artefacts (35.96-x-25.01-x-4.93mm), but it maintains similar proportions. Additionally, this artefact retains its bulb of percussion and striking platform, which are generally removed during the retouching process. Artefact 249 has continuous dorsal scaled backing along the left lateral margin, which has a convex delineation. While there is a considerable amount of concretion on the dorsal surface, the backed edge appears to be very rounded and worn, as does the proximal end. This may be due to movement in the haft. There are several red smears on the ventral surface (roughly perpendicular to the backed edge) and it is possible that it could be resin. Usewear scars are visible along the distal and right lateral margin.

One triangular symmetrical backed artefact was identified in the assemblage (Artefact 297; Figure 6-13: b). The specimen has a slightly irregular and asymmetrical form, but it has still been included amongst the symmetrical backed artefacts as it bears most similarity to them. The artefact was produced on a flake that has two ventral surfaces, which demonstrates that this flake was struck off the ventral surface of a much larger flake. The speckled brown shale flake has been subject to burning as evidenced by the potlid fracture and the high degree of reddening. The backing occurs along the right lateral edge. The distal right backing has a rectilinear delineation, with distinct points at each end. In contrast, the backing along the proximal edge has a nosed delineation and a small portion of the proximal left tip is missing. The unusual shape may be the result of a knapper re-working a broken artefact. Alternatively, this may have been the original shape and it varies from our preconceived views of how such artefacts should appear. The PRI value (PRI=0.56) indicates that over half of the perimeter has been retouched.

There is a fine line between artefacts classified as retouched artefacts and scrapers; however, the three scrapers identified in this assemblage have well-defined working edges with either convex or nosed delineations. Artefact 1041 is an endscraper produced on a sugar chert flake (Figure 6-13: e), which has a yellow staining or patina on its surface. This specimen was recovered from AU4, and it is the lowermost formalised retouched artefact. The distal edge has long dorsal stepped and scaled SAR with a nosed delineation. The artefact also has long ventral retouch on the proximal right edge. The two areas of retouch form a sharp point on the right lateral edge, and this may also have been utilised. The artefact has moderate retouch with a PRI value of 0.59. Artefact 654 is a very small (15.52-x-13.34-x-4.59mm) endscraper that was produced from a dark grey chert flake. Recovered from AU1, this specimen has short steep continuous dorsal scaled retouch with a convex working edge along the distal and right lateral edge. The edge is slightly rounded suggesting considerable use. The artefact has a PRI value of 0.34. Artefact 1716 is a translucent green chert side scraper that was recovered from the surface of the rockshelter. The artefact has been extensively retouched and has a PRI value of 0.73. The scraper edge is on the right lateral edge, and it was formed through long, dorsal SAR, which has a convex delineation. The distal end of the flake has a rectilinear truncation formed by short, ventral SAR. The left lateral edge was also retouched, but the scars are short and occur on the ventral surface.

Edge Modification Analysis

Amongst the 48 retouched and utilised artefacts recovered from HD07-3A-PAD13, 30 specimens are complete (including the single complete surface artefact). There are 56 areas of edge modification on the complete specimens, and Table 6-14 documents these edge modification areas for each retouched and utilised artefact subtype. On average, the scrapers have the highest number of edge modification areas per artefact, while utilised artefacts have the lowest number. With most excavated assemblages, the qualitative edge modification attributes are presented for each analytical unit. Because of the low number of complete retouched artefacts from the site, these attributes have presented together in Table 6-15. The data has been examined for any changes over time and these are discussed below.

Table 6-13 Distribution of retouched and utilised artefacts by analytical unit, HD07-3A-PAD13 rockshelter

Retouched Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Subtype	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*11*	*64.71*	*1*	*100*	*8*	*80.00*	*2*	*66.67*	*9*	*100*	*4*	*80.00*	*35*	*77.78*
Alternate Edge	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	20.00	1	2.22
Alternating	1	5.88	0	0.00	1	10.00	0	0.00	2	22.22	0	0.00	4	8.89
Unifacial	10	58.82	1	100	7	70.00	2	66.67	7	77.78	3	60.00	30	66.67
Utilised Artefact	*1*	*5.88*	*0*	*0.00*	*2*	*20.00*	*0*	*0.00*	*0*	*0.00*	*1*	*20.00*	*4*	*8.89*
Alternating	0	0.00	0	0.00	1	10.00	0	0.00	0	0.00	1	20.00	2	4.44
Unifacial	1	5.88	0	0.00	1	10.00	0	0.00	0	0.00	0	0.00	2	4.44
Symmetrical Backed Artefact	*3*	*17.65*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*4*	*8.89*
Crescent	1	5.88	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	2.22
Crescent – E	2	11.76	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	4.44
Triangle	1	5.88	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	2.22
Scraper (Endscraper)	*2*	*11.76*	*0*	*0.00*	*0*	*0.00*	*1*	*33.33*	*0*	*0.00*	*0*	*0.00*	*2*	*4.44*
Total	**17**	**100**	**1**	**100**	**10**	**100**	**3**	**100**	**9**	**100**	**5**	**100**	**45**	**100**

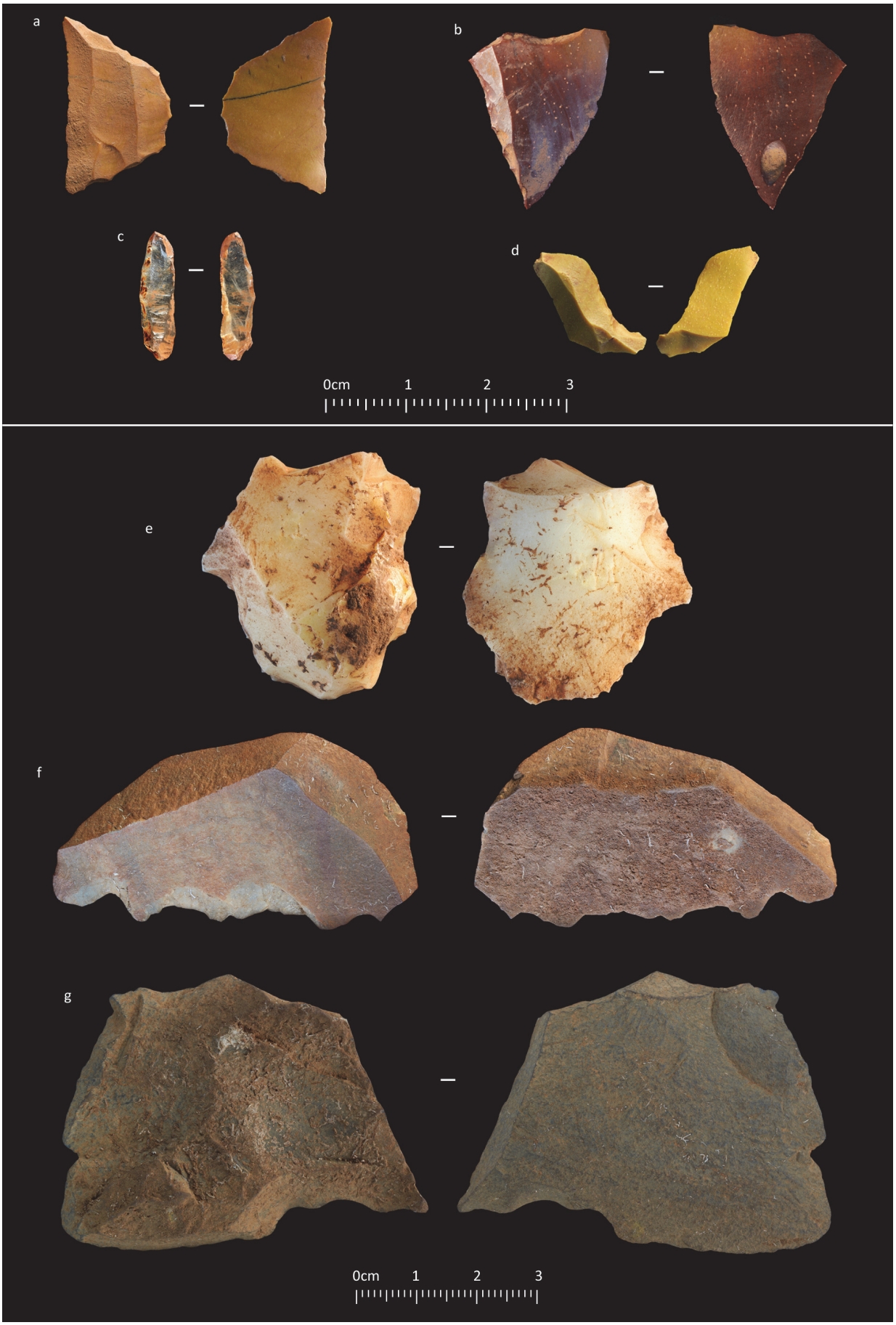

Figure 6-13 Retouched artefacts from HD07-3A-PAD13 rockshelter: a) Artefact 137 (crescent-e) from AU1, b) Artefact 297 (triangle) from AU1, c) Artefact 636 (crescent-e) from AU1, d) Artefact 1476 (retouching flake) from AU1, e) Artefact 1041 (endscraper) from AU4, and f) Artefact 568 from AU5, and g) Artefact 238 from AU6

Table 6-14 Number of edge modification areas on complete artefacts by analytical unit, HD07-3A-PAD13 rockshelter

Retouched Artefact Type	Surface		AU1		AU3		AU4		AU5		AU6		Total	
Subtype	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM
Retouched Artefact	*0*	*0*	*8*	*14*	*3*	*7*	*1*	*2*	*5*	*8*	*3*	*6*	*20*	*37*
Unifacial	0	0	7	10	2	5	1	2	4	5	2	3	16	25
Alternating	0	0	1	4	1	2	0	0	1	3	0	0	3	9
Alternate Edge	0	0	0	0	0	0	0	0	0	0	1	3	1	3
Utilised Artefact	*0*	*0*	*0*	*0*	*2*	*3*	*0*	*0*	*0*	*0*	*1*	*1*	*3*	*4*
Alternating	0	0	0	0	1	1	0	0	0	0	0	0	1	1
Unifacial	0	0	0	0	1	2	0	0	0	0	1	1	2	3
Symmetrical Backed Artefact	*0*	*0*	*4*	*9*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4*	*9*
Crescent	0	0	1	3	0	0	0	0	0	0	0	0	1	3
Crescent – E	0	0	2	4	0	0	0	0	0	0	0	0	2	4
Triangle	0	0	1	2	0	0	0	0	0	0	0	0	1	2
Scraper	*1*	*3*	*1*	*1*	*0*	*0*	*1*	*2*	*0*	*0*	*0*	*0*	*3*	*6*
Endscraper	0	0	1	1	0	0	1	2	0	0	0	0	2	3
Side Scraper	1	3	0	0	0	0	0	0	0	0	0	0	1	3
Total	**1**	**3**	**13**	**24**	**5**	**10**	**2**	**4**	**5**	**8**	**4**	**7**	**30**	**56**

Key: n – number of complete retouched or utilised artefacts; EM – number of edge modification areas

The edge modification types used in the creation of the retouched and utilised artefacts are presented in Table 6-15: A. By far, regular retouch accounts for most areas of edge modification, distantly followed by usewear. Backing is present in small proportions and only occurs in AU1. Other forms of retouch, such as single notches, retouched notches, or truncations only occur occasionally. The single retouched notch was created on a BIF artefact from AU6 (Figure 6-13: g). The large retouched notch was fashioned on the left side of the distal edge, creating a point with a triangular cross-section. The tip of the point is rounded and it appears to have been used. Two of the single notches were created on artefacts from AU3, and one was identified on an artefact from AU5. The two artefacts with truncations both occur late in the occupation of the site, with one from AU1 and the other (a scraper) recovered from the surface of the rockshelter. On Artefact 282 (AU1), the truncation forms a point at the proximal left edge, which looks like it has some usewear (tiny step fractures all along retouched edge).

The position of the edge modification is predominantly on the dorsal surface (Table 6-15: B), and this is consistent throughout the occupation with the exception of AU6 where it is mostly on the ventral surface. However, there are four retouched and utilised artefacts from this analytical unit, with only seven areas of edge modification. It is possible that this small sample is not fully representative of the edge modification trends during this period of time. The single surface artefact also shows a reversal of the general site patterns, with two of its retouch areas being on the ventral surface, while the other is on the dorsal surface. Again, this single artefact cannot be expected to represent the patterns of edge modification during the period of its manufacture.

The angle of the edge modification areas is equally divided between AAR and SAR, with a visual estimation of 60° separating these two categories. SAR is more common amongst the retouch areas, while usewear predominantly has a more acute edge angle (Table 6-15: C). There are minor variations over time, with AAR being more common in AU6, AU5, and AU3, while SAR is more common in AU4, AU1, and in the surface assemblage. The considerably higher incidence of SAR in AU1 may be related to the presence of backed artefacts. The lower proportion of SAR in AU6 and AU5 may hint at the possibility that the artefacts were retouched to a lesser degree than those in the later stages of the occupation, but this is a tenuous hypothesis with such a small sample to base it on.

The extent of retouch is a visual measure of how far the scars extend across the flake, ranging from less than 1mm for usewear to covering. By definition, all of the usewear was classified as having an extent of less than 1mm (Table 6-15: D). When the usewear is removed from the data, it is easier to observe the patterns of retouch extent over time. In most analytical units (AU6, AU3, AU1, and the surface artefact), short retouch is predominant. In AU5, there is an even spread of invasive, long, and short retouch (with only two retouch areas of each extent), as well as one instance of covering retouch. In AU4, long retouch accounts for three of the four retouch areas.

The delineation of an edge modification area is an observation of how the retouch has changed the shape of the original flake. If the shape has remained largely unmodified, the retouch area is classified as having a regular delineation. Regular delineation is by far the most common type in the assemblage, accounting for all of the usewear and a large proportion of the regular retouch (Table 6-15: E). Concave delineation accounts for a quarter of the sample, including all of the single notches, the retouched notch, the truncation, and several instances of regular retouch. Other delineation types, such as convex, rectilinear, nosed (*e.g.*, Figure 6-13: e), denticulate (*e.g.*, Figure 6-13: f), or sinusoidal are rare.

The distribution of the edge modification areas on the artefacts shows that there is a fairly even division between retouch on the left and right lateral edges (Table 6-15: F). Edge modification on the right lateral edge is slightly more common, but with such a small sample the two instances account for nearly a 4% difference. Hence, the variation between the right and left edge modification is negligible. As with most assemblages, distal retouch is more common than proximal retouch. With such a small sample size, it is impossible to determine if there is any variation in the location of the edge modification through time.

The quantitative retouch statistics are presented in Table 6-16, which includes the average retouch length, GIUR, and PRI. The results have been presented by analytical unit, but the samples are too small to identify statistically valid differences over time. Hence, the results will only be discussed for the assemblage as a whole. The average retouch length was determined for 45 edge modification areas (Table 6-16: A). All instances of usewear were excluded from this calculation, as many of the usewear scars were likely created through the use of the artefact rather than from deliberate edge modification. The average length of the retouch areas ranges considerably from 4.51mm to 57.99mm, with an average value of 18.16mm.

Table 6-15 Qualitative edge modification attributes, HD07-3A-PAD13 rockshelter

A. Edge Modification Type	Backing	Notch	Retouch	Ret. Notch	Trunc.	Usewear	Total	
	n	n	n	n	n	n	n	%
Retouched Artefact	0	3	29	1	1	3	37	66.07
Utilised Artefact	0	0	0	0	0	4	4	7.14
Sym. Backed Art.	5	0	0	0	0	4	9	16.07
Scraper	0	0	5	0	1	0	6	10.71
Total n	**5**	**3**	**34**	**1**	**2**	**11**	**56**	**100**
Total %	**8.93**	**5.36**	**60.71**	**1.79**	**3.57**	**19.64**	**100**	**-**
B. Position	n	n	n	n	n	n	n	%
Alternating	0	0	1	1	0	5	7	12.50
Dorsal	5	2	21	0	1	6	35	62.50
Ventral	0	1	12	0	1	0	14	25.00
Total	**5**	**3**	**34**	**1**	**2**	**11**	**56**	**100**
C. Angle	n	n	n	n	n	n	n	%
AAR	0	2	16	0	0	10	28	50.00
SAR	5	1	18	1	2	1	28	50.00
Total	**5**	**3**	**34**	**1**	**2**	**11**	**56**	**100**
D. Extent	n	n	n	n	n	n	n	%
<1mm	0	0	0	0	0	11	11	19.64
Short	5	1	22	1	2	0	31	55.36
Long	0	0	9	0	0	0	9	16.07
Invasive	0	2	2	0	0	0	4	7.14
Covering	0	0	1	0	0	0	1	1.79
Total	**5**	**3**	**34**	**1**	**2**	**11**	**56**	**100**
E. Delineation	n	n	n	n	n	n	n	%
Concave	0	3	9	1	1	0	14	25.00
Convex	2	0	3	0	0	0	5	8.93
Denticulate	0	0	1	0	0	0	1	1.79
Nosed	1	0	1	0	0	0	2	3.57
Rectilinear	2	0	0	0	1	0	3	5.36
Regular	0	0	19	0	0	11	30	53.57
Sinusoidal	0	0	1	0	0	0	1	1.79
Total	**5**	**3**	**34**	**1**	**2**	**11**	**56**	**100**
F. Location	n	n	n	n	n	n	n	%
PE	1	0	1	0	1	0	3	5.36
DE	0	0	3	1	1	1	6	10.71
LLE	1	2	12	0	0	5	20	35.71
RLE	1	1	15	0	0	5	22	39.29
LLE + DE and/or PE	1	0	2	0	0	0	3	5.36
RLE + DE and/or PE	1	0	0	0	0	0	1	1.79
DE + RLE and LLE	0	0	1	0	0	0	1	1.79
Total	**5**	**3**	**34**	**1**	**2**	**11**	**56**	**100**

The GIUR explores the degree of dorsal lateral edge retouch through a ratio of the retouch thickness to the flake thickness. Because the GIUR is limited to dorsal, lateral retouch, there are only 22 areas of retouch suitable for this index (Table 6-16: B). The range for the entire sample expresses the variety in the degree of retouch, from minor (GIUR=0.11) to extensive (GIUR=1.00) retouch. The average value for the sample is 0.52, indicating a moderate extent of dorsal lateral retouch.

The PRI is a measure of how much of an artefact's perimeter has been retouched, by comparing the length of the retouched edge to the perimeter length. This index was determined for 27 complete retouched artefacts, with an average PRI value of 0.30 (Table 6-16: C). This indicates that most artefacts have retouch along approximately 30% of perimeter; although, the range shows that the retouched edge can account for as little as 4% and as high as 73% of the perimeter. There is a trend towards increasing PRI from AU6 to AU1; however, this pattern is questionable due to the small sample sizes. The PRI amongst the different raw material groups suggests that BIF and shale artefacts had the least amount of retouch, while quartz and chert artefacts had considerably more retouch (Table 6-16: D). The low number of both shale and quartz artefacts suggests that the patterns for these raw material types in particular are not robust.

The average size of retouched artefacts decreases through the analytical units, with AU6 having quite large artefacts and AU1 having much smaller artefacts. The average size of the four complete retouched artefacts in AU6 is 43.11mm long (SD=9.46) and 44.61mm wide (SD=18.36), while the flakes in AU1 are considerably smaller on average, measuring 24.16mm long (SD=13.71) and 16.69mm wide (SD=9.31). AU4 shows a deviation from the trend, where its two artefacts have a much larger average size than even those in AU6; however, this is due to one particularly large artefact (84.35-x-51.13-x-21.45mm).

Table 6-16 Summary statistics for the retouch length, GIUR, and PRI, HD07-3A-PAD13 rockshelter

Measurement	AU	Average	Min	Max	SD	EM
A. Retouch Length (mm) by AU	Surface	27.15	20.97	31.36	5.47	3
	AU1	15.71	6.65	40.82	10.62	19
	AU3	18.16	5.57	50.9	15.12	7
	AU4	30.99	9.96	57.99	22.26	4
	AU5	16.23	4.51	45.15	13.70	7
	AU6	14.51	4.7	28.57	8.93	5
	Total	18.16	4.51	57.99	13.06	45
B. GIUR Statistics by AU	Surface	0.57	0.57	0.57	-	1
	AU1	0.54	0.25	1.00	0.27	12
	AU3	0.51	0.28	0.84	0.29	3
	AU4	0.52	0.39	0.66	0.19	2
	AU5	0.56	0.27	1.00	0.39	3
	AU6	0.11	0.11	0.11	-	1
	Total	0.52	0.11	1.00	0.26	22
Measurement	**AU**	**Average**	**Min**	**Max**	**SD**	**n**
C. PRI Statistics by AU	Surface	0.73	0.73	0.73	-	1
	AU1	0.32	0.08	0.63	0.16	13
	AU3	0.34	0.20	0.45	0.12	3
	AU4	0.41	0.23	0.59	0.26	2
	AU5	0.15	0.04	0.31	0.11	5
	AU6	0.18	0.16	0.23	0.04	3
	Total	0.30	0.04	0.73	0.18	27
Measurement	**RM**	**Average**	**Min**	**Max**	**SD**	**n**
D. PRI Statistics by Raw Material	BIF	0.22	0.04	0.45	0.12	10
	Chert	0.37	0.19	0.73	0.19	11
	Quartz	0.40	0.28	0.51	0.16	2
	Shale	0.25	0.06	0.56	0.22	4
	Total	0.30	0.04	0.73	0.18	27

Key: n – number of artefacts; EM – number of edge modification areas; RM – raw material type

Grindstones and Artefacts with Use Polish

Eleven artefacts with evidence of grinding or polish were recovered from HD07-3A-PAD13 (Figure 6-14). They were recovered from each analytical unit with the exception of AU3. These artefacts include a variety of specimens that have been tentatively identified as lower grindstones, upper grindstones (or mullers), and possible polishing or rubbing stones. For greater certainty of the function of these artefacts, further analysis is required (*e.g.*, usewear and residue analysis).

Artefact 618 is the sole artefact with use polish that was identified in AU6. This artefact is a small BIF river cobble that appears to have been broken in half, but there is no clear point of impact, nor is there a positive or negative surface. One surface has a smoother appearance and a darker colour, which may indicate that there is residue on the artefact. The function of this artefact is unclear; however, similar, but smaller, utilised pebbles were identified in the Jundaru assemblage, and they have been shown through usewear analysis to have been rubbed or smoothed (Fullagar 2013).

In AU5, six ground artefacts were recovered, including Artefacts 333, 372, 436, 1165, 1168, and 1214. Artefact 333 (Figure 6-14: b) is a large sub-rectangular BIF river cobble that appears to have been used as a lower grindstone. While the surface has been smoothed as the result of fluvial action, there are areas on both the upper and lower surface where it is can be distinguished that grinding has smoothed the high points. The artefact exhibits some flaking, which is interpreted to be natural exfoliation due to the lack of negative flake scars. Artefact 372 is a large oval BIF river cobble that is convex on one side and concave on the other side. The convex side appears to have a smoothed and ground surface. Due to its convex working surface, it seems unlikely that it would have been used as a lower grindstone, but possibly as an upper grindstone. Artefact 435 is a large BIF river cobble that appears to have been used as a lower grindstone. The high points on one surface have been smoothed, while the other surfaces appear unmodified. Artefact 1165 (Figure 6-14: d) is a small, pentagonal-shaped rounded river pebble that may have been used as a polishing stone or rubbing implement. One surface is more flat, while the other has a more raised and irregular profile. On the flat surface, the raised edges look like they are more worn and they have a darker appearance. On the opposite surface, there is an area that has a dark substance on it as well as a clear smear of yellow ochre. The artefact was collected *in situ* from Unit 5. This artefact is also similar to the small polished pebbles from Jundaru, which were abraded and polished. Artefact 1214 is the final grindstone in AU5, which is again a fragment of a rounded river cobble with evidence of grinding. At least half of the artefact is missing, and the artefact was recovered in two pieces. Grinding is apparent on the surface of the specimen, which may have been used an upper grindstone.

One possible grindstone was recovered from AU4. Like the grindstones from AU6 and AU5, Artefact 330 is a large BIF river cobble that exhibits smoothing on one surface. This artefact is certainly not as clear as the other grindstones from the site, but the area of light smoothing is different than the weathered surface on the rest of the cobble.



Figure 6-14 Grindstones and manuports from HD07-3A-PAD13 rockshelter: a) Artefact 302 from AU1, b) Artefact 333 from AU5, c) Manuport from AU6 (Artefact 479), and d) Artefact 1165 from AU5

Two grindstones were identified in AU1, including an excellent example of a lower grindstone. Artefact 302 was produced on a tabular fragment of BIF, which has thin (*ca.* 2mm) horizontal laminae (Figure 6-14: a). The laminae are a natural weak point, and the top lamina has separated from the rest of the grindstone, likely as the result of weathering. Across the entire upper surface of the grindstone there is extensive smoothing and polishing. The lower surface is rough, and was apparently not utilised. Weighing 5.5kg, this grindstone is the largest recovered from the site (311.98x-x242.7-x-18.18mm). Artefact 703 is a rounded river cobble that has been used as a lower grindstone. The grindstone has a flat surface as well as a convex surface, resulting in a plano-convex cross section. Artefact 302 was recovered *in situ* in Unit 2, with its base resting on the top arbitrary excavation Layer 5 (45-50cmbd). The grindstone was not lying completely flat, but was angled down slightly towards the southeast (max depth 45.5). The tabular BIF fragment is flat and thinly banded, and it does not match the immediate geology of Hope South. The Traditional Owners observed that the raw material is similar to the BIF at the Yandi Mine, approximately 50km north. Similar flat, tabular bands of BIF are observable along the main access road of the Yandi Mine, between the Yandi Village Aerodrome and the west security gate (near Marillana Village). Artefact 703 was recovered *in situ* from Layer 4 of Unit 5 with a maximum depth of 45cmbd. It is conceivable that these two artefacts were utilised in conjunction. A charcoal sample collected just below the base of these artefacts dates to 1462±41 cal BP.

Manuports

Six manuports were identified in the assemblage, and each specimen exhibits a rounded surface typical of river cobbles. Three manuports were recovered from each AU6 and AU5, and their large size makes it inconceivable that they could have been washed into the rockshelter during a high-energy flood. If such an event took place, it would have certainly deposited more than these rare objects. It is most probable that rocks were occasionally selected from the nearby creek and brought into the shelter for some purpose. These artefacts were classified as manuports as they did not exhibit attributes of lithic reduction or show evidence of usewear indicative of a grindstone, hammerstone, or other such object. If the manuports were examined microscopically, it is possible that they may have evidence of usewear that is not visible at the macroscopic level.

The three lowermost manuports recovered from AU6 are Artefacts 479, 602, and 1282. Artefact 479 is a large fragment of a martite-goethite river cobble (80.41-x-61.01-x-23.84mm; Figure 6-14: c). The specimen has an irregular shape, and it appears that the cobble has broken with a smoother surface on one side and a slightly rougher surface on the other side. The manuport bears no evidence of grinding, percussion, or any other usewear. The raw material is very different to that within the rockshelter, so this has also contributed to its identification as a manuport. Artefact 602 is a BIF river cobble that appears to be split in at least two pieces. The fragment recovered from the site does not show a ventral or dorsal surface on the fractured surface; therefore, it cannot be classified as a core or a flake. There is obvious usewear on the artefact, so it has been classified as a manuport. Artefact 1282 appears to be a rounded, natural BIF flake that was sourced from a nearby creek bed. The entire surface of the specimen is smoothed and weathered, indicating that it was not broken or reduced. The rock has a slightly polished appearance on one side, but this was considered to be possibly natural.

The three manuports from AU5 include Artefacts 345, 350, and 1118. Artefact 345 is a moderate-sized BIF river cobble (57.79-x-45.36-x-38.89mm), which has numerous natural fractures. The fractures appear to be fresh and the result of *in situ* weathering. The specimen exhibits no evidence that it has been utilised. Artefact 350 is also a BIF river cobble, which exhibits some natural exfoliation. This specimen is coated in kaolinite, which is a clay mineral that is formed through the weathering of aluminium-silicate rich rocks, such as feldspar. The presence of kaolinite on this rock is most likely natural, as it often forms around rocks, particularly those close to bedrock. Artefact 350 was recovered *in situ* from Unit 2, which has bedrock slowly encroaching into it, and the field excavators noted that most rocks in this layer had a thin coating of kaolinite. Artefact 1118 is the final manuport recovered from AU5. This specimen is slightly smaller than the other two, measuring 38.69mm long, 31.08mm wide, and 12.97mm thick. This BIF manuport looks similar to a flake, but has clearly been rounded after considerable time in the creek bed. It is possible that it is an older flake that was discarded in the creek and weathered over time, or it may even be a natural flake that has been rounded. The artefact shows no signs of use.

Artefact Analysis Summary

A moderate assemblage of artefacts was recovered from HD07-3A-PAD13, spanning an occupation sequence that extends over 40,000 years. The assemblage is predominantly comprised of diagnostic artefacts (88.01%), with flakes being the primary component. In total, 1718 artefacts were recovered from the site, and their distribution over time suggests that there was only intermittent low-intensity occupation of the site.

The raw material analysis demonstrates that the knappers procured river cobbles as their main rock source, and the numerous small ephemeral creeklines surrounding the site would have provided an ample supply of materials. While a large goethitised shale exposure is adjacent to the site (HS-A3) and has been quarried to a limited extent in the past, this material was infrequently used by the occupants of HD07-3A-PAD13. It is theorised that the material was not used due to its brittleness and numerous flaws. In the earlier stages of the occupation, there was a much greater focus on BIF, which was widely available. Beginning in AU4 (*ca.* 31.0±3.1 ka), there is a shift towards an increased use of chert and this intensifies in the later stages of the occupation with a concomitant decline in BIF use. The procurement of chert must have been at a higher cost than that of BIF, shale, goethitised-shale, or quartz, which are abundant in the area surrounding the site. Chert cobbles are much less common and they also tend to be much smaller; although, they may also occur in the same ephemeral creeks.

Forty-three cores are present in the assemblage, including 38 complete specimens, which produced a minimum of 218 flakes. Chert cores are under-represented in the assemblage, and it is suggested that as this material was a scarce resource, it was considered valuable. Knappers would have taken these cores with them from place to place, and most specimens appear in the archaeological record as discarded exhausted cores, or perhaps lost items. Having said that, the two chert cores in the assemblage were classified as being viable despite their small size. Both specimens exhibit hinge terminations, which may have led to their discard. One of the cores also has an axial termination, which may indicate that bipolar reduction was utilised in its reduction.

The reduction methods used at the site remained relatively consistent over time. Rotated cores were predominant, with the

exception of AU5 where most cores were unidirectional. Flakes were generally struck from unprepared cortical or plain striking platforms, with no evidence of core preparation (*e.g.*, shaping, *etc.*). Through the occupation, core size steadily decreased with the largest cores being in the lowest layers of the site and the smallest cores in the most recent phase of site use. This pattern is likely an indirect result of the increased proportion of chert, as the smaller chert cobbles would have inherently limited the size of the cores and flakes.

Using the MNF, it is estimated that the 1410 flakes and flake fragments derive from at least 1054 complete flakes. With 599 complete flakes, this indicates that there was a high degree of flake fragmentation at the site. Distal flake fragments are unusually numerous, and this pattern occurs amongst all raw material types. As the cores showed decreasing sizes through time, so do the flakes. Again, this is largely attributed to the increased utilisation of chert. The flake attributes suggest that expedient reduction methods were employed throughout the occupation, with little or no evidence of platform preparation or overhang modification. The lack of platform rejuvenation flakes also suggests that cores were not maintained using this method. Flakes predominantly had unidirectional dorsal scars, indicating even amongst rotated cores, a single core face was typically reduced in a unidirectional manner (as opposed to alternating between the platforms). The presence of cortical flakes, as well as conjoin sets, suggests that reduction occurred on-site throughout the sequence. There are a small proportion of flakes with problematic terminations, such as hinge, inflexed, plunge, and step, and their regular occurrence may be related to the informal reduction methods and lack of core and platform preparation.

Few retouched and utilised artefacts are present in the assemblage, suggesting that the rockshelter was not a focus for activities or tool production. Seven formalised retouched artefacts were identified, including three scrapers (one from the surface, one from AU1, and one from AU3) and four backed artefacts (all from AU1). Non-formalised retouched artefacts comprised the majority of the sample, with four utilised artefacts identified. Due to the small sample size, it is difficult to identify any trends in the manufacture of retouched artefacts over time. The retouched artefacts repeat the pattern of the cores and flakes, with decreased size in the more recent occupational phases.

6.6 SPECIALIST STUDIES

A number of specialist studies were commissioned to provide further context to the archaeological patterns at HD07-3A-PAD13, including archaeomagnetic analysis (Herries 2013), palynological analysis (Haberle *et al.*, this volume), phytolith analysis (Wallis, this volume), OSL dating (F. Williams, this volume), and a geomorphological study (M. Williams, this volume). While each of these reports are presented in full as separate appendices, the results of the archaeomagnetic, palynological, and phytolith analyses are summarised below. The results of these studies are considered in relation to the archaeological materials and chronology, details that were not provided to these analysts. The results of the OSL dating and the geomorphology have been discussed in previous sections; hence, these reports will not be summarised again. A large assemblage of macrobotanical remains was recovered through flotation, but this has not been subject to further analysis as charcoal that is clearly linked to the human occupation of the site (*e.g.*, charcoal from hearths) is preferable.

Archaeomagnetic Analysis

Forty two sediment samples were submitted to Dr Andrew Herries for archaeomagnetic analysis in order to explore changes in site use and the local environment. This section aims to summarise the results and interpret them within the broader archaeological context. In total, Herries has carried out archaeomagnetic analyses on four of the Hope Downs 1 sites (Djadjiling, Jundaru, HS-A1, and HD07-3A-PAD13) (Herries 2012; Herries 2013), and these studies have demonstrated that this is an important tool in interpreting the occupation history of a site and creating a better understanding of the local environmental changes.

The sediment submitted for analysis includes samples collected in the field from each of the 42 arbitrary excavation layers in Unit 3 (Quad C; Layers 1-42). The sediment was scooped directly into 30ml plastic portion cups. The samples were assigned random numbers prior to submission to ensure that the results are not a product of sequential lab processing and to avoid any bias in the interpretation of the results. A provenance key was provided after the analysis was carried out, and the samples were interpreted in the order of their real stratigraphic association. The depths of the samples discussed below are the maximum depths of the samples (*e.g.*, Layer 2 ranges from 30-35cmbd, and the sample is discussed here as having a depth of 35cmbd). The analyst was not provided any information regarding the archaeological patterns at the site, as to ensure that the archaeomagnetic analysis was carried out independently and without any potential biases.

Herries (2013) defined six zones of differing magnetic susceptibility and the broad patterns that he found are summarised below. The data suggests that Zone 1 (235-210cmbd) was unaltered by human activity and was deposited during a cold glacial climate (Herries 2013). The lowermost sample from Zone 2 (205-180cmbd) shows the first clear signal of anthropogenic alteration, suggesting that the site was first utilised during this time (Herries 2013). Herries also observed that there was a change in the source of the sediment, suggesting a greater input of externally derived sediment. This likely reflects a greater degree of fluvial sedimentation at the site and less exfoliated and weathered bedrock. The archaeomagnetic data indicates that Zone 3 (175-155cmbd) was less anthropogenically altered, while the converse is true of Zone 4 (150-105cmbd). The archaeomagnetic data shows that site use was low during Zone 5 (100-80cmbd), and the data signals a cold climate phase. In Zone 6 there is a shift to a warm climate phase, and there is a concomitant high anthropogenic signal.

With remarkable accuracy, the archaeomagnetic analysis pinpointed the initial occupation of the site and has strong correlations with the artefact densities throughout the occupation sequence. Herries (2013) marked arbitrary excavation Layer 36 (205-200cmbd) as the initial occupation of the site, which shows the first small spike in artefact numbers (n=20). Five artefacts were recovered below this depth from Layers 39 through 37. The archaeomagnetic data was interpreted as showing low site use in Zone 3, increasing in Zone 4, and these patterns are reflected to a degree in the artefact densities. There is a slight drop in artefact numbers in the layers corresponding to Zone 3, and a subsequent rise at the beginning of Zone 4. The artefact densities show a slight rise in numbers over the Zone 4, peaking at the top of the zone (Layer 11, 93 artefacts). This likely represents that transition to Zone 6 (75cmbd to the surface), which Herries (2013) found to be anthropogenically altered during a warm climate phase. The

high artefact densities in these layers show that this was the most intense period of site use.

Significantly, Herries' research has demonstrated local environmental changes at HD07-3A-PAD13. The data indicates that the sediments from Zone 1 through Zone 5 were deposited under cold glacial conditions (Herries 2013). The OSL dates show that the majority of the deposit was indeed deposited at the onset of glacial conditions. The transition to the Holocene occurs during SL2, which has not been dated. The archaeomagnetic analysis indicates that the sediment in Zone 6 was deposited under warm conditions (Herries 2013).

Sedimentary, Charcoal, and Palynological Analysis

A series of sediment samples from Unit 3 (Layers 1-38, Quad C) were submitted to PalaeoWorks for sedimentary, micro-charcoal, and palynological analysis. The analysis was carried out by Simon Haberle, Feli Hopf, and Phil Roberts, and their results are presented in Chapter 13 (see also Haberle *et al.* 2013). The following paragraphs summarise their results and correlate them with the archaeological patterns and chronology for the site.

There is increased organic content within the sediment from Layer 4, and pollen was only well-preserved above Layer 11. The pollen analysis indicates that the local vegetation consisted of sclerophyll woodland dominated by *Corymbia sp*. with a grass understorey (Haberle *et al.*, this volume); however, below Layer 11 both the proportion of pollen and its diversity declines, limiting further interpretations. Interestingly, the site does not show the increase in grass that the neighbouring site did in the uppermost excavation layer.

There are two peaks in burned grass phytoliths, one in Layers 11 to 10 and a second more intense peak in Layer 7 (55-60cmbd). At HD07-3A-03, there was a peak in burned grass phytoliths in Layer 8 (3241±52 cal BP), and the similarity of the depth of these samples may indicate that they reflect the same local fire event. In Layers 11 and 10, there are slightly elevated frequencies of burned artefacts (20.93% and 13.16%), while Layer 7 has a relatively low frequency of burned artefacts (10.34%). It is possible that natural fire events may have caused some heat alterations of artefacts; however, there is a lower frequency of thermally altered artefacts near the front of the rockshelter (more susceptible to bushfires) than at the middle and back of the shelter.

Phytolith Analysis

Sediment samples from Unit 3 (Layers 1-38, Quad C) were submitted phytolith analysis to Dr Lynley Wallis at the Aboriginal Environments Research Centre at the University of Queensland. The results of the phytolith analysis are presented in Chapter 12 (see also Wallis 2013). The following paragraphs summarise the Wallis' results, incorporating her findings with the broader archaeological patterns and other specialist studies.

The samples submitted for analysis include bulk samples of sediment collected during the excavation from the first 38 arbitrary excavation layers in Unit 3. The sediment was placed into a sieve with 1mm mesh, and sieved onto a dustpan and then placed into a resealable plastic bag. The samples were assigned random numbers prior to submission to ensure that the results are not a product of sequential lab processing or that there was any bias in the interpretation of the results. A provenance key was provided after the analysis was carried out, and the samples were interpreted in the order of their real stratigraphic association. The depths of the samples discussed below are the maximum depths of the samples (*e.g.*, Layer 2 ranges from 30-35cmbd, and the sample is discussed here as having a depth of 35cmbd). The analyst was not provided any information regarding the archaeological patterns at the site, as to ensure that the phytolith analysis was carried out independently and without any potential biases.

One aspect of the phytolith analysis was to determine the proportion of organic matter throughout the sequence. Wallis (this volume) found that organic matter was highest in the first two arbitrary excavation layers, but it decreased slightly and remained relatively consistent until Layer 38. This is unusual as most sites have decreasing proportions of organic matter through time (Wallis, this volume). There is a minor peak in the organic matter in Layer 37, which shows only minimal evidence of occupation. The peak in organic matter in Layer 33 also corresponds with a peak in artefact densities; however, there is not a consistent correlation between high organic materials and peaks in artefact densities.

Phytoliths were preserved throughout the sequence, with higher average proportions than either Jundaru or Djadjiling (Wallis, this volume). Wallis (this volume) notes that the sediment pH values can affect the preservation of phytoliths, with silica solubility rising particularly after a pH of 9. From Layer 8 through to the base of the excavation, the pH values were consistently high, ranging from 8.5 to 9.5; hence, there has been good preservation at HD07-3A-PAD13 despite the possible effects of chemical dissolution. The low artefact numbers at this site compared to Jundaru suggest that the site was utilised less intensively; therefore, it is expected that there would be fewer phytoliths introduced into the site due to the human occupation. Wallis (this volume) suggests that if there was low utilisation of the site, it may have had a greater macropod occupation, with scat being a contributor of phytoliths. Another plausible explanation for the higher abundance of phytoliths at this site is that the fluvial deposition may have introduced more phytoliths (Wallis, this volume). Both of these scenarios fit the archaeological interpretations of the site, and it is possible that they both may have shaped the phytolith assemblage.

There are small variations in phytolith abundance through time. The two greatest peaks were observed in Layer 38 and Layer 17 (Wallis, this volume). Layer 38 occurs during the initial occupation of the site and one artefact was recovered from this layer, as well as two artefacts from the underlying Layer 39. It is only in Layer 36 where there are considerable numbers of artefacts. The low abundance of artefacts suggests that this peak may not be directly related to the human occupation of the site. Layer 17 only has a moderate density of artefacts (n=19); however, the preceding layer had a much higher concentration (n=42). Interestingly, there are high proportions of phytoliths in Layers 7 and 6, which show a trough in the artefact densities. These layers correlate to AU2 and the top of SL2 and the mud wasp deposit. A localised fire event was identified in Layer 7 through burned phytoliths (see also Haberle *et al.*, this volume), and it is possible that a greater abundance of phytoliths was introduced due this fire event or greater utilisation of the shelter by macropods. The subsequent patterns for phytolith percentages and artefact densities are similar for Layers 5 through 1. Wallis (this volume) suggests that there may be a background level of phytoliths at the site, perhaps introduced by animals occupying the rockshelter (*e.g.*, macropods).

Wallis (this volume) divides the sequence into three phytolith zones. Zone 1 is further divided into Zone 1a (Layer 38) and Zone 1b (Layer 37 to Layer 28). Zone 1a shows a high proportion of phytoliths and has a peak in tree phytoliths, while

Zone 1b shows a decline in phytolith abundance with much lower proportions of phytoliths from trees. There is also a shift from Panicoid to Chloridoid grasses from Zone 1a to Zone 1b. Zone 1 roughly corresponds to AU6, during which the environmental conditions at HD07-3A-PAD13 appear to have fluctuated. In Zone 2 (Layer 28 to Layer 11) there was a continued decline in the proportion of trees and shrubs, while grasses increased. This phytolith zone correlates to AU5 to early AU3, encompassing the LGM and terminal Pleistocene. Zone 3 includes arbitrary excavation Layers 10 through 1 and corresponds to mid-AU3 to AU1. In this phytolith zone, there is an increase in trees and a reduction in grasses and Wallis (this volume) observes that the phytolith assemblage in this zone reflects the modern vegetation patterns. As Wallis (this volume) suggested based on the phytolith assemblage alone, this phase corresponds to the beginning of the Holocene with the return to warmer climatic conditions.

Diatoms were observed throughout the sequence and peak in Layer 6 (the top of SL2). Previous studies of mud wasp nests from Carpenter's Gap 1, northern Australia, identified a small number of diatoms (Wallis 2002: 37). Wallis (2002: 37) notes that as the mud wasp nests break down, these diatoms will be introduced to the sediment within the rockshelter. It is possible that the mud wasps also could have introduced diatoms into the deposit at HD07-3A-PAD13; however, the fluvial sedimentation is also a strong candidate for diatom deposition.

6.7 DISCUSSION

HD07-3A-PAD13 is a small rockshelter that is located near the west edge of Hope South, and excavations have revealed that the site was utilised intermittently since at least 47.1±4.8 ka. This site provides greater understanding of the early occupants of the inland Pilbara, but it is also important for its unique site formation processes. The site is currently located at the proposed edge of the Hope South mine pit, and it is likely that the site will be impacted as the mine expands. In the past, mine planners have considered the archaeological significance of similar sites (*e.g.*, Djadjiling rockshelter), and they have been able modify their impact footprint to avoid impacting such places of significant Aboriginal heritage. As site avoidance outcomes have proven to be mutually advantageous in the past, it has been recommended that the proponent avoid directly impacting HD07-3A-PAD13.

HD07-3A-PAD13 is one of three sites in the Hope Downs 1 lease with an occupation extending more than 40,000 years (see Djadjiling and HS-A1), with Jundaru having been occupied slightly later. The timing of the initial occupation of the site was determined using OSL dating, and the lowermost sample yielded a result of 63.1±8.4 ka (AdBL10014). The date of this sample is considered by the project managers to be anomalous due to its early age. A date of 47.1±4.8 ka (AdBL10013) was determined for a sediment sample collected between 172.5 and 181.5cmbd (midpoint of 177cmbd), and this age provides a better estimate for the initial occupation of the site. Artefacts were recovered from below this OSL sample up to a maximum depth of 220cmbd; however, there may have been rapid sediment deposition during this period. The upper range of the initial occupations of both Djadjiling and HS-A1 are in good agreement with this age, providing additional support for this interpretation of the dates.

In some respects, using OSL dating to provide chronological context to archaeological remains is more challenging than using radiocarbon dating. OSL is used to date the sediment and more specifically, its last exposure to sunlight. As a result, this method does not actually date the human occupation, but its age is inferred from the associated artefacts. In contrast, it is often possible to select samples for radiometric dates that are directly associated with the human occupation (*e.g.*, charcoal in a hearth feature, *etc.*). However, such samples were not available from HD07-3A-PAD13 and isolated charcoal fragments identified in the deposit were used for the AMS dates.

The chronology of the site correlates well with environmental changes observed through the specialist studies, which have been summarised in Table 6-17. The archaeomagnetic data shows that the sediment was deposited under cool conditions until Layer 10 (mid-AU3), after which there was a transition to warmer conditions (Herries 2013). Within the same layer, Wallis (this volume) saw an increase in the proportion of tree and shrub phytoliths, suggesting greater effective precipitation. Similar patterns were observed in the pollen studies, with a lower diversity of pollen from Layer 11, while above this layer the pollen indicates a vegetation community consistent with sclerophyll woodland with an understorey of grass (Haberle *et al.*, this volume). While there are no dates for this period of environmental transition, it occurs within AU3.

The site formation contexts at HD07-3A-PAD13 set it apart from the other Pleistocene sites at Hope Downs 1, as well as from most other rockshelters in the study area. Most rockshelters investigated thus far in the Hope Downs 1 lease had deposits with a high proportion of angular rock fragments derived through the physical weathering of the rockshelter and a small component of fine sediment derived through the chemical breakdown of the rock in the deposit and through aeolian deposition. The deposit at HD07-3A-PAD13 was a stark contrast, with the silty loam having been deposited by low-energy floodwaters. The homogeneity of the silty loam and lack of any larger-sized alluvial sediment indicate that the water was very slow moving. It is easy to imagine these low energy flood waters creeping towards the rockshelter and depositing silt as the water retreated.

The position of the shelter in relation to the ephemeral creek appears to have been an important factor leading to the accumulation of the silty loam. To the south of the rockshelter, the ephemeral creek follows the edge of the BIF hillslope. Immediately before reaching the site, a large BIF exposure juts into the path of the stream causing the creation of a pool where the stream has eroded a deep depression against the rock (just visible in Figure 6-3). The BIF outcrop likely caused the water to slow, and the decreased velocity would have lowered the threshold for the suspended load. As the floodwaters moved beyond this point, the valley opened up and the floodwaters would have spread across the floodplain and into HD07-3A-PAD13.

Table 6-17 Summary of results, HD07-3A-PAD13 rockshelter

AU	Excavation Layer	Depth (cmbd)	Strat. Layers (Unit 4)	Artefact Count	Dates	Archaeomagnetic Zones[1]	Sedimentary, Charcoal, and Palynological Analysis[2]	Phytolith Zones[3]
1	1	surface-30	1	92	747±39 cal BP (28cmbd)	Zone 6 – warmer climate	beginning of increased organic content	Zone 1 - increase in trees; reduced grasses; modern plant regime
	2	30-35	1	93				
	3	35-40	1	81	280±101 cal BP (38cmbd)			
	4	40-45	1	113				
	5	45-50	1/2	121	1462±41 cal BP (47cmbd)		beginning of well-preserved pollen; sclerophyll woodland with a grass understorey	
2	6	50-55	2	59				
	7	55-60	2	58				
3	8	60-65	2	93				
	9	65-70	2	152				
	10	70-75	2	172				
	11	75-80	2	93		Zone 5 - low site use; cold climate		Zone 2 - decline in trees & shrubs; increase in grasses
4	12	80-85	2	37			poor preservation of pollen; lower diversity	
	13	85-90	2/3	36				
5	14	90-95	2/3	29	31.0±3.1 ka (93±1.5cmbd)			
	15	95-100	3	24				
	16	100-105	3	16		Zone 4 - higher anthropogenic alteration; cold climate		
	17	105-110	3	19				
	18	110-115	3	42				
	19	115-120	3	6	29.0±2.9 ka (119±1.5cmbd)			
	20	120-125	3	6				
	21	125-130	3	19				
	22	130-135	3	26				
	23	135-140	3	29				
	24	140-145	3	29				
	25	145-150	3	28	36.0±3.6ka (148.5±1.5cmbd) 33.7±3.4 ka (149±1.5cmbd)			
	26	150-155	3	13		Zone 3 - less anthropogenic alteration; cold climate		Zone 1b - decline in phytolith abundance; shift to Chloridoid grasses; low peak in organic matter
	27	155-160	3	26	27.6±2.5 ka (157±4.5cmbd)			
	28	160-165	3	22				
	29	165-170	3	26	33.9±2.5 ka (168±4.5cmbd)			
6	30	170-175	3/4	10				
	31	175-180	4	19	47.1±4.8 ka (177±4.5cmbd)	Zone 2 - beginning anthropogenic alteration; cold climate; change in sediment source		
	32	180-185	4	23				
	33	185-190	4	39				
	34	190-195	4	18	63.1±8.4 ka (194±4.5cmbd)			
	35	195-200	4	20				
	36	200-205	4	20				
	37	205-210	4	2		Zone 1 - unaltered by humans; cold glacial climate		Zone 1a (L38) - peak in tree phytoliths; Panicoid grasses
	38	210-215	4	1				
	39	215-220	5	2				
7	40	220-225	5	0				
	41	225-230	5	0				
	42	230-239	5	0				

Sources: [1] Herries 2013; [2] Haberle *et al.*, this volume; [3] Wallis, this volume

The site's chronology demonstrates that there were phases of rapid sediment deposition during a period of cool and arid conditions (see Herries, this volume). As Williams (this volume) notes, this rapid deposition of sediment during the glacial period seems incongruent with the onset of a phase of aridity 'unless the aridity was punctuated by occasional extreme events'. A similar phenomenon was identified in the Flinders Ranges in South Australia, where large fluvial deposits accumulated during the late Pleistocene (Haberlah *et al.* 2010). Deposition slowed dramatically in AU4 (80-90cmbd), which appears to correspond to peak LGM conditions. Low sediment accumulation continued through the transition into post-glacial times; although, the mud wasp brood chambers make interpretation of the deposit more difficult. The mud wasp brood chambers indicate that there was available moisture for their construction during this phase.

The rock component at the site is negligible in comparison to sites such as Djadjiling, Jundaru, and HS-A1, but the proportion of rock did increase with depth. There also appeared to be a concentration of larger rock fragments between Layers 14 to 12, which is the transition from SL3 to SL2 and AU5 to AU4. It is possible that the greater proportion of roof collapse is a response to different environmental conditions. The noticeable accumulation in Layers 14 through 12 may also be due to the decline in sediment deposition from Layer 13 onwards.

Low-lying rockshelters such as HD07-3A-PAD13 are often disregarded by archaeologists with the belief that such sites would enviably be subject to scouring from floodwaters; however, this site emphatically demonstrates the need to investigate any site with accumulated sediment. The site was also recorded as a 'potential archaeological site' due to the lack of cultural materials on its surface. Four flakes were later identified on the shelter surface (as the result of several weeks

spent at this site), but the results of the excavation demonstrate that there is no correlation between the presence of surface artefacts and the possibility of buried archaeological material.

The distribution of artefacts throughout the sequence indicates that the site was occupied on numerous occasions; however, the low numbers of artefacts from each excavation layer indicates that occupation was neither intense nor lengthy. Site use appears to have been low during the initial occupation, contrary to the pattern at Djadjiling. There was an increase in site use between approximately 33.9±2.5 and 31.0±3.1 ka (AU5), followed by a period of low utilisation in AU4, which is believed to represent occupation during the peak of the LGM. The archaeomagnetic analysis indicates a 'distinct cold climate phase' and a low anthropogenic signal during AU4 (Herries 2013). There was a subsequent peak in artefact discard rates and this greater intensity of site occupation can also been seen in the archaeomagnetic data (Herries 2013). This peak in site use was concurrent with improved environmental conditions as indicated by the archaeomagnetic, phytolith, and pollen data (Herries, this volume; Haberle *et al.*, this volume; Wallis, this volume).

At the beginning of the late Holocene, there was a drop in the proportion of artefacts. At the neighbouring site, HD07-3A-03, there were also low artefact densities in the layer dating to the first half of the late Holocene, but artefact numbers quickly increased from that point onwards. HD07-3A-PAD13 showed greater artefact densities once again in AU1, equal to that in AU3. Across the creek, HD07-3A-03 had much higher site use, and it is possible that these occupations are related. HD07-3A-03 may have been an activity area for the group, with its greater diversity of retouched artefacts and large artefact assemblage, while HD07-3A-PAD13 may have been used on a more limited basis.

Throughout the occupation, there was a low proportion and diversity of retouched artefacts, suggesting that the site was not a focus of activities. A primary activity area may be located near the site, or perhaps across the creek at HD07-3A-03 as suggested above. Units 5 and 6 had greater artefact densities hinting at the possibility that the rockshelter entrance was an area that was more heavily utilised. A number of grindstones are present in the assemblage, which may have been discarded when the individuals departed the site, or perhaps they were purposefully left at the site so they would be available when the group returned.

During the MIB40 investigations, it was not possible to extend the excavation area further due to time constraints. If the site will be impacted in the future, further excavation may be warranted to explore the deposits at the front of the shelter, as well as on the terrace.

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Chapter 7

Excavations at HS-A1 Rockshelter

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HS-A1 (DAA ID 18716) is a rockshelter on the west edge of Hope South Figure 7-1) that was occupied as early as 40,670±939 cal BP, making it the third site of this antiquity identified at Hope Downs 1 (HD07-3A-PAD13 and Djadjiling), with Jundaru and Hope 1-41 having been occupied slightly later. The rockshelter was identified during a heritage survey conducted by MHA, who later carried out test-excavation of a 1-x-1m unit (Edwards *et al.* 2001: 144). The site was assessed as having low to moderate archaeological significance due to the lack of deeply accumulated sediments and the small to moderate-sized artefact assemblage, and MHA recommended that the proponent apply to the DAA for a ministerial Section 18 permit to disturb the rockshelter. (Edwards *et al.* 2001). As a condition of the permit, further excavations at HS-A1 were carried out by ACHM in October 2008 (under Section 16 Permit 423 issued 25 October 2007; Thorley 2007) as part of the Hope Downs 1 Mitigative Salvage Program (MIB40).

HS-A1 is situated just beyond edge of the Hope South mine pit, but its buffer intersects with the impact footprint of the Hope South mine pit. It is possible that the site could be indirectly impacted by the mining operations in the vicinity of the site. Considering the antiquity of the site and the potential to gain additional information about the past Aboriginal occupation through further excavation, it was recommended that the site be protected from the impacts of the mining development.

7.1 SITE SETTING AND DESCRIPTION

HS-A1 occupies the Newman land system and the rockshelter formed in the MacCleod member of the Marra Mamba Iron Formation. This site is one of many rockshelters in the range that forms the west border of Hope South. Rockshelters are dotted along the sides of the numerous gullies that dissect the range, with their ephemeral creeks flowing from the southwest to the northwest. The rockshelter is located on the north side of a gully, which has a small, ephemeral creek that flows out onto the stony plains to the northeast (Figure 7-3), and immediately to the south of the site is another large rockshelter, HD07-3A-14 (see Law *et al.* 2009). The two rockshelters are essentially separated by a large pillar of more resistant bedrock and formed through the physical weathering of a layer that has a high proportion of limonite, which is quite soft and porous. HD07-3A-14 was not subject to excavation under the Hope Downs 1 Mitigative Salvage Project as it lies beyond the impact footprint. A third, smaller rockshelter is located approximately 50m up the gully (HD07-3A-PAD9), and on the stony plains below the site to the northeast is open artefact scatter HD07-3A-01 (*ca.* 560m away).

HS-A1 is a very large rockshelter, with a maximum width of 16.6m at the entrance, depth of 6.6m, and height of 4.4m (Figure 7-4). The broad entrance has an east-southeast aspect (110°). The roof is highest near the centre of the shelter, and it slopes down towards the back and sides. On the south side of the shelter there are numerous large blocks of roof collapse, indicating that the overhang was once much greater on this side of the shelter. On the north side of the shelter, an area of exposed bedrock slopes down into the shelter floor. Behind the dripline is a relatively flat expanse of silty sediment with exfoliated fragments of roof collapse. The deposit slopes down from the rockshelter walls to the dripline. Beyond the dripline, there is a steeply-inclined slope down to the gully base, approximately 15m below. Bedrock is exposed across areas of this slope; however, it is largely covered with colluvium derived from the physical weathering of the rockshelter. Unlike the deposit inside the rockshelter, there is no accumulation of fine sediment fraction amongst the rocks, possibly due to erosion from overland flow on the exposed slope.

The ochreous walls of the rockshelter are covered with white evaporite speleothems that occur in numerous forms (Figure 7-2), which are the result of water percolation through the bedrock. Evaporites were also identified in the sediment during the excavation, which had cemented the sediment together, and a sample of this cemented sediment was submitted for analysis and was determined to be predominantly halite with a small proportion of gypsum (discussed in further detail in the following section). Regardless of the mineralogy of the precipitate, their occurrence on the rockshelter walls demonstrates that water seeped through the bedrock, depositing the minerals on the walls and aiding in the breakdown of the bedrock. Halite and gypsum flowers (pictured in Figure 7-2 left) 'often grow from waters issuing from crevices and fractures in the cave wall and their growth contributes to the parts of the cave wall breaking away or spalling (salt weathering)' (Warren 2006: 515).

Within the rockshelter, a small amount of leaf litter was observed along with occasional larger fragments of burned wood. Sparse hummock grasses occur up to the dripline of the shelter, as well as on the hillslope above the shelter. There are several snappy gums on the south side of the shelter on the hillslope below the entrance. The trees have been damaged by bushfires, and this is the likely source of the burned wood fragments on the surface of the shelter. According to the vegetation survey carried out by Mattiske Consulting Pty Ltd (2009), the vegetation community in the gully is classified as being tall acacia shrubland (C3 community, see Table 1-2), while hummock grasslands (S2 community) occupy the hillslopes to the east and west of the gully. The vegetation below the shelter and within the gully was very sparse at the time of the investigation due to a relatively recent bushfire.

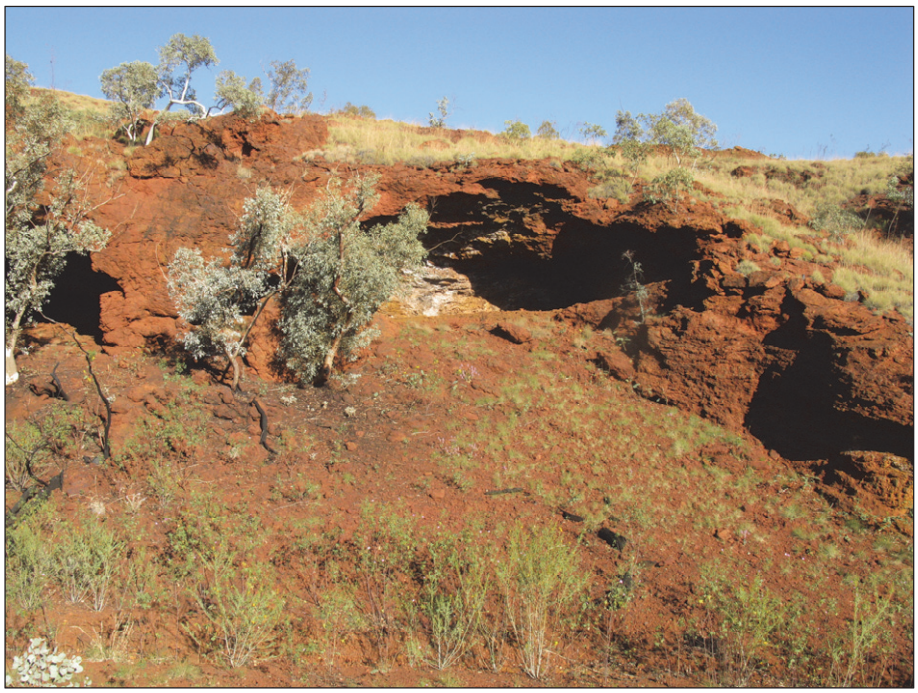

Figure 7-1 Photograph of HS-A1 rockshelter (facing west)



Figure 7-2 Close-up of the evaporites on the rockshelter walls at HS-A1

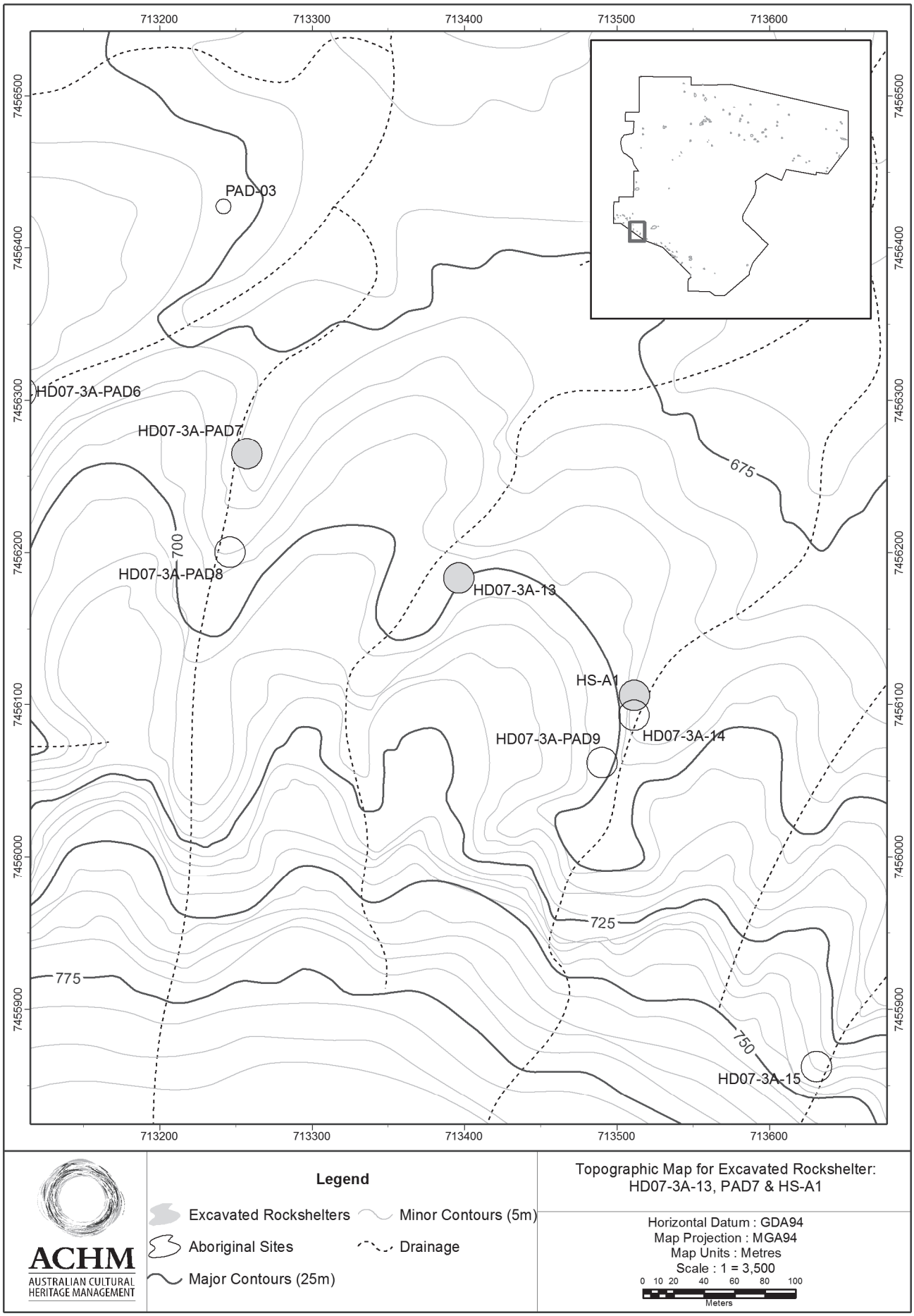

Figure 7-3 Topographic map for HS-A1 rockshelter

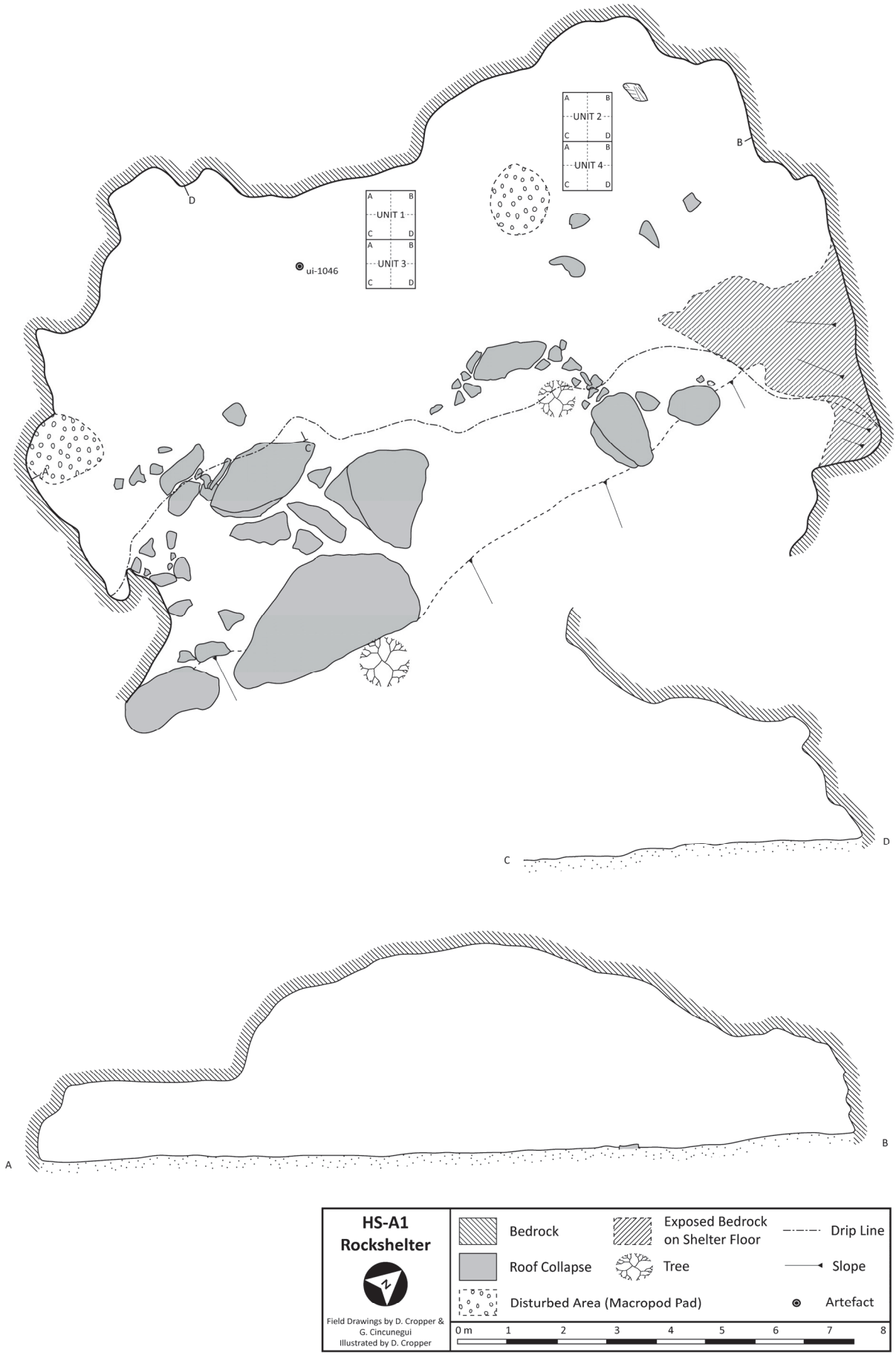

Figure 7-4 HS-A1 rockshelter plan and cross-sections

The surface of the shelter had evidence of macropod occupation with at least two shallow depressions identified as macropod sleeping pads or wallows, including one near to Unit 4 (see Figure 7-4). There were numerous of macropod faecal pellets within the shelter, further supporting this interpretation.

7.2 SUMMARY OF FIELD INVESTIGATIONS

Excavations were carried out at HS-A1 by MHA in 1994 and by ACHM in 2008. Edwards *et al.* (2001: 179) assessed the site as having low to moderate archaeological significance based on the shallow deposit and small to moderate artefact densities. Based on this assessment, Edwards *et al.* (2001) recommended that the proponent apply to the DAA for a ministerial Section 18 permit to disturb the rockshelter. While no further investigation of the site was recommended, additional excavation at HS-A1 was stipulated as a condition of the Section 18 permit in order to assess the significance (Carpenter 2002). ACHM conducted excavations at HS-A1 in October 2008, identifying numerous hearth features and recovering a sizeable artefact assemblage. Importantly, the site was found to have been occupied as early as 40,670±939 cal BP, establishing HS-A1 as one of three sites of this antiquity at Hope Downs 1. The following sections summarize the outcomes of the MHA test excavations, and provide an overview of ACHM's field investigations.

Previous Excavations at HS-A1

HS-A1 was initially recorded by MHA during their 1992 to 1993 Hope Downs survey (Edwards *et al.* 2001: 144). A number of surface artefacts were observed during the initial recording, which prompted test excavation by MHA (Edwards *et al.* 2001). The team placed a 1.0-x-1.0m test unit in the central floor area of the rockshelter. The unit was excavated in 5cm arbitrary spits to a depth of 44cm below ground surface, at which point it was reported that bedrock was encountered across much of the floor of the test unit (Edwards *et al.* 2001: 144). The team excavated a further 10cm in one corner of the excavation unit. It was reported that 'owing to the increasing quantity of weathered bedrock… further investigation [was] impractical' (Edwards *et al.* 2001: 144).

Edwards *et al.* (2001: 144) recovered 176 chipped stone artefacts from HS-A1. Most of the assemblage was classified as flake debitage, consisting of 155 flaked pieces, 19 flakes, and two retouched/utilised artefacts (Edwards *et al.* 2001: 144). The principal raw materials used for artefact manufacture were banded ironstone (75%), silicified shale (9.6%), quartz (4.5%), silicified mudstone (3.4%), silicified dolerite (2.8%), silicified tuff (2.3%), and chert (2.3%) (Edwards *et al.* 2001: 144).

The antiquity of the rockshelter was not determined, presumably due to a lack of datable material. No faunal remains were recovered, and no other kinds of organic materials are mentioned in the site report (Edwards *et al.* 2001).

ACHM Excavations at HS-A1

In October 2008, a team of archaeologists and Traditional Owners carried out excavations at HS-A1. Upon removing the backfill from the excavation unit previously excavated by MHA (re-named Unit 3), it was evident that the excavation did not terminate at bedrock, but at layer of cemented sediment. A grid was established for the site in line with the MHA excavations. Unit 1 was positioned immediately to the east of Unit 3, enabling the expansion of the MHA excavation unit. With the discovery of cemented sediment in Unit 3, the team decided that it would be best to open a second excavation unit some distance away, and Unit 2 was established three metres northeast (Figure 7-5; Figure 7-4). A fourth excavation unit was eventually opened to the west of Unit 2, after excavations revealed excellent preservation of hearths, numerous flaked stone artefacts, and a much lower degree of cemented sediment. In total, four 1-x-1m excavation units were excavated (Units 1-4).

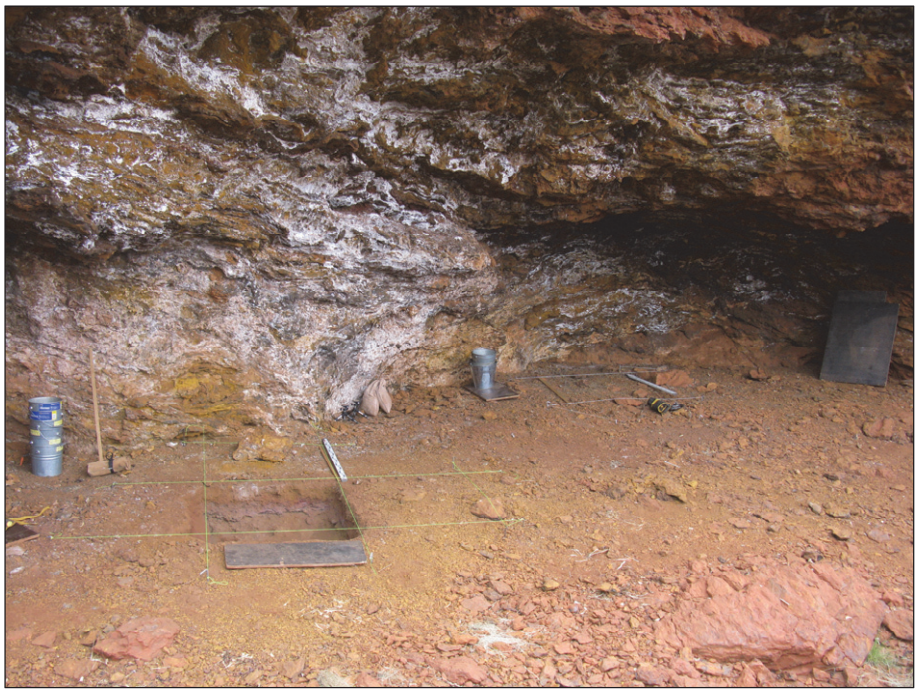

Figure 7-5 Position of the excavation units at HS-A1; Units 1 and 3 in foreground and Units 2 and 4 in the background

The surface elevations of the excavation units varied considerably, with surface elevations in Units 1 and 3 ranging from 25.5 to 40cmbd and from 6.0 to 28.5cmbd in Units 2 and 4. As a result, it was not possible to keep arbitrary excavation layers at the same elevations throughout the site. In Unit 1, the first arbitrary layer levelled off the unit at a depth of 35cmbd. In Units 2 and 4, Layer 1 terminated at a depth of 20cmbd; however, this meant only a small amount of sediment was excavated from Unit 4 due to the slope. Once the backfill was removed from Unit 3, the surface elevations ranged from 61 to 67cmbd with the exception of a sondage in the east corner, which ranged in depth between 77 and 90cmbd. The first layer excavated in Unit 3 evened the unit out at 70cmbd, and this was assigned as Layer 8 so that it would correspond to the arbitrary layers of Unit 1.

During the excavation at HS-A1, the team encountered sediment that had been cemented together immediately beneath the loose surface sediment. The cemented sediment was much more prevalent in Units 1 and 3 than in Units 2 and 4, where it occurred sporadically. The high degree of cemented sediment made excavation extremely difficult in some areas. Small archaeological hand picks were used to excavate carefully through the cemented sediment; however, in some circumstances it was so heavily cemented that rock picks were required. The cemented sediment also made it challenging to identify features or artefacts *in situ*, as well as to keep the excavation layers perfectly flat.

Undulating bedrock was revealed across both excavation trenches. The deepest deposit was identified in Unit 3 (*ca.* 82cm). The depth of accumulated sediment in Units 2 and 4 was considerably less, with a maximum depth of 61.5cm. Like the surface of the excavation units, the bedrock also sloped down towards the southeast.

Due to the high level of cementation, some of the sediment could not be dry sieved, as the clumps of cemented sediment would not break down (Figure 7-6). Even when soaked in water, the sediment remained cemented together. Not knowing the exact composition of the substance binding the sediment together, the team tried soaking the sediment in a diluted solution of phosphoric acid (<1%), which is commonly used as a cleaning solution for removing the hard water stains. Prior to using this solution on the excavated sediment, research was conducted to ensure that it would not be damaging to the archaeological material that we anticipated recovering from the site. Bone and teeth were identified as being potentially vulnerable to such a solution. No other practical way of breaking down the material could be found during the excavation, short of physically crushing it. The latter option risked damaging all archaeological remains encapsulated within the sediment; hence, it was decided that only the cemented excavated sediments would be soaked in the solution. The solution had no visible effect on flaked stone artefacts or on macrobotanical remains (*e.g.*, charcoal, seeds, *etc.*). The sieving team closely monitored the progress of the soaking excavated sediment, and they processed the sediment as quickly as was practicable (approximately 1 hour soaking time).

A large assemblage of macrobotanical remains was recovered during the flotation of the coarse and fine fraction (4.5kg). Flotation is an ideal method for collecting organic remains, as they typically float to the surface and can be skimmed off; however, the cementation of the deposit may have stopped a large proportion of the charcoal in Units 1 and 3 from floating. For example, only 582g of floated macrobotanic remains were recovered from Units 1 and 3, while charcoal was abundant throughout the deposit. Faunal remains were recovered from 33 separate contexts, which were predominantly in Units 2 and 4. The faunal remains have not been subject to analysis, but have been archived for future research. Amongst the faunal remains are emu eggshell fragments from Units 2 (Layers 4-5) and Unit 4 (Layer 9, 52.5cmbd). As is discussed in the previous chapter on Jundaru, emus lay eggs on a seasonal basis typically between early April through September (Western Australia Department of Environment and Conservation 2009; Malecki and Martin 2002: 167). If the eggs were a food item, they suggest that the site was occupied in autumn or winter.



Figure 7-6 Cemented sediment from the excavation at HS-A1

7.3 STRATIGRAPHY

The excavation at HS-A1 exposed bedrock across the two trenches and revealed an accumulated deposit with a maximum depth of 82cm (Figure 7-7). The depth of sediment varied considerably across the excavation units and the depth of the deposit was considerably less in many areas. In the two excavation trenches, the stratigraphy was consistent with the exception that much of the sediment within Units 1 and 3 being highly cemented.

With the high proportion of cemented sediment in the deposit at HS-A1, a sample from Unit 3 (65cmbd) was submitted for analysis in order to determine its composition. The sample was analysed by Professor Robert Gilkes and Emielda Yusiharni of the School of Earth and Environment at the University of Western Australia (Gilkes and Yusihami 2013). The results of the analysis demonstrated that the crystalline minerals in the sample are halite, maghemite, hematite, sylvite, quartz, and gypsum (listed in order of their relative proportions). The presence of the iron minerals maghemite and hematite is not surprising considering the geological formation; however, the identification of halite as the major component of the sample was unexpected. Halite, sylvite, and gypsum are all chemically precipitated salts, which precipitate as saturated water moves

through the sediment (Warren 2006: 2, 38). The cemented sediments become increasingly predominant in areas close to bedrock, indicating that the bedrock was the source of the salt-enriched water.

It is not clear when the evaporates were deposited at the site. Halite and gypsum evaporates can accumulate and dissolve on a relatively fast scale due to their high water solubility (Warren 2006: 515). The salts have natural preservative qualities (Warren 2006: 2), which may have actually aided the preservation of the deposits and organic remains at the site. The salts on the rockshelter walls could have been a resource utilised by the past occupants of the site; although, there is no evidence for this at this time.

The depth of deposit at HS-A1 was found to be shallow in comparison with other Pleistocene sites investigated at Hope Downs 1, with a maximum depth of 82cm, and in areas of Unit 4 there was as little as 40.5cm of accumulated sediment. This suggests that there were much slower rates of sediment deposition at HS-A1 than in comparison with Djadjiling or Jundaru, which have similar modes of deposition. The deposit predominantly accumulated through the physical weathering of the rockshelter, and as such the sediment is primarily geogenic in origin (*i.e.*, deposited through natural erosional processes). Over time, small angular rock fragments and occasional larger rocks exfoliated from the rockshelter roof and walls. The fine silt fraction was the result of *in situ* chemical weathering of the rock and aeolian deposition. The human occupation at the site also contributed to the sediment, and this is most evident by the hearth features.

Three stratigraphic layers were defined on the basis of colour changes and differences in the matrix composition. In general, there was an increase in the rock component through the profile. The stratigraphic profiles presented in Figure 7-8 and Figure 7-9 were illustrated and defined separately by each excavation team, and there are slight differences in the matrix composition. These differences are likely related to the fact that the true composition of the matrix in Units 1 and 3 was very difficult to evaluate due to the effects of the cemented sediment. Therefore, the discussion below will focus on the observations from Units 2 and 4, but will also draw from the findings in Units 1 and 3.

Stratigraphic Layer 3 - SL3 was the lowermost deposit in the profile and had the highest component of rock and a low proportion of fine silt (50% soil, 20% fine rock, 20% small rock, and 10% coarse rock). The deposit had a proportion of angular rock fragments that were the result of weathering of the bedrock on the floor of the rockshelter, as well as from fragments that fell to the ground from the rockshelter roof and walls. There were numerous patches of mineralised sediment, which was the result of chemical weathering of the rock. The mineralised areas often had distinct colours due to the banding in the BIF. Many of the rocks throughout the layer were coated with a white powdery substance believed to be kaolinite, and when disturbed, the kaolinite gave the surrounding sediment a greyish appearance. SL3 was minimally represented in Units 2 and 4, while there is a much greater accumulation in Units 1 and 3. The difference in these two areas may be related to the slope and relief of the bedrock across the floor of the rockshelter.

Stratigraphic Layer 2 - The transition to SL2 was subtle and marked by a decrease in the proportion of rock and a lack of degraded bedrock (60% soil, 20% fine rock, 10% small rock, and 10% coarse rock). The two layers were both yellowish red (5YR 4/6) and the same mode of deposition was largely responsible for the two layers, with SL3 having the additional input of degraded bedrock. Many of the rocks were coated in kaolinite, and this was much more prevalent in the east side of the deposit.

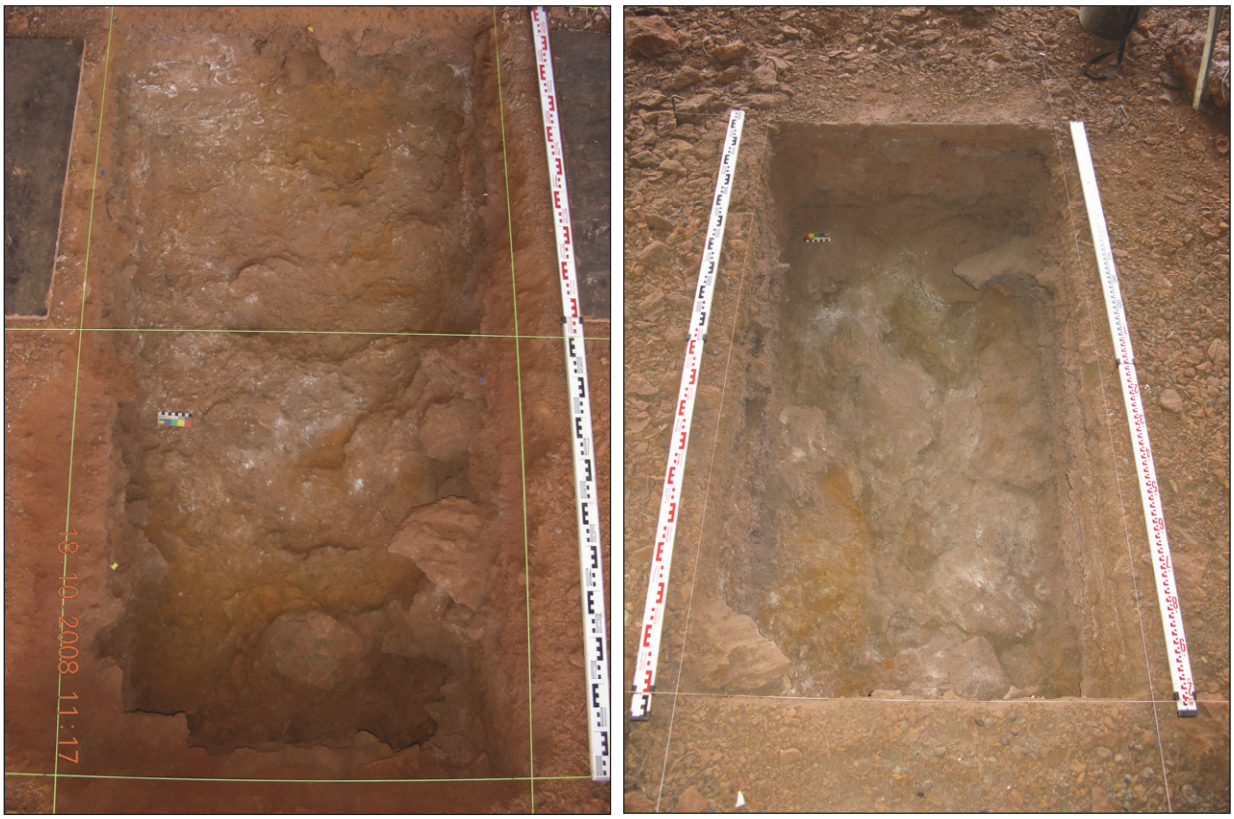

Figure 7-7 Bedrock exposed across the base of excavation Units 1 and 3 (left) and Units 2 and 4 (right), HS-A1 rockshelter

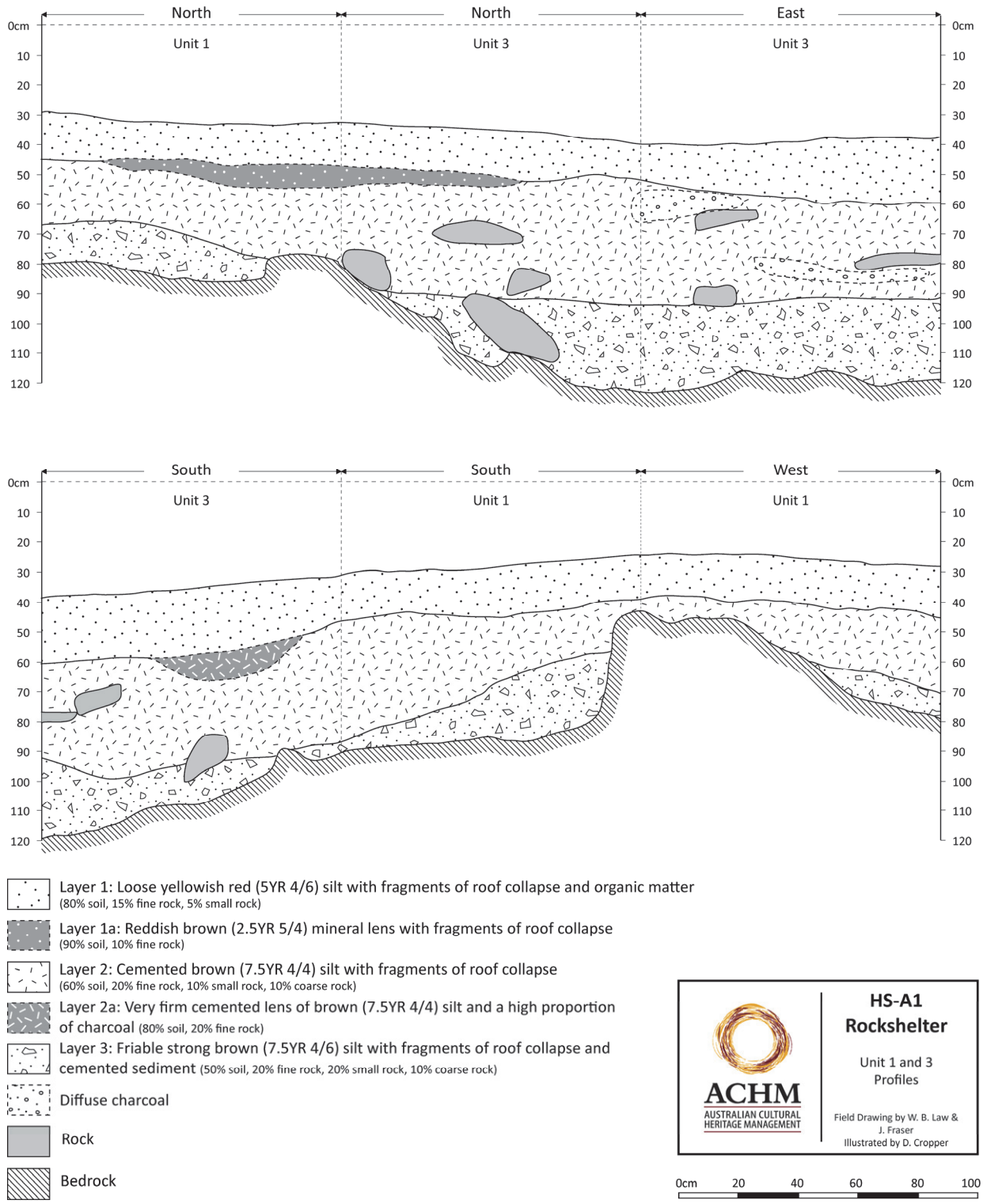

Figure 7-8 Unit 1 and Unit 3 profiles for HS-A1 rockshelter

Stratigraphic Layer 1 - SL1 comprised the uppermost 25 to 20cm of the deposit, and it had a lower proportion of rock and higher amount of silt (80% soil, 15% fine rock, and 5% small rock). The layer also had a much greater organic component, particularly in the upper 10cm. Decomposed macropod scat accounted for most of the organic matter, but the excavation team also noted occasional insect cocoons (possibly mud wasp), leaves, wood fragments, and grass. In some areas within the first arbitrary layer, there were compacted areas of organic material (predominantly decomposing macropod scat). Some of the organic remains were relatively deeply buried and well preserved. For example, in Unit 1 (Quad D) a cluster of grass heads was preserved amongst cemented sediment at a depth of 47 to 48.5cmbd (*ca.* 15-16.5cmbs). In Unit 4, dead locusts were found between arbitrary excavation Layers 3 through 6. The preservation of the organic matter may be related to the evaporate salts in the deposit, which occurred as early as arbitrary Layer 2. Charcoal was abundant throughout the layer.

7.4 RADIOMETRIC DATES

Five charcoal samples were submitted to the Radiocarbon Dating Laboratory at the University of Waikato, including three specimens from features (Features 2, 6, and 5) and two samples from arbitrary excavation layers (Table 7-1). Each sample was collected *in situ* and the depth below datum is provided in the table below. Due to the high degree of cemented sediment in Units 1 and 3, only a basal charcoal sample was selected from this area, while the remaining four samples were selected from Units 2 and 4, where there was excellent preservation of features. The approximate depth below surface is also reported, and this is calculated using the average surface elevation for each excavation unit. The average surface elevations for Units 2, 3, and 4 are 17, 23, and 36cmbd respectively.

The lowermost charcoal samples collected from Units 2 and 3 were submitted for AMS dating to determine the timing of the initial occupation of the rockshelter, which suggest that the site was occupied between 40,670±939 and 40,248±936 cal BP. Despite the fact that the samples were collected from two trenches, located several metres apart, there is excellent agreement in the ages. A small number of artefacts was recovered from contexts below each of the samples, but no additional charcoal was recovered; hence, these dates provide an estimate for the onset of occupation and it is likely that the first use of the site slightly pre-dates this chronology. For example, in Unit 2 eight artefacts were recovered from Layer 11 and one specimen was recovered from Layer 12. A similar pattern is observed for Unit 3 (Layer 13, n=16; Layer 14, n=4).

A large charcoal sample from Feature 5 yielded a date of 28,200±188 cal BP. As is discussed below, Feature 5 is one of the earliest combustion features identified at HS-A1. Samples Wk-26742 and Wk-26741 were recovered 10cm apart, indicating that over this period of approximately 12,500 years there was very slow deposition. Less than one centimetre of sediment accumulated at the site each millennium (0.80cm/millennium). Between samples Wk-26741 and Wk-26740 there is a difference in elevation of 25.5cm, which suggests that there was slightly more rapid deposition at the site (1.01cm/millennium). This difference is nominal, suggesting that there were continuous site formation processes throughout the occupation history of the site.

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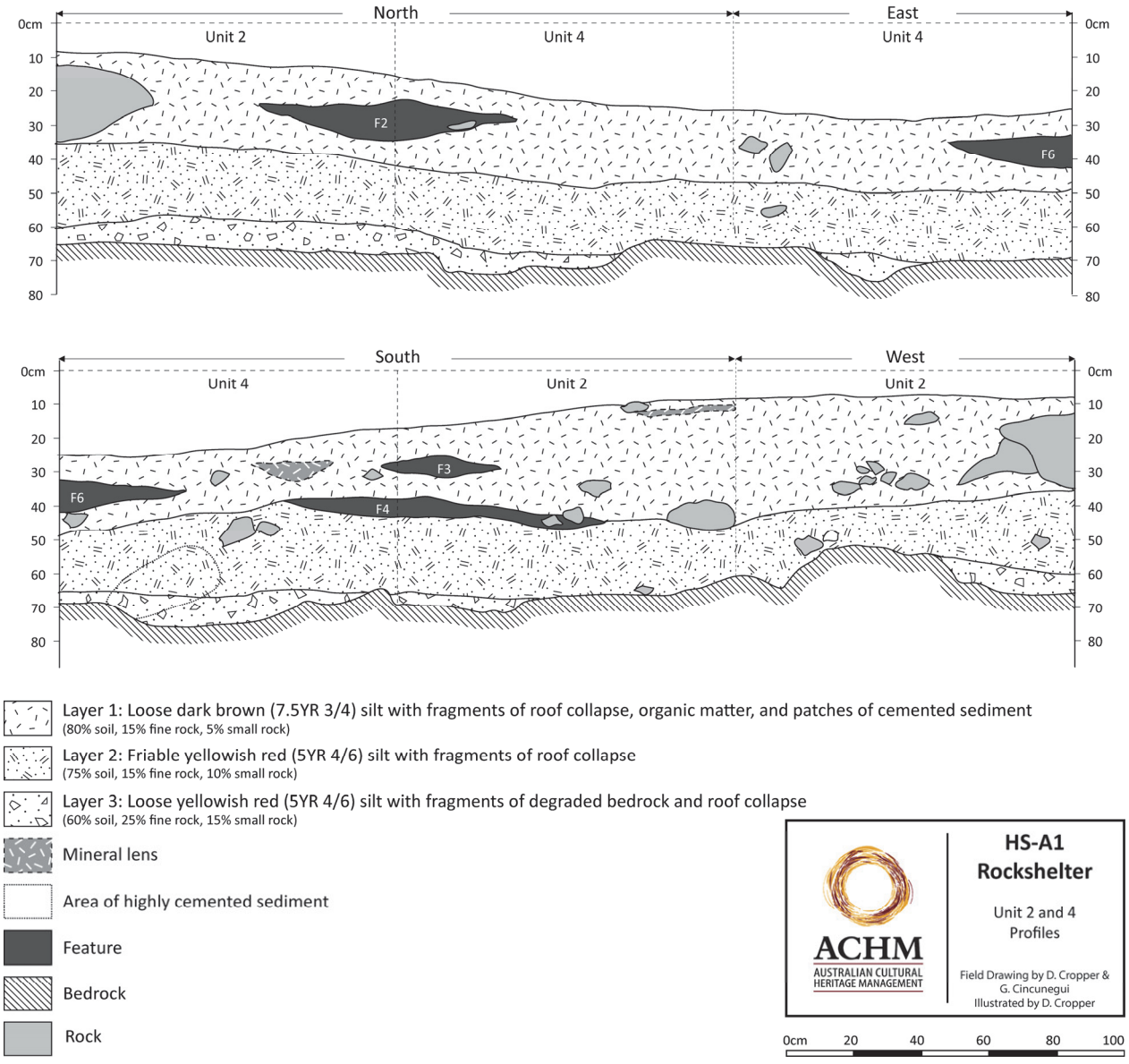

Figure 7-9 Unit 2 and Unit 4 profiles for HS-A1 rockshelter

Table 7-1 AMS radiocarbon results, HS-A1 rockshelter

Lab Code	Sample No.	Material	Context	Strat. Layer	Depth (cmbd)	Depth (cmbs)	$\delta^{13}C$	^{14}C Age (BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-26740	c-2001	Charcoal	F2 (U2-L03.1)	1	26	~9	-23.4±0.2	2958±30	3240 to 3004	3113±58
Wk-32638	c-2017	Charcoal	F6 (U4-L04.1)	1	34.5	~11.5	-25.0±0.2	2901±25	3156 to 2956	3036±50
Wk-26741	c-2009	Charcoal	F5 (U2-L08.1)	2	54	~37	-22.3±0.2	23,378±153	28,561 to 27,841	28,200±188
Wk-26743	c-1007	Charcoal	U3-L12-QB	3	88	~52	-24.2±0.2	35,175±914	42,085 to 38,533	40,248±936
Wk-26742	c-2012	Charcoal	U2-L10-QD	3	64	~47	-23.4±0.2	35,617±958	42,328 to 38,784	40,670±939

The charcoal samples collected from Features 2 and 6 indicate that these two combustion features were created at similar times, approximately 3000 years ago. The depths of the samples below datum are quite dissimilar, but the features are located near the sloping surface of the excavation units and the samples have similar depths below the surface. This suggests that in the near-surface layers (and possibly throughout the deposit), the cultural remains are related to the sloping surface.

While the dates for the site cluster at the late and early stages of the occupation, the position of sample Wk-26741 in relation to the other four dates suggests that there is a linear age-depth trend when plotted according to depth below surface. Additional dating is required to substantiate this theory.

7.5 COMBUSTION FEATURES

Seven features were identified during the excavation of Units 2 and 4, and they span the Pleistocene and Holocene occupation. Feature 1 was initially believed to be a combustion feature due to its distinct dark grey to black colour and lens shape; however, this has since been determined to be a discrete lens of degraded mineralised rock. The remaining six features are all combustion features, from which considerable quantities of charcoal were recovered through flotation. The charcoal from these features has been subject to macrobotanical analysis by Dr Andrew Fairbairn (2013). Charcoal samples from three of the features were submitted for AMS radiocarbon dating, providing chronological context. In the following paragraphs, the features are described from oldest to youngest with reference to their matrix, their structure, and their associated materials.

Pleistocene Features

Feature 7 – Feature 7 was the lowermost feature at the site and is interpreted to be a hearth based on its layered appearance, which consisted of white ash on top, followed by black ash with fragments of charcoal, over heat-reddened soil. The sediment had a greasy texture and charcoal was only present in the black layer. The oval feature was identified on the south side of Unit 4 and would have slightly extended into Unit 2; however, it was not detected when Unit 2 was excavated. The maximum dimensions of the feature in Unit 4 measured 21cm long by 30cm wide. Feature 7 was identified below Feature 4, but with several centimetres of brown sediment separating them. The feature was flat on the top, with elevations ranging between 49 and 49.5cmbd. The basin-shaped base had a maximum depth of 52.5cmbd. The matrix had a pH of 8, which is consistent with the underlying layer, but more alkaline than the overlying layer.

The analysis of the wood charcoals indicates that the wood used in the fire included mulga, wattle, *Eucalyptus*, and Myrtaceae (Fairbairn 2013). Feature 7 has far more *Acacia* charcoals than any other combustion feature at HS-A1, including a high component of mulga. Similarly high proportions of wattle and mulga were identified amongst the Pleistocene features at Djadjiling (Fairbairn, this volume).

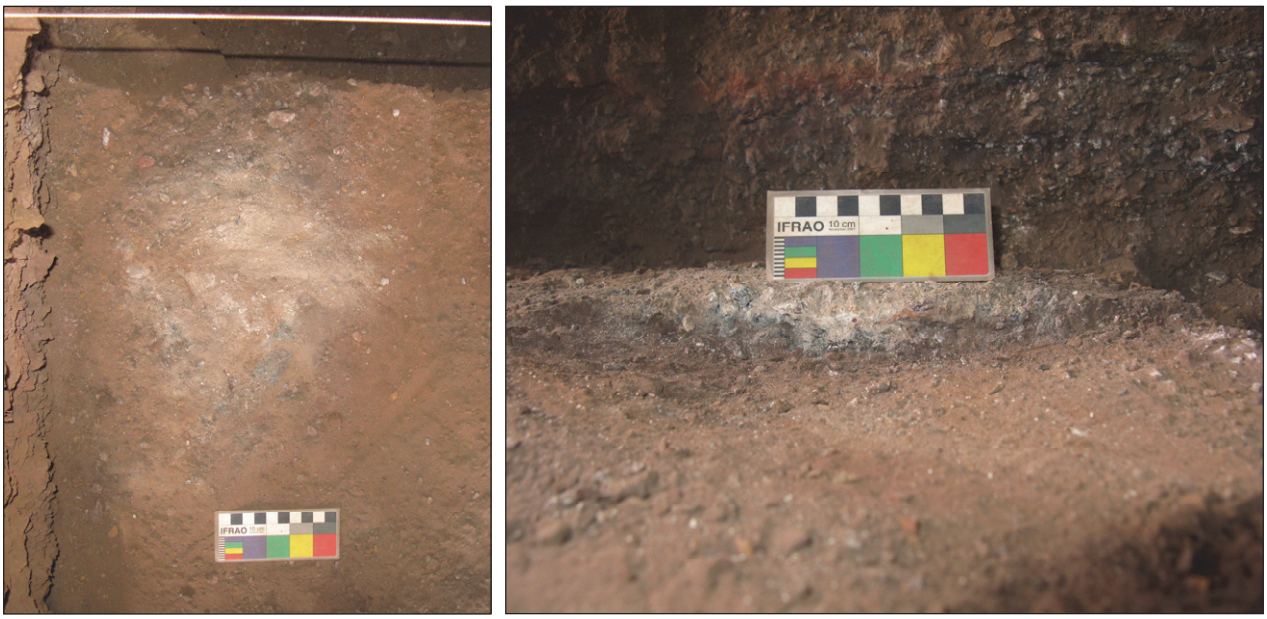

Figure 7-10 Feature 7 overview (left) and profile (right) in Unit 4 at HS-A1 rockshelter

Feature 5 – Feature 5 was an oval shaped hearth, measuring 92cm in length and 46cm in width. A charcoal sample from the feature yielded a date of 28,200±188 cal BP. While not as clearly defined as many of the other features, Feature 5 also exhibited layering with concentrated lenses of very dark grey (5YR 3/1) ash and white ash interspersed with small layers of reddish brown sediment. There was considerable mottling surrounding the feature, suggesting some disturbance either by fauna or humans. It is possible that the disturbance occurred during the use of the hearth, as there is a distinctive lens of reddened baked sediment in Unit 4. The matrix has pH value of 7.5 to 8, which is consistent with the surrounding sediment. There was a close spatial relationship between Features 5 and 7, but the stratigraphic relationship indicates that Feature 5 to be younger than Feature 7. Feature 5 spanned both Units 2 and 4 and occurred in the north half of the excavation trench.

The analysis of the wood charcoals shows that there was abundance of *Ficus platypoda* (Fairbairn 2013), which bears edible fruit. *Ficus platypoda* is not present in the project area today, and this may represent an introduced piece of wood. Wattle and mulga charcoals are well represented, while gum charcoals are at their lowest proportion of all of the HS-A1 hearths (Fairbairn 2013).

Four flaked stone artefacts were recovered from the Feature 5 matrix. Three of the four specimens exhibit signs of burning (potlidding, crazing, and loss of colour). The artefacts include two flaked pieces and one fragment of heat shatter, all produced from white and translucent chert. Additionally, a dark grey chert potlid was recovered from the matrix. The burned artefacts may indicate that they were discarded when the fire was in use, or they may have been on the surface and inadvertently burned.

Feature 4 – Feature 4 was a hearth that was identified in Units 2 (Quad C) and 4 (Quad A) on the basis of a colour change to dark grey (7.5YR 3/1) and an increase the proportion of charcoal. The feature exhibited a layered appearance that consisted of white ash over a thin reddish layer atop the dark grey deposit with small charcoal fragments, which comprised the majority of the feature. Beneath the feature, the sediment was reddened indicating *in situ* burning.

The feature was first identified at 38cmbd, with the basal measurement being 46cmbd. The maximum length of the feature was 82cm, and its full width could be determined as it continued into the south baulk. The feature had a plano-convex cross-section, suggesting that a shallow hollow may have been created for the fire. The pH of the matrix was seven, similar to the values of the surrounding sediment.

The composition of the wood charcoals in Feature 4 shows a distinctly different pattern that the overlying features. Feature 4 has a wide variety of charcoal types, including at least seven different wood types (*Eucalyptus*, Myrtaceae, mulga, wattle, and an indeterminate type; Fairbairn, this volume), and this could indicate a different woodland composition at this time. Five flaked stone artefacts were recovered from Feature 4, including one utilised dark grey chert flake. None of the artefacts are heat affected, suggesting they were discarded in the hearth after it had cooled.

Feature 4 occurred at the transition between SL2 and SL1, and while this feature would have been an ideal candidate for dating, charcoal fragments suitable for radiocarbon dating were not identified during the excavation. The associated living surface of this plano-convex feature is estimated to be approximately 40cmbd, as this is where the feature pinches out along the edges. The age-depth trend suggests that this feature was utilised during in the early warming after the LGM, possibly between 16,000 and 15,000 years ago.

Holocene Features

Feature 6 – Feature 6 was a large hearth that was identified in Unit 4 on the basis of a colour and matrix change. The feature was initially believed to be disturbed by bioturbation and by macropod activity in Quad A, as ashy sediment covered the majority of Quads B to D (Figure 7-11), but with increased depth, it was found that beneath this thin layer of ash were two discernible areas of dark grey sediment. In Quads B and D, the circular concentration consisted of dark grey sediment with reddened soil beneath. In Quad C, the feature was deepest and it had a layer of light yellow to orange ashy sediment (7.5YR 7/3 to 7.5YR 8/3) on the top, followed by dark grey sediment with significant amounts of charcoal over reddened soil (Figure 7-12). There was some cemented sediment at the base. The deposit in the areas between these two concentrations had a mottled appearance comprised of grey ashy sediment and brown sediment. The top of the hearth appears to have been disturbed (either by humans or kangaroos), which spread ashy sediment over a wide area. Some of the ash may also have been deliberately removed and deposited nearby.

The matrix was extremely alkaline, with a pH of 10. Because of this unusual result, the pH was tested three times on separate samples. The two samples from Quad B yielded pH values of 10, while the Quad C sample had a pH of 7, which was consistent with surrounding sediment. Many hearths have slightly more alkaline pH values, but such high values are uncommon. It is possible that something burned in the feature (*e.g.*, food item or different plants) caused the high pH.

The surface elevations of Feature 6 ranged from 30 to 33.5cmbd, with the southeast extent being lower. The primary concentration of the feature was in Quad C, where it reached depths of 44cmbd. In the centre of is concentration, the maximum thickness was 11.5cm (32.5 to 44cmbd; Figure 7-12). The second concentration of dark grey sediment (between Quads A and D) was much more ephemeral, with a maximum thickness of 3cm (30 to 33cmbd). The cross-section of the main concentration in Quad C was plano-convex, and the considerable thickness suggests that an area may have been excavated for the fire. This is also supported by the fact that the vertical extent of the ashy sediment is fairly limited elsewhere. The full extent of Feature 6 cannot be determined as it continues into the south and east baulks. The size and thickness of this feature may indicate that it was utilised as an ash or charcoal cooking pit. Similar features were identified at Djadjiling and Jundaru.

In total, 27 flaked stone artefacts were recovered from the Feature 6 matrix, including a reddened core, a fragment of a backed artefact, a retouched artefact, and two utilised artefacts. Most of the artefacts do not show signs of heat alteration, suggesting they were discarded in the feature once the hearth had cooled. The backed artefact fragment was reddened and it is possible that it may have been broken during the de-hafting process and discarded in the fire. Faunal remains were also recovered while the sorting of the fine rock fraction. The macrobotanical analysis identified a range of charred non-wood plant macrofossils within the floated organic remains, including Myrtaceae fruit (two types), *Proteaceae* seed fragment, *Triodia* spikelet, thorns, twigs, indeterminate seeds, and indeterminate endocarp (Fairbairn 2013). There were also two specimens that have been provisionally identified as spinifex resin (Fairbairn 2013).



Figure 7-11 Feature 6 in Unit 4 at HS-A1 rockshelter



Figure 7-12 cross-section of Feature 6 (Quad c) at HS-A1 rockshelter

Based on the results of the radiocarbon dates, Features 2 and 6 are contemporaneous. A charcoal sample collected from 34.5cmbd yielded a date of 3036±50 cal BP, which overlaps with the date range of the sample from Feature 2. While the samples clearly have different elevations below datum, the considerable slope from the east side of the trench to the west side of the trench means that charcoal samples from each feature have similar elevations below the surface. This suggests that Features 2, 3, and 6 are all contemporaneous, and that there was an intense focus of activity in this area of the site approximately 3000 years ago. This interpretation is further supported by the similar composition of the wood charcoals of the three features, albeit with a slightly greater variety of wood types represented in Feature 6 (Fairbairn 2013).

Feature 3 – Feature 3 was an ash lens identified in Units 2 and 4 that was presumed to be the southern extent of Feature 2. The feature was located to the south of Feature 2, but it was separated from it by deposit of brown sediment. There was a significant amount of organic material within the feature (decomposed macropod scats), and it is possible that macropod activity may have disturbed the surrounding sediment, making it appear as though Features 2 and 3 were two separate entities.

The feature was identified by a change in the sediment colour and composition, comprising a lens of yellowish ashy sediment

at the top with a dark grey to black layer (10YR 2/1) at the base. Unlike Feature 2, there was no observable reddening below the dark grey layer, nor was heat-affected rock observed. This may suggest that ash was removed from the main fire (Feature 2), and deposited in this area. Feature 3 was more linear and diffuse than the well-defined plan-convex cross-section of Feature 2. Patches of the feature were cemented, whereas other areas were quite loose. There were no recoverable fragments of charcoal from Feature 3. Three flaked stone artefacts were recovered from the matrix and none show signs of being heated. The macrobotanical analysis identified that the primary wood source in the hearth was from the Myrtaceae family (including eucalypts), with only a very small wattle component (Fairbairn 2013).

The feature extended into the south baulk so its maximum width could not be determined; however, the excavated extent measured 25cm. The upper elevations of the feature were slightly higher in the east (24.5 to 26cmbd) while the west side was slightly lower (27 to 27.5cmbd).

Feature 2 – Feature 2 was a hearth that extended across Units 2 (predominantly Quad D; Figure 7-13) and 4 (Quad A-B), which was identified on the basis of a colour change to very dark grey (7.5YR 3/1) and a change in the matrix composition. The feature was layered with a patch of reddish yellow ash at the top (7.5YR 6/6; likely white but stained by the surrounding soil), followed by a black layer (10YR 2/1). There was a significant amount of heat-affected rock within and surrounding the feature, including a large piece of red chert in the middle of the hearth. Some areas of the deposit had cemented sediment; while this appears to have preserved the feature, it also made it very difficult to excavate. At the west end of the feature, there was a slight depression with decomposed macropod scats, indicating this area to have been disturbed by macropod activity. Reddened (burned) sediment was identified beneath the feature.

The full extent of the feature could be determined as it continued into the north baulk; however, it measured approximately 70cm in length. The feature had a very pronounced plano-convex cross-section, with the upper elevations ranging from 24.5cmbd in the far east side to 26cmbd on the east side. The base of the feature sloped down towards its midpoint, with a maximum depth of 32.5cmbd.

Nineteen flaked stone artefacts were recovered from the Feature 2 matrix, including two potlids. Apart from the potlids, six other flakes also exhibit attributes of having been affected by heat. This suggests that the artefacts were either resting on the surface on which the fire was built, or that the artefacts were discarded in the fire. The wood charcoals in the hearth indicate that wood from the Myrtaceae family (including *Eucalyptus*) were used as fuel sources (Fairbairn 2013). Amongst the floated macrobotanic remains, Fairbairn (2013) also identified possible spinifex resin and a Myrtaceae fruit.

A radiocarbon date was determined for a sample collected from Feature 2 at a depth of 26cmbd, which dates Feature 2 to 3113±58 cal BP. The shape of the feature suggests that when the fire was constructed, a small hollow was dug into the ground; hence the date may best indicate the upper elevation of the feature. Based on the stratigraphic relationship of Features 2 and 3, it is anticipated that these combustion features are contemporaneous.

Feature 1 – Feature 1 was the uppermost 'feature' identified at HS-A1, and it was identified on the basis of a colour change to dark reddish grey to black (5YR 2.5/1). A small amount of kaolinite was present amongst the matrix, which made the sediment appear. The feature was identified in Unit 2, and it extended across Quads A and C (Figure 7-14). After encountering degrading mineral lenses in subsequent excavation layers, the excavation team re-evaluated their interpretation of this feature, deciding that it is likely a degrading mineral lens that happens to have a dark grey to black colour. The lack of charcoal and ash support this interpretation.

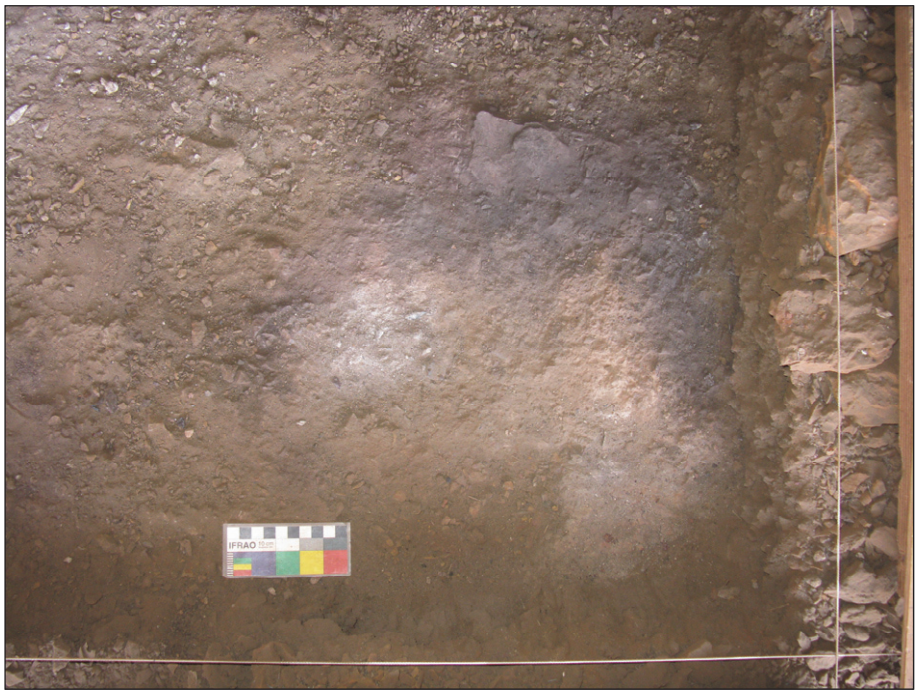

Figure 7-13 Feature 2 in Unit 2 at HS-A1 rockshelter



Figure 7-14 Feature 1 in Unit 2 at HS-A1 rockshelter

7.6 ARTEFACT ANALYSIS

An assemblage of 1430 artefacts was recovered during the investigations at HS-A1, including a large grindstone that was present on the surface of the rockshelter (Artefact 1430). Each artefact in the assemblage was subject to a full technological analysis according to the methodology outlined in Chapter 4. The artefact analysis was performed by Dawn Cropper. The following sections document the division of the assemblage into analytical units, the distribution of artefacts throughout the sequence, and the results of the analysis.

Division of Analytical Units

The division of analytical units enables comparisons of the assemblage through time, recognising the fact that this moderate-sized assemblage was deposited over a period of approximately 40,000 years. Creating the analytical units for a site that has a considerable slope can be challenging, particularly if it was excavated in arbitrary excavation layers as was HS-A1. Units 4 and 3 are located downslope from their adjacent excavation units, Units 2 and 1. While it would be simple to base the division of analytical units on the surface elevations of the excavation units, it is not certain that the sloping surface was continuous throughout the occupation of the site. Moreover, there is considerable slope even within the individual excavation units.

Analytical Unit 6 – AU6 is the lowermost analytical unit and it encompasses all of the archaeological sterile excavation layers. Unit 3 had the deepest deposit with a total of 19 arbitrary layers excavated; however, no cultural material was recovered from Unit 3 below Layer 15. Only two other excavation layers are included within AU6, Layer 14 from both Units 1 and 4. In Unit 2, only 12 excavation layers were excavated and artefacts were present in all layers.

Analytical Unit 5 – AU5 is the basal cultural unit, including Layers 11 to 12 in Units 1, 2, and 4. The radiocarbon date of the charcoal sample obtained from Layer 12 of Unit 3 suggests that this layer is roughly contemporary with Layer 10 in Unit 2; therefore, Layers 11 and 12 of Unit 3 have been included with the next analytical unit. The distribution of artefacts in Unit 3 also supports this classification. AU5 also incorporates Layer 13 in Units 1, 3, and 4, as well as Layer 14 of Unit 3. With the exception of Unit 3, Layer 11 was selected as the dividing point between AU5 and AU4 as there is a decline in artefact numbers below this point. The upper boundary of this analytical unit is dated to between 40,248±936 and 40,670±939 cal BP.

Analytical Unit 4 – AU4 begins over 40,000 years ago, and the lower boundary of AU4 roughly follows the transition between SL3 and SL4. AU4 includes excavation Layers 9 and 10 in all excavation units. Due to the considerable dip in the bedrock between Units 1 and 3, two additional excavation layers also are included from Unit 3 (Layers 12 and 11; see Figure 7-8). The distribution of artefacts in these layers and the radiocarbon dates from Units 2 and 3 also helped to establish this analytical unit. The upper boundary occurs mid-way through SL2.

Analytical Unit 3 – AU3 is loosely equivalent to the upper half of SL2, and it includes Features 5 and 7. A charcoal sample from Feature 5 provides an age estimate for this layer, indicating that it dates to approximately 28,200±188 cal BP. Apart from Unit 3, AU3 includes arbitrary excavation Layers 8 and 7 from each excavation unit. ACHM resumed excavation of Unit 3 at arbitrary excavation Layer 8 where it had been left by the MHA team (61-67cmbd in most areas, with the sondage reaching depths between 77 and 90cmbd); hence, AU3 only includes a single layer (Layer 8) from Unit 3.

Analytical Unit 2 – AU4 comprises excavation Layers 6 and 5 in Units 1, 2, and 4, and it incorporates Feature 4. Feature 4 has not been dated, but based on the age-depth suggests it was most likely utilised during in the early warming period after the LGM. While only including two arbitrary excavation layers, this phase of site use represents the transition from the Pleistocene through to the mid-Holocene.

Analytical Unit 1 – AU1 includes arbitrary excavation Layers 1 through 4 in Units 1, 2, and 4, incorporating Features 1, 2, 3, and 6. Features 2 and 6 have been dated to 3113±58 and

3036±50 cal BP respectively, and Feature 3 appears to have been utilised during this same phase of occupation. AU1 represents the last phase of site use, possibly beginning in the mid-Holocene prior to the use of the combustion features and continuing until the late Holocene. A large grindstone resting atop of the rockshelter surface suggests that the site was utilised on a very limited basis into the recent past.

Artefact Distribution

In total, 1430 artefacts were recovered during the latest investigations at HS-A1, including 1429 artefacts from the excavations in Units 1 through 4, as well as the collection of one large lower grindstone southwest of Units 1 and 3 (ui-1046, see Figure 7-4). The assemblage size is comparable to Djadjiling and HD07-3A-PAD13, with Djadjiling having an assemblage of 1316 artefacts and 1718 artefacts were recovered from HD07-3A-PAD13. None of these sites has an assemblage comparable to the size of the Jundaru assemblage.

An overwhelming majority of the artefacts in the assemblage are classified as diagnostic artefacts, including flakes, retouched/utilised flakes, cores, and a grindstone. Flakes account for most of the diagnostic artefacts, while the other diagnostic artefact types are much less common. Eighty-five non-diagnostic artefacts are present in the assemblage, with flaked pieces accounting for the majority followed closely by heat shatter. Only one manuport was identified in excavation Layer 1 of Unit 2, a rounded quartz cobble with a small number of natural fractures.

The distribution of the artefacts throughout the sequence is presented in Table 7-2, which groups the artefacts by the analytical units that were defined in the previous section. As ACHM only began excavating Unit 3 at Layer 8 (AU3), there is no continuous column of artefacts from this excavation unit. In order to show the relative proportions of artefacts from each excavation unit within the five analytical units, their frequencies are presented in Figure 7-15 (features are incorporated into the layer in which they were identified). The artefact analysis methodology utilised by ACHM and MHA varies significantly (see Chapter 4 versus Edwards *et al.* 2001: 51-59). As Edwards *et al.* (2001: 51-59) do not present all of their data by arbitrary excavation layer (or spit), it is difficult to combine the results of the two analyses.

Edwards *et al.* (2001: 147) report that in the upper portion of Unit 3, 19 flakes, 2 retouched (or utilised artefacts), and 155 flaked pieces were recovered, and their distribution over time is not reported by artefact type. The low proportion of flakes and extremely high number of flaked pieces recovered by the MHA team does not correspond with the findings from similar layers in Units 1, 2, and 4. It is possible that the cemented sediment prevented full recovery of the artefacts from these layers, but this is not discussed in the MHA report; hence, this remains a hypothesis. I also argue that a large proportion of the flaked pieces is not cultural, but is simply angular fragments of exfoliated bedrock.

As is discussed in the previous section, it was difficult to divide the sequence into analytical units due to the sloping deposit; however, the distribution of artefacts by excavation layer shows that there are peaks in site use in AU4 and AU1 amongst a high background of site use. In the earliest phase of site occupation (AU5), the site appears to have only been visited occasionally with 67 flaked stone artefacts having been identified. The majority of the artefacts in AU5 were recovered from the excavation layers immediately below AU4. This suggests that there was limited use of the site preceding 40,248±936 to 40,670±939 cal BP.

The artefacts in AU4 comprise approximately 23% of the assemblage, with most specimens having been recovered from arbitrary excavation Layer 9. As with the majority of the assemblage, most of the artefacts are from Unit 4 and there are also a large number of artefacts from Unit 2 (Figure 7-15). In contrast, there is a much smaller component from Units 1 and 3. This suggests that the north area of the site had a greater focus of activity in the past. There are three conjoin sets from Unit 4 in Layer 10, demonstrating the lack of disturbance to this layer. Only flakes were refitted in the conjoin sets, suggesting that the cores may have been taken with the knapper or perhaps were discarded elsewhere at the site.

In AU3, there is a moderate decline in artefact numbers, and this remains consistent for AU2 as well. These phases of site use span the entire LGM and continue into the Holocene. While there are 443 artefacts in these two layers, they represent many millennia of occupation; hence, the site was only sporadically utilised over these periods. There are low artefact numbers in excavation Layers 8 through 6, which begin to rise slightly in Layer 5. Layer 5 may mark the end of the glacial period and a small increase in site use.

AU1 is the final period of site occupation, which begins from the mid-Holocene onwards. There is a clear increase in the proportion of artefacts and together with the shorter span of this analytical unit, it can be surmised that there was more frequent or longer habitation at HS-A1. Backed artefacts are only present from AU1 onwards and this is consistent with the timing of backed artefacts at other sites in the lease. There are also three conjoin sets from AU1, including one set from Unit 2 (Layer 1) and two sets from Unit 4 (Layer 2-3).

Table 7-2 Artefact distribution by analytical unit, HS-A1 rockshelter

Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diagnostic Artefacts	*1*	*100*	*561*	*94.92*	*219*	*96.48*	*194*	*89.81*	*309*	*94.21*	*61*	*91.04*	*1345*	*94.06*
Core	0	0.00	5	0.85	1	0.44	2	0.93	5	1.52	2	2.99	15	1.05
Flake	0	0.00	523	88.49	207	91.19	180	83.33	291	88.72	56	83.58	1257	87.90
Retouched / Utilised Flake	0	0.00	33	5.58	11	4.85	12	5.56	13	3.96	3	4.48	72	5.03
Grindstone	1	100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.07
Non-Diagnostic Artefacts	*0*	*0.00*	*30*	*5.08*	*8*	*3.52*	*22*	*10.19*	*19*	*5.79*	*6*	*8.96*	*85*	*5.94*
Flaked Piece	0	0.00	19	3.21	6	2.64	11	5.09	9	2.74	5	7.46	50	3.50
Heat Shatter & Potlid	0	0.00	10	1.69	2	0.88	11	5.09	10	3.05	1	1.49	34	2.38
Manuport	0	0.00	1	0.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.07
Total	**1**	**100**	**591**	**100**	**227**	**100**	**216**	**100**	**328**	**100**	**67**	**100**	**1430**	**100**

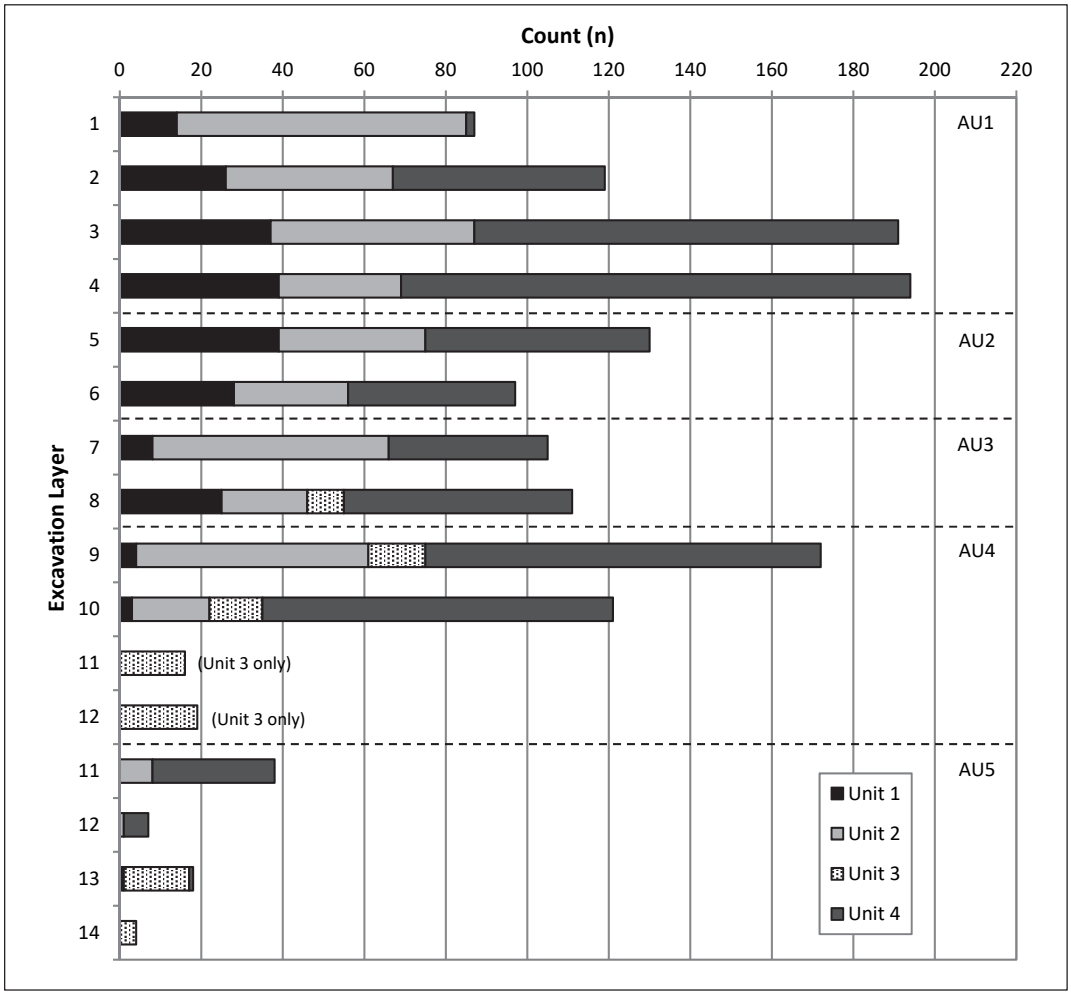

Figure 7-15 distribution of artefacts by excavation layer for HS-A1 rockshelter

One artefact was identified on the surface of the shelter, a large lower grindstone. Edwards *et al.* (2001: 144, 147-148) noted that flaked stone artefacts were identified on the surface of the shelter, and four to five specimens were collected, including a retouched artefact (inconsistencies in Table 56 in the MHA report cause uncertainty in the number of artefacts collected from the surface). The assemblage from the initial test excavation is currently stored by RTIO in Belmont, WA.

Raw Materials

The raw material of each artefact was classified according to the types defined in Chapter 4. The distribution of raw materials in the assemblage is presented by count in Table 7-3 and by weight in Table 7-4. The following discussion of the raw material analysis focuses on the absolute and relative frequency of each material type rather than on its weight, as there are considerable differences in the weight of the various materials. Iron-rich raw materials, such as BIF and martite-goethite, are considerably heavier than siliceous materials like quartz and chert; therefore, the data is skewed towards the heavier materials. The weights of each material type have been included below in the event that it may be useful for inter-site or regional comparisons. The data for the surface grindstone has not been included in the table below, but it has been described in the section on grindstones below.

As Table 7-3 documents, there are clear changes in the raw material preferences throughout the occupation of HS-A1. The proportion of chert through time varies considerably, and there are two troughs in chert use in AU5 and AU2. Chert was only occasionally used in AU4 and AU3, but there is a sharp spike in the manufacture of artefacts from chert in AU1. There is a variety of chert types in the assemblage, and their proportions also vary amongst the analytical units. For example, dark grey chert is predominant in AU4, but there is also a small number of other chert varieties represented. AU3 shows a similar pattern, with dark grey chert being only slightly more common than the other varieties. In AU2, there are three types of chert present in the sample with dark grey chert and greyish brown chert accounting for ten of the 11 specimens. In AU1, the pattern changes, and olive chert is most common, but it is followed closely in abundance by dark grey chert and greyish brown chert artefacts. Artefacts were manufactured from an additional 11 other chert types in AU1.

Table 7-3 Distribution of raw material types by count and analytical unit, HS-A1 rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
BIF	*133*	*22.50*	*66*	*29.07*	*72*	*33.33*	*112*	*34.15*	*17*	*25.37*	*400*	*27.99*
Homogenous BIF	133	22.50	65	28.63	71	32.87	112	34.15	17	25.37	398	27.85
Laminate BIF	0	0.00	1	0.44	1	0.46	0	0.00	0	0.00	2	0.14
Chert	*181*	*30.63*	*11*	*4.85*	*24*	*11.11*	*40*	*12.20*	*3*	*4.48*	*259*	*18.12*
Creamy Grey	1	0.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.07
Dark Grey	39	6.60	5	2.20	7	3.24	16	4.88	2	2.99	69	4.83
Dashed Black	8	1.35	0	0.00	0	0.00	1	0.30	0	0.00	9	0.63
Greyish Brown	35	5.92	5	2.20	1	0.46	3	0.91	0	0.00	44	3.08
Light Green-Grey	2	0.34	0	0.00	1	0.46	0	0.00	0	0.00	3	0.21
Olive	56	9.48	0	0.00	3	1.39	2	0.61	0	0.00	61	4.27
Pink and Green	1	0.17	0	0.00	0	0.00	3	0.91	0	0.00	4	0.28
Red	16	2.71	0	0.00	2	0.93	2	0.61	0	0.00	20	1.40
Speckled Black	1	0.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.07
Sugar	5	0.85	0	0.00	5	2.31	6	1.83	0	0.00	16	1.12
Trans. Dark Grey	1	0.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.07
Trans. Green	10	1.69	0	0.00	1	0.46	2	0.61	0	0.00	13	0.91
White & Trans.	3	0.51	1	0.44	4	1.85	4	1.22	0	0.00	12	0.84
Yellow Trans.	3	0.51	0	0.00	0	0.00	1	0.30	1	1.49	5	0.35
Goethitised Shale	*40*	*6.77*	*24*	*10.57*	*9*	*4.17*	*26*	*7.93*	*6*	*8.96*	*105*	*7.35*
Limonite	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.61*	*0*	*0.00*	*2*	*0.14*
Martite-Goethite	*4*	*0.68*	*6*	*2.64*	*2*	*0.93*	*0*	*0.00*	*0*	*0.00*	*12*	*0.84*
Quartz	*65*	*11.00*	*35*	*15.42*	*38*	*17.59*	*75*	*22.87*	*9*	*13.43*	*222*	*15.54*
Quartz	54	9.14	34	14.98	37	17.13	72	21.95	9	13.43	206	14.42
Quartz Crystal	11	1.86	1	0.44	1	0.46	3	0.91	0	0.00	16	1.12
Shale	*162*	*27.41*	*83*	*36.56*	*67*	*31.02*	*71*	*21.65*	*32*	*47.76*	*415*	*29.04*
Brown Shale	160	27.07	83	36.56	65	30.09	67	20.43	31	46.27	406	28.41
Green Shale	2	0.34	0	0.00	2	0.93	4	1.22	1	1.49	9	0.63
Vitreous Goethite	*6*	*1.02*	*2*	*0.88*	*4*	*1.85*	*2*	*0.61*	*0*	*0.00*	*14*	*0.98*
Total	**591**	**100**	**227**	**100**	**216**	**100**	**328**	**100**	**67**	**100**	**1429**	**100**

Table 7-4 Distribution of raw material types by weight and analytical unit, HS-A1 rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		Total	
	g	%	g	%	g	%	g	%	g	%	g	%
BIF	*721.27*	*59.08*	*513.47*	*63.20*	*566.29*	*70.53*	*739.31*	*34.17*	*143.97*	*28.78*	*2684.31*	*48.81*
Homogenous BIF	721.27	59.08	510.56	62.84	561.17	69.89	739.31	34.17	143.97	28.78	2676.28	48.66
Laminate BIF	0	0.00	2.91	0.36	5.12	0.64	0	0.00	0	0.00	8.03	0.15
Chert	*59.78*	*4.90*	*2.73*	*0.34*	*6.79*	*0.85*	*37.04*	*1.71*	*18.09*	*3.62*	*124.43*	*2.26*
Creamy Grey	0.67	0.05	0	0.00	0	0.00	0	0.00	0	0.00	0.67	0.01
Dark Grey	17.45	1.43	0.93	0.11	0.42	0.05	17.77	0.82	18.08	3.61	54.65	0.99
Dashed Black	3.09	0.25	0	0.00	0	0.00	0.36	0.02	0	0.00	3.45	0.06
Greyish Brown	7.7	0.63	1	0.12	0.25	0.03	12.87	0.59	0	0.00	21.82	0.40
Light Green-Grey	0.18	0.01	0	0.00	0.03	0.00	0	0.00	0	0.00	0.21	0.00
Olive	14.21	1.16	0	0.00	4.19	0.52	0.12	0.01	0	0.00	18.52	0.34
Pink and Green	0.12	0.01	0	0.00	0	0.00	0.1	0.00	0	0.00	0.22	0.00
Red	4.81	0.39	0	0.00	0.64	0.08	0.19	0.01	0	0.00	5.64	0.10
Speckled Black	0.27	0.02	0	0.00	0	0.00	0	0.00	0	0.00	0.27	0.00
Sugar	3.44	0.28	0	0.00	1.03	0.13	0.53	0.02	0	0.00	5	0.09
Trans. Dark Grey	0.76	0.06	0	0.00	0	0.00	0	0.00	0	0.00	0.76	0.01
Trans. Green	6.83	0.56	0	0.00	0.01	0.00	0.35	0.02	0	0.00	7.19	0.13
White & Trans.	0.08	0.01	0.8	0.10	0.22	0.03	3.55	0.16	0	0.00	4.65	0.08
Yellow Trans.	0.17	0.01	0	0.00	0	0.00	1.2	0.06	0.01	0.00	1.38	0.03
Goethitised Shale	*181.89*	*14.90*	*96.26*	*11.85*	*73.12*	*9.11*	*189.28*	*8.75*	*11.76*	*2.35*	*552.31*	*10.04*
Limonite	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1.02*	*0.05*	*0*	*0.00*	*1.02*	*0.02*
Martite-Goethite	*32.49*	*2.66*	*140.18*	*17.25*	*2.06*	*0.26*	*0*	*0.00*	*0*	*0.00*	*174.73*	*3.18*
Quartz	*27.05*	*2.22*	*12.02*	*1.48*	*20.18*	*2.51*	*66.47*	*3.07*	*21.22*	*4.24*	*146.94*	*2.67*
Quartz	24.99	2.05	12	1.48	20.15	2.51	60.21	2.78	21.22	4.24	138.57	2.52
Quartz Crystal	2.06	0.17	0.02	0.00	0.03	0.00	6.26	0.29	0	0.00	8.37	0.15
Shale	*142.27*	*11.65*	*47.2*	*5.81*	*102.62*	*12.78*	*1126.21*	*52.06*	*305.28*	*61.02*	*1723.58*	*31.34*
Brown Shale	142.07	11.64	47.2	5.81	102.05	12.71	1124.26	51.97	305.23	61.01	1720.81	31.29
Green Shale	0.2	0.02	0	0.00	0.57	0.07	1.95	0.09	0.05	0.01	2.77	0.05
Vitreous Goethite	56.14	4.60	0.62	0.08	31.87	3.97	4.03	0.19	0	0.00	92.66	1.68
Total	**1220.89**	**100**	**812.48**	**100**	**802.93**	**100**	**2163.36**	**100**	**500.32**	**100**	**5499.98**	**100**

Widely-available local raw materials were strongly utilised by the knappers at HS-A1, suggesting that the procurement strategies focused on materials that were easily obtained from the immediate area. Shale is a principal raw material in the assemblage and it is slightly more common than BIF. The vast majority of the shale artefacts in the assemblage were classified as brown shale. Shale accounts for nearly half of the AU5 assemblage, and perhaps this high proportion is due to the limited sample size from this analytical unit. The high number of shale artefacts could indicate discrete reduction events; although, no conjoin sets were identified. In AU4 through AU1, shale is less common and comprises between 36.56% and 21.65% of the assemblage. BIF appears to have been a consistently-used raw material throughout the sequence, accounting for between 22.5% and 34.15% of the assemblage. The lowest use of BIF is in the last stage of the occupation, while it is slightly higher in the earlier phases of site use, particularly in AU4 and AU3. Goethitised shale is also a consistently appearing material in the assemblage; although, it remains in low proportions throughout the sequence. Goethitised shale is abundant in geological formations around HS-A1 and it is not surprising that this raw material was utilised by the occupants of the site. The low frequency of the raw material may be due to its brittle nature; hence, other materials were preferred. Other materials, such as limonite, martite-goethite, and vitreous goethite occur infrequently in the assemblage, and it is likely that these materials only were used opportunistically.

Quartz also forms a small, but constant, part of the assemblage with its proportions ranging from a low of 11% in AU1 to a high of 22.87% in AU4. Quartz cobbles are generally widely available in ephemeral gullies, and while it is a fine-grained material, it also contains many flaws making knapping more difficult. Having said that, most of the quartz artefacts in the assemblage are flakes (n=193), with only a small number of flaked pieces (n=21). There are also quartz retouched artefacts, cores, and a manuport.

Table 7-5 provides a breakdown of the raw material trends amongst the three main diagnostic artefact types: cores, flakes, and retouched/utilised flakes. By examining the raw material usage in this way, it may be possible to identify material preferences. The low number of retouched/utilised artefacts and cores in the assemblage means that one or two artefacts can have a significant effect on the relative proportion for the various raw material types. In contrast, flakes comprise the bulk of the assemblage and their proportions mirror distribution of raw material types for the assemblage as a whole.

The raw materials represented amongst the cores are only a small proportion of those present in the assemblage as a whole. There are a number of scenarios that may account for this discrepancy. One possibility is that many of the flakes were not produced at the site; however, this seems contrary to the largely expedient nature of the assemblage. Another potential explanation is that many of the cores were discarded in an area of the site that was not excavated. While this seems plausible, particularly with such a large site, other sites have also yielded low proportions of cores (*e.g.*, Djadjiling). A large area of the rockshelter was excavated at Djadjiling, leaving little chance that the knappers may have discarded the cores elsewhere at the site. This may indicate that many cores were taken from the site as the knappers departed, and this may be particularly true for high-quality materials that are often under-represented.

Retouched and utilised artefacts are rare in the assemblage; hence, discerning patterns of raw material preference in their manufacture is difficult. AU1 shows the most obvious pattern of raw material use that differs from the assemblage as a whole. Over half of the retouched and utilised artefacts were produced from chert, while the average for the assemblage is 30.63%. This indicates that knappers were deliberately selecting chert flakes over other material types for retouched and utilised artefacts. Goethitised shale specimens also are slightly over-represented over the entire sequence, possibly due to the proximity of this resource. In contrast, quartz flakes were seldom retouched.

All artefacts were examined for evidence of thermal alteration (*e.g.*, crazing, potlidding, *etc.*) as well as any other material alterations, such as patination, abraded appearance, or coatings (*e.g.*, concretions). Most artefacts exhibited no clear signs of having been heated or burned (n=1296). Under a tenth of the assemblage bears traits associated with thermal alteration, and shale is the most common material to bear signs of thermal alteration. Ninety-six specimens bore severe heat fractures (potlidding or crazing), suggestive of rapid heating or burning as opposed to controlled and intentional heat treatment. Two specimens exhibited loss of colour, which is a common effect of thermal damage. Thirty-five artefacts had a reddened appearance and two specimens had a glossy appearance. With such a small proportion of the heated artefacts not displaying thermal damage, it is unlikely that the knappers were deliberately heat-treating raw materials to improving their knapping qualities. It is possible that some artefacts were discarded in hearths, while others may have been inadvertently burned as campfires were constructed on old living surfaces on which there happened to be artefacts. One artefact, a retouched flake (Artefact 589), has retouch scars with a glossy appearance, which can occur if an artefact has been retouched after it was heated. This specimen may provide rare evidence for intentional heat treatment.

Material alterations, other than as a result of heating, are rare in the assemblage and were only noted on 21 specimens. Yellowish staining occurs on quartz (n=4), quartz crystal (n=1), and sugar chert (n=1), and it is possible that this may be another expression of thermal alteration (see Ballin 2008: 51-52). Alternatively, it is possible that this may be a rust-like coating. An oxidised or rusty appearance is common for many of the coarser-grained raw materials, and where it was particularly predominant it was identified. Five BIF artefacts exhibit this oxidised appearance, and it may be due to the particular composition of the rock and how it weathers. Eight artefacts exhibited cemented sediment or a mineralised deposit on part of the surface. In two cases, the artefact was partially encrusted by evaporites, while the other specimens had a thinner coating. Two of the BIF artefacts have an abraded appearance. On one specimen (Artefact 439), all edges have a slightly rounded appearance, while on Artefact 1245 the dorsal surface has an abraded and polished appearance and there is one very highly polished area.

Cores

Fifteen cores were recovered from HS-A1, and this number of cores over the long occupation history of the site makes it difficult to draw meaningful insights from the data. There is a considerable discrepancy in the number of cores between the HS-A1 and HD07-3A-PAD13 assemblages, with the latter being slightly larger. In the HD07-3A-PAD13 assemblage, 43 cores and core fragments were identified. There are even more cores in the Djadjiling assemblage, which is smaller and has a very high proportion of non-diagnostic artefacts.

Table 7-5 Raw material trends for cores, flakes, and retouched and utilised flakes, HS-A1 rockshelter

Artefact Type	AU1		AU2		AU3		AU4		AU5		Total	
Raw Material Type	n	%	n	%	n	%	n	%	n	%	n	%
Cores	*5*	*100*	*1*	*100*	*2*	*100*	*5*	*100*	*2*	*100*	*15*	*100*
BIF	0	0.00	1	100	2	100	0	0.00	0	0.00	3	20.00
Chert	1	20.00	0	0.00	0	0.00	0	0.00	0	0.00	1	6.67
Goethitised Shale	2	40.00	0	0.00	0	0.00	1	20.00	0	0.00	3	20.00
Quartz	1	20.00	0	0.00	0	0.00	3	60.00	1	50.00	5	33.33
Shale	1	20.00	0	0.00	0	0.00	1	20.00	1	50.00	3	20.00
Flakes	*523*	*100*	*207*	*100*	*180*	*100*	*291*	*100*	*56*	*100*	*1257*	*100*
BIF	127	24.28	62	29.95	66	36.67	103	35.40	17	30.36	375	29.83
Chert	149	28.49	9	4.35	17	9.44	38	13.06	2	3.57	215	17.10
Goethitised Shale	33	6.31	20	9.66	7	3.89	18	6.19	5	8.93	83	6.60
Limonite	0	0.00	0	0.00	0	0.00	2	0.69	0	0.00	2	0.16
Martite-Goethite	4	0.76	6	2.90	2	1.11	0	0.00	0	0.00	12	0.95
Quartz	58	11.09	33	15.94	29	16.11	68	23.37	5	8.93	193	15.35
Shale	149	28.49	76	36.71	55	30.56	60	20.62	27	48.21	367	29.20
Vitreous Goethite	3	0.57	1	0.48	4	2.22	2	0.69	0	0.00	10	0.80
Retouched/Utilised Flakes	*33*	*100*	*11*	*100*	*12*	*100*	*13*	*100*	*3*	*100*	*72*	*100*
BIF	4	12.12	3	27.27	4	33.33	6	46.15	0	0.00	17	23.61
Chert	19	57.58	2	18.18	1	8.33	1	7.69	1	33.33	24	33.33
Goethitised Shale	2	6.06	4	36.36	2	16.67	2	15.38	1	33.33	11	15.28
Quartz	1	3.03	0	0.00	1	8.33	0	0.00	0	0.00	2	2.78
Shale	5	15.15	1	9.09	4	33.33	4	30.77	1	33.33	15	20.83
Vitreous Goethite	2	6.06	1	9.09	0	0.00	0	0.00	0	0.00	3	4.17
Total	**561**	**-**	**219**	**-**	**194**	**-**	**309**	**-**	**61**	**-**	**1344**	**-**

Qualitative Core Attributes

All of the cores in the assemblage are complete, and cores were found in each of the five analytical units. The majority of the cores are from AU4 and AU1, and this is expected as these analytical units had the greatest number of artefacts. Unidirectional cores account for two-thirds of the sample, with two rotated cores, two bidirectional cores, and one alternate-platform core in the assemblage (Table 7-6: A). The dominance of unidirectional cores is striking and may reflect the reliance on locally abundant raw materials. All of the unidirectional cores retain some cortex, and apart from the two exhausted quartz crystal cores (Figure 7-16: a; discussed in more detail below), they generally were not highly reduced.

Rotated cores are typically quite common in the Hope Downs 1 assemblages, so it is surprising that only two specimens were identified at HS-A1 (Figure 7-16: c). It is likely that the two bidirectional cores are simply rotated cores that happen to have their platforms opposed from each other, as in neither instance were the opposed platforms used alternately. The rotated cores were produced on coarser-grained local raw materials, including goethitised shale and brown shale. Two of the cores have a high number of negative scars (13 and 15), while the BIF core only exhibits two negative flake scars.

The two bidirectional cores were produced on olive chert (Artefact 1339; Figure 7-16: b) and goethitised shale (Artefact 391). Artefact 391 retained cortex over a large portion of the surface (33-65%) and six negative flake scars were observed. A number of step scars were identified and this may have prompted the knapper to rotate the core and use the opposite platform. There is no evidence to suggest that the knappers utilised the platforms alternately. Artefact 1339 is a small core (32.85-x-14.58-x-13.33mm), and it is the only chert core in the assemblage. Despite a high proportion of cortex remaining on the core (33-65%), at least ten flakes were removed using cortical striking platforms. The core has feather and hinge terminations, with the latter possibly leading to the discard of the core. As with Artefact 391, the platforms do not appear to have been used alternately.

Artefact 611 is the single alternate-platform core in the assemblage, which was produced on a large piece of coarse-grained brown shale that retains a considerable amount of cortex (Figure 7-16: d). The knapper utilised the short edge of the block to remove flakes from both the upper and lower faces, creating a bifacial platform. The shape of the block appears to have largely dictated how it was reduced, and this is essentially a variant of a rotated core. At least 15 flakes were produced from this core. One of the core faces is heavily stepped, which likely led the knapper to begin removing flakes from the other core face. Several large flakes were then successfully removed until stepping once again occurred.

In addition to a core's reduction strategy, it can also be classified according to the morphology of its negative scars. All of the cores in the HS-A1 exhibited exclusively flake scars, with no blade scars having been observed. In the analysis of the flakes, approximately 4% of the complete flakes had blade proportions and they occurred in AU4, AU3, and AU1. With such a low number of blades in the assemblage and so few cores, it is not surprising that none of the cores exhibit blade scars. It is likely that blades were produced occasionally through normal core reduction, as there is currently no evidence for standardised blade production.

The cores in the assemblage show an even division of cortical and plain striking platforms, as well as one instance of a facetted platform (Table 7-6: B). The rotated cores predominantly have plain platforms, with previously knapped surfaces making ideal platforms when the core is rotated. The unidirectional cores generally have cortical platforms, but a number also have plain platforms. On these specimens, the knapper made use of a naturally fractured surface for the platform. The facetted platform was observed on the bidirectional olive chert core, and such platforms are exceptionally rare.

Table 7-6 Qualitative attributes for cores by analytical unit, HS-A1 rockshelter

A. Core Type*	AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Alternate	0	0.00	0	0.00	0	0.00	1	20.00	0	0.00	1	6.67
Rotated	1	20.00	0	0.00	1	50.00	0	0.00	0	0.00	2	13.33
Unidirectional	2	40.00	1	100	1	50.00	4	80.00	2	100	10	66.67
Bidirectional	2	40.00	0	0.00	0	0.00	0	0.00	0	0.00	2	13.33
Total	**5**	**100**	**1**	**100**	**2**	**100**	**5**	**100**	**2**	**100**	**15**	**100**
B. Platform Type	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Cortex	2	40.00	1	100	1	50.00	2	40.00	1	50.00	7	46.67
Facetted	1	20.00	0	0.00	0	0.00	0	0.00	0	0.00	1	6.67
Plain	2	40.00	0	0.00	1	50.00	3	60.00	1	50.00	7	46.67
Total	**5**	**100**	**1**	**100**	**2**	**100**	**5**	**100**	**2**	**100**	**15**	**100**
C. Avg. No. Scars	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg
BIF	0	0.00	1	6.00	2	2.00	0	0.00	0	0.00	3	3.33
Chert	1	10.00	0	0.00	0	0.00	0	0.00	0	0.00	1	10.00
Goethitised Shale	2	9.50	0	0.00	0	0.00	1	5.00	0	0.00	3	8.00
Quartz	1	8.00	0	0.00	0	0.00	3	5.00	1	2.00	5	5.00
Shale	1	2.00	0	0.00	0	0.00	1	15.00	1	7.00	3	8.00
Total	**5**	**7.80**	**1**	**6.00**	**2**	**2.00**	**5**	**7.00**	**2**	**4.50**	**15**	**6.20**
D. Reduction Potential	**AU1**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Exhausted	1	20.00	0	0.00	0	0.00	1	20.00	0	0.00	2	13.33
Viable	4	80.00	1	100	2	100	4	80.00	2	100	13	86.67
Total	**5**	**100**	**1**	**100**	**2**	**100**	**5**	**100**	**2**	**100**	**15**	**100**

The number of scars on a core can provide an indicator of how intensely it was reduced, but this is a broad measure of reduction intensity as knappers could have produced more flakes from larger cores. Additionally, highly reduced cores will only show the most recent removals. Throughout the sequence at HS-A1, there are too few cores to consider patterns of negative scar numbers by raw material type as presented in Table 7-6: D. There is an average of 6.2 negative scars for all cores in the assemblage, and this is higher for the rotated (10 scars/core) and bidirectional (8 scars/core) cores. The unidirectional cores show much lower reduction intensity (4.7 scars/core) and this is only boosted by the two quartz crystal cores that have much higher scar counts than the others. With those two cores removed from the sample, the average is reduced to 3.6 scars per core. Apart from the quartz crystal cores, there is no clear pattern between the raw material and the number of negative flake scars. For example, one brown shale core exhibits the greatest number of scars (n=15), but there are also two other specimens with considerably fewer scars (7 and 2 respectively). The goethitised shale cores show a similar pattern, with some being more highly reduced than others. The greater reduction of the quartz crystal and olive chert core is likely related to the quality and lower availability of these materials. This theory is based more upon the trends found in other assemblages at Hope Downs 1, rather than on these three artefacts because valid patterns cannot be determined for such a small sample.

The two exhausted cores in the assemblage are from AU1 and AU4, were both produced from quartz crystal, and are amongst the sample of unidirectional cores (Table 7-6: D). Artefact 85 is tiny and measures 10.2mm long, 16.88mm wide, and 10.76mm thick. The core still retains crystal faces on over a third of its surface, but the knappers were able to remove at least eight flakes. The earlier flakes ran the entire length of the core, while the last flakes are stepped and remained close to the platform. Its small size and the step terminations would have made further reduction extremely difficult. Artefact 615 is also very small (14.84-x-232.12-x-17.14mm) and exhibits ten unidirectional scars with step and feather terminations. The core retains crystal faces on a small proportion of the surface, but it is unlikely that it could have been further reduced as the platform is heavily stepped where most of the flakes were removed. Stepping likely led the knapper to abandon this core.

Quantitative Core Attributes

The quantitative statistics for complete cores is presented in Table 7-7, including the maximum dimensions, mass, and dimensions of the smallest and largest negative flake scars. The average core measures 29.36mm (SD=13.52) long, 45.70mm (SD=25.84) wide, and 34.43mm (SD=35.90) thick. There are very high standard deviation values, and this is largely due to Artefact 611 as it has a relatively normal length, but it is extremely wide and thick. With such a small sample, it is not possible to identify any trends in the size of cores over the occupation sequence.

The size of cores varies considerably, from the smallest core (Artefact 85, 10.2-x-15.88-x-10.76mm) in AU1 to the largest core (Artefact 611, 39.26-x-106.72-x-148.02mm) in AU4. These two specimens demonstrate that the raw material has a great effect on the size of the cores in the assemblage. The smallest core was produced on a quartz crystal, which will almost always be very small. The largest core was produced on a tabular fragment of brown shale that was likely collected from near the site. This is also illustrated by the fact that most of the cores have a considerable proportion of cortex remaining, and only two specimens have no cortex. One of the cores without cortex has natural fractures, while the other core was extensively reduced.

The dimensions of the largest and smallest negative flake scars were recorded for each complete core to provide an estimate of the size range of flakes produced by the cores in the assemblage. The average maximum flake dimensions become progressively larger in the earlier analytical units (Table 7-7: E), while the minimum scar size is fairly similar with the exception of AU3.

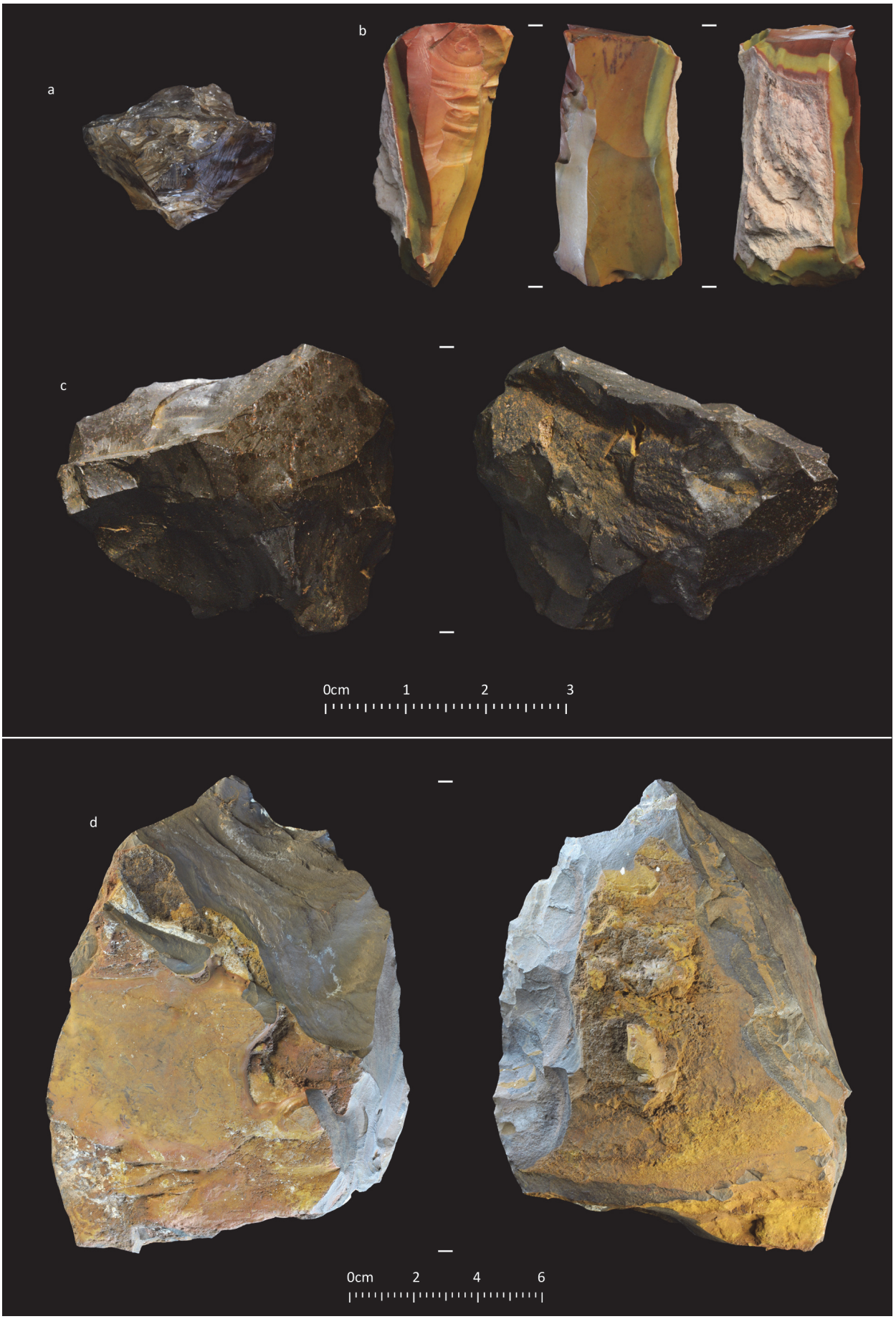

Figure 7-16 Cores from HS-A1 rockshelter: a) unidirectional core (artefact 615; au4), b) bidirectional core (artefact 1339; au1), c) rotated core (artefact 29; au1), and d) alternate-platform core (artefact 611; au4)

Table 7-7 Quantitative attributes for complete cores by analytical unit, HS-A1 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	5	23.88	43.01	10.2	13.58
	2	1	45.10	45.1	45.1	-
	3	2	39.61	42.55	36.67	4.16
	4	5	25.84	41.32	11.81	13.72
	5	2	33.66	46.76	20.55	18.53
B. Max Width (mm)	1	5	28.85	46.98	14.58	13.33
	2	1	46.85	46.85	46.85	-
	3	2	70.65	81.21	60.08	14.94
	4	5	53.82	106.72	23.12	36.15
	5	2	42.03	51.1	32.96	12.83
C. Max Thickness (mm)	1	5	27.24	67.7	10.76	23.29
	2	1	13.51	13.51	13.51	-
	3	2	23.10	26.09	20.1	4.24
	4	5	45.40	148.02	17.14	57.40
	5	2	46.75	66.95	26.55	28.57
D. Mass (g)	1	5	30.27	92.88	1.31	38.07
	2	1	57.86	57.86	57.86	-
	3	2	91.77	95.44	88.09	5.20
	4	5	235.91	1028.2	5.87	445.04
	5	2	148.40	277.21	19.58	182.17
Measurement	**AU**	**Count**	**Average Length (mm)**	**SD**	**Average Width (mm)**	**SD**
E. Average Maximum Negative Scar Dimensions	1	5	16.78	4.95	19.06	7.67
	2	1	19.43	-	17.00	-
	3	2	32.51	6.16	27.85	8.18
	4	5	30.72	24.51	29.91	29.00
	5	2	31.97	17.95	29.67	2.71
F. Average Minimum Negative Scar Dimensions	1	5	12.92	2.54	15.13	5.71
	2	1	8.18	-	6.30	-
	3	2	27.45	13.31	28.53	7.22
	4	5	10.30	4.11	13.45	5.74
	5	2	9.68	1.14	12.35	2.18

Flakes

Flakes comprise 87.97% of the assemblage, including 393 complete specimens as well as 865 flake fragments (Table 7-8). It is important that the proportions of complete and broken flakes are identified clearly in an assemblage, as those with high proportions of broken flakes may appear to have greater artefact densities than those with lower flake fragmentation rates. The MNF index is a means of estimating the minimum number of flakes present in an assemblage (Hiscock 2002). Using the calculation MNF = C + T + CL + BL, it is estimated that the 1258 flakes and flake fragments represent at least 897 complete flakes (MNF = 393 + 361 + 107 + 36).

Table 7-8 Flake fragmentation, HS-A1 rockshelter

Longitudinal Fragmentation	Transverse Fragmentation				
	Complete	Distal	Prox.	Medial	Total
Complete	393	361	69	65	888
Left + Left LCS	99	36	15	30	180
Right + Right LCS	107	34	20	15	176
Medial	4	4	1	4	13
Total	**603**	**435**	**105**	**114**	**1257**

The MNF also makes it possible to estimate the percentage of broken flakes in the assemblage, which is calculated to be 56.19% (percentage of broken flakes = (MNF - complete flakes) / MNF x 100). Flakes can break both longitudinally (with left, medial, and right fragments) and transversely (with proximal, medial, and distal fragments), and flake fragmentation can be caused by a number of factors. They can be broken during flake production, and these breaks tend to be longitudinal, while transverse fragmentation is more likely to occur as the result of trampling (Hiscock 1985: 87). The assemblage has a very high proportion of distal fragments, but longitudinal flake fragmentation is also common. High proportions of distal flake fragments are something that is common to most excavated assemblages, and the reason for the discrepancy between the number of distal and proximal flakes remains unclear. The pattern is repeated in assemblages analysed by different individuals, including those with considerable experience. While it is possible that human error may play a role in this discrepancy, it seems unlikely that the pattern would be consistent even amongst various analysts.

The percentage of broken flakes at HS-A1 is extremely high compared to other excavated assemblages. For example, it is 28.5% at Djadjiling, 43.17% at HD07-3A-PAD13, and 40.90% at Jundaru. In contrast to the other three Pleistocene sites, HS-A1 has a very shallow deposit. As no abrupt boundaries were identified in the stratigraphic sequence (which could indicate erosion of the deposit), it is believed that the rate of sediment accumulation was much slower at this site. Slower sediment accumulation would have meant that artefacts were exposed on the surface for greater periods of time, making them more prone to trampling. AU5 (65.85%), AU3 (60.61%), and AU2 (61.44%) all have particularly high percentages of broken flakes, while the values are slightly lower for AU4 (52.71%) and AU1 (54.74%). It is possible that there were even lower rates of sediment accumulation during AU5, AU3, and AU2, leading to increased trampling and artefact breakage.

Flake Subtypes

Apart from blades, the assemblage does not contain any unique flake types, such as platform rejuvenation flakes, ridge blades, or spalls. Sixteen of the complete flakes, or roughly 4%, have the proportions of blades, meaning that they are at least twice as long as they are wide. The blades occur in AU4 (n=6), AU3 (n=6), and AU1 (n=4), and they were predominantly produced on coarse-grained raw materials. One specimen was produced from greyish brown chert and two blades were produced from quartz. As discussed in the previous section, the low incidence of blades in the assemblage and the lack of blade cores and debitage related to the production of blades is strong evidence that these blades were not systematically produced. Instead, it is likely that blades were occasionally produced through standard reduction methods.

Quantitative Flake Attributes

Table 7-9 presents the quantitative data for complete flakes in the HS-A1 assemblage, including the maximum dimensions, axis dimensions, mass, elongation index, and parallel index. Additionally, the platform dimensions and exterior platform angle are presented for complete flakes as well as all proximal flakes that are longitudinally complete. The data for each of these attributes is presented by analytical unit so that any variations over time can be identified.

The average maximum dimensions are relatively consistent for artefacts within AU4 through AU2, while the artefacts in AU5 are slightly smaller (Table 7-9: A-C). The artefacts in AU1 are considerably smaller than those in the earlier stages of the site's occupation history, and this is also mirrored in the average maximum width and thickness. When the artefact dimensions are examined by raw material types, a pattern emerges. On average, chert artefacts have the smallest dimensions (7.28-x-8.47-x-1.90mm), and the increase in chert in AU1 explains the considerable drop in artefact size during this phase of site use. Quartz and quartz crystal artefacts are also small (average size 8.49-x-8.69-x-3.13mm); however, they are present throughout the sequence. Martite-goethite, BIF, and goethitised shale artefacts are the largest, and the lower proportion of these material types in AU1 also contributes to the smaller average dimensions of the AU1 sample. Interestingly, AU5 shows a different pattern with the three chert flakes having a larger average size (16.10-x-17.36-x-3.9mm), albeit exceeded by the average dimensions of the BIF flakes (18.67-x-20.15-x-8.49mm). It is the goethitised shale and shale artefacts in AU5 that reduce the average values, as these artefacts are particularly small. The axis dimensions show similar patterns; albeit, with slightly smaller flake sizes (Table 7-9: D-F).

For each dimension, the standard deviation values are very high and are nearly equal to the average values in some instances. The high standard deviation values indicate that the data is not normally distributed, but is divided between the small and large size extremes. The assemblage has far more small flakes than large flakes, but these large outliers skew the data. When the maximum length is examined by quartiles, the first quartile ranges in size between 1.87 and 5.83mm, the second quartile ranges between 5.83 and 11.53mm, and flakes in the third quartile are between 11.53 and 20.92mm. A quarter of all flakes in the assemblage measure between 20.92mm and 68.51mm in length. Therefore, three-quarters of the flakes have lengths less than 20.92mm.

The dimensions of the complete flakes can also be used to explore patterns of flake shape through the elongation index (Table 7-9: H) and the parallel index (Table 7-9: I). The elongation index is a measure that determines the tendency towards flake elongation through a calculation of the maximum width to the maximum length. The average elongation index values show that most flakes in the assemblage are slightly longer than they are wide. As discussed above, there are 16 blades in the assemblage and the trends in the elongation index generally follow the appearance of blades in the assemblage. AU3 has the greatest proportion of blades, which account for 11.54% of all complete flakes, and this analytical unit also has the greatest elongation index value. This is also repeated with AU4, which has six blades that account for 6.25% of all complete flakes. AU2 shows a trend towards slight elongation; however, no blades were observed. In AU1, four blades were identified, but this analytical unit has the lowest elongation index value. This suggests that most artefacts are slightly wider than they are long. Amongst the various raw material types, goethitised shale has the greatest tendency towards elongation (1.20), followed by quartz (1.10) and martite-goethite (1.10), while limonite (0.64) and chert (0.87) were generally more squat on average.

The parallel index is a metric evaluation of flake form that compares the platform width to the axis width. As such, it provides information regarding the shape of the flake from its platform to its midpoint. The average values in each analytical unit show that flakes generally expand towards their midpoint. Approximately a fifth of the complete flakes (n=78) contract from the platform towards the midpoint, while most flakes expand away from the platform. When rounded to two decimal places, there are six flakes that have parallel forms from their platform to midpoint, as well as numerous others that are very close.

The striking platform on a flake is a small remnant of the core's striking platform; therefore, it retains important information regarding the methods that the knapper used in its manufacture. Quantitative attributes, such as the platform dimensions (Table 7-9: J-K) and the exterior striking platform angle (Table 7-9: L) have been shown in experimental research to affect flake morphology and size (Dibble and Rezek 2009; Pelcin 1997b). In the HS-A1 assemblage, the average platform width is narrow in AU5, but there is a considerable increase in AU4. From AU4 to AU1, there is a steady decrease in the average platform width. The average platform width values show high standard deviation values, indicating that there is considerable variance in the data. With standard deviation values nearing the average values (particularly for AU1 and AU5), it is evidence that many of the values cluster at the extremes of the size range. When the average platform width values are compared with the average maximum width values, there is an identical pattern, which demonstrates that platform size is strongly dependent on the size of the artefact itself. In order to explore patterns of platform width variation that are independent of flake size, a ratio of the striking platform width to the maximum flake width can be used. Amongst the complete flakes, the average ratios are very consistent, with an average value of 1.85. There is a general trend towards reducing values from AU5 (1.86) to AU3 (1.74), with a spike in AU2 (1.97) that decreases slightly in AU1 (1.88). The higher values indicate slightly narrower striking platforms, but it is worth noting that the standard deviation values are again quite high, showing that there is considerable variation within the sample. When the various raw materials are examined, limonite (1.19) and quartz (1.49) have the widest platforms, while chert (2.04) and vitreous goethite (2.63) tend to have narrower platforms.

Table 7-9 Quantitative flake attributes by analytical unit, HS-A1 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	172	11.48	46.39	2.22	8.85
	2	59	18.30	68.51	3.29	14.43
	3	52	17.89	59.98	4.23	12.45
	4	96	17.31	51.4	2.99	10.74
	5	14	14.13	41.87	1.87	11.44
B. Max Width (mm)	1	172	12.61	89.53	3.17	10.46
	2	59	18.39	52.16	3.40	13.53
	3	52	16.08	49.00	4.00	10.42
	4	96	17.46	52.79	2.31	10.76
	5	14	14.72	36.97	4.87	11.28
C. Max Thickness (mm)	1	172	3.37	16.46	0.30	3.07
	2	59	5.25	20.61	0.76	4.39
	3	52	4.96	21.63	0.53	4.17
	4	96	4.96	15.13	0.59	3.25
	5	14	5.13	20.14	0.78	6.20
D. Axis Length (mm)	1	172	10.21	38.60	1.52	8.01
	2	59	16.38	49.98	3.12	12.75
	3	52	15.67	53.65	4.13	10.75
	4	96	15.92	50.01	2.73	10.53
	5	14	12.70	41.38	1.77	10.94
E. Axis Width (mm)	1	172	10.84	77.21	2.70	9.02
	2	59	15.68	44.31	3.11	11.14
	3	52	14.04	46.47	3.71	9.62
	4	96	15.09	43.62	2.22	9.15
	5	14	12.93	31.90	4.44	9.74
F. Axis Thickness (mm)	1	172	2.82	13.54	0.33	2.61
	2	59	4.53	18.82	0.68	4.10
	3	52	4.40	20.38	0.71	4.02
	4	96	4.04	12.48	0.61	2.65
	5	14	4.33	19.78	0.77	5.20
G. Mass (g)	1	172	1.84	50.21	0.01	5.16
	2	59	6.58	90.64	0.01	14.54
	3	52	5.24	72.22	0.01	12.61
	4	96	3.07	19.68	0.01	4.49
	5	14	4.36	35.77	0.01	9.84
H. Elongation Index	1	172	0.96	3.43	0.28	0.47
	2	59	1.02	1.89	0.38	0.38
	3	52	1.19	2.79	0.55	0.53
	4	96	1.07	2.91	0.45	0.47
	5	14	0.99	1.90	0.33	0.44
I. Parallel Index	1	172	1.59	4.86	0.58	0.75
	2	59	1.70	5.22	0.50	0.89
	3	52	1.50	4.54	0.60	0.75
	4	96	1.56	5.04	0.64	0.98
	5	14	1.66	3.63	0.81	0.95
J. Platform Width (mm)	1	199	7.78	45.94	0.87	7.29
	2	66	9.50	25.27	1.14	6.00
	3	61	10.31	40.91	1.39	7.39
	4	116	11.38	38.40	1.11	7.96
	5	20	8.97	31.13	3.35	6.46
K. Platform Thickness (mm)	1	199	2.43	19.97	0.19	2.69
	2	66	3.26	13.32	0.28	2.75
	3	61	3.45	12.97	0.41	2.91
	4	116	3.46	11.87	0.18	2.41
	5	20	2.98	12.47	0.62	3.14
L. Platform Angle (°)	1	199	75.55	102.00	30.00	13.58
	2	66	76.50	123.00	34.00	16.90
	3	61	73.49	106.00	36.00	15.53
	4	116	74.51	108.00	34.00	13.51
	5	20	77.10	116.00	42.00	19.05

Note: Measurements A-I are for complete flakes. Platform measurements (J-L) include all complete flakes and all proximal flakes that are longitudinally complete.

Platform thickness is generally considered to have a greater effect on the form of the flake than platform width, with thicker platforms generally producing larger flakes (Dibble 1997; Pelcin 1997a). As with the platform width, the average platform thickness values show relatively low values for AU1 and AU5, while AU4 through AU2 have greater average values. This pattern is certainly related to the average size of the artefacts. To try and determine if there are any patterns in the flake thickness that are not simply a result of smaller and larger flakes, another ratio is used (maximum thickness/platform thickness). The average values range between 1.62 in AU1 and 1.95 in AU4, with lower values indicating thicker platforms and higher numbers equating to narrower platforms. AU2 (1.92) and AU3 (1.95) have similar values, as do AU1 (1.62), AU3 (1.65) and AU5 (1.74). Standard deviation values are, once again, high. Limonite (1.04), quartz (1.51), vitreous goethite (1.52), and martite-goethite (1.55) have relatively thick platforms, while goethitised shale (2.03) flakes have thin platforms. BIF (1.80), chert (1.78), and shale (1.71) flakes fall towards the middle of the range for the sample and indicate moderately thick platforms.

Over the course of the HS-A1 occupation, there is a small amount of variation in the average exterior striking platform angle. The average values steadily decrease from AU5 to AU3, but in AU3 they spike and then decrease slightly in AU1. This pattern follows the same trend as the platform width ratio. While there are several degrees of variation between the five analytical units, the standard deviation values are moderately high, particularly in AU5. With this in mind, it seems that the exterior striking platform angle remained relatively consistent through time.

Qualitative Flake Attributes

The qualitative attributes for proximal flakes and complete flakes are presented in Table 7-10: A-D, including the platform type, evidence of overhang modification, presence of lipping, and the type of bulb of percussion. The vast majority of the sample exhibits plain striking platforms, which are distantly followed by cortical platforms. These two platform types were also most commonly represented on the cores. The frequency of plain platforms is greater amongst the flakes than cores. This may be a reflection of the small sample of cores that are present in the assemblage, and it may indicate that more heavily reduced cores, which are more likely to have plain platforms, were removed from the site. The assemblage also includes a small number of other platform types, including linear, facetted, dihedral, and crushed platforms. Greater platform variety is present in the AU4 and AU1 samples, possibly due to the larger number of artefacts. Cortical platforms are greatest in AU4, which also has the highest proportion of coarser-grained local materials. This may reflect the expedient use of these materials.

A small fraction of the assemblage exhibits overhang modification. Facetting was recorded on 11 specimens, with eight of those being from AU1. Twelve flakes also have crushed overhangs, and this often occurs when the platform is not properly prepared, typically with a weak acute overhang leading to failure. In most instances, the crushed overhangs occurred in AU1. In AU1, all of the flakes with crushed and facetted platforms were produced from chert. The rarity of facetted overhangs indicates that it was not a typical part of the reduction strategy, but its presence in the assemblage suggests that this technique was known to the knappers who simply chose not to use it. The low incidence of both crushed platforms and crushed overhangs implies that the knappers had high success rates in their knapping without overhang modification.

Lipping and diffuse bulbs of percussion were once believed to be traits of soft-hammer percussion, but more recent work has demonstrated that these characteristics can occur on flakes produced through both hard-hammer and soft-hammer techniques (Pelcin 1997a). Other factors, such as the angle of force and thickness of the platform, are believed to contribute to the appearance of these attributes (Pelcin 1997a). Pronounced lipping was observed on 60 of the 462 complete and proximal flakes in the assemblage. This suggests that occasionally flakes were struck with lower angles of force (Bonnichsen 1974: 165; Pelcin 1997a). The proportion of artefacts with lipping is similar to other assemblages (*e.g.*, HD07-3A-PAD13). Less than two-thirds of the complete and proximal flakes exhibit diffuse bulbs of percussion, with AU4 having the lowest proportion and AU5 having the greatest proportion.

For complete flakes, the dorsal surface has a number of attributes that provide information regarding the knapping methods utilised by the knappers. These attributes include the proportion of dorsal cortex (Table 7-10: E), the number of dorsal scars (Table 7-10: F), and the scar orientation (Table 7-10: G). Most flakes in the assemblage do not have any dorsal cortex, and with increasing proportions of cortex there are decreasing numbers of artefacts. The number of completely cortical flakes shows a minor reversal of the trend, with a slight increase in numbers from the previous category. All but one of the cortical flakes was produced on a raw material type that is abundant in the local area (BIF, brown shale, martite-goethite, quartz, and goethitised shale). The single completely cortical chert flake was classified as being sugar chert, and it was recovered from AU4. All of the flakes with over a two-thirds dorsal cortex were also produced from widely-available local materials, and in the 33 to 65% dorsal cortex category, there is only one chert flake. Chert flakes only become more numerous in the lowermost category of dorsal cortex (n=6). The low proportion of chert flakes with dorsal cortex indicates that chert cores were more highly reduced than cores of other raw material types. The presence of flakes in all categories is a good indication that all stages of reduction took place on site; although, it is possible that cores of some raw material types, such as chert, were brought to the site in a partially reduced state.

For each complete flake, the number of dorsal scars was counted, and this can provide a broad measure of the reduction stages that occurred on site as well as the reduction intensity. However, there can be a variation due to the size of the artefact and size of the scars. The number of flake scars ranges from zero (for completely cortical specimens) to ten, but most flakes exhibit between one and four negative scars. Over the course of the occupation sequence, this pattern remained largely the same. Chert and BIF flakes have a slightly greater proportion of flakes with four negative scars as compared with the other raw materials. The larger size of the BIF flakes may account for the greater number of scars, but chert flakes are typically much smaller, once again suggesting that they are more highly reduced. Flakes with more than five scars or more scars are exceptional.

Table 7-10 Qualitative flake attributes by analytical unit, HS-A1 rockshelter

A. Platform Type [cp]	AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Cortical	28	14.07	11	16.67	12	19.67	29	25.00	0	0.00	80	17.32
Crushed	3	1.51	0	0.00	0	0.00	0	0.00	0	0.00	3	0.65
Dihedral	6	3.02	2	3.03	2	3.28	5	4.31	1	5.00	16	3.46
Facetted	3	1.51	2	3.03	0	0.00	6	5.17	1	5.00	12	2.60
Linear	13	6.53	2	3.03	4	6.56	5	4.31	1	5.00	25	5.41
Plain	146	73.37	49	74.24	43	70.49	71	61.21	17	85.00	326	70.56
Total	**199**	**100**	**66**	**100**	**61**	**100**	**116**	**100**	**20**	**100**	**462**	**100**
B. Overhang Removal	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Crushed	9	4.52	0	0.00	2	3.28	1	0.86	0	0.00	12	2.60
Facetted	8	4.02	0	0.00	0	0.00	2	1.72	1	5.00	11	2.38
None	182	91.46	66	100	59	96.72	113	97.41	19	95.00	439	95.02
Total	**199**	**100**	**66**	**100**	**61**	**100**	**116**	**100**	**20**	**100**	**462**	**100**
C. Lipping [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
No	179	89.95	58	87.88	52	85.25	97	83.62	16	80.00	402	87.01
Yes	20	10.05	8	12.12	9	14.75	19	16.38	4	20.00	60	12.99
Total	**199**	**100**	**66**	**100**	**61**	**100**	**116**	**100**	**20**	**100**	**462**	**100**
D. Bulb of Percussion [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Diffuse	125	62.81	43	65.15	41	67.21	69	59.48	15	75.00	293	63.42
Prominent	74	37.19	23	34.85	20	32.79	47	40.52	5	25.00	169	36.58
Total	**199**	**100**	**66**	**100**	**61**	**100**	**116**	**100**	**20**	**100**	**462**	**100**
E. Dorsal Cortex [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
None	130	75.58	38	64.41	36	69.23	60	62.50	8	57.14	272	69.21
1-32%	32	18.60	14	23.73	10	19.23	19	19.79	4	28.57	79	20.10
33-65%	5	2.91	2	3.39	3	5.77	11	11.46	0	0.00	21	5.34
66-99%	1	0.58	3	5.08	0	0.00	1	1.04	1	7.14	6	1.53
100%	4	2.33	2	3.39	3	5.77	5	5.21	1	7.14	15	3.82
Total	**172**	**100**	**59**	**100**	**52**	**100**	**96**	**100**	**14**	**100**	**393**	**100**
F. Dorsal Scars [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
0	4	2.33	2	3.39	3	5.77	5	5.21	1	7.14	15	3.82
1	25	14.53	7	11.86	5	9.62	18	18.75	2	14.29	57	14.50
2	58	33.72	17	28.81	19	36.54	29	30.21	5	35.71	128	32.57
3	55	31.98	17	28.81	11	21.15	31	32.29	4	28.57	118	30.03
4	21	12.21	9	15.25	9	17.31	10	10.42	0	0.00	49	12.47
5	6	3.49	4	6.78	2	3.85	0	0.00	1	7.14	13	3.31
6	3	1.74	1	1.69	2	3.85	1	1.04	0	0.00	7	1.78
8	0	0.00	2	3.39	1	1.92	1	1.04	0	0.00	4	1.02
10	0	0.00	0	0.00	0	0.00	1	1.04	1	7.14	2	0.51
Total	**172**	**100**	**59**	**100**	**52**	**100**	**96**	**100**	**14**	**100**	**393**	**100**
G. Scar Orientation [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Unidirectional	132	76.74	45	76.27	41	78.85	77	80.21	9	64.29	304	77.35
Bidirectional	1	0.58	1	1.69	1	1.92	2	2.08	1	7.14	6	1.53
Rotated	15	8.72	6	10.17	3	5.77	6	6.25	0	0.00	30	7.63
NA	4	2.33	2	3.39	3	5.77	5	5.21	1	7.14	15	3.82
Indeterminate	20	11.63	5	8.47	4	7.69	6	6.25	3	21.43	38	9.67
Total	**172**	**100**	**59**	**100**	**52**	**100**	**96**	**100**	**14**	**100**	**393**	**100**
H. Form [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Dist. Contracting	42	24.42	13	22.03	20	38.46	34	35.42	5	35.71	114	29.01
Dist. Expanding Distally	103	59.88	35	59.32	26	50.00	46	47.92	7	50.00	217	55.22
Leaf	13	7.56	4	6.78	2	3.85	5	5.21	1	7.14	25	6.36
Parallel-Sided	1	0.58	0	0.00	0	0.00	2	2.08	0	0.00	3	0.76
Sub Parallel	13	7.56	7	11.86	4	7.69	9	9.38	1	7.14	34	8.65
Total	**172**	**100**	**59**	**100**	**52**	**100**	**96**	**100**	**14**	**100**	**393**	**100**

I. Profile [c]	AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Concave	54	31.40	27	45.76	14	26.92	25	26.04	3	21.43	123	31.30
Convex	38	22.09	13	22.03	13	25.00	23	23.96	4	28.57	91	23.16
Straight	71	41.28	17	28.81	19	36.54	41	42.71	7	50.00	155	39.44
Twisted	9	5.23	2	3.39	6	11.54	7	7.29	0	0.00	24	6.11
Total	**172**	**100**	**59**	**100**	**52**	**100**	**96**	**100**	**14**	**100**	**393**	**100**
J. Cross-section [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Left Triangle	46	26.74	13	22.03	10	19.23	20	20.83	2	14.29	91	23.16
Right Triangle	26	15.12	12	20.34	17	32.69	20	20.83	1	7.14	76	19.34
Plano-convex	25	14.53	11	18.64	6	11.54	15	15.63	5	35.71	62	15.78
Symmetric Triangle	12	6.98	4	6.78	5	9.62	11	11.46	2	14.29	34	8.65
Trapezoid	56	32.56	16	27.12	11	21.15	24	25.00	3	21.43	110	27.99
Irregular	7	4.07	3	5.08	3	5.77	6	6.25	1	7.14	20	5.09
Total	**172**	**100**	**59**	**100**	**52**	**100**	**96**	**100**	**14**	**100**	**393**	**100**
K. Termination [cd]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Axial	3	0.92	1	0.81	3	2.73	0	0.00	0	0.00	7	0.93
Cortical Axial	8	2.46	0	0.00	5	4.55	3	1.86	1	2.94	17	2.25
Feather	252	77.54	97	78.23	80	72.73	116	72.05	27	79.41	572	75.86
Hinge	28	8.62	12	9.68	12	10.91	22	13.66	3	8.82	77	10.21
Inflexed	5	1.54	1	0.81	0	0.00	3	1.86	1	2.94	10	1.33
Step	29	8.92	13	10.48	10	9.09	17	10.56	2	5.88	71	9.42
Total	**325**	**100**	**124**	**100**	**110**	**100**	**161**	**100**	**34**	**100**	**754**	**100**

Key: cp - complete and proximal flakes; c - complete flakes; cd - complete and distal flakes

The direction of the dorsal scars reveals how the knapper oriented the core while removing a sequence of flakes. Over three-quarters of the flakes exhibit unidirectional scars and this corresponds to the findings of the core analysis. Flakes with rotated scars are not frequent in the assemblage, and presumably this is due to the fact that once the knapper had rotated the core, they did not alternate between platforms but removed flakes unidirectionally from the new platform. Six flakes exhibited bidirectional negative scars. In 38 instances it was not possible to identify definitively the orientation of the scars; these flakes were produced on a wide variety of materials, but many of the specimens were small with 23 of the flakes having lengths of 10mm or less.

The complete flakes in the assemblage also provide the opportunity to explore patterns in flake morphology, including flake form (Table 7-10: H), profile (Table 7-10: I), and cross-section (Table 7-10: J). Flake form is a visual characterisation of the shape of the flake and this attribute is a natural complement to the parallel index. Flake form differs from the parallel index in that it considers the entire form from the proximal to distal tip, whereas the parallel index only examines how the flake shape changes from the platform to the midpoint. While the two attributes use different methods to consider the morphology of the flake, there are similar results. The qualitative measure of flake form has a slightly lower proportion of distally expanding flakes; although, this remains the primary shape. Approximately 29% of the flakes have a distally contracting form, and a small number of flakes are sub-parallel-sided, leaf-shaped, and parallel-sized. It is interesting to observe that the six parallel-sided flakes identified through the parallel index were not considered to be parallel-sided or sub-parallel-sided; instead they were classified as either distally expanding or distally contracting. Through time, flake morphology remains consistent, although there are slightly more distally expanding flakes in AU2 and AU1.

The complete flakes in the assemblage primarily have straight and concave profiles, followed closely by flakes with convex profiles. There is little variation in flake profile over time, with the exception of concave flakes being slightly more numerous in AU3 and straight flakes being more common in AU5. Flake cross-section is varied, with trapezoid specimens being slightly more common. There is a general increase in flakes with trapezoid cross-sections up through the sequence. Other cross-section types, such as left triangle, right triangle, and plano-convex are also quite common and there are minor variations throughout the sequence. AU5 has a high occurrence of plano-convex flakes.

The termination is the final attribute examined for 754 complete flakes and distal flakes that are longitudinally complete. The termination is where a flake detaches from its core, and a number of variables can affect its formation. Throughout the sequence, feather terminations were recorded on over three-quarters of the sample. Feather terminations are generally considered to be the ideal termination type. Other termination types (such as hinge, step, and inflexed) can hamper further core reduction, sometimes leading to the abandonment of a core face or to core discard. Such problematic terminations occur in the assemblage and account for up to a fifth of the sample. Most of the hinge, step, and inflexed terminations occur on BIF flakes (n=68), followed by shale (n=35), and chert (n=30). Within the different raw material types, the raw materials with the greatest relative frequency of these problematic terminations are limonite, vitreous goethite, and martite-goethite; however, these material types are represented by a small number of flakes. Chert flakes have an average of 22.39% of these terminations, and the relative proportion is lowest in AU1 (14.58%) where chert flakes are most common. Axial and cortical axial terminations are relatively infrequent, with 24 specimens identified. Axial terminations are often associated with bipolar reduction (Odell 2004: 58); although, they may also occur through hand-held reduction techniques. No plunge terminations were identified.

In some assemblages there have been correlations between the termination types and the exterior striking platform angle; hence, there is the potential that platform angle may affect the formation of the various termination types. Complete flakes

with step terminations have the highest external platform angle (77.84°), while hinged and inflexed flakes have slightly lower platform angles (73.60° and 74° respectively) that are similar to the average for flakes with feather terminations (74.30°). There are only four complete flakes with axial terminations, and they have quite acute exterior platform angles (70.75°), while flakes with cortical axial terminations have slightly higher platform angles (76.67°, n=9). In other assemblages (*e.g.*, HD07-3A-03 and HD07-3A-PAD13), flakes with cortical axial and axial terminations had considerably higher striking platform angles.

Retouched and Utilised Artefacts

Seventy-one retouched and utilised artefacts were recovered from HS-A1, comprising 4.97% of the assemblage. Table 7-11 presents the retouched and utilised artefacts present in the assemblage by analytical unit. Most of the retouched and utilised artefacts were recovered from the last phase of occupation, with 46.48% of the sample being from AU1. While AU1 has a greater number of retouched and utilised artefacts, their relative proportion within the artefact assemblage remains consistent throughout the occupation of the site with values ranging between a high of 5.56% in AU3 and a low of 3.96% in AU4 (see Table 7-2). When examined against the other Pleistocene assemblages, the proportion of retouched artefacts is relatively low at HS-A1 in comparison with Djadjiling (12.61%; Law and Cropper 2012), but it is consistent with and even slightly higher than at HD07-3A-PAD13 and Jundaru.

The assemblage of retouched and utilised artefacts is primarily comprised of non-formalised retouched and utilised artefacts, but it also contains a small number of formalised retouched artefacts, including backed artefacts, a burin, and a tula (Table 7-11). All of the formalised implements are in AU1 with the exception of the transverse burin. The following sections briefly describe the formalised retouched artefacts before the general patterns of secondary edge modification are considered.

Formalised Retouched Artefacts

Four artefacts with backing were identified in the assemblage, including an asymmetrical backed artefact (Bondi), a symmetrical specimen (trapeze – NLB), and two indeterminate fragments. All of the backed artefacts were recovered from AU1, with the lowermost specimen (Artefact 1363) having been found amongst the matrix of Feature 6, which has been dated to 3036±50 cal BP. The trapeze with no lateral backing (Artefact 283) was recovered from the surface layer of Unit 2, and it was produced on a greyish brown chert flake (Figure 7-17: a). The artefact has backing along the distal and proximal ends, which forms two oblique truncations that angle towards the right lateral edge. On the left lateral edge, there is alternating usewear that is more pronounced from the mid-point towards the distal edge. There is also a small amount of scaled ventral AAR on the proximal left edge. There are a number of red smears and blobs on the ventral surface, and it is possible that these may be resin.

Artefact 841 is an excellent example of a Bondi point, which was produced on a dark grey chert flake (Figure 7-17: c). The Bondi point is long and thin, measuring 29.61mm long, 5.29mm wide, and 2.54mm wide. The proximal end of the flake appears to have been snapped off, and then it was bifacially backed along the entire right lateral edge, forming a straight rectilinear edge. On the distal left margin there is short, stepped and scaled, dorsal AAR that forms a sharp point as it meets the backed edge. Just beyond the retouch, there is a large notch that appears to be edge damage, as it is not consistent with the retouch. This may have occurred during the de-hafting process. The artefact bears signs of thermal alteration (fine crazing and loss of colour), which may have occurred during the de-hafting process. There is a distinct line along the backed and distal margin where the crazing and loss of colour dissipates. Perhaps this is where the artefact was hafted, with the resin protecting these areas of the artefact from the effects of thermal alteration.

Two backed artefact fragments were also identified in the assemblage. One specimen was found in the same layer as the Bondi point (U4-L03), and this artefact may also have originated from a Bondi point. The distal backed artefact fragment was produced on a dashed black chert flake, and it has dorsal backing along the left lateral edge. There is also a small amount of ventral retouch on the right lateral edge. It is possible that this artefact could have been produced to replace the Artefact 841, as it has similar width (4.68mm) and thickness (2.25mm). The second backed artefact (Artefact 1363) fragment was produced on an olive chert flake, and only the distal section was recovered. The artefact has dorsal backing along the distal edge, which forms an oblique truncation that angles up towards the left lateral edge. This artefact may have been from a broken symmetrical backed artefact, such as a trapeze.

Table 7-11 Distribution of retouched and utilised artefacts by analytical unit, HS-A1 rockshelter

Retouched or Utilised Artefact Type	AU1		AU2		AU3		AU4		AU5		Total	
Subtype	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*15*	*45.45*	*6*	*60.00*	*9*	*75.00*	*9*	*69.23*	*1*	*33.33*	*40*	*56.34*
Alternate Edge	0	0.00	0	0.00	1	8.33	1	7.69	0	0.00	2	2.82
Alternating	2	6.06	3	30.00	2	16.67	2	15.38	0	0.00	9	12.68
Unifacial	13	39.39	3	30.00	6	50.00	6	46.15	1	33.33	29	40.85
Utilised Artefact	*13*	*39.39*	*4*	*40.00*	*3*	*25.00*	*4*	*30.77*	*1*	*33.33*	*25*	*35.21*
Alternating	3	9.09	2	20.00	1	8.33	1	7.69	1	33.33	8	11.27
Unifacial	10	30.30	2	20.00	2	16.67	3	23.08	0	0.00	17	23.94
Asymmetrical Backed Artefact (Bondi)	*1*	*3.03*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.41*
Symmetrical Backed Artefact (Trapeze - NLB)	*1*	*3.03*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.41*
Backed Artefact (Indeterminate)	*2*	*6.06*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*2.82*
Burin (Transverse)	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*33.33*	*1*	*1.41*
Tula (Slug)	*1*	*3.03*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.41*
Total	**33**	**100**	**10**	**100**	**12**	**100**	**13**	**100**	**3**	**100**	**71**	**100**

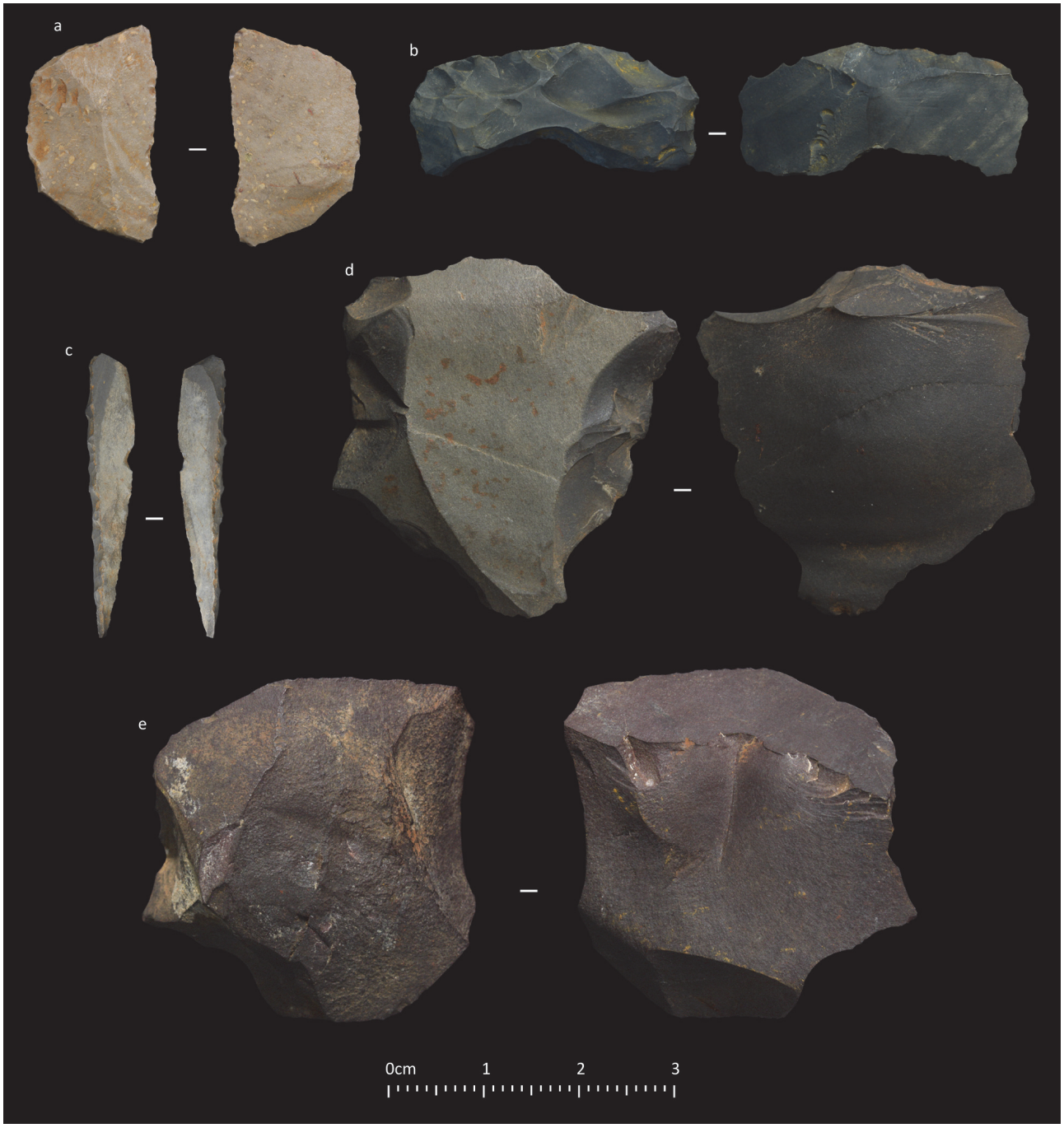

Figure 7-17 Retouched artefacts from HS-A1 rockshelter: a) trapeze – NLB (Artefact 283; AU1), b) tula slug (Artefact 3252; AU1), c) Bondi point (Artefact 841; AU1), d) unifacial retouched artefact (Artefact 1133; AU4), and e) retouched artefact (Artefact 498; AU3)

A dark grey chert tula slug was found in the surface layer of Unit 1 (Figure 7-17: b). The artefact is classified as being a possible tula slug, as a large potlid removed most of the distal edge. Due to the large potlid, the tula was not considered to be complete, but a proximal fragment. The artefact is severely heat affected, with numerous potlids and crazing. Along the distal and left margin, the artefact exhibits scaled dorsal retouch forming a distinct convex edge. On the right lateral edge, there is also scaled dorsal SAR forming a convex edge; however, in both cases, the retouch is interrupted by the potlid and its full extent cannot be determined. It is possible that the heat fractures sustained by this artefact may have been caused during the de-hafting process, as the resin would have needed to have been heated in order to remove the artefact from the haft.

Artefact 627 is a proximal fragment of a transverse burin that was recovered from Layer 12 of Unit 2. The artefact was produced on a brown shale flake, and the only retouch scars on the flake are three transverse facets on the proximal edge. There has been little research on the appearance of burin technology in Australia, and the identification of this artefact in AU5 demonstrates that burin technology was utilised as early as 40,248±936 to 40,670±939 cal BP.

Edge Modification Analysis

Of the 71 retouched and utilised artefacts, only a small proportion (n=29) were classified as being complete (Table 7-12). There are 58 areas of secondary edge modification on the complete retouched and utilised artefacts, which are presented by artefact subtype and analytical unit in Table 7-12.

The backed artefacts have the greatest number of edge modification areas per artefact, followed by the retouched artefacts. On average, utilised artefacts have the least number of edge modification areas per artefact. With most excavated assemblages, the qualitative edge modification attributes are presented for each analytical unit; however, they have been presented together in Table 7-13 due to the low number of complete retouched artefacts from this site. The data has been examined for any changes over time and these are discussed below.

The edge modification types used in the creation of the retouched and utilised artefacts are presented in Table 7-13: A. Regular retouch accounts for over half of the edge modification areas, followed closely by usewear. Other methods of edge modification are rare, but include retouched notches, backing, and single notches. Backing only occurs in AU1 on the two complete backed artefacts in the sample, a Bondi point and a trapeze. The notches are more common in the earlier stages of the site's occupation, in AU4 and AU3. One artefact from AU4 (Artefact 589) exhibits both a retouched notch as well as a single notch, and there is continuous retouch between the two notches. From AU3, Artefact 498 also has one retouched notch (distal) as well as a concave area of retouch on the proximal half of the right lateral margin (Figure 7-17: d). These two areas of retouch have formed a very distinct point between them and the point has a triangular cross-section. The pointed tip exhibits usewear and may have been utilised in an awl-like manner, but this would need to be confirmed through usewear analysis.

The position of the various types of edge modification is presented in Table 7-13: B. Over two-thirds of the edge modification was created on the dorsal surface of the artefacts (*e.g.*, Figure 7-17: e), and all of the notches and retouched notches were formed through dorsal retouch. The backing in the assemblage is primarily dorsal, but there is also one instance of bifacial backing. Artefacts were only occasionally retouched on their ventral surfaces, while even fewer show alternating retouch. Alternating usewear is more common, but remains a distant second to dorsal usewear. Over time, the same patterns exist with the exception of AU5 where alternating edge modification is more common. There are only three instances of edge modification in AU5 that derive from one utilised artefact and one retouched artefact; hence, this sample is not statistically significant. AU2 also shows a slightly higher proportion of alternating edge modification, but again there are only seven areas of edge modification on four artefacts.

The angle of the edge modification was visually classified as being either acute (AAR, <60°) or steep (SAR, >60°). All but one instance of usewear was classified as being acute (Table 7-13: C), and this results in a generally higher proportion of AAR for all areas of edge modification. Amongst the areas of retouch, there is an even distribution between AAR (n=19) and SAR (n=19). There are minor variations over time, but with such a small sample the differences between the analytical units do not provide robust evidence for differences in artefact manufacture. For example, AU5 has only one retouched area and it is classified as SAR. One exception is AU1, which has a high proportion of SAR (n=7). The predominance of SAR in AU1 is due to the presence of backed artefacts in the sample; hence, this difference is tied to a technological change.

By definition, all of the usewear was classified as having an extent less than 1mm and this accounts for over a third of the sample (Table 7-13: D). The retouched areas tend to stay close to the margin of the artefact, with 63.13% of the retouched areas having been classified as short. A further 14 areas of retouch were classified as long retouch, but no invasive or covering retouch was identified. All of the long retouch was identified amongst the artefacts from AU3, AU4, and AU5.

Delineation characterises if edge modification modifies the plan of the knapped edge, recording the shape of the edge if it has been modified (*e.g.*, rectilinear, denticulate, convex, *etc.*) or noting if the artefact has retained its regular form. The majority of edge modification areas in the sample have regular delineations (Table 7-13: E), indicating that the shape has not been altered. All of the usewear has regular delineation, which increases the overall frequency of regular delineation for all areas of edge modification. When instances of usewear are removed from the sample and retouch is examined, there is a broader distribution of delineation although regular retouch is predominant (n=22). Retouch areas with concave delineations are second in abundance, and this accounts for all retouched notches, notches, and many retouch areas that did not have a concavity deep enough to be classified as a notch. Four instances of rectilinear retouch were noted, as well as one instance each of convex and denticulate retouch. Both the convex and denticulate retouch occurs on Artefact 487 from AU3, which also has a retouched notch.

Most of the edge modification occurs on the right and left lateral margins (Table 7-13: F), and there is little difference to separate the two edges. Both the retouched edges as well as utilised areas are fairly evenly distributed between the right and left margins. There are no instances of retouch on the proximal margin, but distal retouch and usewear is common. Rarely, the retouch continues from a lateral margin onto the distal margin.

Table 7-12 Number of edge modification areas on complete artefacts by analytical unit, HS-A1 rockshelter

Retouched Artefact Type	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
Subtype	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM
Retouched Artefact	*4*	*6*	*2*	*3*	*8*	*14*	*4*	*13*	*1*	*1*	*19*	*37*
Alternate Edge	0	0	0	0	1	3	0	0	0	0	1	3
Alternating	2	3	0	0	1	2	0	0	0	0	3	5
Unifacial	2	3	2	3	6	9	4	13	1	1	15	29
Utilised Artefact	*3*	*4*	*2*	*4*	*1*	*2*	*1*	*2*	*1*	*2*	*8*	*14*
Alternating	0	0	1	3	0	0	0	0	1	2	2	5
Unifacial	3	4	1	1	1	2	1	2	0	0	6	9
Asymmetrical Backed Artefact	*1*	*3*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*3*
Symmetrical Backed Artefact	*1*	*4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*4*
Total	**8**	**14**	**4**	**7**	**9**	**16**	**5**	**15**	**2**	**3**	**29**	**58**
Key: n – number of complete retouched or utilised artefacts; EM – number of edge modification areas												

Table 7-13 Qualitative edge modification attributes, HS-A1 rockshelter

A. Edge Modification Type	Backing	Notch	Retouch	Ret. Notch	Usewear	Total	
	n	n	n	n	n	n	%
Retouched Artefact	0	1	27	4	5	37	63.79
Utilised Artefact	0	0	1	0	13	14	24.14
Asym. Backed Art.	1	0	1	0	1	3	5.17
Sym. Backed Art.	2	0	1	0	1	4	6.90
Total n	**3**	**1**	**30**	**4**	**20**	**58**	**100**
Total %	**5.17**	**1.72**	**51.72**	**6.90**	**34.48**	**100**	-
B. Position	n	n	n	n	n	n	%
Alternating	0	0	4	0	7	11	18.97
Bifacial	1	0	0	0	0	1	1.72
Dorsal	2	1	20	4	13	40	68.97
Ventral	0	0	6	0	0	6	10.34
Total	**3**	**1**	**30**	**4**	**20**	**58**	**100**
C. Angle	n	n	n	n	n	n	%
AAR	0	0	18	1	19	38	65.52
SAR	3	1	12	3	1	20	34.48
Total	**3**	**1**	**30**	**4**	**20**	**58**	**100**
D. Extent	n	n	n	n	n	n	%
<1mm	0	0	0	0	20	20	34.48
Short	3	0	21	0	0	24	41.38
Long	0	1	9	4	0	14	24.14
Total	**3**	**1**	**30**	**4**	**20**	**58**	**100**
E. Delineation	n	n	n	n	n	n	%
Concave	0	1	5	4	0	10	17.24
Convex	0	0	1	0	0	1	1.72
Denticulate	0	0	1	0	0	1	1.72
Rectilinear	3	0	1	0	0	4	6.90
Regular	0	0	22	0	20	42	72.41
Total	**3**	**1**	**30**	**4**	**20**	**58**	**100**
F. Location	n	n	n	n	n	n	%
DE	0	0	7	0	5	12	20.69
LLE	0	0	12	1	7	20	34.48
RLE	1	1	10	3	8	23	39.66
LLE + DE and/or PE	0	0	1	0	0	1	1.72
RLE + DE and/or PE	2	0	0	0	0	2	3.45
Total	**3**	**1**	**30**	**4**	**20**	**58**	**100**

Key: LLE – Left Lateral Edge, RRL – Right Lateral Edge, DE – Distal Edge, PE – Proximal Edge

Grindstone Analysis

One lower grindstone was recovered from the surface of the rockshelter (Artefact 1430; Figure 7-18). The presence of the grindstone was not noted by MHA excavation team, even though it was approximately 1m from their test pit. The grindstone is medium-sized, measuring 153.92mm long, 108mm wide, and 32.44mm thick. The specimen was produced on a slab of coarse-grained BIF and one surface has clear signs of grinding. The ground surface is smoothed and there is a grey substance adhering to many areas. This specimen is an excellent example of a lower grindstone. It is possible that it was used to process food items, such as seeds; however, residue analysis would be needed to confirm this theory.

Manuports

One manuport was recovered from the first layer of Unit 2 (Quad D). The artefact is a rounded quartz cobble that was likely collected from drainage channel at the base of the gully, or perhaps from another nearby drainage channel. The artefact retains abraded cortex on over two-thirds of its surface, but it also has several natural fractures. There are no clear signs of use on the artefact. It is possible that it could have been used as an upper grindstone. The individual who brought this cobble to the site may have even intended to reduce it as a core, but as there are no obvious indicators of its use, it remains classified as a manuport.

Artefact Analysis Summary

ACHM recovered an assemblage of 1430 artefacts during their excavations at HS-A1, and the radiocarbon dates indicate that these artefacts were deposited as early as 40,248±936 to 40,670±939 cal BP. A small number of artefacts were found below the charcoal samples submitted for these dates, suggesting that the initial occupation may even be slightly earlier. The assemblage is primarily comprised of diagnostic artefacts, such as flakes, retouched/utilised artefacts, and cores. One grindstone was also recovered from the surface of the shelter. Non-diagnostic artefacts make up a small proportion of the assemblage (5.94%), including flaked pieces, heat shatter (and potlids), and a manuport. Over the 40,000-year occupation of HS-A1, artefact density was relatively low, and this is consistent with both Djadjiling and HD07-3A-PAD13. There is a slight peak in the proportion of artefacts in AU4 as well as in AU1, indicating that site use was greatest prior to the onset of the glacial period as well as from the late mid-Holocene onwards.

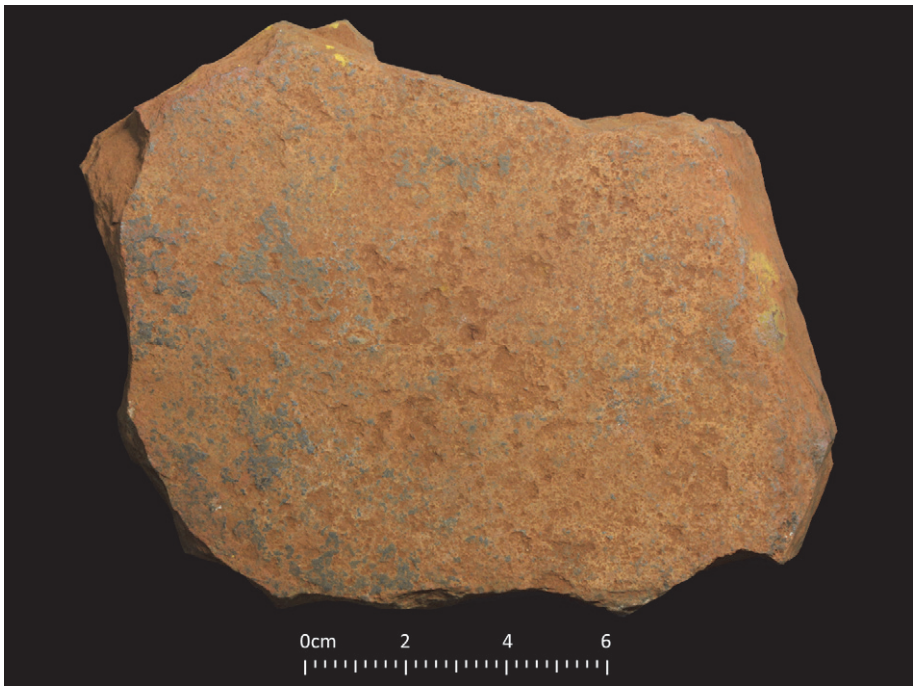

Figure 7-18 Grindstone (artefact 1430) recovered from the surface of HS-A1 rockshelter

The density and diversity of artefacts in the assemblage recovered by ACHM differs considerably with that recovered by the MHA team. Throughout most of Unit 3, the MHA team excavated the unit to an approximate depth of 30cmbs, with the exception of one corner that reached a maximum depth of 45cmbs (based on measurements taken by ACHM upon the removal of the backfill). In this volume of sediment, which Edwards *et al.* (2001: 144) estimate to be 0.44 cubic metres, 176 flaked stone artefacts were recovered; however, 88.1% were classified as flaked pieces (n=155), leaving 21 diagnostic artefacts. In the same layers of the adjacent excavation unit (Unit 1), 191 artefacts were recovered with 179 specimens being diagnostic and only 12 specimens being non-diagnostic. This suggests that the recovery methods utilised by the MHA team may not have recovered all of the artefacts from these layers, possibly due to the cemented sediment, which ACHM found to encapsulate artefacts. As a result, the data from the initial testing of HS-A1 is not comparable with the dataset presented in this monograph.

The knappers at HS-A1 focused on the use of widely-available local raw materials, such as BIF, shale, and quartz. These materials were likely collected from the area immediately surrounding the rockshelter, as indicated by the predominance of rough cortex. Some specimens have smooth, abraded cortex, suggesting that occasionally cobbles were also collected from drainage channels. In AU1, the raw material procurement strategies shifted and the knappers incorporated a much greater proportion of chert. Chert is much less abundant in the landscape, although, it too is locally available. The size of artefacts diminished in AU1 and this is likely due to the fact that only smaller chert cobbles were available. While chert was more difficult to procure, many varieties are present in the assemblage indicating that flakes were produced from a number of different cores. However, one chert core was recovered from the site. This may indicate that knappers took their chert cores with them as they departed the site.

The technological analysis of the cores and flakes indicate that the knappers utilised expedient reduction methods with little variation over time. HS-A1 shows a slightly higher proportion of unidirectional cores than other Pleistocene sites; although, the small sample may not be statistically significant. Two bidirectional cores are among the sample, and it is likely that these are simply a variant of the other rotated cores in the assemblage. The alternate-platform core from AU4 does show a different method of core reduction, with an alternate or bifacial platform being utilised by the knapper. The shape of the raw material may have influenced the method used to reduce this particular specimen. Core size varied through the sequence, but patterns are hard to assess with such small sample sizes.

Like all assemblages, flakes and flake fragments are the most numerous artefact type, accounting for 87.90% of the assemblage. The MNF index estimates that the 1258 flakes and flake fragments derive from at least 897 complete flakes. This suggests that there is a very high proportion of broken flakes in the assemblage (56.19%). It is proposed that due to the low sedimentation rates at the site, flakes would have been on the surface for longer and would have been more susceptible to breakage due to trampling as well as through damage from falling rocks. Flake size is fairly consistent between AU4 and AU2, but there is a sharp decline in artefact size in AU1 and this appears to be related to the increased use of chert. The flakes also demonstrate the assemblage was produced using expedient reduction methods. Plain and cortical platforms were preferred, and there is little evidence of either platform or overhang preparation. While cores do not appear to have been systematically prepared or maintained, there are few crushed overhangs or platforms in the assemblage. The orientation of the dorsal negative scars indicates that knappers primarily reduced cores unidirectionally, and there are few flakes with rotated or bidirectional scars. This implies that even on rotated or bidirectional cores, a single core face was utilised at a time. Problematic terminations (step, hinge, and inflexed) occur on approximately 21% of all complete and distal flakes, which could be an outcome of the lack of core preparation and maintenance. Amongst the cores, it appears that knappers adopted a strategy of core rotation when a core face became unworkable due to such flaws. While such terminations can impede core reduction, there was an abundance of raw material

at the site, particularly coarser-grained varieties; hence, it was not necessary to take measures against their occurrence.

Retouched and utilised artefacts account for 4.97% of the assemblage, and include a small number of formalised implements, such as backed artefacts, a burin, and a tula. The backed artefacts and tula were all recovered from AU1, and their relative chronology is consistent with the known temporal extent of these artefacts. A transverse burin was identified in AU5, demonstrating that burin reduction was a technique that was in use during the early occupation of the Pilbara. Non-formalised retouched and utilised artefacts account for the bulk of the sample, including 40 retouched artefacts and 25 utilised artefacts. While 71 artefacts were identified with either retouch or usewear, only 29 specimens were considered to be complete. With such a small sample of complete artefacts, identifying robust patterns of artefact manufacture over time was not possible. The only definitive technological change identified through time was the introduction of backing in AU1.

7.7 SPECIALIST STUDIES

In order to provide further context to the archaeological patterns and better understanding of the site formation processes, three specialist studies were commissioned: 1.) sedimentary, charcoal, and palynological analysis (see Haberle et al., this volume), 2.) macrobotanical analysis (Fairbairn 2013) and 3.) sediment analysis of the cemented sediments (Gilkes and Yusihami 2013). The following section summarises the results of the sedimentary/charcoal/palynological and macrobotanical analyses, considering the outcomes of the study with respect to the archaeological materials and chronology. The results of the cemented sediment analysis were discussed previously and are not summarised again here.

Sedimentary, Charcoal and Palynological Analysis

A series of sediment samples from Unit 1 were submitted to PalaeoWorks for sedimentary, micro-charcoal, and palynological analysis. The analysis was carried out by Simon Haberle, Feli Hopf, and Phil Roberts, and their results are presented as Chapter 13 (see also Haberle *et al.* 2013). The following paragraphs summarise their results and correlate them with the archaeological patterns and chronology for the site.

Haberle et al (this volume) found that pollen were well-preserved in the samples and indicate that the sclerophyll woodland was dominated by *Eucalyptus* sp. and *Calytrix* sp. up to 3000 years ago, after which *Corymbia* sp. became predominant with increased grassy understory. They attribute this change to an increase in local burning. It is interesting that the charcoal analysis indicated that local fires only increased after Layer 5, as this correlates well with the pattern of combustion features at the site.

Macrobotanical Analysis

Dr Andrew Fairbairn was engaged to conduct a macrobotanical analysis of charcoal samples from the hearth features at HS-A1 in order to determine the types of woody plant species used as fuel in the combustion features. The study also considered if the macrobotanical evidence could provide information regarding environmental change through the occupation, as well as to determine if any plant remains in the assemblage could provide insight into past subsistence. Fairbairn's full report can be found elsewhere (Fairbairn 2013), and the following paragraphs summarise his results of the HS-A1 analysis.

Charcoal samples from the flotation of Features 2 to 7 were submitted for analysis. A sample from Feature 1 was not submitted, as this deposit was later determined not to be a combustion feature. While nearly 8kg of floated macrobotanical remains were recovered from the excavation, the samples from combustion features were targeted for this analysis as they can be directly linked with human activity at the site. As with all of the specialist studies, the samples were submitted without provenance data and were assigned random sample numbers to avoid any inadvertent bias in the interpretation of the data. Once the analysis had been completed, the specialist was provided with the provenance of the features.

The wood charcoals from the combustion features at HS-A1 are dominated by *Eucalyptus*, with the exception of Feature 5 (Fairbairn 2013). Mulga (*Acacia aneura*) is most common in the Pleistocene features (Features 4, 5, and 7); although, there is also a small component amongst the Feature 6 charcoals (Fairbairn 2013). Fairbairn (2013) suggests that the presence of mulga in these features may indicate they were used at a time when there was a 'more stable rainfall pattern… as mulga requires high rainfall to germinate'. Fairbairn (2013) notes that there is greater diversity in the wood charcoal types in the older hearth features, and Feature 6 also mirrors this trend.

Ficus platypoda was identified in Feature 5, and Fairbairn (2013) notes that this charcoal type matches an indeterminate type found at PAD 3. Considering the local vegetation and the past environmental conditions, *Ficus platypoda* is not likely to have been local (Fairbairn 2013). The wood would have been sourced from better watered areas, and it is possible that it was a wooden artefact that was placed in the fire (Fairbairn 2013). Weeli Wolli spring may have been a potential source of this wood. Importantly, the native rock fig bears edible fruit, but there is no evidence that they were consumed at the site.

The composition of the wood charcoal assemblage from Feature 6 is very distinct from that of Features 3 and 2, which are believed to have been utilised at a similar time. It is possible that the different charcoal composition may reflect different usage of the hearths, at least during this phase of the occupation. Features 2 and 3 are much smaller and thinner than Feature 6, which has considerable breadth and depth. The large size of the latter feature may indicate that it was used as a cooking or roasting pit.

Small fragments of spinifex resin were identified in Features 2 and 6 (Fairbairn 2013). A distal backed artefact fragment was also found in Feature 6, and its presence together with the resin may indicate that the fire was utilised for de-hafting a spent artefact and replacing it with a new specimen. Numerous heated artefacts were identified amongst the Feature 2 matrix, and in the arbitrary excavation layer adjacent to the feature a heat-affected Bondi point was identified, as well as the distal fragment of another backed artefact. This may suggest that de-hafting also occurred during the use of Feature 2. Spinifex was also identified in a late Holocene feature at Jundaru (Fairbairn 2013).

7.8 DISCUSSION

HS-A1 is a large rockshelter on the west side of Hope South that was previously tested by MHA (Edwards *et al.* 2001: 144). Subsequent archaeological excavations conducted by ACHM have demonstrated that the site was occupied by at least 40,248±936 to 40,670±939 cal BP and possibly slightly earlier. The site is considered to have high archaeological significance for several reasons. HS-A1 has a long occupational history that

spans from the Pleistocene through the LGM and into the late Holocene, and it is now one of five sites at Hope Downs 1 demonstrating a pattern of early and repeated site use. The investigations have yielded a moderate-sized artefact assemblage and have revealed well-preserved combustion features, with one such feature dating to 28,200±188 cal BP. In contrast to the other Pleistocene sites at Hope Downs 1, only a very small proportion of the site has been excavated to date, and the site still retains great potential for providing new information. One of the difficulties with most Pleistocene sites is that only small artefact assemblages are recovered, and at HS-A1 there remains the potential to gain further knowledge of past technological strategies if a larger sample is obtained.

HS-A1 is currently located beyond the proposed boundary of the Hope South mine pit; however, its buffer intersects with the impact footprint of the mine pit. It is possible that the site could be indirectly impacted by the mining operations in the vicinity of the site. It was recommended that RTIO avoid direct and indirect impacts to HS-A1 and develop a management plan for the site. If RTIO cannot avoid impacting this site, either indirectly or directly, further archaeological investigation of HS-A1 was recommended. There is high potential that this site has buried cultural material from the occupation that spans Pleistocene through Holocene that could make significant contributions to Aboriginal archaeology.

HS-A1 is the fifth Pleistocene site identified at Hope Downs 1, and it is the third site to yield evidence of Aboriginal occupation by 40,000 years ago. The dates for the initial occupation of HS-A1 correlate well with that of both Djadjiling and HD07-3A-PAD13, suggesting that there was a small population utilising the rockshelters of Hope Downs 1 during this time period. Throughout the entire occupation, artefact discard rates are low. Roughly averaged, one artefact was left per square metre each century at the site (excluding Unit 3); although, this varied slightly over time. It is likely that, like most sites on the Hope Downs 1 lease, there were long periods of site disuse that were punctuated by intermittent and ephemeral occupation.

Six well-preserved combustion features were identified in Units 2 and 4. Many of the features retained a layered appearance with a light ashy upper layer, followed by a dark grey matrix that overlaid reddened rocks and sediment. Feature 6 had the largest horizontal extent and was also the deepest, reaching up to 11.5cm in depth. A diverse range of wood was used in the fire, unlike the contemporary smaller hearths (Features 2 and 3). It is possible that Feature 6 may have been a charcoal cooking pit, while the smaller features may have had a different purpose. Similar pit-like features were identified at Djadjiling and Jundaru.

While relatively small amounts of cemented sediment were first encountered during the excavation of Jundaru, it was during the HS-A1 excavation that these precipitates caused difficulty for the excavation team. The sediment in Units 1 and 3 were heavily cemented, so much so that excavation was compared to digging through bedrock. The cemented sediment is now known to be due to the chemical precipitation of salts, predominantly halite, sylvite, and gypsum. These minerals were deposited in areas of HS-A1 where salt-saturated water flowed through the bedrock and into the sediment. While the cemented sediment made excavation challenging, it is also possible that it may have helped to preserve some organic material.

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Chapter 8

Excavations at Djadjiling Rockshelter (HD07-1A-04)

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HD07-1A-04 is a medium-sized rockshelter located in Hope South that was initially identified by ACHM during the Hope 1 South Survey in early 2007 (Law *et al.* 2009). Two artefacts were observed at the site during the heritage survey, including a BIF flake and a broken grindstone fragment that were identified on the surface of the rockshelter (Law *et al.* 2009: 81). While these artefacts certainly did not hint at the long occupational history of the site, it was argued that the site could be archaeologically significant due to the apparent depth of sediment accumulation and the potential for deeply buried cultural material (Law *et al.* 2009: 81). Law *et al.* (2009: 81) recommended that the archaeological significance of the site could only be properly assessed once sub-surface testing was conducted. The position of the rockshelter placed it within an area planned for infrastructure for the nearby Hope South 1 mining pit. In accordance with the 2002 Section 18 permit, the proponent applied for a Section 16 permit to undertake mitigative salvage at the site, and Permit 423 was granted on 25 October 2007 (Thorley 2007).

In late 2007, HD07-1A-04 was subject to excavations during the Hope South Stage 2 (MIB50) excavation program. The outcome of field investigations determined that the site has an archaeological sequence dating as early as 41,000 years ago, placing it amongst the oldest known Aboriginal sites in the Pilbara and the Australian arid zone. These results increase the scientific value of the rockshelter and enhance the cultural significance of the locality for the Traditional Owners. In recognition of this significant place, the site was named 'Djadjiling Rockshelter' by MIB elders as a reflection of the creation myth associated with the surrounding Djadjiling Range.

Prior to test-excavations at Djadjiling, RTIO proposed to utilise the gully for water drainage associated with the Hope South 1 mining pit, which would have involved the construction of a water pipeline and support walls along the base of the gully. In addition, the main retaining wall for the Hope South 1 pit was planned for construction approximately three metres west of the site. After the antiquity of the Aboriginal occupation of the site was established, it was recommended that Djadjiling should be permanently protected from mining activities and associated infrastructure and that the site should be kept accessible for future visits by Traditional Owners, for site monitoring, and for future research (Law *et al.* 2008).



Figure 8-1 Djadjiling rockshelter prior to excavation (G. Houghton pictured)



Figure 8-2 Topographic map for Djadjiling rockshelter

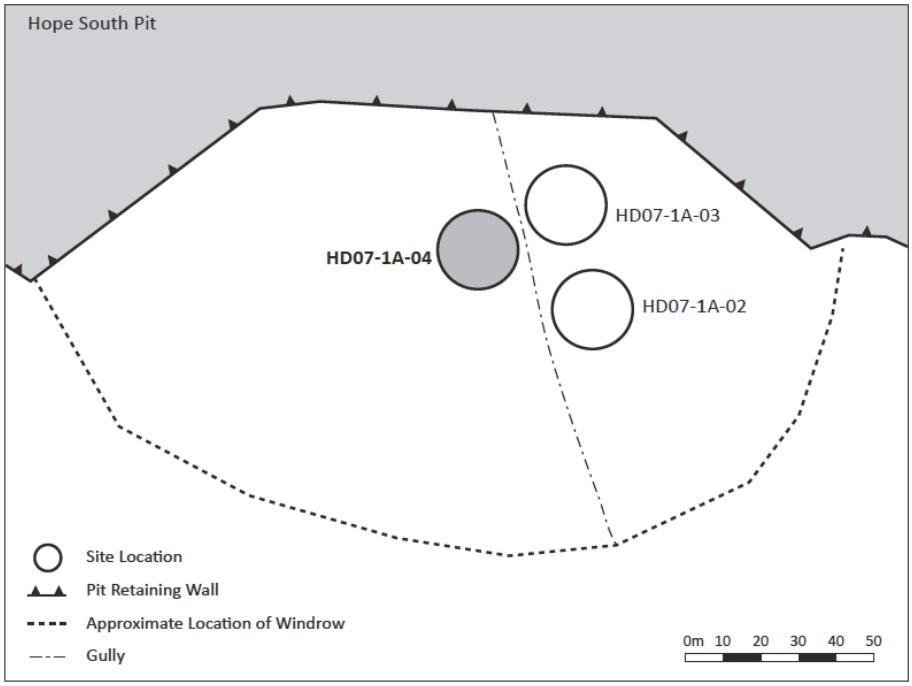

Figure 8-3 Illustration of the re-designed Hope South pit retaining wall and windrows (after Figure 3, Appendix I in Davis and Lowery 2009)

A management plan was developed for the site (Appendix I in Davis and Lowery 2009) that notes although the operating entity has ministerial consent to use the land that the site occupies, the proponent has chosen to protect the site. As Figure 8-3 illustrates, the mine planners have re-designed the retaining wall for the Hope South 1 mining pit, which is now approximately 24m from the site (MIB had requested a buffer of 70m; see Appendix I in Davis and Lowery 2009). A metal pole fence was constructed along the edge of the pit, and windrows were constructed along the east, west, and south boundaries (Appendix I in Davis and Lowery 2009). In order to reduce the vibration in the shelter, ventilation holes were dug along the pit edge and blasting charges are kept to a minimum (Appendix I in Davis and Lowery 2009). Inside the rockshelter, the backfilled deposit and surrounding unexcavated deposit is protected by a layer of geotechnical cloth and 50-x-50cm blocks of drillers casing foam was placed onto the geotechnical cloth to provide added protection in the event or roof collapse geotechnical. The rockshelter continues to be monitored for vibration due to blasting and is regularly inspected.

8.1 SITE SETTING AND DESCRIPTION

Djadjiling is situated near the mouth of a small gully that flows to the north-northeast. The rockshelter has an east aspect, and it is positioned midway between the crest of the hill and the base of the steep-sided gully (Figure 8-1). On the opposite and east side of the gully are rockshelters HD07-1A-03 (25m to the northeast) and HD07-1A-02 (33m to the southeast). Together, these three sites are relatively isolated from other archaeological sites in the mining lease, with the next closest sites being approximately half a kilometre away

The rockshelter is relatively long and narrow, with maximum measurements of 17m wide, 4.5m deep, and 1.75m high (Figure 8-4). The majority of the rockshelter has a lower roof height, averaging approximately 1.3m, and it slopes down to the south. The estimated ground surface area is 34 square metres. The rockshelter floor slopes considerably from the south to the north. At the south end of the shelter, there is a relatively flat and broad area that is directly behind an accumulation of large slabs of roof collapse. It is this area that was selected for the test excavation. As the rockshelter narrows to the northeast, the surface begins to slope significantly downwards, only flattening out again in the northern-most section of the shelter.

The rockshelter was formed within the MacLeod Member of the Marra Mamba Iron Formation. Its walls exhibit distinct banding that vary between soft and permeable, yellow limonite and harder, dark reddish brown BIF. White precipitated minerals are apparent on the rockshelter walls (likely calcite, gypsum, or halite), and they are particularly concentrated on the limonite bands. The surface of the rockshelter is covered with small and medium-sized, shaly fragments of exfoliated bedrock that have physically weathered from the rockshelter itself. There is evidence of macropod occupation, as demonstrated by scat (both recent and degrading). Unlike many rockshelters investigated at Hope Downs 1, there is only a limited amount of other organic material inside the rockshelter (*e.g.*, leaf litter). This is likely due to the roof collapse blocking the entrance to the shelter.

Most of the rockshelter's entrance is blocked by large slabs of roof collapse, leaving only a narrow and low entryway at the north end of the shelter. The sheer quantity of the rockfall at the front of the shelter attests to the extent of the overhang in the past. At the south end of the shelter, the accumulated blocks of rockfall nearly reach the top of the existing overhang, significantly restricting access to the rockshelter from this side of the site. The height of the roof collapse deposit decreases to the north.



Figure 8-4 Djadjiling rockshelter site plan

For safety reasons, the research team did not excavate near the blocks of roof collapse; however, visual observation suggests that there is only a moderate amount of sediment accumulated around the rocks. While it is difficult to pinpoint the exact timing of the roof collapse, it is likely to have occurred at some time during the early to middle Holocene; this hypothesis is discussed in more detail below. The large mass of rockfall blocking the entrance has undoubtedly protected the deposit within shelter; although, it may made the rockshelter a less favourable site for past Aboriginal occupation as suggested by the sparse Holocene archaeological record.

The gully vegetation consists of open tall acacia shrublands (C3 communities; see Table 1-2) with occasional eucalypts (Mattiske Consulting Pty Ltd 2009). The trees are widely spaced and spinifex grasses are the dominant vegetation. Because of the natural barrier created by the rockfall along the shelter's entrance, no vegetation encroached into rockshelter. Hummock grasslands (S4 communities) occupy the uplands that surround the gully (Mattiske Consulting Pty Ltd 2009).

8.2 SUMMARY OF FIELD INVESTIGATIONS

The salvage of HD07-1A-04 was carried out in five field trips between October 2007 and March 2008. A brief summary of the investigations at Djadjiling are provided below.

A 1-x-1m test unit (Unit 1) was placed near the south rear wall of the shelter. This area was chosen for the placement of the excavation unit because it was surmised that this would contain the deepest depth of deposit based on the shelter's morphology. Despite low numbers of flaked stone artefacts in the upper metre of the deposit, excavation continued and cultural materials were recovered to a depth of 1.5m below surface. In accordance with mine safety procedures, the excavation was halted at this depth. Based on the variety of cultural materials recovered from the excavation and depth of the cultural deposit, HD07-1A-04 was assessed as having high archaeological significance (Law and Cropper 2007). It was recommended that further investigations into the HD07-1A-04 deposit were warranted to determine the age, depth, and extent of the cultural deposit (Law and Cropper 2007).

Two charcoal samples were submitted for radiocarbon dating in order to provide an indication of the antiquity of the occupation of the site. These initial results demonstrated that the occupation at Djadjiling spanned from at least 29,380±212 cal BP (128.5cmbd) to 2858±45 cal BP (27cmbd). These results were viewed as being consistent with other Pleistocene sites in the Hamersley Ranges, including Newman Rockshelter (Brown 1987; Comtesse 2003), Newman Orebody XXIX (Maynard 1980), and Jundaru (Edwards *et al.* 2001: 68); however, Djadjiling held the potential for excavations to reveal even earlier archaeological material, as bedrock had not been reached.

The excavation was expanded to encompass an area of 3-x-1.5m. This involved opening five additional excavation units adjacent to Unit 1, covering approximately 50% of the total surface area within this part of the rockshelter. Units 2 and 4 were placed immediately to the north and south of Unit 1, creating a 3-x-1m trench. A further three 1-x-0.5m units (Units 3, 5, and 6) were positioned along the east margin of this trench. All units were excavated to bedrock.

During the course of the excavations at the site, 1316 artefacts were recovered and ten features were identified. Numerous charcoal samples were collected from these features for radiometric dating.

The excavation trench was backfilled and covered with geotechnical fabric. The entire rockshelter floor was covered to protect the unexcavated deposits from possible future bioturbation (*e.g.*, macropod activity, human disturbance through site visitation and monitoring, *etc.*).



Figure 8-5 End of Trip 2 at Djadjiling rockshelter (D. Wright, D. Cropper, and G. Houghton pictured left to right)

8.3 STRATIGRAPHY

The Djadjiling excavations revealed a deposit over two metres deep (Figure 8-7). Bedrock was exposed across the excavation trench, and it sloped steeply from the north (Unit 3, 130cmbd) to the south (Unit 5, 220cmbd). The accumulation of the rockshelter sediment is strongly linked with the local geology and its formation within the MacLeod Member of the Marra Mamba Iron Formation, which is very shaly and easily eroded (Blockley *et al.* 1993: 54). The majority of the deposit consisted of angular rock fragments produced through physical weathering or exfoliation of the rockshelter roof and walls. The remainder of the deposit was comprised of silt derived through chemical weathering of the bedrock and aeolian deposition. The proportion of exfoliated roof fall and silt varied throughout the layers, but in general, with increased depth, the quantity of rock increased and the deposit had less cohesion.

The primary component of the rockshelter deposit was produced through the spalling of the rockshelter itself, and there are a number of factors that may have influenced the rates of weathering. Cold conditions are known to influence the weathering of bedrock in caves and rockshelters (Farrand 2001: 554; Goldberg and Macphail 2006: 186-187), particularly if temperatures drop below freezing. While freezing temperatures are currently rare in the region, research suggests that in the arid interior of Australia temperatures between 45,000 and 16,000 cal BP were up to 9°C lower that present (Miller *et al.* 1997). However, it remains unlikely that these conditions would have been suitable for there to have been prolonged freezing of water within the bedrock to promote rock fracture. While freeze-thaw processes may not have had a major role in the physical weathering of the BIF rockshelters in the Pilbara, repeated wetting and drying of the bedrock may have been an important factor in the formation of rockshelter deposits. This theory is substantiated by the archaeomagnetic analysis (Herries, this volume), which found that there appears to be different rates of sedimentation during the warm (and wet) and cool (and arid) phases.

Because of its considerable height above the gully base, the rockshelter is not subject to gully flooding, but it does receive some colluvial wash during extreme rainfall events. Moreover, there is clear evidence of groundwater having moved through the deposit. A large storm passed over the mine lease during one field trip, and over 100mm of rain fell in a matter of hours. When the rockshelter was inspected the following morning, water had seeped through the bedrock and through the entire deposit. In addition, a small amount of fresh colluvium was deposited in the southwest corner of the rockshelter, where the bedrock meets the area of roof collapse. Fibrous calcite (Figure 8-6) was present throughout the deposit and was most common in sediment adjacent to bedrock. White precipitate minerals were also observed on the rockshelter walls. The occurrence of these precipitates is most certainly the result of the movement of groundwater through the sediment and the bedrock.

Like all rockshelters investigated at Hope Downs 1, biogenic sediments (derived from plants and animals that occupy the rockshelter; Farrand 2001: 539) were observed at Djadjiling. Decomposing macropod scat was generally restricted to the first two arbitrary layers; although, it was noted up to a maximum depth of 33cmbd. Fine roots extended through the deposit, as deep as 150cmbd. The excavation team identified two white ant nests at considerable depth (Unit 6, 100-115cmbd; and Unit 2, 85-90cmbd). Mud wasp brood chambers were noted up to a maximum depth of 35cmbd. These brood chambers would have been constructed on the roof of the rockshelter and subsequently fell onto the floor surface of the shelter.

Seven stratigraphic layers (SL) were identified at Djadjiling, forming a sequence of strong brown and reddish brown sediments (Figure 8-7; Figure 8-8). The stratigraphic layers were defined by subtle changes in the sediment colour and the matrix composition, which are strongly influenced by the weathering of the different coloured bands of bedrock within the rockshelter. While the Munsell colour notations show only a slight difference amongst the layers, these colour changes were clearly observable in the field, and Figure 8-8 illustrates these distinct colour changes.

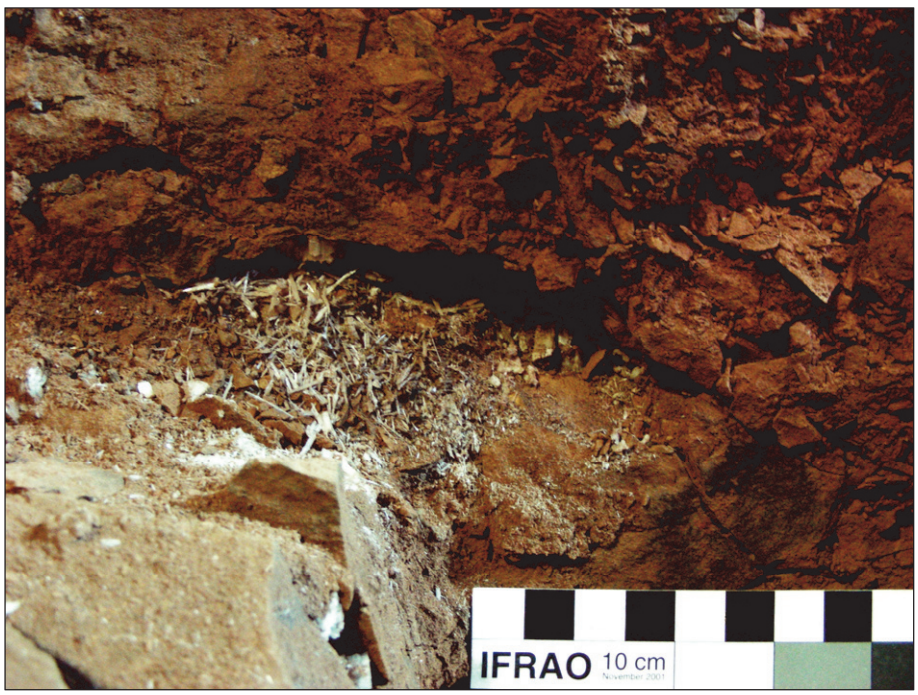

Figure 8-6 Fibrous calcite along the wall of Unit 2 (Layer 12) at Djadjiling rockshelter

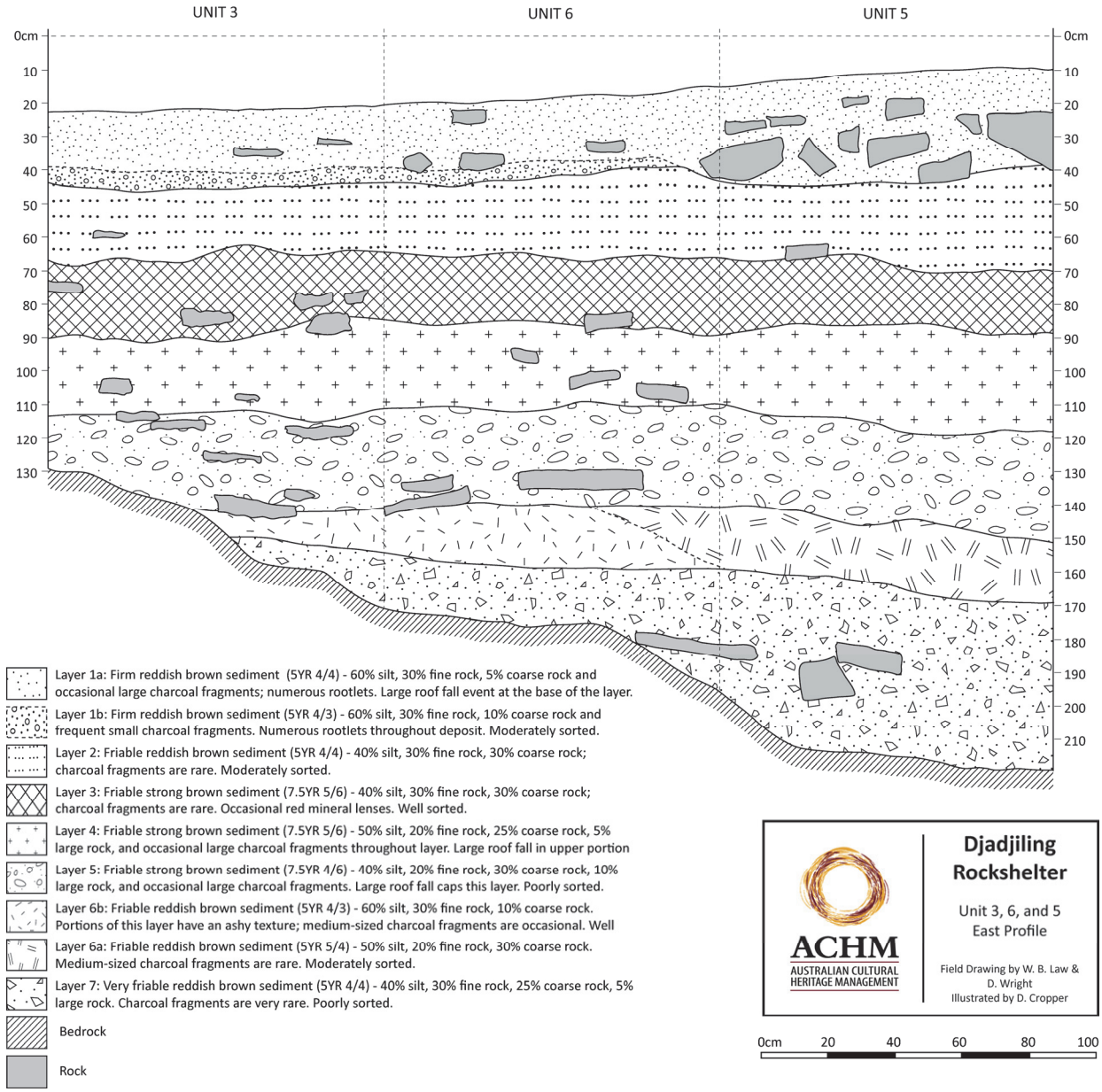

Figure 8-7 East stratigraphic section of Units 3, 5, and 6 at Djadjiling rockshelter

Stratigraphic Layer 7 - SL7 is defined as very loose reddish brown (5YR 4/4) deposit comprised primarily of exfoliated rock (40% silt, 30% fine rock, 25% coarse rock, and 5% large rock). There was little sediment cohesion, and the sediment had a gravelly appearance due to the low proportion of silt. The low proportion of silt in the deposit may be due to water moving through the deposit, slowly removing the finest sediment particles over time. Charcoal fragments were exceptionally rare. In his archaeomagnetic analysis of samples from this layer, Herries (this volume) found that the magnetic susceptibility (MS) results indicated anthropogenically unaltered sediments and a cold climate signal.

Stratigraphic Layer 6 - SL6 is divided into two components: SL6a (50% silt, 20% fine rock, and 30% coarse rock) and SL6b (60% silt, 30% fine rock, and 10% coarse rock). In general, the deposit was loose and reddish brown with slightly more silt than in the underlying SL7. There was a slight colour difference between SL6a (5YR 5/4) and SL6b (5YR 4/3), and this is likely due to the fact that the latter is ashier with occasional medium-sized charcoal fragments. SL6b also had a slightly higher proportion of silt than SL6a. SL6b contained the lowermost feature identified at Djadjiling, Feature 10. At the top of SL6 was a roof collapse event, which marked the transition to SL5 together with a colour and matrix composition change. Herries' (this volume) archaeomagnetic analysis indicates that SL6 has the greatest anthropogenic overprint of the Djadjiling sequence, and he argues that it represents the most intense phase of occupation at the site. Moreover, the data suggests that there was a short warm phase coincident with SL6 (Herries, this volume).

Stratigraphic Layer 5 - SL5 had a strong brown (7.5YR 4/6) colour and the matrix composition is similar to that of SL7. The sediment was loose and gravelly, with a matrix composition of approximately 40% silt, 20% fine rock, 30% coarse rock, and 10% large rock. While charcoal was infrequent, there were occasional large fragments, and Feature 9 was identified within this layer. The archaeomagnetic analysis suggests that during this period there was limited occupation and a return to a cooler climate, which persist through SL3 (Herries, this volume).

Stratigraphic Layer 4 - SL4 consisted of strong brown (7.5YR 5/6) sediment with a matrix composition of approximately 50% silt, 20% fine rock, 25% coarse rock, and 5% large rock. There were occasional large charcoal fragments throughout the deposit, and two hearth features (Features 5 and 8) were identified within this stratigraphic layer. Like SL5, the archaeomagnetic analysis indicated that this deposit accumulated during a cool period, and apart from the two features, there was no evidence of anthropogenically altered deposits (Herries, this volume).

Stratigraphic Layer 3 - SL3 comprised a loose, strong brown (7.5YR 5/8) layer that had a composition of 40% silt, 30% fine rock, and 30% coarse rock. Although Feature 4 was identified at the base of SL3, charcoal fragments were rare throughout the layer. Occasional brightly coloured mineral lenses were noted and are interpreted as *in situ* weathering of exfoliated fragments of the bedrock that happen to have this distinct colouration. When this layer was encountered during the excavation, it was clearly defined by the colour change from reddish brown to strong brown; however, the matrix composition is identical to SL2. The archaeomagnetic analysis demonstrates an increase in anti-ferromagnetic content, which Herries (this volume) interprets as indicative of a change in the weathering of the rockshelter. The data also suggests that the coldest conditions occurred during this phase, and there is no evidence of anthropogenically-altered deposits amongst the arbitrary excavation layers (Herries, this volume).

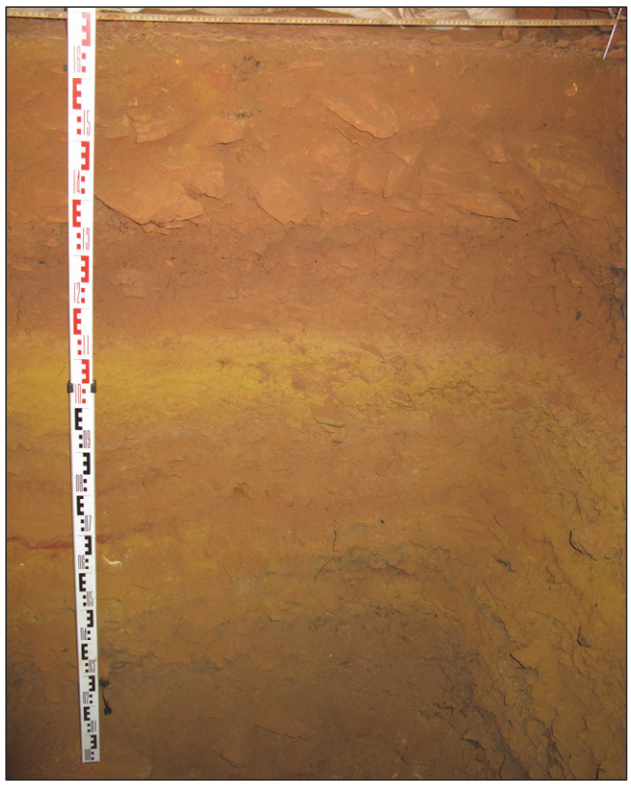

Figure 8-8 Photograph of the east section of Unit 5 at Djadjiling

Stratigraphic Layer 2 - SL2 was easily distinguished by its distinctive reddish brown (5YR 4/4) colour. The deposit was loose and primarily comprised of exfoliated rock (40% silt, 30% fine rock, and 30% coarse rock). Charcoal was rare throughout the matrix, and no hearth features were identified within this layer. At the transition between SL 2 and SL1 there was a roof collapse event. While only medium-sized blocks of roof collapse were identified in the excavated deposits, this event may be contemporaneous with the collapse of the rockshelter overhang. As the contact between SL2 and SL1 has been dated to 7024±73 cal BP, it could indicate an early Holocene date for the overhang collapse. The archaeomagnetic data from this layer show a transition from cold conditions to warm conditions, but there remains little evidence of human alteration of the deposits (Herries, this volume).

Stratigraphic Layer 1 - SL1 is divided into two components: SL1a (60% silt, 25% fine rock, 5% coarse rock, and 10% large rock) and SL1b (60% silt, 30% fine rock, and 10% coarse rock). SL1b was an extensive charcoal-rich lens that has a slightly darker colour (5YR 4/3, reddish brown) than the surrounding SL1a. This lens also had a higher density of fine roots than in the rest of SL1. SL1a differed from the rest of the deposit because of its friable to firm texture, which was largely due to the higher ratio of silt to rock, and perhaps the higher organic content in this layer may have an effect. Fine roots extended through the layer and there were occasional large fragments of charcoal. In comparison to the underlying stratigraphic layers, the greatest number of features was identified in SL1, including Features 1, 2, 3, 6, and 7. The archaeomagnetic analysis shows a return to site use, with evidence of heavy anthropogenic alteration of the sediments during a warm climatic phase (Herries, this volume). Each of the hearth features in this layer has strong MS signals, particularly Feature 7 (Herries, this volume).

8.4 RADIOMETRIC DATES

Fourteen *in situ* charcoal samples were submitted to the University of Waikato Radiocarbon Dating Laboratory in New Zealand for AMS and conventional radiocarbon dating. The samples were selected from features, arbitrary excavation layers, and key stratigraphic changes. The radiocarbon results listed in Table 8-1 provide a temporal framework for the archaeological sequence and reveal that the site was first occupied approximately 41,000 years ago. The radiocarbon results have also been published elsewhere (see Law *et al.* 2009).

To determine the onset of sediment accumulation in the rockshelter, two basal charcoal samples were dated from SL7. Samples Wk-23314 (28,461±223 BP) and Wk-23315 (33,584±410 BP) were collected at depths of 170.5 and 193cmbd. These samples were not associated with cultural material, and they were collected more than 10cm and 30cm below the earliest cultural layer respectively. These ages do not fit conformably in the chronological sequence and are argued by the authors to be anomalous (see also Law *et al.* 2009). The most likely explanation for these anomalous dates is that younger charcoal fell into the trench from exposed section walls during excavation, and it was not recognized as intrusive. As discussed above, the sediment in SL7 is extremely loose, as it is largely composed of exfoliated rock with a very low proportion of fine sediment. Due to the lack of sediment cohesion, it is reasonable that a piece of charcoal could have fallen in and not be recognized as intrusive.

Three dates offer stratigraphically sound ages for SL6, indicating an age of approximately 41,000 to 40,000 cal BP. The base of the layer is dated by charcoal samples Wk-23313 (40,911±580 cal BP) and Wk-23312 (40,546±615 cal BP). Wk-23313 was determined on a charcoal sample collected *in situ* from an arbitrary excavation layer context, while the charcoal sample submitted for Wk-23312 was recovered from a small hearth feature (Feature 10). A third date, Wk-22787 (40,267±642 cal BP), provides an age estimate for the middle of SL6, and this sample was also collected from an arbitrary

excavation layer. While the contact between SL6 and SL5 has not been directly dated, it is estimated to date between approximately 38,500 and 39,500 years ago based on an age-depth curve.

Charcoal samples bracketing the middle and upper limit of SL5 date to approximately 30,000 years ago (Wk-23311 and Wk-22786). Samples Wk-23311 (30,377±235 cal BP) and Wk-22786 (29,380±212 cal BP) were collected *in situ* from arbitrary excavation layer contexts at depths of 117cmbd and 128.5cmbd. The authors acknowledge that there is a slight inversion between these dates; however, we believe that the inversion is negligible in the reconstruction of the past occupation of the site. In this circumstance, two different radiocarbon dating methods were used to process the samples, and it is possible that this may have affected the results as even a small amount of modern contamination can significantly alter older age estimates. AMS pre-treatment is more rigorous than standard radiometric pre-treatment and therefore, removes more of the modern contamination (Petchey 2008, pers. com., 2 July). It is also possible that bioturbation (*e.g.*, kangaroo pads or human activity) could have caused minor disturbed the deposit, mixing the charcoal from different layers. Other post-depositional disturbances, such as large slabs of rock falling from the roof of the shelter, may have caused some minor mixing of the deposit.

Three charcoal samples (Wk-23310, Wk-23309, and Wk-23308) near the contact of SL3 and SL4 were submitted for radiocarbon dating, which produced dates between 23,624±161 and 23,820±185 cal BP. Together with the upper age of SL5, these results indicate that SL4 was deposited between approximately 30,000 and 24,000 years ago. Two of these samples, Wk-23308 (19,943±84 BP) and Wk-23309 (19,949±84 BP), were collected from features, and one sample, Wk-23310 (19,757±83 BP), was collected from an arbitrary layer context. Stratigraphically, samples Wk-23308 and Wk-23309 are above Wk-23310 and should therefore be younger; thus, there is an inversion with these samples. Although there are slight statistical differences between these dates at one standard deviation, they do not represent a discrepancy because all three age estimates overlap at two standard deviations (Petchey 2008, pers. com., 2 July). A further consideration for this inconsistency is the inbuilt age of wood; long-lived trees can add hundreds of years to a sample; for example, mulga can live up to 250 years (Crisp 1978). In addition, mulga can stand dead for up to 75 years, and even when the tree has fallen, the wood can persist for another 60 years (Sinclair 2004). Unfortunately, macrobotanical identification of the samples was not undertaken prior to submitting the samples for dating.

Near the midpoint of SL3, a radiocarbon determination of 21,436±126 cal BP (Wk-22785) was obtained. The close spatial relationship of samples Wk-22785 and Wk-23308 suggest that there was extremely low sedimentation during this period, or it could indicate a zone of mixing in the deposit. The upper boundary of SL3 was not directly dated, but it is estimated to be approximately 16,500 cal BP based on an age-depth curve.

SL2 represents the transition from the terminal Pleistocene to the early Holocene at Djadjiling. As discussed above, the lower boundary of this layer is estimated to date to approximately 16,500 cal BP. A charcoal sample collected from the midpoint of SL2 yielded an age of 14,907±214 cal BP (12,621±63 BP, Wk-23307). The transition between SL2 and SL1 dates to 7024±73 cal BP (6130±38 BP, Wk-23306), indicating an early Holocene stratigraphic change during which there is an episode of roof collapse.

When the dates from SL6 through SL1 are plotted on an age-depth curve, they are closely clustered to the trend line, suggesting relatively constant sediment accumulation over time. The exception to this rule is Wk-23307, which deviates from the trend and shows that there was low deposition from the beginning of SL3 (*ca.* 23,820±185 to 23,624±161 cal BP) to 14,907±214 cal BP. The low deposition rates, which correspond to the peak of the LGM, may be attributed to the hyperarid conditions that have been demonstrated for this period (see Section 1.2). If the physical weathering of the rockshelter is related to cyclical wetting and drying, then during the hyperarid conditions of the LGM there would be fewer times when the rockshelter was subject to saturation.

Table 8-1 AMS and radiocarbon results, Djadjiling rockshelter

Lab Code	Sample No.	Material	Context	Strat. Layer	Depth (cmbd)	Depth (cmbs)	$\delta^{13}C$	^{14}C Age (BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-22784*	c-06	Charcoal	U1-QC-F02	1a	27	14.5	-23.4±0.2	2766±32	2946 to 2784	2858±45
Wk-23306	c-161	Charcoal	U6-QB-L06	1b	43	29	-24.6±0.2	6130±38	7160 to 6912	7024±73
Wk-23307	c-229	Charcoal	U6-QB-L09	2	58	40	-24.4±0.2	12,621±63	15,222 to 14,256	14,907±214
Wk-22785	c-20	Charcoal	U1-QA-L19	3	83	70.5	-23.6±0.2	17,975±72	21,705 to 21,172	21,436±126
Wk-23308	c-101	Charcoal	U4-QB-F4	3	83-85	75	-22.1±0.2	19,943±84	24,208 to 23,450	23,813±184
Wk-23309	c-112	Charcoal	U4-QD-F5	4	88-96	80	-23.6±0.2	19,949±84	24,216 to 23,457	23,820±185
Wk-23310	c-231	Charcoal	U6-QA-L16	4	94	77.5	-22.0±0.2	19,757±83	23,921 to 23,301	23,624±161
Wk-23311	c-183	Charcoal	U5-QB-L22	5	117	104	-21.6±0.2	25,519±154	30,786 to 29,693	30,377±235
Wk-22786*	c-35	Charcoal	U1-QD-L26	5	128.5	112.5	-22.1±0.2	24,522±129	29,696 to 28,615	29,380±212
Wk-22787	c-44	Charcoal	U1-QA-L30	6a	148	137	-22.0±0.2	35,159±537	41,365 to 38,955	40,267±642
Wk-23312	c-221	Charcoal	U6-QA-F10	6b	157	142.5	-23.3±0.2	35,396±518	41,576 to 39,189	40,546±615
Wk-23313	c-234	Charcoal	U5-QB-L30	6a	159	145	-22.8±0.2	35,753±546	41,901 to 39,548	40,911±580
Wk-23314	c-224	Charcoal	U5-QB-L33	7	170.5	158.5	-23.2±0.2	28,461±223	33,451 to 31,932	32,815±402
Wk-23315	c-225	Charcoal	U4-QA-L39	7	193	180.5	-23.0±0.2	33,584±410	39,442 to 37,017	38,317±604
Note: * denotes conventional method; all other dates are AMS										

The summer monsoon was re-initiated approximately 14,000 years ago (Wyrwoll and Miller 2001: 127), and this corresponds with an increase in sedimentation rates between 14,907±214 cal BP and 7024±73 cal BP, the latter date marking the transition between SL2 and SL1. Significantly, this age also provides an estimate of the roof collapse event at the base of SL1. This event coincides with a peak in precipitation between 7000 and 6000 years ago (Quigley *et al.* 2010: 1093), and it is possible that the large accumulation of roof collapse at the entrance of the rockshelter dates to this period.

The uppermost age of 2858±45 cal BP (Wk-22784) was determined for a sample selected from near the midpoint of SL1, 27cmbd or approximately 14.5cmbs. The sample was collected *in situ* from Feature 2, a well-preserved late Holocene hearth. A large heat-shattered blade was recovered *in situ* resting on top of this feature, implying that this recent feature is relatively undisturbed.

8.5 COMBUSTION FEATURES

Ten combustion features were identified during the HD07-1A-04 excavation. In the following section, the features are described in order from oldest to most recent, and they are grouped according to those identified in the Pleistocene layers and those in the Holocene layers (Table 8-2). The distribution of the features is illustrated in Figure 8-9 and Figure 8-10. The dimensions of the features are discussed in terms of width, which is analogous to the x-axis of the excavation unit (*i.e.*, north-south at Djadjiling), and length, corresponding to the y-axis of the excavation unit (*i.e.*, east-west).

Pleistocene Features

Feature 10 - Feature 10 was the lowermost feature identified at Djadjiling, dating to 40,546±615 cal BP; it was the only feature identified in SL6. The feature was defined on the basis of a colour change and the concentration of small charcoal fragments. The sediment within the feature was considerably darker (5YR 2.5/2, dark reddish brown) than the sediment in the adjacent arbitrary layer (5YR 3/4, dark reddish brown). The feature is classified as a charcoal lens, as reddened sediment was not observed beneath the charcoal concentration. The feature was identified in Unit 6 Quad A and appears to have extended into Unit 1; however, it was not identified in Unit 1, possibly due to poor lighting conditions during the initial excavation of the 1-x-1m unit. Due to its plano-convex cross section, the maximum depth range of the feature was near its centre, where it ranged from 155 to 161cmbd. Herries (this volume) found that the MS susceptibility values for Feature 10 were not that dissimilar to the surrounding sediment because of the high degree of anthropogenic alteration of the entire layer and the signal caused by the warm climate phase.

Feature 9 - Feature 9 was a sub-circular hearth feature that consisted of a dense concentration of charcoal, 130 to 134cmbd. The feature rests within SL5, and during the excavation, it was identified within Quads A and B of Unit 5 and was excavated as Layer 24.1. The feature was small, measuring 25-x-30cm, and had a lenticular cross section, which reached maximum thickness at the centre (4cm). The underlying sediment and rocks were reddened, demonstrating *in situ* heating. A retouched brown shale flake was recovered from the feature matrix. This feature is the least distinguishable from the surrounding sediment by its magnetic susceptibility results (Herries, this volume), suggesting that it was a small, single-use hearth.

Feature 8 - Feature 8 occurred within SL4. It was a small circular hearth feature that was first observed during the excavation of Layer 20 of Unit 6. Excavated as Layer 20.1, the feature rested in Quad A and it appeared to have extended slightly into Unit 1, where it was not detected. Like Feature 10, this feature was likely missed in Unit 1 due to the difficult excavation conditions during the initial testing of the site. The feature was defined by a concentration of charcoal over reddened sediment. As the feature had a lenticular cross-section, its maximum extent is near the centre of the feature where its depth ranges from 113.5 to 118cmbd. The maximum dimensions of the feature as it was excavated are 26cm wide and 25cm long.

Feature 5 - Feature 5 was a medium-sized charcoal-rich hearth that was recorded in SL4 (Layers U4-L18.1, U5-L16.1, and U6-L15.1), just below the transition to SL3. The feature had a circular plan with maximum dimensions of 55-x-52cm. The feature was excavated in Units 4, 5, and 6 and its plan suggests that it would have extended into Unit 1; however, the feature was not identified in this unit. This feature may not have been identified in Unit 1 because of the poor lighting conditions. It is also possible that the feature was partially disturbed by large pieces of roof collapse, which were recorded in the corresponding layer of Unit 1.

Table 8-2 Combustion features presented from oldest to youngest, Djadjiling rockshelter

Feature Number	Feature Type	Excavation Unit(s)	AU	Max Depth Range (cmbd)	pH	Median Calibrated Age (cal BP)	Comments
10	Charcoal Lens	6, 1*	6	155-161	4.5	40,546±615	Oldest dated feature at Hope Downs 1
9	Hearth	5	5	130-134	4.5		
8	Hearth	6, 1*	4	113.5-118	4.5		
5	Hearth	1*, 4, 5, 6	4	90-98	4.5	23,820±185	
4	Hearth	1*, 4	3	81-84	4.5	23,813±184	
3	Hearth	1	1	26-32	5		
2	Hearth	1, 4, 6	1	22-37	5-7	2858±45	Possible pit-hearth; heat-shattered retouched blade on top of feature
1	Hearth	1	1	21-25.5	5		
6	Hearth	5, 4*, 6*	1	15-22	6		
7	Hearth	5, 4*	1	11-13	8.5-9		
* the feature likely would have extended slightly into the unit, but was not detected during excavation							

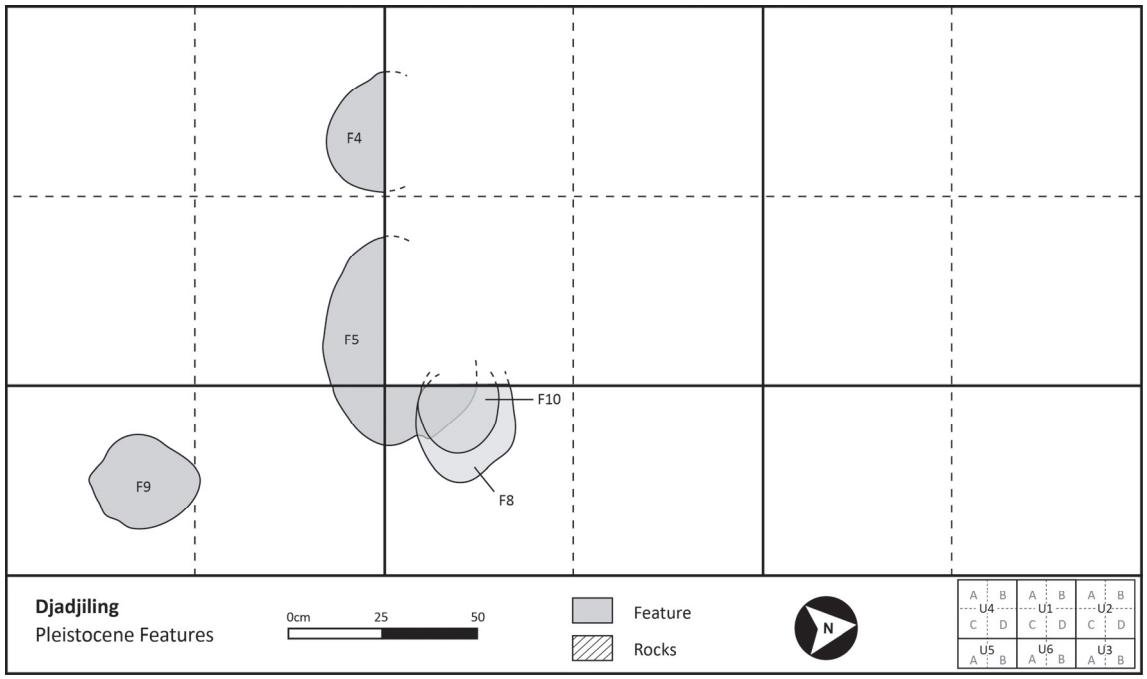

Figure 8-9 Distribution of Pleistocene combustion features at Djadjiling rockshelter

The excavation team identified the feature on the basis of a colour change and a high concentration of charcoal. The feature matrix was comprised of dark brown silt, small and coarse fragments of rock fall, and charcoal. The sediment and rocks underlying the feature showed evidence of being heat affected, both bearing a deep red colour. The feature had a lenticular cross-section, and as a result, the maximum depth range was recorded near the centre of the feature, measuring from 88 to 98cmbd. The upper levels of the edge of the feature ranged from 89cmbd along the northwest to 92cmbd along the southeast side, while lower levels of edge ranged from 92 to 93cmbd. The elevations suggest that Feature 5 should be slightly older than Feature 4, and this is supported by an AMS age estimate that dates the feature to 23,820±185 cal BP (WK 23309). One flaked piece was recovered from the feature matrix.

Feature 4 - Feature 4 was a small hearth identified in SL3 and recorded as Layer 17.1 in Unit 4. The matrix of the feature consisted of reddish brown ashy silt, coarse and fine rock, and charcoal. The excavator noted burned or reddened sediment and heat-affected rock at the base of the feature. The upper extent of this feature was difficult to define, as there was only a subtle change in the colour and amount of charcoal from the overlying and surrounding Layer 17, which had a strong brown (7.5YR 5/8) colour. Despite this, archaeomagnetic analysis of a sediment sample from this feature demonstrated that it 'is by far the most prominent and most magnetically enhanced deposit in the rockshelter' (Herries, this volume). Herries (this volume) notes that there is a lack of a background anthropogenic signal in the surrounding sediments. This suggests that throughout SL3, the rockshelter was seldom used.

The excavation of the feature in Unit 4 suggests that it would have extended into Unit 1. While excavating Layers 18 and 19 in Unit 1, a high proportion of charcoal and heat-affected rock was noted in Quadrant A, but it did not appear to have defined limits. This may be due to the lack of clarity of the upper bounds of the feature, combined with poor lighting conditions while excavating Unit 1. It is estimated that half of the feature was revealed in Unit 4, where it was observed to have semi-circular plan (32-x-15cm) and a lenticular cross section. Due to the lenticular cross-section, the maximum thickness of the feature is near the middle (81-84cmbd), while around the margins, the upper edge of the feature measured 83cmbd and the lower edge ranged from 83.5 to 85cmbd.

A charcoal sample (c-101) recovered *in situ* from the base of the feature was submitted for an AMS age estimate, and the results indicate that Feature 4 dates to 23,813±184 cal BP (Wk-23308). This date confirms the stratigraphic relationship identified during the excavation that Feature 4 represents a more recent period of Aboriginal occupation at Djadjiling, than Feature 5. Together, these two features demonstrate that around 24,000 years ago, there was intermittent occupation of the rockshelter, but there is a subsequent decline in site use, with the next feature dating to the late Holocene.

Holocene Features

The transition from the terminal Pleistocene to the Holocene occurred during SL2, but no archaeological features were identified dating to this phase of site occupation. The archaeomagnetic data indicates that the SL2 deposits were relatively unaltered (Herries, this volume), further supporting the lack of burning events during this time period. Only late Holocene features were identified in SL1, and they only occur stratigraphically above a phase of significant roof collapse. Archaeomagnetic analysis of the features demonstrate that they all have strong MS signatures that stand out from the surrounding background sediment (Herries, this volume).

Feature 3 - Feature 3 was a small circular charcoal-rich lens that was identified just as the excavation of Unit 1, Layer 6 began. The excavator defined the outline of the feature by removing the overlying sediment, and then it was excavated in section as a separate layer (U1-L7). The maximum extent of the feature measured 28-x-28cm with a maximum thickness of 6cm. The feature had a lenticular cross-section, and its upper levels ranged between 26 and 27cmbd. The maximum depth was recorded at the centre of the feature (32cmbd).

The matrix of the feature was comprised of fine red (10R 4/8) silt, heat-fractured rock, and charcoal; the sediment had a pH value of 5. At the base of the feature, the excavator observed

reddened sediment and heat-fractured rock. The feature was clearly separated from the surrounding and overlying yellowish red sediment on the basis of colour and the concentration of charcoal. The wood charcoals represented in this feature showed a different composition to the other hearth features at Djadjiling, with mulga only comprising a very small proportion of the assemblage (Fairbairn 2012). Gum and Myrtaceae appear to have been the predominant fuel source for this hearth (Fairbairn 2012).

Despite the fact that the top of Feature 3 had slightly lower elevations than the top of Feature 2, the exact relationship of these features is difficult to determine without radiocarbon dates from the Feature 3. Feature 2 began slightly above Feature 3, but its depth extended beyond that of Feature 3. Moreover, the modern surface of Unit 1 sloped, with a maximum difference of 7.5cm between the southeast corner and the northwest corner. It is reasonable to assume that in the past, the surface of the rockshelter sloped slightly. Therefore, the authors believe that Features 3 and 2 were likely contemporaneous or separated by only a short period of time. Feature 3 was quite an ephemeral event in comparison to large and well-defined Feature 2 hearth. The different natures of these two features may indicate that they had different functions.

Feature 3 occupied a similar spatial extent as Feature 1, but the stratigraphic relationship demonstrates that it was used prior to Feature 1. The excavation team found that the two features were separated by a layer of yellowish red sediment (U1-L6) that ranged in thickness from 0.5cm to 3cm.

Feature 2 - Feature 2 was a large hearth that extended over three units: Unit 1, Unit 4, and Unit 6 (Figure 8-11; see also Figure 8-5). The feature was first identified in Unit 1, where it was excavated in two layers (U1-L5 and U1-L9). The excavation of the feature in Unit 1 was complex, as the edge was difficult to delineate in the south corner of Unit 1. It is possible that this area was disturbed, either during the use of the hearth (*e.g.,* pit hearth) or after it was abandoned (*e.g.*, kangaroo pad), as there was a significant dip in the feature and the edge was less defined. Upon further excavation of Unit 1, the southern extent of the feature was clarified, showing that the feature continued into both Units 4 and 6.

The feature matrix consisted of very dark grey ashy sediment with abundant large and medium-sized fragments of charcoal. Burned rock was observed within the feature, and the sediment underlying the feature also exhibited evidence of thermal alteration (reddened) and appeared to be more consolidated than sediment in the surrounding arbitrary layers.

The shape of the feature is best described being sub-oval to irregular, with maximum dimensions of 54-x-113cm. Another unusual characteristic of Feature 2 is that the top of the feature sloped down to the east, with the upper levels ranging from 22cmbd in the west to 25cmbd in the east. The maximum depth of the feature (37cmbd) was recorded in Unit 6 near its east extent. The top of the feature was relatively flat, while the base of the feature was rounded, giving it a plano-convex cross-section (Figure 8-11).

The irregular shape may be the result of re-use of the hearth or post-depositional disturbance, but it is most likely that this disturbance was related to use of the feature. The size and depth of the feature suggest that it is an ash pit cooking feature. The disturbance may be the result of moving the ashes while inserting and removing the food item. Unfortunately, no faunal remains were recovered in the feature or in the surrounding arbitrary excavation layers.

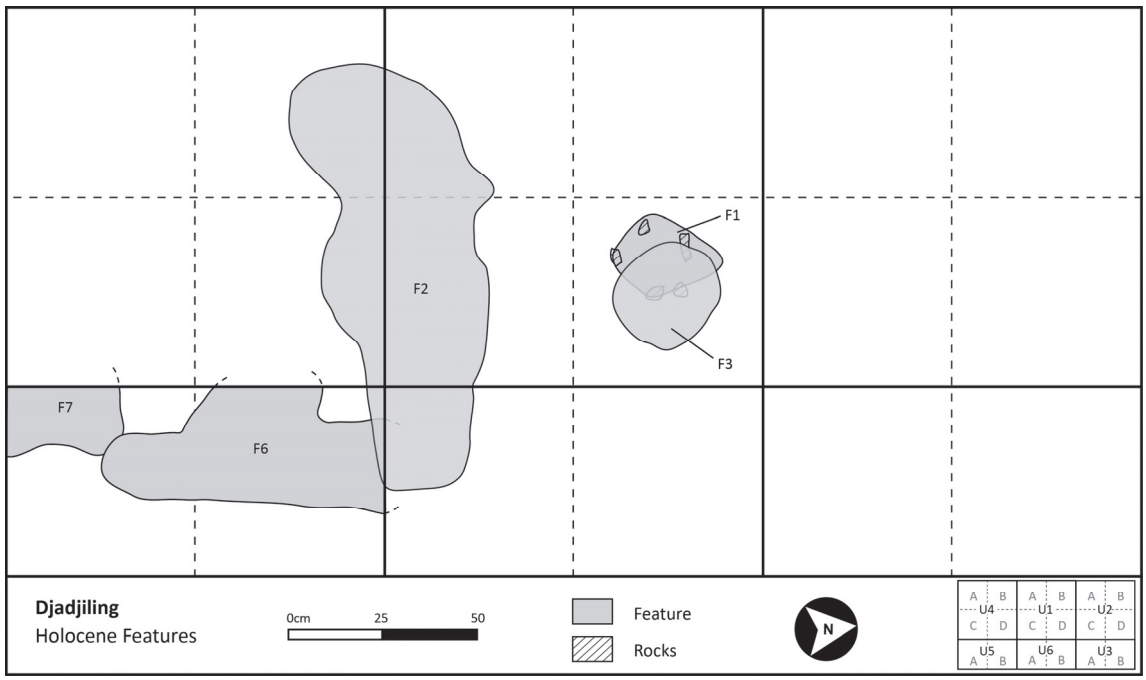

Figure 8-10 Distribution of Holocene combustion features at Djadjiling rockshelter



Figure 8-11 Photograph of Feature 2 cross-section in the south wall of Unit 1, Djadjiling rockshelter



Figure 8-12 Conjoined Artefact 10, recovered *in situ* above Feature 2, Djadjiling rockshelter

A charcoal sample recovered from the hearth was submitted for conventional radiocarbon dating, and it demonstrates that the feature was utilised during the late Holocene, approximately 2858±45 cal BP. In Unit 4, a number of flat-lying heat-shattered artefact fragments were uncovered *in situ* immediately above the feature (21-22cmbd, U4-L3). These artefact fragments conjoin to form a large retouched blade (Artefact 10, Figure 8-12), which must have been discarded while the hearth was still hot. Usewear analysis of this artefact suggests that it may have been used to cut and scrape soft tissue, such as skin or flesh (Fullagar 2013). Three flakes were recovered from the feature matrix itself (Artefacts 11, 1102, and 1103), and each was produced from a different raw material type.

Feature 1 - Feature 1 was a small ovoid-shaped hearth was identified in Unit 1 when excavating the arbitrary Layer 3 (20-25cmbd). Once the extent of the feature was defined, the feature was carefully excavated in section and recorded as a separate layer (U1-L4). The matrix of the feature was comprised of fine-grained ashy sediment and numerous small fragments of roof collapse. While there was little change in the colour of the feature from the surrounding brown soil, the matrix of the feature had a high proportion of charcoal. At the base of the feature there were several heat-affected rocks. The small hearth had maximum dimensions of 20-x-25cm, and it had a bowl-shaped or plano-convex cross-section. The top of the feature was identified at 21cmbd and the base ranged from 24.5 to 25.5cmbd. The location of Feature 1 was very similar to that of the underlying Feature 3; however, the two features were clearly separated by a thin layer (0.5-1.5cm) of brown sediment with no charcoal. The relative elevations and stratigraphic relationships demonstrate Feature 1 to be younger than Features 2 and 3.

Feature 6 - Feature 6 was a dense concentration of charcoal over reddened sediment with a very thin layer of white ashy sediment atop the dark grey charcoal layer. The feature was first encountered at 15cmbd within Layer 1 of Unit 5, and it was excavated as two separate contexts (L1.2 – upper F6 and L1.3 – Lower F6) because it extended into Layer 2. The maximum depth of the feature was 22cmbd. Within the feature there were large fragments of charcoal that increased in number with depth.

While most features have roughly circular or oval shapes, this feature was unique as it had a linear form that extended through the middle of Quads A and B. The feature was not detected in the adjacent Unit 6, as it was only present as a small ephemeral pocket of charcoal at the edge of the excavation unit, and it did not extend across the unit. When it was first encountered in Unit 5, the feature's shape was sub-oval and the charcoal was

concentrated near the centre of the east extent of Quad B. However, as the excavators uncovered the feature, the charcoal concentration shifted towards the middle of Quads A and B, taking on a linear shape that measured 26-x-75cm. Through the main concentration of the feature, the cross-section was lens-shaped.

The unusual shape of the features led the excavators to hypothesize that it may have been a burned log, and the 'dog-leg' identified at the top of the feature may be a smaller branch coming off the larger branch. The reddened sediment beneath the feature demonstrates *in situ* burning; however, this feature is clearly different to other hearth features identified at Djadjiling, and this initially raised the possibility that it was not a cultural feature. One theory is that the branch may have fallen into the rockshelter and was subsequently burned during a bushfire. However, due to the nature of the rockshelter's entrance and overhang, it is unlikely that this branch would have fallen into or have been transported into the rockshelter by natural means. Moreover, while bushfires are prevalent in the surrounding area, the large blocks of roof collapse almost entirely seal the entrance to the rockshelter making it implausible that this branch caught on fire during a natural bushfire. It is therefore most likely that this feature does represent past human activity in the rockshelter and should be regarded as a hearth feature. This interpretation is also supported by the macrobotanical analysis, which found that a range of woody plants are represented amongst the charcoal (*e.g.*, mulga, wattle, gum, and Myrtaceae; Fairbairn, this volume). An indeterminate wood charcoal type was also identified, and it comprises a significant proportion of the sample (Fairbairn 2012). Apart from Feature 6, this unidentified wood type was only identified Feature 10, which occurs in the earliest occupation of the site (Fairbairn 2012).

Feature 7 - Feature 7 was the uppermost and youngest hearth feature identified at Djadjiling. The feature was first detected while excavating Layer 1 of Unit 5 (Quad A), and after delineating its edges, it was excavated as Layer 1.1. The feature had an irregular ovoid shape, measuring 19-x-21cm, but its full extent could not be determined as it extends in to the south baulk as well as into Unit 4, where it was not detected. The layered feature consisted of a thin upper layer of light grey ashy sediment that overlies a charcoal-rich layer. Reddened sediment was identified beneath the feature, demonstrating *in situ* burning. The feature had a lenticular cross-section that reaches its maximum thickness (2cm) in the southeast corner of Quad A, which appeared to be near the centre of the feature. The feature was identified is just below the surface (11-12cmbd) and it extended to 13cmbd.

The archaeomagnetic analysis of a sediment sample from this feature identified a particularly high MS value, greater than all of the other Holocene features (Herries, this volume). It is unclear why the MS values of this feature stand out, especially when compared with Feature 2. One possible explanation is that this the only feature identified at Djadjiling that retained a layered appearance (in contrast, many of the PAD 3 features exhibited this quality), which may indicate it is extremely well-preserved with very limited or no mixture with the background sediment.

8.6 ARTEFACT ANALYSIS

A moderate assemblage of flaked stone artefacts was recovered during the excavation at Djadjiling, and it demonstrates that the rockshelter was intermittently occupied over the past 41,000 years. The assemblage includes 1314 flaked stone artefacts, one manuport, and a grindstone. Each artefact was subject to a full technological analysis using the methodology outlined in Chapter 4. The assemblage is divided into analytical units, which enable comparisons of the data over time.

Division of Analytical Units

In order to facilitate discussion of the analytical results from the Djadjiling excavations, seven analytical units (AU) have been defined, largely on the stratigraphic layers. Revision of these boundaries was necessary in order to marry the stratigraphic changes with the arbitrary excavation layers and features, and each analytical unit is clearly defined below. Mean calibrated radiocarbon dates and age estimates based on age-depth curves provide a temporal framework for the analytical units and the associated material culture.

Analytical Unit 7 – AU7 generally corresponds to SL7 and encompasses all arbitrary excavation layers beginning from the exposed bedrock at the base of the trench (maximum depth 220cmbd) through to 165cmbd. The initiation of sedimentation could not be established, but AU7 terminates between 40,546±615 and 40,911±580 cal BP.

Analytical Unit 6 – AU6 represents the earliest evidence of site occupation at Djadjiling, which occurs between 165cmbd and 140cmbd and correlates approximately to SL6. The lower boundary of this analytical unit dates between 40,546±615 and 40,911±580 cal BP, while the upper boundary is slightly more difficult to establish. While SL6 dips slightly towards the north, the upper boundary of AU6 was established as 140cmbd, as this includes the majority of the stratigraphic layer. Based on an age-depth curve of the mean calibrated dates, it is estimated that the upper boundary of AU6 is approximately 38,000 cal BP. AU6 is estimated to cover a maximum time span of 2911 years.

Analytical Unit 5 – AU5 includes all arbitrary layers between 140 and 115cmbd, encompassing Feature 9. This analytical unit is roughly analogous to SL5. The lower boundary is estimated to be approximately 38,000 cal BP, and the age of the upper boundary is slightly later than the charcoal the mean calibrated date of 30,377±235 cal BP. Using these ages, it is estimated that AU5 was deposited over a maximum period of 7623 years.

Analytical Unit 4 – AU4 generally equivalent with SL4, and it ranges in depth between 115 and 90cmbd. The lower boundary of the analytical unit is likely slightly later than 30,377±235 cal BP. The upper of the boundary of the layer dates to between 23,813±184 and 23,624±161 cal BP. AU4 is estimated to cover a maximum time span of approximately 6753 years.

Analytical Unit 3 – Beginning at a depth of 90cmbd and continuing until 70cmbd, AU3 is comparable to SL3. The lower of the boundary of the layer dates to between 23,813±184 and 23,624±161 cal BP, coincident with the onset of the peak of the LGM. While the upper boundary of this layer has not been directly dated, it is estimated to be approximately 16,500 cal BP based on an age-depth curve. This suggests that AU3 was deposited over a maximum period of 7313 years.

Analytical Unit 2 – AU2 is comparable with SL2, and it ranges in depth between 70 and 40cmbd. The lower boundary is approximately dated to 16,500 cal BP, with a date of 14,907±214 cal BP determined for a sample collected near the midpoint of this layer (58cmbd). The upper limit of the layer is dated to 7024±73 cal BP. AU2 spans a maximum period of 9476 years, covering an important transitional period through

the end of the LGM and the terminal Pleistocene, and into the early Holocene.

Analytical Unit 1 – AU1 represents the last phase of occupation at Djadjiling rockshelter, which is generally equivalent to SL1. AU1 is defined as encompassing all of the arbitrary layers and features between 40cmbd and the surface. The transition between AU2 and AU1 is dated to 7024±73 cal BP, and this date also provides a temporal marker for a roof collapse event at the beginning of this analytical unit. A date of 2858±45 cal BP was determined near the midpoint of the analytical unit, and considering the typical rates of sediment deposition and that two artefacts were identified on the surface of the rockshelter, it is reasonable to assume that the site was last utilized in the last several hundred years. The maximum duration of AU1 is estimated to be approximately 7024 years.

Artefact Distribution

The distribution of stone artefacts recovered from Djadjiling by analytical unit is presented in Table 8-3, and the frequency of artefact discard by each excavation layer is illustrated in Figure 8-13. In total, 1316 artefacts were recovered from the excavation, including one grindstone fragment collected from the rockshelter surface that was not within the excavation area.

Table 8-3 Artefact distribution by analytical unit, Djadjiling rockshelter

Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diagnostic Artefacts	*0*	*0*	*100*	*76.92*	*129*	*84.87*	*48*	*60.00*	*99*	*64.71*	*100*	*73.53*	*402*	*60.54*	*878*	*66.79*
Core	0	0	2	1.54	3	1.97	0	0.00	2	1.31	4	2.94	6	0.90	17	1.29
Flake	0	0	87	66.92	93	61.18	40	50.00	82	53.59	56	41.18	337	50.75	695	52.81
Retouched / Utilised Flake	0	0	11	8.46	33	21.71	8	10.00	15	9.80	40	29.41	59	8.89	166	12.61
Grindstone	1	100	0	0	0	0	0	0	0	0	0	0	0	0	1	0.08
Non-Diagnostic Artefacts	*0*	*0*	*30*	*23.08*	*23*	*15.13*	*32*	*40.00*	*54*	*35.29*	*36*	*26.47*	*262*	*39.46*	*437*	*33.21*
Flaked Piece	0	0	19	14.62	11	7.24	17	21.25	26	16.99	26	19.12	231	34.79	330	25.08
Heat Shatter & Potlid	0	0	11	8.46	12	7.89	15	18.75	28	18.30	9	6.62	31	4.67	106	8.05
Manuport	0	0	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	0	0.00	1	0.08
Total	**1**	**100**	**130**	**100**	**152**	**100**	**80**	**100**	**153**	**100**	**136**	**100**	**664**	**100**	**1316**	**100**

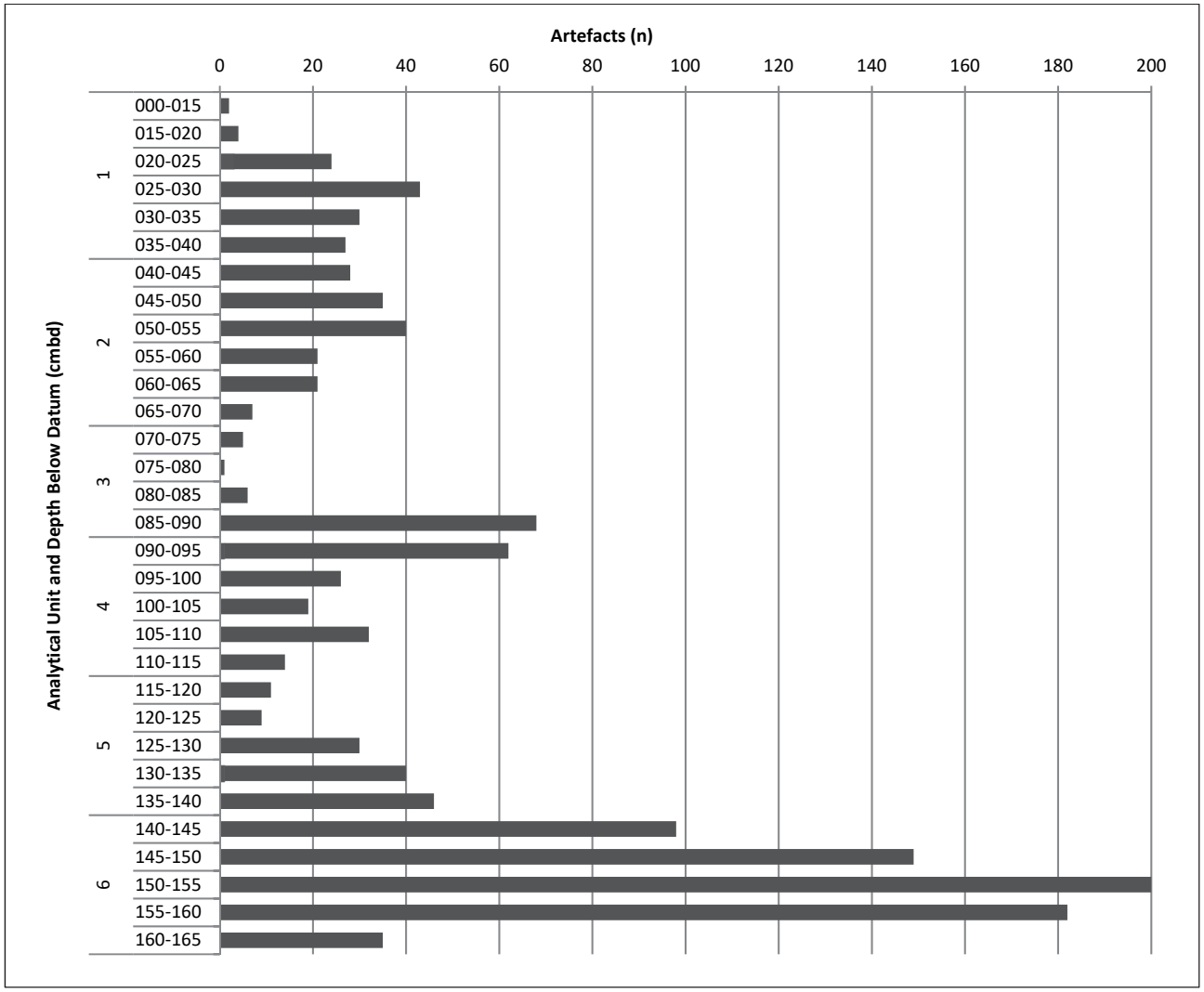

Figure 8-13 Artefact distribution by analytical unit, Djadjiling rockshelter

The following sections discuss the division of the assemblage into diagnostic and non-diagnostic groups and examine the distribution of the excavated artefact assemblage by analytical unit. It has been organised in this manner to characterise the nature of the assemblage throughout time.

Table 8-3 divides the assemblage into diagnostic and non-diagnostic artefact groups. The Djadjiling assemblage is comprised of 66.79% diagnostic artefacts and a third of the assemblage is made up of non-diagnostic artefacts. The proportion of non-diagnostic artefacts is very high and there is a greater frequency than in any other large excavated assemblages from Hope Downs 1. The proportion of non-diagnostic artefacts is highest at Djadjiling through AU3 to AU6. In AU3 and AU4, there are fairly equal proportions of flaked pieces and heat shatter, but in the lower analytical units (and particularly in AU6), the non-diagnostic artefacts are dominated by flaked pieces. The increased proportion of flaked pieces in the lower occupation layers corresponds with a significant increase in quartz use at the site, and these raw material trends are discussed in more detail in the following section. When quartz cores are reduced, they often produce a large quantity of shatter or flaked pieces in comparison with other raw material types.

This change in raw material use may be one reason for the higher proportions of flaked pieces in AU6. In addition, highly fragmented quartz flakes are also more difficult to identify as flakes due to the uneven fracture that can sometimes occur in this material (with the force of percussion following incipient fractures, faults, or crystal planes rather than fracturing conchoidally). The single manuport in the assemblage is a natural fragment of sugar chert, which appears to have been utilised.

A total of 664 stone artefacts was recovered from AU6, which is the initial occupational phase that dates to roughly 41,000 to 38,000 years ago. The artefacts discarded in AU6 account for 50.5% of the total site assemblage. While AU6 has the largest proportion of artefacts throughout the occupation sequence, it also has the highest number of non-diagnostic artefacts, and as is discussed above, a large proportion of these artefacts are quartz flaked pieces. Despite the high number of flaked pieces, 60.54% of the AU6 artefacts are considered to be diagnostic, including a sizeable assemblage of flakes and retouched artefacts. Although refitting was not purposefully undertaken during the analysis, at least six sets of conjoining artefacts were identified throughout the analytical unit (see Figure 8-14). There is little vertical difference between the conjoined artefacts, suggesting that there is minimal or no disturbance to this deposit.

Following the initial phase of site use, sedimentation rates and artefact discard rates decrease significantly from 140 to 70cmbd, or approximately AU5 through AU3. These layers demonstrate a sudden drop in artefact numbers. In AU5 (*ca*. 140-115cmbd) and AU4 (*ca*. 115-90cmbd) 136 and 153 artefacts were recorded respectively. The proportion of artefacts declines further in AU3 (*ca*. 90-70cmbd), with 81 artefacts recovered. AU3 represents the lowest phase of artefact discard and roughly correlates to the period between 24,000 to 16,500 years ago.

In general, the artefact discard rates observed in the terminal Pleistocene (AU2) and Holocene (AU1) sequence are consistent with the pattern demonstrated in AU5 and AU4. AU2 contained 152 flaked stone artefacts, and 130 artefacts were recovered from AU1. No backed artefacts or other prominent middle to late Holocene stone artefact technologies are present in the assemblage.

Raw Materials

The counts and weights of raw materials selected for artefact manufacture are presented in Table 8-4 and Table 8-5. Due to the considerable weight of iron-rich rock, determining raw material use based on weight alone can be somewhat misleading. Many iron-rich raw materials such as BIF, goethitised shale, and martite-goethite will naturally weigh more than other siliceous raw materials. In this circumstance, weight is not necessarily a good variable to investigate the distribution of raw materials in the site. However, it is still a useful variable to report, as it does provide information pertaining to the consumption of raw materials.

The Djadjiling assemblage was produced from a wide variety of raw materials (Table 8-4 and Table 8-5). The majority of the flaked stone artefacts have been manufactured on chert (37.87%), quartz (31.56%), BIF (14.30%), and shale (10.87%). To some degree, this pattern may be attributed to the fracture mechanics of these materials. Chert is the best quality raw material for artefact manufacture because it fractures conchoidally, it has relatively predictable knapping outcomes, and chert artefacts maintain hard-wearing and durable sharp edges. Quartz, although crystalline, is a relatively poor knapping material because fracture is difficult to control due to incipient crystal lattice structures, and it often results in unevenly fragmented and splintered flaked pieces. Quartz artefacts do have sharp, functional edge margins; however, they are quickly dulled from normal wear and tear. BIF and shale fracture conchoidally and result in artefacts with fairly durable edges, but due to their coarse-grained nature, their fracture is much harder to control.

There is a considerable amount of variation in the visual appearance of the chert assemblage. For example, as Table 8-4 indicates, the analysts identified that at least 14 varieties of chert were procured for artefact manufacture (for individual raw material descriptions see Chapter 4). The most prevalent variety is dark grey chert, which is also the most regularly exploited chert variety throughout time at Djadjiling. Other notable chert varieties include olive, light greenish-grey, and white and translucent cherts, but the prevalence of artefacts manufactured from these cherts is minimal in comparison to dark grey chert. Several other cherts were also identified, but artefacts were manufactured from these varieties far less frequently.

There are marked changes in the distribution and consumption of raw materials over time at Djadjiling. In preglacial AU6, quartz artefacts constitute 56.17% of the assemblage by count; however, much of the AU6 quartz artefact assemblage is highly fragmented, resulting in the exceptionally high artefact counts. The AU6 quartz assemblage totals 373 artefacts, including two cores, 166 flakes (broken and unbroken), seven retouched flakes, one potlid, and 197 flaked pieces. In AU5 through AU1, quartz was procured much less frequently (n=21), and the overall trend indicates that its prevalence as a raw material diminishes over time.

Table 8-4 Distribution of the number of raw material types by analytical unit, Djadjiling rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
BIF	*37*	*28.46*	*49*	*32.24*	*5*	*6.25*	*14*	*9.15*	*38*	*27.94*	*45*	*6.78*	*188*	*14.30*
Homogenous BIF	33	25.38	45	29.61	4	5.00	13	8.50	29	21.32	37	5.57	161	12.24
Laminate BIF	4	3.08	4	2.63	1	1.25	1	0.65	9	6.62	8	1.20	27	2.05
Chert	*51*	*39.23*	*46*	*30.26*	*71*	*88.75*	*125*	*81.70*	*47*	*34.56*	*158*	*23.80*	*498*	*37.87*
Dark Grey	31	23.85	25	16.45	64	80.00	88	57.52	22	16.18	69	10.39	299	22.74
Greyish Brown	1	0.77	4	2.63	0	0.00	2	1.31	2	1.47	4	0.60	13	0.99
Light Green-Grey	0	0.00	1	0.66	0	0.00	22	14.38	2	1.47	9	1.36	34	2.59
Olive	8	6.15	2	1.32	1	1.25	3	1.96	5	3.68	28	4.22	47	3.57
Red	8	6.15	2	1.32	4	5.00	1	0.65	4	2.94	6	0.90	25	1.90
Speckled Black	1	0.77	0	0.00	0	0.00	0	0.00	1	0.74	4	0.60	6	0.46
Sugar	0	0.00	1	0.66	0	0.00	1	0.65	2	1.47	7	1.05	11	0.84
Translucent Green	0	0.00	2	1.32	0	0.00	0	0.00	0	0.00	0	0.00	2	0.15
White & Trans.	1	0.77	8	5.26	1	1.25	6	3.92	3	2.21	15	2.26	34	2.59
Thylo	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.15	1	0.08
Creamy Grey	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	3	0.45	4	0.30
Pink and Green	1	0.77	0	0.00	1	1.25	2	1.31	5	3.68	9	1.36	18	1.37
Dashed Black	0	0.00	1	0.66	0	0.00	0	0.00	0	0.00	1	0.15	2	0.15
Trans. Dark Grey	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.30	2	0.15
Goethitised Shale	*14*	*10.77*	*5*	*3.29*	*0*	*0.00*	*1*	*0.65*	*4*	*2.94*	*18*	*2.71*	*42*	*3.19*
Limonite	*0*	*0.00*	*1*	*0.66*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.08*
Martite-Goethite	*5*	*3.85*	*4*	*2.63*	*0*	*0.00*	*2*	*1.31*	*6*	*4.41*	*3*	*0.45*	*20*	*1.52*
Quartz	*3*	*2.31*	*11*	*7.24*	*1*	*1.25*	*7*	*4.58*	*21*	*15.44*	*373*	*56.17*	*416*	*31.63*
Quartz	3	2.31	11	7.24	1	1.25	7	4.58	20	14.71	373	56.17	415	31.56
Quartz Crystal	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	0	0.00	1	0.08
Shale	*20*	*15.38*	*35*	*23.03*	*3*	*3.75*	*4*	*2.61*	*18*	*13.24*	*63*	*9.49*	*143*	*10.87*
Brown Shale	17	13.08	31	20.39	2	2.50	2	1.31	11	8.09	24	3.61	87	6.62
Green Shale	3	2.31	4	2.63	1	1.25	2	1.31	7	5.15	39	5.87	56	4.26
Indeterminate	*0*	*0.00*	*1*	*0.66*	*0*	*0.00*	*0*	*0.00*	*2*	*1.47*	*4*	*0.60*	*7*	*0.53*
Total	**130**	**100**	**152**	**100**	**80**	**100**	**153**	**100**	**136**	**100**	**664**	**100**	**1315**	**100**

Table 8-5 Distribution of the weight of raw material types by analytical unit, Djadjiling rockshelter

Raw Material Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%
BIF	*135.38*	*25.04*	*235.17*	*35.20*	*23.15*	*22.63*	*44.54*	*20.43*	*174.02*	*32.20*	*354.05*	*25.44*	*966.31*	*27.92*
Homogenous BIF	104.06	19.25	227.65	34.08	16.2	15.83	40.81	18.72	143.96	26.63	284.12	20.42	816.8	23.60
Laminate BIF	31.32	5.79	7.52	1.13	6.95	6.79	3.73	1.71	30.06	5.56	69.93	5.03	149.51	4.32
Chert	*43.87*	*8.12*	*40.62*	*6.08*	*78.4*	*76.62*	*134.55*	*61.71*	*97.94*	*18.12*	*261.08*	*18.76*	*656.46*	*18.97*
Dark Grey	35.58	6.58	19.82	2.97	77.48	75.72	62.03	28.45	24.5	4.53	135.47	9.74	354.88	10.25
Greyish Brown	0.24	0.04	4.24	0.63	0.00	0.00	9.86	4.52	0.62	0.11	2.55	0.18	17.51	0.51
Light Green-Grey	0.00	0.00	3.23	0.48	0.00	0.00	42.09	19.31	0.3	0.06	2.43	0.17	48.05	1.39
Olive	1.65	0.31	0.48	0.07	0.07	0.07	1.79	0.82	2.88	0.53	32.9	2.36	39.77	1.15
Red	6.08	1.12	1.26	0.19	0.5	0.49	0.04	0.02	3.43	0.63	0.673	0.05	11.983	0.35
Speckled Black	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.05	5.38	0.39	5.71	0.16
Sugar	0.00	0.00	0.96	0.14	0.00	0.00	0.13	0.06	3.49	0.65	13.12	0.94	17.7	0.51
Trans. Green	0.00	0.00	0.64	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.02
White & Trans.	0.23	0.04	8.12	1.22	0.24	0.23	18.27	8.38	31.98	5.92	23.74	1.71	82.58	2.39
Thylo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.68	0.55	7.68	0.22
Creamy Grey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	7.28	0.52	7.29	0.21
Pink and Green	0.03	0.01	0.00	0.00	0.11	0.11	0.34	0.16	30.46	5.64	24.85	1.79	55.79	1.61
Dashed Black	0.00	0.00	1.87	0.28	0.00	0.00	0.00	0.00	0.00	0.00	3.29	0.24	5.16	0.15
Trans. Dark Grey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.12	1.72	0.05
Goethitised Shale	*10.12*	*1.87*	*10.68*	*1.60*	*0.00*	*0.00*	*0.03*	*0.01*	*6.08*	*1.12*	*14.07*	*1.01*	*40.98*	*1.18*
Limonite	*0.00*	*0.00*	*1.91*	*0.29*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.91*	*0.06*
Martite-Goethite	*68.15*	*12.61*	*45.44*	*6.80*	*0.00*	*0.00*	*0.72*	*0.33*	*140.28*	*25.95*	*174.21*	*12.52*	*428.8*	*12.39*
Quartz	*27.76*	*5.14*	*3.6*	*0.54*	*0.28*	*0.27*	*6.78*	*3.11*	*43.56*	*8.06*	*235.52*	*16.92*	*317.5*	*9.17*
Quartz	27.76	5.14	3.6	0.54	0.28	0.27	6.78	3.11	43.32	8.01	235.52	16.92	317.26	9.17
Quartz Crystal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.04	0.00	0.00	0.24	0.01
Shale Total	*255.32*	*47.23*	*330.47*	*49.47*	*0.49*	*0.48*	*31.4*	*14.40*	*60.5*	*11.19*	*334.19*	*24.02*	*1012.37*	*29.25*
Brown Shale	253.25	46.85	323.43	48.41	0.46	0.45	29.61	13.58	49.53	9.16	33.06	2.38	689.34	19.92
Green Shale	2.07	0.38	7.04	1.05	0.03	0.03	1.79	0.82	10.97	2.03	301.13	21.64	323.03	9.33
Indeterminate	*0.00*	*0.00*	*0.15*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*	*18.13*	*3.35*	*18.44*	*1.33*	*36.72*	*1.06*
Total	**540.6**	**100**	**668.04**	**100**	**102.32**	**100**	**218.02**	**100**	**540.51**	**100**	**1391.56**	**100**	**5075.05**	**100**

The most substantial change in the distribution of raw materials occurred during the LGM. Prior to this hyperarid period, chert constituted 23.8% (AU6) to 34.56% (AU5) of the assemblage. The percentage of chert significantly increases in AU4 and AU3, when 81.7% and 88.75% of the total artefact assemblage was manufactured from this raw material. This marked increase correlates with the peak of the LGM, suggesting that chert was specifically targeted for artefact manufacture by the populations that visited the site at this time (Table 8-4). After the LGM, the percentage of chert decreases in the terminal Pleistocene to 30.26% (AU2) and then rises slightly to 39.23% for the remaining Holocene (AU1).

BIF and shale have a somewhat inverse relationship with chert during the LGM. In AU4 and AU3, the percentages of flaked artefacts manufactured from BIF and shale drop significantly, and together, they comprise only 11.76% (AU4) to 10.00% (AU3) of the LGM assemblage. The use of these coarse-grained raw materials increases substantially during the terminal Pleistocene and Holocene, and when combined, they represent approximately half of the AU2 and AU1 assemblages.

Table 8-6 examines the raw material trends for the primary diagnostic artefact types, including cores, flakes and retouched (and utilised) artefacts. There is a low frequency of cores throughout time at Djadjiling, so the small sample is statistically inadequate to examine raw material use within this diagnostic artefact category. However, there is a sufficient sample of flakes and retouched flakes to investigate the general patterning of raw material use by diagnostic artefact category over time. For instance, in preglacial AU6, there is a high frequency of quartz flake manufacture. Although much of the assemblage is fragmented, it is clear that quartz was prominently flaked by the initial site occupants. In total, 49.26% of the AU6 flakes were manufactured from quartz. The second most regularly knapped raw material from this time is chert, comprising 24.04% of the flakes. Most of the retouched flake assemblage from AU6 is made from chert, suggesting the early site visitors placed some value on the quality of fine grained chert over more locally abundant coarse-grained raw materials. This also demonstrates that while most of the flakes were produced from quartz, chert flakes (and shale flakes to a lesser degree) were preferentially selected for retouched and utilised flakes.

Local coarse-grained raw materials such as BIF, shale, goethitised shale, and martite-goethite form the most substantial portion of the flake and retouched flake assemblage in AU5. Chert flakes and retouched flakes continue to occur, but to a slightly lesser degree than their coarse-grained counterparts. Unlike preglacial AU6, there are very few diagnostic artefacts made from quartz.

There is a significant increase in chert flakes and retouched flakes during the LGM in AU4 and AU3. With their numbers combined, the primary diagnostic chert artefacts constitute 75.76% to 85.42% of the sample in AU4 and AU3. In AU4, nearly all the retouched flakes were manufactured from chert, and in AU3, the entire retouched flake assemblage is chert. Only two cores were deposited at the site during the peak LGM (AU4), and the cores were produced from chert. The AU4 and AU3 raw material patterns indicate that individuals were specifically procuring chert and possibly manufacturing some chert artefacts at the rockshelter. The high percentage of chert flakes and retouched flakes suggests that chert was an important component of the mobile toolkit utilised by the rockshelter's LGM residents, and the evidence suggests that chert was preferred to the locally available and more abundant coarse-grained materials.

In the terminal Pleistocene (AU2), the use of coarse-grained raw materials for flake production increased and surpassed chert flake manufacture. The combined number of BIF, shale, goethitised shale, limonite, and martite-goethite primary diagnostic artefacts comprises 68.22% of the sample from AU2. Diagnostic chert artefacts constitute only 24.03% of the assemblage from this time in comparison. It is interesting that the shift to manufacturing a larger proportion of the artefact assemblage from local raw materials corresponds to a time of climatic amelioration. The increased use of local raw material is also observable in the retouched and utilised flake assemblage.

Table 8-6 Raw material trends for cores, flakes, and retouched and utilised flakes, Djadjiling rockshelter

Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Raw Material Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cores	*2*	*100*	*3*	*100*	*0*	*0.00*	*2*	*100*	*4*	*100*	*6*	*100*	*17*	*100*
BIF	0	0.00	1	33.33	0	0.00	0	0.00	1	25.00	1	16.67	3	17.65
Chert	0	0.00	0	0.00	0	0.00	2	100	1	25.00	0	0.00	3	17.65
Martite-Goethite	0	0.00	0	0.00	0	0.00	0	0.00	1	25.00	1	16.67	2	11.76
Quartz	1	50.00	0	0.00	0	0.00	0	0.00	1	25.00	2	33.33	4	23.53
Shale	1	50.00	2	66.67	0	0.00	0	0.00	0	0.00	2	33.33	5	29.41
Flakes	*87*	*100*	*93*	*100*	*40*	*100*	*82*	*100*	*56*	*100*	*337*	*100*	*695*	*100*
BIF	30	34.48	41	44.09	5	12.50	13	15.85	25	44.64	35	10.39	149	21.44
Chert	32	36.78	15	16.13	33	82.50	63	76.83	17	30.36	81	24.04	241	34.68
Goethitised Shale	9	10.34	3	3.23	0	0.00	1	1.22	1	1.79	10	2.97	24	3.45
Limonite	0	0.00	1	1.08	0	0.00	0	0.00	0	0.00	0	0.00	1	0.14
Martite Goethite	4	4.60	3	3.23	0	0.00	2	2.44	4	7.14	2	0.59	15	2.16
Quartz	0	0.00	9	9.68	0	0.00	3	3.66	5	8.93	166	49.26	183	26.33
Shale	12	13.79	20	21.51	2	5.00	0	0.00	4	7.14	41	12.17	79	11.37
Indeterminate	0	0.00	1	1.08	0	0.00	0	0.00	0	0.00	2	0.59	3	0.43
Retouched / Utilised Flakes	*11*	*100*	*33*	*100*	*8*	*100*	*15*	*100*	*40*	*100*	*59*	*100*	*166*	*100*
BIF	2	18.18	6	18.18	0	0.00	1	6.67	10	25.00	6	10.17	25	15.06
Chert	4	36.36	16	48.48	8	100	10	66.67	14	35.00	28	47.46	80	48.19
Goethitised Shale	3	27.27	2	6.06	0	0.00	0	0.00	1	2.50	2	3.39	8	4.82
Martite-Goethite	0	0.00	1	3.03	0	0.00	0	0.00	1	2.50	0	0.00	2	1.20
Quartz	0	0.00	0	0.00	0	0.00	1	6.67	1	2.50	7	11.86	9	5.42
Shale	2	18.18	8	24.24	0	0.00	3	20.00	11	27.50	14	23.73	38	22.89
Indeterminate	0	0.00	0	0.00	0	0.00	0	0.00	2	5.00	2	3.39	4	2.41
Total	**100**	**-**	**129**	**-**	**48**	**-**	**99**	**-**	**100**	**-**	**402**	**-**	**878**	**-**

Approximately half of the AU2 retouched and utilised flake assemblage was manufactured from coarse-grained raw materials. The trends observed in AU2 continue in AU1, with no significant variation in percentages amongst the diagnostic artefact categories. The incidence of diagnostic artefacts made from coarse-grained raw materials represents 63% of the sample, and a little more than half of retouched and utilised flake assemblage was manufactured on coarse materials such as BIF, goethitised shale, martite-goethite, and shale.

Cores

In total, 17 cores were recovered from the Djadjiling excavations (Figure 8-14), and 16 core specimens are complete, lacking any evidence of natural breakage or fragmentation. Broken core specimens are not included in the quantitative analysis to avoid skewing the statistical results. The dimensions and mass for complete cores is presented for each analytical unit in Table 8-7. As illustrated in the table, there is a small sample size of cores distributed throughout time at Djadjiling, so statistically significant temporal trends in artefact size and weight cannot be identified. There is much variability in the size and mass of the specimens, and presented together, the specimens do not reveal much information on the intensity of core reduction.

The qualitative characteristics of the Djadjiling core assemblage are also extremely varied, as illustrated in Table 8-8. The small sample size of cores again hinders our ability to make broad, statistically reliable characterisations of the core assemblage throughout time. Despite this limitation, the data is included so that many of subtle physical characteristics of the core assemblage are documented for other researchers. Rotated and unidirectional cores are predominant in the assemblage, with one bidirectional core. Throughout the sequence, core reduction focused on flake production and when blades were produced, it appears to be fortuitous rather than a deliberate technological choice. There is no evidence to suggest that knappers prepared their cores or core platforms prior to flake detachment. Plain striking platforms are slightly more common than cortical platforms, and this suggests that knappers utilised previously knapped surfaces (amongst the rotated cores) and natural exfoliated surfaces among the unidirectional cores. The number of dorsal flake scars provides a simple measure of reduction intensity; although, it should be taken into account that larger cores will naturally be able to produce more flakes. The greatest average number of flake scars is in AU4 and the lowest number of scars is in AU2; however, the small sample sizes are too small to provide reliable data. Only one core was assessed as being exhausted on the basis of its small size; Artefact 1063 is a unidirectional brown shale core that was used to produce at least four flakes.

Possibly the most important finding of the core analysis is the discovery of a core and associated conjoining flakes from preglacial AU6 (Figure 8-14: c). Artefact 1211 is a speckled green shale core, provenanced and excavated *in situ* from 150cmbd in Unit 1. A flake (Artefacts 1220) and one retouched flake (Artefact 1197) discovered nearby refit onto the specimen, demonstrating a sequence of rotated core reduction (Figure 8-14).

Table 8-7 Quantitative attributes for complete cores by analytical unit, Djadjiling rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	2	52.21	86.59	17.83	48.62
	2	3	54.26	77.06	40.01	19.95
	4	1	27.31	27.31	27.31	-
	5	4	27.00	59.27	14.46	21.58
	6	6	51.36	77.01	24.22	18.54
B. Max Width (mm)	1	2	49.83	56.36	43.29	9.24
	2	3	46.89	64.14	37.03	14.99
	4	1	28.33	28.33	28.33	-
	5	4	35.82	47.54	23.88	9.68
	6	6	51.27	64.32	20.64	16.44
C. Max Thickness (mm)	1	2	30.21	31.03	29.39	1.16
	2	3	29.00	44.92	13.06	15.93
	4	1	22.86	22.86	22.86	-
	5	4	23.63	41.45	13.87	12.53
	6	6	35.29	49.94	11.28	13.93
D. Mass (g)	1	2	112.20	196.81	27.59	119.66
	2	3	93.04	206.18	22.89	98.92
	4	1	17.01	17.01	17.01	-
	5	4	34.42	95.68	6.91	41.78
	6	6	93.54	185.23	29.06	66.70
Measurement	**AU**	**Count**	**Average Length (mm)**	**SD**	**Average Width (mm)**	**SD**
E. Average Maximum Negative Scar Dimensions	1	2	24.62	28.26	25.65	20.87
	2	3	26.88	14.88	27.33	11.25
	4	1	20.67	-	9.41	-
	5	4	14.43	5.09	22.86	6.00
	6	6	26.03	15.81	23.29	11.48
	1	2	24.62	28.26	25.65	20.87
F. Average Minimum Negative Scar Dimensions	1	2	9.29	6.58	15.22	6.12
	2	3	21.59	9.06	22.70	8.55
	4	1	14.18	-	7.42	-
	5	4	6.74	3.38	11.34	8.03
	6	6	15.54	10.35	20.65	9.73
	1	2	9.29	6.58	15.22	6.12

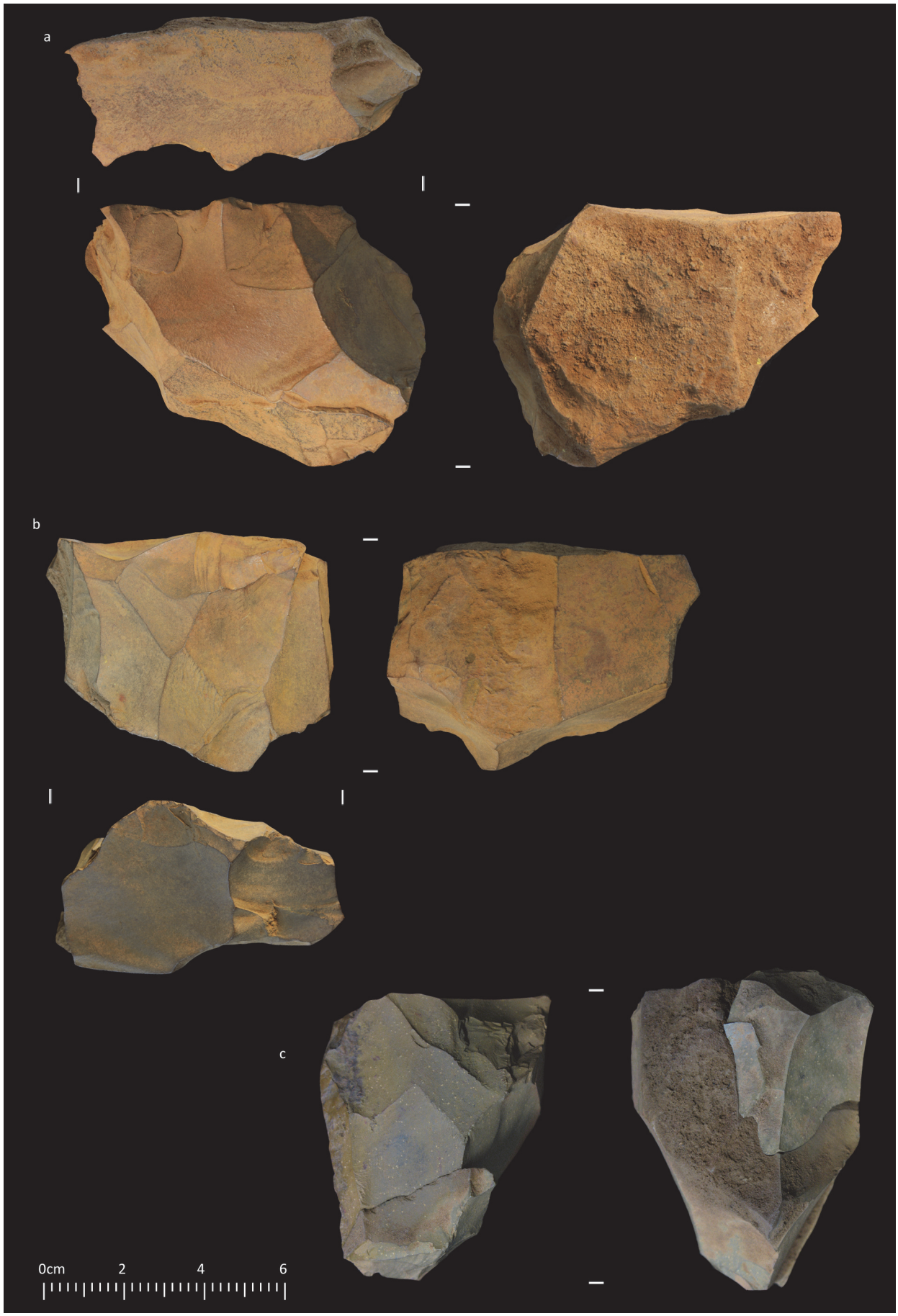

Figure 8-14 Cores from Djadjiling rockshelter: a) Artefact 1342 from AU1, b) Artefact 1047 from AU2, and c) refit core from AU6, including Artefacts 1211 (core), 1220 (flake - right), and 1197 (retouched flake – left)

Table 8-8 Qualitative attributes for complete cores by analytical unit, Djadjiling rockshelter

A. Core Type*	AU1		AU2		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Rotated	1	50.00	1	33.33	1	100	1	25.00	3	50.00	7	43.75
Unidirectional	1	50.00	2	66.67	0	0.00	3	75.00	2	33.33	8	50.00
Bidirectional	0	0.00	0	0.00	0	0.00	0	0.00	1	16.67	1	6.25
Total	**2**	**100**	**3**	**100**	**1**	**100**	**4**	**100**	**6**	**100**	**16**	**100**
B. Platform Type	**AU1**		**AU2**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Plain	1	50.00	2	66.67	1	100	2	50.00	4	66.67	10	62.50
Cortex	1	50.00	1	33.33	0	0.00	2	50.00	2	33.33	6	37.50
Total	**2**	**100**	**3**	**100**	**1**	**100**	**4**	**100**	**6**	**100**	**16**	**100**
C. Scar Type	**AU1**		**AU2**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Flake	2	100	3	100	0	0.00	4	100	6	100	15	93.75
Mixed flake/blade	0	0.00	0	0.00	1	100	0	0.00	0	0.00	1	6.25
Total	**2**	**100**	**3**	**100**	**1**	**100**	**4**	**100**	**6**	**100**	**16**	**100**
D. Avg. No. Scars	**AU1**		**AU2**		**AU4**		**AU5**		**AU6**		**Total**	
	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg
BIF	0	0.00	1	1.00	0	0.00	1	12.00	1	9.00	3	7.33
Chert	0	0.00	0	0.00	1	13.00	1	1.00	0	0.00	2	7.00
Quartz	1	1.00	0	0.00	0	0.00	1	3.00	2	3.00	4	2.50
Shale	1	12.00	2	7.50	0	0.00	0	0.00	2	14.50	5	11.20
Martite-Goethite	0	0.00	0	0.00	0	0.00	1	7.00	1	5.00	2	6.00
Total	**2**	**6.50**	**3**	**5.33**	**1**	**13.00**	**4**	**5.75**	**6**	**8.17**	**16**	**7.13**
E. Reduction Potential	**AU1**		**AU2**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%
Exhausted	0	0.00	1	33.33	0	0.00	0	0.00	0	0.00	1	6.25
Viable	2	100	2	66.67	1	100	4	100	6	100	15	93.75
Total	**2**	**100**	**3**	**100**	**1**	**100**	**4**	**100**	**6**	**100**	**16**	**100**

* Note – core type is presented for all cores, while all other attributes are presented for complete cores

The core (Artefact 1211) has four striking platforms and 16 negative flake scars (mostly feather terminated). Cortex remains on less than a third of the core surface. The resulting conjoin set not only provides insight on core reduction techniques from roughly 40,000 years ago, but it also demonstrates that the AU6 sediments are undisturbed (Figure 8-14).

Flakes

In total, 695 flakes and flake fragments were recovered from the Djadjiling excavations (Table 8-9). The assemblage consists of 409 unbroken flakes and 286 flake fragments. The assemblage also contains a number of specific flake types that are characterised by unique morphological features or reduction techniques. These distinctive flake types include blades, ridge flakes, platform rejuvenation flakes, and bipolar flakes. Blades are the most common flake subtype, and these are discussed below with regard to the flake elongation index. None of these specific flake types are abundant or form a representative sample of the flake assemblage, and it is likely that they were a random knapping product rather than an intentional design. Only one ridge flake, one platform rejuvenation flake, and one bipolar flake were recovered from the deposit. Platform rejuvenation flakes can be indicative of core platform rejuvenation; however, only one platform rejuvenation flake is present in AU6, and it could have been randomly produced from core rotation. Also in AU6 is a bipolar quartz flake, which is the result of hammer and anvil core reduction. Ridge flakes are often associated with the production of blades, but there is very little evidence to suggest blades were purposefully produced as a stone tool technology.

Utilising Hiscock's (2002) methodology for quantifying the size of flake assemblages, it is likely that the assemblage is derived from a minimum of 572 flakes (MNF = 409 + 112 + 40 + 11). Based on the MNF and the number of unbroken flakes, it is estimated that 28.5% of the flake assemblage is fragmented (percentage of broken flakes = (MNF - complete flakes) / MNF x 100). It is unclear if the fragmentation occurred on site or if particular broken flake fragments were selected and carried to the rockshelter. It is plausible that particular flake fragments were intentionally selected, as there is a large disparity between the number of complete width distal (n=112) and proximal flake fragments (n=38); however, it cannot be determined if distal fragments are intentionally selected and transported to site, or perhaps, if after breakage, proximal fragments have been carried away from the rockshelter. Relatively high proportions of distal flake fragments are common amongst excavated assemblages, but this assemblage shows a much greater disparity between the two groups than most other assemblages. There are a disproportionate number of right and left longitudinal flake fragments, with complete right longitudinal flakes being slightly more common than complete left longitudinal flakes. There is negligible difference between left and right transversely broken fragments.

Table 8-9 Flake fragmentation, Djadjiling rockshelter

Longitudinal Fragmentation	Transverse Fragmentation				
	Complete	Distal	Prox.	Medial	Total
Complete	409	112	37	17	575
Left + Left LCS	27	9	5	7	48
Right + Right LCS	40	11	4	4	59
Medial	2	2	3	6	13
Total	**478**	**134**	**49**	**34**	**695**

Quantitative Flake Attributes

The flake assemblage was subject to a number of quantitative attribute measurements, and these results are presented for each analytical unit in Table 8-10. A total of 409 complete flakes are used for the calculations in Table 8-10: A-I, while 446 proximal and complete flake platform measurements are reported for the calculations in Table 8-10: J-L.

Table 8-10 Quantitative flake attributes by analytical unit, Djadjiling rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	52	15.74	58.84	3.51	12.57
	2	64	14.62	35.05	4.31	7.62
	3	22	13.29	39.56	4.46	9.78
	4	46	12.81	41.50	3.61	8.56
	5	32	17.01	37.68	3.17	9.84
	6	193	11.60	57.88	2.64	9.46
B. Max Width (mm)	1	52	16.25	73.36	1.74	12.45
	2	64	16.01	46.02	3.74	8.91
	3	22	16.14	39.04	5.48	10.91
	4	46	14.53	43.87	3.40	9.62
	5	32	17.72	48.09	2.84	10.15
	6	193	11.30	42.91	1.85	8.31
C. Max Thickness (mm)	1	52	4.07	14.23	0.70	3.54
	2	64	4.27	11.59	0.95	2.59
	3	22	3.62	9.78	0.86	2.94
	4	46	3.97	13.61	0.64	3.27
	5	32	5.45	15.82	0.92	3.71
	6	193	3.60	14.51	0.53	3.02
D. Axis Length (mm)	1	52	15.07	58.32	3.51	12.40
	2	64	13.48	31.50	3.68	6.98
	3	22	11.98	35.04	3.44	8.40
	4	46	12.00	41.69	2.61	8.64
	5	32	15.74	36.32	3.17	9.32
	6	193	10.46	55.84	2.16	8.86
E. Axis Width (mm)	1	52	14.30	51.03	1.74	10.26
	2	64	14.04	42.21	3.72	7.89
	3	22	13.33	34.62	3.77	9.21
	4	46	12.18	30.18	0.91	7.32
	5	32	15.68	47.96	2.81	9.17
	6	193	9.79	40.17	2.72	7.35
F. Axis Thickness (mm)	1	52	3.67	13.57	0.07	3.36
	2	64	3.70	11.15	0.73	2.31
	3	22	3.32	9.62	0.84	2.69
	4	46	3.32	11.34	0.01	2.71
	5	32	4.94	14.87	0.71	3.55
	6	193	3.11	14.15	0.42	2.71
G. Mass (g)	1	52	3.40	48.86	0.01	8.05
	2	64	1.85	18.97	0.01	2.96
	3	22	1.69	9.76	0.01	2.92
	4	46	1.78	18.76	0.01	3.40
	5	32	3.51	26.69	0.01	5.84
	6	193	1.48	30.73	0.01	3.78
H. Elongation Index	1	52	1.07	3.46	0.36	0.61
	2	64	1.00	2.45	0.38	0.43
	3	22	0.85	1.43	0.38	0.26
	4	46	1.02	2.70	0.35	0.56
	5	32	1.02	3.24	0.42	0.52
	6	193	1.10	3.33	0.32	0.55
I. Parallel Index	1	52	1.67	3.43	0.66	0.75
	2	64	1.66	5.27	0.73	0.90
	3	22	1.93	7.59	0.65	1.54
	4	46	1.46	3.22	0.24	0.65
	5	32	1.70	6.22	0.81	1.25
	6	193	1.56	5.65	0.50	0.83
J. Platform Width (mm)	1	62	9.27	37.80	1.43	7.02
	2	68	9.96	34.09	2.13	6.82
	3	23	8.74	23.83	1.31	6.29
	4	47	10.08	36.48	1.41	8.38
	5	37	11.99	41.62	1.52	8.96
	6	209	7.26	39.56	1.11	6.25
K. Platform Thickness (mm)	1	62	3.09	10.19	0.42	2.50
	2	68	3.20	8.14	0.63	2.08
	3	23	2.46	10.79	0.41	2.72
	4	47	3.48	13.40	0.38	3.00
	5	37	4.17	14.71	0.45	3.33
	6	209	2.71	12.71	0.38	2.32

Measurement	AU	Count	Average	Max	Min	SD
L. Platform Angle (°)	1	62	76.24	102.00	37.00	11.45
	2	68	74.91	120.00	36.00	15.36
	3	23	80.78	125.00	60.00	17.97
	4	47	70.32	100	20.00	15.91
	5	37	73.78	130.00	30.00	20.81
	6	209	74.69	113.00	28.00	13.84

The quantitative results suggest that there are subtle fluctuations in the average maximum flake dimensions and average axial dimensions over time. Variations in flake size are only slight and as the standard deviation suggests, the differences are not statistically significant (Table 8-10: A-F). Thus, the size of the average flake remains relatively uniform throughout the history of the site. Trends in flake elongation are reported as the elongation index (Table 8-10: H). The index shows that for the most part, flakes are not elongated, and flake length is relatively uniform through time. The flakes discarded at Djadjiling are generally as long as they are wide; thus, it does not appear the flakes were manufactured or selected for elongated features. There is slight decrease in flake elongation in AU3, at the peak of the LGM, but the decrease is not statistically significant. Blades are defined as elongated flakes with a length that is double their width. The Djadjiling assemblage has 28 flakes that are considered blades based upon this definition (including the platform rejuvenation flake, which also has blade proportions). Blades make up only 6.45% of the complete flake assemblage; thus, the low percentile suggests that their production was random rather than purposeful. The analytical unit with the highest frequency of blades is AU6 (n=16), but they only comprise 8.29% of the complete flakes from this analytical unit.

The expanding, contracting, or parallel morphology of flake margins is measured using the parallel index (Table 8-10: I). The results indicate that from the striking platform, flake margins tend to expand towards the midpoint of the flake, rather than contract or be parallel. Over time, the analytical unit trend suggests that flake margins became more expansive; however, the slight increase in not statistically significant, as there is large and obvious overlap in the standard deviation of these results.

Flake platform dimensions were recorded for all complete and all proximal flakes (that are longitudinally complete). Flake platform size remains relatively constant throughout time, with no obvious temporal trends. Among analytical units, the average platform width varies between 7.26 and 11.99mm, and this follows the general trends in flake width. The range of flake platform thicknesses is also relatively constant, ranging between 2.71 and 4.19mm. In relation to the maximum thickness, there is relative consistency in the platform thickness over time. However, AU4 exhibits the narrowest platforms and AU3 has the widest platforms relative to their maximum thickness. AU3 and AU4 also show the only considerable differences in the exterior striking platform angles, with AU3 having the highest average exterior striking platform angle (80.78°) and AU4 having the lowest (70.32°). The other analytical units have average values within approximately two degrees (74° to 76°).

Qualitative Flake Attributes

The qualitative attributes of complete flakes is recorded in Table 8-11 and provides further insight on flake technology and reduction trends at Djadjiling rockshelter. Qualitative attributes were recorded wherever possible for each flake specimen, and they are reported, as appropriate, for complete, proximal, and distal flakes (Table 8-11 : A-K).

Proximal and complete flakes were used to examine a number of qualitative flake platform attributes (Table 8-11: A-D). In reviewing the platform types, a clear pattern is observed. Throughout time, it is evident that plain platforms were preferred by the previous Djadjiling occupants. A total of 68.61% of all flake platforms are plain, lacking any additional remnant scars or evidence of striking platform preparation. Cortical platforms are the second most common platform type, comprising 13.23% of the complete and proximal flake assemblage. There is no clear pattern in the temporal distribution or range of remaining platform types, as linear, dihedral, winged, crushed, and facetted platforms occur in similar frequency throughout the deposit. There is little evidence of platform preparation as overhang removal rarely occurs in the assemblage.

There is an interesting pattern with the bulb of percussion over time at Djadjiling. In AU6, flakes with diffuse bulbs of percussion are more common than flakes with prominent bulbs. This pattern is due to the large proportion of quartz flakes in the assemblage, and prominent bulbs are less likely to occur due to the crystal lattice planes of quartz. While diffuse bulbs of percussion occur on flakes of all of the different raw material types, the majority of diffuse bulbs in AU6 are on quartz flakes (n=87). Beginning in AU5 and continuing to AU1, there is a steady increase in the number of flakes with prominent platforms. It is likely that flakes exhibiting prominent bulbs of force are tightly connected to the properties of the raw material, rather than changes to the knapping strategy employed.

In the past, archaeologists inferred that platform lipping may be indicative of soft hammer percussion; however, lipping cannot be attributed to a specific knapping technique but is related to the angle of force applied during the flake removal (Pelcin 1997a: 620). At Djadjiling, only 34 (7.62%) of the flakes exhibited lipping, and this attribute is represented equally across coarse and fine-grained raw materials. Therefore lipped flakes do not seem to be related to raw material types, and they are uncommon in the assemblage.

Complete flakes provide the best means for studying reduction trends and flake morphology. The amount of dorsal cortex remaining on complete flakes provides a means to investigate generalised patterns of flake removal and intensity of flake reduction. For example, flake assemblages formed at localities where the initial core reduction activities occur are likely to have a high percentage of dorsal cortex. These assemblages typically form at sites located near the source of the raw material, and there is typically a low diversity of raw materials within the assemblage. Conversely, flake assemblages manufactured from cores or stone artefacts that have been subject to more extensive reduction will usually exhibit little dorsal cortex. Most often, assemblages of this nature form at habitation sites located away raw material source, and a diverse number raw materials will be represented.

Table 8-11 Qualitative flake attributes by analytical unit, Djadjiling rockshelter

A. Platform Type [cp]	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cortical	9	14.52	12	17.65	3	13.04	4	8.51	10	27.03	21	10.05	59	13.23
Dihedral	4	6.45	2	2.94	0	0.00	0	0.00	0	0.00	5	2.39	11	2.47
Linear	4	6.45	3	4.41	2	8.70	1	2.13	2	5.41	17	8.13	29	6.50
Plain	35	56.45	45	66.18	18	78.26	39	82.98	21	56.76	148	70.81	306	68.61
Winged	5	8.06	5	7.35	0	0.00	2	4.26	1	2.70	5	2.39	18	4.04
Crushed	0	0.00	0	0.00	0	0.00	0	0.00	1	2.70	3	1.44	4	0.90
Facetted	4	6.45	1	1.47	0	0.00	1	2.13	2	5.41	10	4.78	18	4.04
Chapeau de Gendarme	1	1.61	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.22
Total	**62**	**100**	**68**	**100**	**23**	**100**	**47**	**100**	**37**	**100**	**209**	**100**	**446**	**100**
B. Overhang Removal [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Crushed	3	4.84	3	4.41	1	4.35	3	6.38	1	2.70	14	6.70	25	5.61
Faceting	4	6.45	4	5.88	3	13.04	3	6.38	8	21.62	6	2.87	28	6.28
None	55	88.71	61	89.71	19	82.61	41	87.23	28	75.68	189	90.43	393	88.12
Total	**62**	**100**	**68**	**100**	**23**	**100**	**47**	**100**	**37**	**100**	**209**	**100**	**446**	**100**
C. Lipping [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
False	59	95.16	63	92.65	21	91.30	40	85.11	34	91.89	195	93.30	412	92.38
True	3	4.84	5	7.35	2	8.70	7	14.89	3	8.11	14	6.70	34	7.62
Total	**62**	**100**	**68**	**100**	**23**	**100**	**47**	**100**	**37**	**100**	**209**	**100**	**446**	**100**
D. Bulb of Percussion [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diffuse	12	19.35	25	36.76	6	26.09	20	42.55	17	45.95	120	57.42	200	44.84
Prominent	50	80.65	43	63.24	17	73.91	27	57.45	20	54.05	89	42.58	246	55.16
Total	**62**	**100**	**68**	**100**	**23**	**100**	**47**	**100**	**37**	**100**	**209**	**100**	**446**	**100**
E. Dorsal Cortex [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
None	28	53.85	36	56.25	12	54.55	37	80.43	18	56.25	150	77.72	281	68.70
1-32%	12	23.08	12	18.75	6	27.27	8	17.39	6	18.75	25	12.95	69	16.87
33-65%	3	5.77	6	9.38	1	4.55	0	0.00	4	12.50	6	3.11	20	4.89
66-99%	3	5.77	3	4.69	2	9.09	0	0.00	2	6.25	2	1.04	12	2.93
100%	6	11.54	7	10.94	1	4.55	1	2.17	2	6.25	10	5.18	27	6.60
Total	**52**	**100**	**64**	**100**	**22**	**100**	**46**	**100**	**32**	**100**	**193**	**100**	**409**	**100**
F. Dorsal Scars [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0	6	11.54	7	10.94	1	4.55	1	2.17	2	6.25	10	5.18	27	6.60
1	11	21.15	13	20.31	6	27.27	7	15.22	4	12.50	49	25.39	90	22.00
2	11	21.15	17	26.56	9	40.91	13	28.26	15	46.88	65	33.68	130	31.78
3	11	21.15	19	29.69	3	13.64	15	32.61	8	25.00	45	23.32	101	24.69
4	7	13.46	6	9.38	1	4.55	7	15.22	1	3.13	13	6.74	35	8.56
5	2	3.85	2	3.13	2	9.09	1	2.17	1	3.13	3	1.55	11	2.69
6	3	5.77	0	0.00	0	0.00	2	4.35	0	0.00	5	2.59	10	2.44
7	0	0.00	0	0.00	0	0.00	0	0.00	1	3.13	1	0.52	2	0.49
8	1	1.92	0	0.00	0	0.00	0	0.00	0	0.00	2	1.04	3	0.73
Total	**52**	**100**	**64**	**100**	**22**	**100**	**46**	**100**	**32**	**100**	**193**	**100**	**409**	**100**
G. Scar Orientation [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Unidirectional	26	50.00	26	40.63	11	50.00	12	26.09	13	40.63	46	23.83	134	32.76
Bidirectional	0	0.00	2	3.13	0	0.00	0	0.00	0	0.00	1	0.52	3	0.73
Rotated	16	30.77	19	29.69	6	27.27	21	45.65	12	37.50	26	13.47	100	24.45
NA	6	11.54	7	10.94	1	4.55	1	2.17	2	6.25	10	5.18	27	6.60
Ind	4	7.69	10	15.63	4	18.18	12	26.09	5	15.63	110	56.99	145	35.45
Total	**52**	**100**	**64**	**100**	**22**	**100**	**46**	**100**	**32**	**100**	**193**	**100**	**409**	**100**
H. Form [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Contracting Distally	8	15.38	15	23.44	8	36.36	16	34.78	13	40.63	57	29.53	117	28.61
Expanding Distally	36	69.23	35	54.69	12	54.55	20	43.48	14	43.75	110	56.99	227	55.50
Leaf	3	5.77	5	7.81	0	0.00	3	6.52	3	9.38	9	4.66	23	5.62
Parallel-sided	3	5.77	4	6.25	0	0.00	3	6.52	1	3.13	3	1.55	14	3.42
Sub-parallel	2	3.85	5	7.81	2	9.09	4	8.70	1	3.13	14	7.25	28	6.85
Total	**52**	**100**	**64**	**100**	**22**	**100**	**46**	**100**	**32**	**100**	**193**	**100**	**409**	**100**

I. Profile [c]	AU1		AU2		AU3		AU4		AU5		AU6		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Concave	10	19.23	11	17.19	2	9.09	9	19.57	2	6.25	48	24.87	82	20.05
Convex	10	19.23	14	21.88	5	22.73	7	15.22	10	31.25	47	24.35	93	22.74
Straight	30	57.69	38	59.38	14	63.64	26	56.52	19	59.38	83	43.01	210	51.34
Twisted	2	3.85	1	1.56	1	4.55	4	8.70	1	3.13	15	7.77	24	5.87
Total	**52**	**100**	**64**	**100**	**22**	**100**	**46**	**100**	**32**	**100**	**193**	**100**	**409**	**100**
J. Cross-section [c]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Left Triangle	9	17.31	9	14.06	4	18.18	14	30.43	6	18.75	36	18.65	78	19.07
Right Triangle	4	7.69	11	17.19	5	22.73	5	10.87	4	12.50	39	20.21	68	16.63
Plano-convex	9	17.31	16	25.00	2	9.09	6	13.04	8	25.00	44	22.80	85	20.78
Symmetric Triangle	5	9.62	8	12.50	5	22.73	6	13.04	8	25.00	22	11.40	54	13.20
Trapezoid	22	42.31	6	9.38	4	18.18	2	4.35	1	3.13	24	12.44	59	14.43
Irregular	3	5.77	14	21.88	2	9.09	13	28.26	5	15.63	28	14.51	65	15.89
Total	**52**	**100**	**64**	**100**	**22**	**100**	**46**	**100**	**32**	**100**	**193**	**100**	**409**	**100**
K. Termination [cd]	**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**AU6**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Axial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8	3.11	8	1.54
Feather	42	65.63	51	69.86	18	72.00	50	79.37	29	74.36	182	70.82	372	71.40
Hinge	13	20.31	11	15.07	5	20.00	5	7.94	5	12.82	29	11.28	68	13.05
Inflexed	1	1.56	1	1.37	1	4.00	3	4.76	4	10.26	5	1.95	15	2.88
Plunge	3	4.69	2	2.74	0	0.00	1	1.59	0	0.00	2	0.78	8	1.54
Step	5	7.81	8	10.96	1	4.00	4	6.35	1	2.56	31	12.06	50	9.60
Total	**64**	**100**	**73**	**100**	**25**	**100**	**63**	**100**	**39**	**100**	**257**	**100**	**521**	**100**
Key: cp - complete and proximal flakes; c - complete flakes; cd - complete and distal flakes														

As Table 8-11: E indicates, most of the Djadjiling complete flake assemblage is composed of tertiary flakes, lacking any dorsal cortex. The percentage of tertiary flakes varies throughout time, ranging from 53.85 to 80.43% and averaging 68.70%. Also, as previously discussed, a diverse number of raw materials were employed for artefact manufacture at the site. The overall reduction signature suggests that many of the flakes were produced elsewhere and transported to the site. There are only a moderate number of cores discarded at Djadjiling, and in AU6, there is a conjoin set that demonstrates the some flakes were produced on site. However, low percentage of cortical flakes and high diversity of raw materials suggests that most reduction activities occurred off-site, and much of the flake assemblage was transported to the rockshelter.

To a certain degree, this argument is substantiated by the number of dorsal scars recorded for each flake specimen. As Table 8-11: F indicates, complete flakes with three or more dorsal scars comprise approximately one-third of the assemblage in each analytical unit. This dorsal scar pattern implies that a significant proportion of the flake assemblage was manufactured from late stage cores or is perhaps associated with flake retouch.

A number of the qualitative attributes listed in Table 8-11 provides a good indication of flake morphology. For example, in Table 8-11: H, the overall shape or form of each complete flake indicates that more than half of the assemblage has distally expanding margins (55.50%). This dominant pattern holds true throughout the site history, and it supports the pattern observed by the parallel index (Table 8-10: I). Contracting distal flake margins are the second most common flake form, accounting for 28.61% of the assemblage. Leaf-shaped (5.62%), sub-parallel-sided (6.85%), and parallel flakes (3.42%) are comparatively rare in the assemblage. For the most part, this overall pattern is maintained throughout each analytical unit.

The ventral profile of each complete flake is reported in Table 8-11: I. The majority of the flake assemblage has a straight ventral profile. The second most common profile is convex ventral surfaces, followed closely by concave ventral surfaces. Convex ventral surfaces are presumably caused by pronounced bulbs of percussion, and may be indicative of the force of the blow used to remove the flake. The proportion of straight, convex, and concave flakes remain relatively constant throughout time. Occasionally, some ventral flake profiles exhibit twisted morphology, but this is relatively uncommon.

In cross-section, flake morphology is extremely variable throughout time, and no clear pattern exists. As Table 8-11: J indicates, there is a fairly even representation of different flake cross-section types. Therefore, flake cross-section as a qualitative attribute is not particularly useful in discerning technological variation in flake morphology.

Flake terminations offer some insight on the skill of past knappers or perhaps the quality of the raw materials used for artefact manufacture. At Djadjiling, feather flake terminations are the most common type observed on the complete and distal flake assemblage, accounting for 71.40% of all terminations. They are followed by hinge (13.05%) and step (9.60%) terminations. This trend is observed, more or less, within all analytical units, and no distinctive pattern is observable amongst the remaining termination types (*e.g.*, plunge, inflexed, axial, and cortical axial). Feather terminations are generally a more desirable outcome in flint knapping because they do not inhibit further core reduction like step, hinge, or plunging terminations often do. Therefore, the high proportion of feather terminated flakes suggests flake removal was controlled by skilled individuals.

Retouched and Utilised Artefacts

In total, 166 retouched or utilised artefacts were recovered from the Djadjiling excavations (Table 8-12; Figure 8-15). It is interesting that there are no distinctive retouch technologies such as backed artefacts, tulas, scrapers, or burins in the assemblage, and it shows that there a high degree of variability in the retouched and utilised flake assemblage and regular, or systematically produced, stone tool forms are rare. The Djadjiling assemblage suggests that formalised retouched artefact technologies did not comprise a significant proportion of the early Aboriginal tool kit. Despite the lack of formalised tools, Djadjiling has a very high frequency of retouched and utilised artefacts in comparison with other large excavated

assemblages (*e.g.*, HD07-1A-07, 2.19%; PAD 3, 4.1%; PAD 4, 3.53%; Law and Cropper 2011; Cropper 2011).

Of the prominent retouch technologies exhibited at Djadjiling, unifacially retouched flakes are the most common, totalling 73 specimens. There are only 15 flakes with alternating retouch (*i.e.*, scars on both the ventral and dorsal surface along the same edge), and Table 8-12 also indicates that retouched flakes with alternate edge retouch (n=5; *i.e.*, ventral retouch on one lateral edge and dorsal retouch along the opposite edge) rarely occur in the assemblage. There are 73 utilised flakes in the assemblage, and they exhibit slightly more variation than amongst the retouched artefacts. There are nearly equal proportion of utilised flakes with unifacial and alternating scars, whereas bifacial and alternate edge specimens are rare.

Over time, the proportion of retouched and utilised artefacts varies amongst the analytical units. AU6 and AU2 have fairly equal proportions of artefacts in each group, while in AU5 and AU1, there are higher proportions of retouched than utilised artefacts. In AU4 and AU3, utilised artefacts are predominant. The reason for these fluctuations may be due to the small sample sizes in most of the analytical units, whereas AU2 and AU6 have the largest sample size and show similar numbers of artefacts with in each category.

Amongst the 113 complete retouched and utilised flakes, there are 275 areas of edge modification areas that can be used to explore patterns of artefact manufacture (Table 8-13). The modified areas include 188 edge modification areas on the 65 complete retouched artefacts, averaging 2.89 edge modification areas per artefact. The unifacially retouched artefacts have the lowest average number of edge modification areas, but this group also has a larger and more robust sample than the alternating and alternate edge retouched artefacts. The 48 complete utilised artefacts have a total of 87 areas of usewear, which averages to be 1.81 edge modification areas per artefact and is slightly lower than amongst the retouched artefacts.

There are a variety of different types of edge modification, and the data for the assemblage is presented in Table 8-14. By definition, all edge modification areas on utilised artefacts are classified as usewear, but there is a range of different edge modification types amongst the retouched artefacts. Regular retouch is by far the most common, but many of the retouched artefacts also have areas of usewear (micro-flaking less than 1mm long). Other retouch types are only seen in rare instances and include retouched notches, single notches, irregular retouch areas, and truncations.

A number of the complete retouched flake specimens exhibited characteristics suitable for quantitative reduction statistics such as retouch length, GIUR, and the PRI; these statistics are presented in Table 8-15: A-D. The average length was calculated for 110 retouch areas (the 78 usewear areas on the retouched artefacts is not included), and the average length is 14.08mm, which is similar to the average length of flakes in the assemblage. There are very high standard deviations indicating that the data is skewed towards the minimum and maximum extremes, rather than having a normal distribution. There are 56 retouch areas on 38 individual retouched artefacts that are suitable for the GIUR. Within this small sample, the average GIUR is 0.36 and this is fairly consistent throughout the occupation. The low GIUR indicates that many of the retouched artefacts had limited retouch and had the potential to be reduced much further.

Table 8-12 Distribution of retouched and utilised artefacts by analytical unit, Djadjiling rockshelter

Retouched Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Subtype	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*8*	*72.73*	*16*	*48.48*	*2*	*25.00*	*6*	*40.00*	*27*	*67.50*	*34*	*57.63*	*93*	*56.02*
Unifacial	7	63.64	10	30.30	2	25.00	6	40.00	24	60.00	24	40.68	73	43.98
Alternating	0	0.00	6	18.18	0	0.00	0	0.00	2	5.00	7	11.86	15	9.04
Alternate Edge	1	9.09	0	0.00	0	0.00	0	0.00	1	2.50	3	5.08	5	3.01
Utilised Artefact	*3*	*27.27*	*17*	*51.52*	*6*	*75.00*	*9*	*60.00*	*13*	*32.50*	*25*	*42.37*	*73*	*43.98*
Unifacial	1	9.09	7	21.21	4	50.00	5	33.33	4	10.00	13	22.03	34	20.48
Alternating	2	18.18	10	30.30	2	25.00	4	26.67	9	22.50	10	16.95	37	22.29
Bifacial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.69	1	0.60
Alternate Edge	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.69	1	0.60
Total	**11**	**100**	**33**	**100**	**8**	**100**	**15**	**100**	**40**	**100**	**59**	**100**	**166**	**100**

Table 8-13 Edge modification areas on complete retouched and utilised artefacts by analytical unit, Djadjiling rockshelter

Retouched Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Subtype	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM
Retouched Artefact	*6*	*22*	*11*	*28*	*2*	*7*	*4*	*12*	*23*	*69*	*19*	*50*	*65*	*188*
Unifacial	5	19	8	20	2	7	4	12	20	59	13	28	52	145
Alternating	0	0	3	8	0	0	0	0	2	7	4	15	9	30
Alternate Edge	1	3	0	0	0	0	0	0	1	3	2	7	4	13
Utilised Artefact	*1*	*1*	*11*	*18*	*5*	*8*	*6*	*13*	*9*	*18*	*16*	*29*	*48*	*87*
Unifacial	1	1	6	8	3	4	3	6	2	3	7	12	22	34
Alternating	0	0	5	10	2	4	3	7	7	15	7	15	24	51
Bifacial	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Alternate Edge	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Total	**7**	**23**	**22**	**46**	**7**	**15**	**10**	**25**	**32**	**87**	**35**	**79**	**113**	**275**

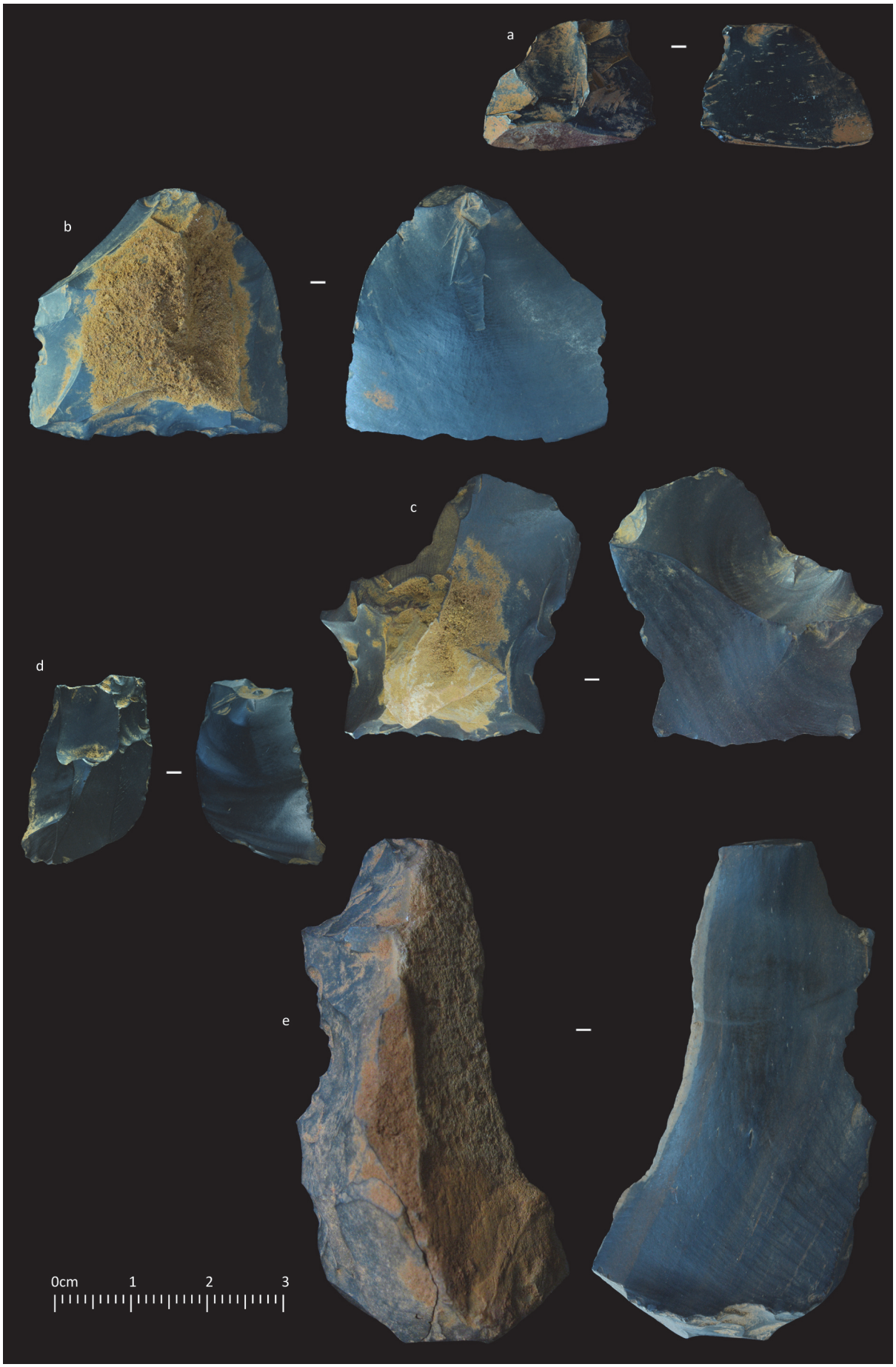

Figure 8-15 Retouched chert artefacts from the occupation sequence at Djadjiling rockshelter: a) Artefact 54 from AU2, b) Artefact 89 from AU3, c) Artefact 126 from AU4, d) Artefact 1077 from AU5, and e) Artefact 602 from AU6

Table 8-14 Edge modification types on complete retouched and utilised artefacts by analytical unit, Djadjiling rockshelter

Retouched Artefact Type	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Edge Modification Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*22*	*95.65*	*28*	*60.87*	*7*	*46.67*	*12*	*48.00*	*69*	*79.31*	*50*	*63.29*	*188*	*68.36*
Retouch	12	52.17	16	34.78	4	26.67	6	24.00	31	35.63	32	40.51	101	36.73
Usewear	9	39.13	11	23.91	3	20.00	5	20.00	32	36.78	18	22.78	78	28.36
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	4	4.60	0	0.00	4	1.45
Notch	0	0.00	0	0.00	0	0.00	1	4.00	1	1.15	0	0.00	2	0.73
Irregular Ret. Area	0	0.00	1	2.17	0	0.00	0	0.00	1	1.15	0	0.00	2	0.73
Truncation	1	4.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Utilised Artefact	*1*	*4.35*	*18*	*39.13*	*8*	*53.33*	*13*	*52.00*	*18*	*20.69*	*29*	*36.71*	*87*	*31.64*
Usewear	1	4.35	18	39.13	8	53.33	13	52.00	18	20.69	29	36.71	87	31.64
Total	**23**	**100**	**46**	**100**	**15**	**100**	**25**	**100**	**87**	**100**	**79**	**100**	**275**	**100**

Table 8-15 Summary statistics for the retouch length, GIUR, and PRI, Djadjiling rockshelter

Measurement	AU	Average	Min	Max	SD	EM
A. Retouch Length (mm) by AU	AU1	12.59	2.79	49.81	15.11	13
	AU2	10.90	2.62	26.12	7.63	17
	AU3	11.04	1.83	33.14	14.82	4
	AU4	15.43	3.55	26.05	8.88	7
	AU5	14.65	2.15	41.14	10.6	37
	AU6	15.78	2.75	50.22	12.5	32
	Total	14.08	1.83	50.22	11.35	110
B. GIUR Statistics by AU	AU1	0.34	0.21	0.57	0.12	6
	AU2	0.35	0.19	0.71	0.15	11
	AU3	0.45	0.21	0.83	0.34	3
	AU4	0.34	0.15	0.78	0.30	4
	AU5	0.39	0.15	0.80	0.18	18
	AU6	0.30	0.12	0.87	0.20	14
	Total	0.36	0.12	0.87	0.19	56
Measurement	AU	**Average**	**Min**	**Max**	**SD**	**n**
C. PRI Statistics by AU	AU1	0.21	0.05	0.51	0.16	6
	AU2	0.16	0.02	0.45	0.13	11
	AU3	0.20	0.03	0.37	0.24	2
	AU4	0.26	0.13	0.42	0.12	4
	AU5	0.25	0.03	0.87	0.21	23
	AU6	0.23	0.07	0.48	0.14	19
	Total	0.23	0.02	0.87	0.17	65
Measurement	RM	**Average**	**Min**	**Max**	**SD**	**n**
D. PRI Statistics by Raw Material	BIF	0.15	0.04	0.44	0.11	13
	Chert	0.24	0.03	0.51	0.12	24
	Goethitised Shale	0.39	0.16	0.66	0.25	3
	Indeterminate	0.44	0.37	0.56	0.10	3
	Martite-Goethite	0.32	0.19	0.45	0.19	2
	Quartz	0.14	0.07	0.29	0.09	6
	Shale	0.23	0.02	0.87	0.24	14
	Total	0.23	0.02	0.87	0.17	65

Key: n – number of artefacts; EM – number of edge modification areas; RM – raw material type

The PRI was calculated for the 65 complete retouched artefacts, and on average, the retouch artefacts have retouch along less than a quarter of the perimeter length. The PRI statistics are relatively consistent over time, and the high standard deviations negate any minor differences in the data. When compared across the different raw material types, it appears that BIF and quartz have the least amount of retouch and goethitised shale and an indeterminate raw material type have the greatest retouch; however, the sample sizes are too small to evaluate these differences properly.

Throughout time, there are no statistically significant changes in retouch length, PRI, or GIUR. The principle reason that these measurements are not conclusive is because there is a lack of adequate sample size for most of the analytical units; thus, without an appropriate sample, it is not possible to confidently identify changes in these particular measurements. This issue also affects the reporting of the PRI by raw material, as retouched flakes made from chert offer the only substantial sample size.

Throughout most of the Djadjiling occupation, the position of the edge modification (*i.e.*, negative scar location) for both retouch and usewear is on the dorsal surface of the flake (Table 8-16). Dorsal edge modification accounts for nearly half of the sample, but AU2 shows a much lower proportion (26.09%) and AU3 a higher proportion (80%) in comparison with the rest of the assemblage. Table 8-16 indicates that alternating retouch and usewear are the second most commonly occurring form of edge modification. However, there is a huge disparity between the occurrence of alternating scars derived from retouch and usewear. Approximately 90% of alternating scars occur as usewear, indicating that they most often occur as less than 1mm scars. Ventrally directed scars occur 17.45% of

the time, and there is an equal incidence of ventral scars as usewear retouch. Bifacial edge modification is very rare and occurs in only three instances of bifacial usewear were identified.

The angle of edge modification often provides an indication of the intensity of reduction activities. As Table 8-17 suggests, the angle of edge modification is dominated by AAR (<60°) in all analytical units at Djadjiling. On average, AAR occurs in 74.55% of instances. SAR (>60°) happens to a lesser degree, in around 25.09% of edge modification instances. Most of the usewear can be classified as AAR (n=141), as there was comparatively little SAR (n=23) usewear amongst the assemblage. In one instance, an artefact had an area of rounded usewear and this was classified as being not applicable (NA).

Short retouch is predominant amongst the retouched edge modification areas (n=104), and there are six instances of long retouch (5 regular retouch areas and one single notch). These trends in retouch extent are continuous throughout the six analytical units, and this data suggests that retouch intensity and artefact curation was very low throughout the occupation of the site.

The delineation of the retouched areas is dominated by regular retouch throughout time (Table 8-18). Regular retouch does not significantly alter the natural shape of the flake, and this is consistent with the patterns of retouch that show that most artefacts were minimally modified. On average, areas of regular retouch account for 89.09% of the assemblage in each analytical unit. Concave retouch is the second most common delineation observed, representing 7.27% of the areas of retouch. It is interesting that the concave retouch is most prevalent in the AU4 and AU5, which represent the onset of the LGM and the LGM proper; however, the sample size of concave retouched specimens is comparatively small and may not be statistically valid. Apart from concave retouch, other delineation types that change the shape of the retouched or utilised edge are very rare in the assemblage.

Table 8-19 explores the location patterns of retouch and usewear amongst the 275 areas of edge modification. The data suggests that there does not seem to have been a preference for the modification of the left lateral edge or right lateral edge, as both lateral margins have a comparable incidence of retouch and usewear. A total of 44 areas of retouch and 64 areas of usewear were observed on the left lateral edge, and 42 areas of retouch and 58 areas of usewear were identified along the right lateral edge of the assemblage. AU1 has a slightly lower frequency of edge modification on the left than right margin, but this analytical unit also has one of the smaller sample sizes.

Table 8-16 Retouch and/or usewear position and modification type by analytical unit, Djadjiling rockshelter

Scar Position	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Edge Modification Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Alternating	*2*	*8.70*	*22*	*47.83*	*2*	*13.33*	*6*	*24.00*	*36*	*41.38*	*22*	*27.85*	*90*	*32.73*
Retouch	1	4.35	1	2.17	0	0.00	0	0.00	6	6.90	0	0.00	8	2.91
Usewear	1	4.35	21	45.65	2	13.33	6	24.00	30	34.48	22	27.85	82	29.82
Dorsal	*14*	*60.87*	*12*	*26.09*	*12*	*80.00*	*16*	*64.00*	*36*	*41.38*	*44*	*55.70*	*134*	*48.73*
Retouch	6	26.09	10	21.74	4	26.67	6	24.00	19	21.84	22	27.85	67	24.36
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	3	3.45	0	0.00	3	1.09
Notch	0	0.00	0	0.00	0	0.00	1	4.00	1	1.15	0	0.00	2	0.73
Truncation	1	4.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Irregular Ret. Area	0	0.00	1	2.17	0	0.00	0	0.00	1	1.15	0	0.00	2	0.73
Usewear	7	30.43	1	2.17	8	53.33	9	36.00	12	13.79	22	27.85	59	21.45
Ventral	*7*	*30.43*	*12*	*26.09*	*0*	*0.00*	*3*	*12.00*	*14*	*16.09*	*12*	*15.19*	*48*	*17.45*
Retouch	5	21.74	5	10.87	0	0.00	0	0.00	6	6.90	10	12.66	26	9.45
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Usewear	2	8.70	7	15.22	0	0.00	3	12.00	7	8.05	2	2.53	21	7.64
Bifacial	*0*	*0.00*	*0*	*0.00*	*1*	*6.67*	*0*	*0.00*	*1*	*1.15*	*1*	*1.27*	*3*	*1.09*
Usewear	0	0.00	0	0.00	1	6.67	0	0.00	1	1.15	1	1.27	3	1.09
Total	**23**	**100**	**46**	**100**	**15**	**100**	**25**	**100**	**87**	**100**	**79**	**100**	**275**	**100**

Table 8-17 Incidence of acute angle retouch (AAR) and steep angle retouch (SAR) by analytical unit, Djadjiling rockshelter

Retouch Angle	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Edge Modification Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AAR (<60°)	*17*	*73.91*	*37*	*80.43*	*15*	*100*	*19*	*76.00*	*63*	*72.41*	*54*	*68.35*	*205*	*74.55*
Retouch	9	39.13	9	19.57	4	26.67	2	8.00	21	24.14	15	18.99	60	21.82
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	2	2.30	0	0.00	2	0.73
Irregular Ret. Area	0	0.00	1	2.17	0	0.00	0	0.00	1	1.15	0	0.00	2	0.73
Usewear	8	34.78	27	58.70	11	73.33	17	68.00	39	44.83	39	49.37	141	51.27
SAR (>60°)	*6*	*26.09*	*8*	*17.39*	*0*	*0.00*	*6*	*24.00*	*24*	*27.59*	*25*	*31.65*	*69*	*25.09*
Retouch	3	13.04	7	15.22	0	0.00	4	16.00	10	11.49	17	21.52	41	14.91
Retouched notch	0	0.00	0	0.00	0	0.00	0	0.00	2	2.30	0	0.00	2	0.73
Truncation	1	4.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Notch	0	0.00	0	0.00	0	0.00	1	4.00	1	1.15	0	0.00	2	0.73
Usewear	2	8.70	1	2.17	0	0.00	1	4.00	11	12.64	8	10.13	23	8.36
NA	*0*	*0.00*	*1*	*2.17*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.36*
Usewear	0	0.00	1	2.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Total	**23**	**100**	**46**	**100**	**15**	**100**	**25**	**100**	**87**	**100**	**79**	**100**	**275**	**100**

Table 8-18 Delineation of edge modification by analytical unit, Djadjiling rockshelter

Delineation	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Edge Modification Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Regular	*18*	*78.26*	*45*	*97.83*	*14*	*93.33*	*18*	*72.00*	*75*	*86.21*	*75*	*94.94*	*245*	*89.09*
Retouch	9	39.13	15	32.61	3	20.00	2	8.00	24	27.59	28	35.44	81	29.45
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Irregular Ret. Area	0	0.00	1	2.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Usewear	9	39.13	29	63.04	11	73.33	16	64.00	50	57.47	47	59.49	162	58.91
Concave	*2*	*8.70*	*0*	*0.00*	*0*	*0.00*	*3*	*12.00*	*11*	*12.64*	*4*	*5.06*	*20*	*7.27*
Retouch	1	4.35	0	0.00	0	0.00	2	8.00	6	6.90	4	5.06	13	4.73
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	3	3.45	0	0.00	3	1.09
Truncation	1	4.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Irregular Ret. Area	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Usewear	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	1	0.36
Rectilinear	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*4.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.36*
Retouch	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	1	0.36
Sinusoidal	*1*	*4.35*	*1*	*2.17*	*1*	*6.67*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*1.09*
Retouch	1	4.35	1	2.17	1	6.67	0	0.00	0	0.00	0	0.00	3	1.09
Nosed	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*8.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.73*
Retouch	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	1	0.36
Usewear	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	1	0.36
Denticulate	2	8.70	0	0.00	0	0.00	1	4.00	1	1.15	0	0.00	4	1.45
Retouch	1	4.35	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	2	0.73
Notch	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	1	0.36
Usewear	1	4.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Total	**23**	**100**	**46**	**100**	**15**	**100**	**25**	**100**	**87**	**100**	**79**	**100**	**275**	**100**

Table 8-19 Location and type of edge modification by analytical unit, Djadjiling rockshelter

Retouch Location	AU1		AU2		AU3		AU4		AU5		AU6		Total	
Edge Modification Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
DE	*6*	*26.09*	*6*	*13.04*	*4*	*26.67*	*7*	*28.00*	*18*	*20.69*	*19*	*24.05*	*60*	*21.82*
Retouch	2	8.70	1	2.17	1	6.67	3	12.00	5	5.75	8	10.13	20	7.27
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Truncation	1	4.35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Usewear	3	13.04	5	10.87	3	20.00	4	16.00	11	12.64	11	13.92	37	13.45
LLE	*6*	*26.09*	*22*	*47.83*	*7*	*46.67*	*9*	*36.00*	*33*	*37.93*	*29*	*36.71*	*106*	*38.55*
Retouch	4	17.39	7	15.22	2	13.33	1	4.00	12	13.79	12	15.19	38	13.82
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Notch	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	1	0.36
Irregular Ret. Area	0	0.00	1	2.17	0	0.00	0	0.00	1	1.15	0	0.00	2	0.73
Usewear	2	8.70	14	30.43	5	33.33	7	28.00	19	21.84	17	21.52	64	23.27
RLE	*11*	*47.83*	*17*	*36.96*	*4*	*26.67*	*9*	*36.00*	*32*	*36.78*	*27*	*34.18*	*100*	*36.36*
Retouch	6	26.09	8	17.39	1	6.67	2	8.00	11	12.64	12	15.19	40	14.55
Retouched Notch	0	0.00	0	0.00	0	0.00	0	0.00	2	2.30	0	0.00	2	0.73
Usewear	5	21.74	9	19.57	3	20.00	7	28.00	19	21.84	15	18.99	58	21.09
RLE + DE	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*1.15*	*3*	*3.80*	*4*	*1.45*
Retouch	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	0	0.00	1	0.36
Usewear	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	3.80	3	1.09
LLE + DE	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*3.45*	*1*	*1.27*	*4*	*1.45*
Retouch	0	0.00	0	0.00	0	0.00	0	0.00	2	2.30	0	0.00	2	0.73
Usewear	0	0.00	0	0.00	0	0.00	0	0.00	1	1.15	1	1.27	2	0.73
DE + LLE + RLE	*0*	*0.00*	*1*	*2.17*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.36*
Usewear	0	0.00	1	2.17	0	0.00	0	0.00	0	0.00	0	0.00	1	0.36
Total	**23**	**100**	**46**	**100**	**15**	**100**	**25**	**100**	**87**	**100**	**79**	**100**	**275**	**100**
Key: LLE – Left Lateral Edge, RRL – Right Lateral Edge, DE – Distal Edge, PE – Proximal Edge														

There are no instances of retouch or usewear along the proximal edge of a flake, but distal edge modification is common. The distal edge is modified slightly less than the lateral edges, with 23 areas of retouch and 37 areas of usewear documented. The remaining instances of edge modification occur as the continuation of usewear and retouch from a lateral margin onto the distal margin. Altogether, continuous retouch and usewear occurring along more than one lateral margin occurs in nine instances. This result suggests that edge modification tends to occur on the left or right lateral flake edges, followed by the distal margin.

Although the Djadjiling retouched flaked assemblage lacks any formal stone tool types or prominent, measureable diachronic changes in reduction patterns, it would be erroneous to infer that the assemblage is not complex. In actuality, the Djadjiling retouched flake assemblage is highly diverse and does exhibit complex retouching behaviours, and a sample of the retouched artefacts from AU2 through AU6 has been illustrated in Figure 8-15 (Artefact 10, Figure 8-12, is an excellent example of a retouched artefact from AU1). Dark grey chert artefacts (and one dashed black chert artefact) were selected for Figure 8-15 as they demonstrate the continuity of retouching

practices over the long occupation history at Djadjiling. There is certainly nothing in the retouched assemblage that shows technological or stylistic changes; although, data from other sites shows that new retouching technologies were utilised by at least the mid-Holocene (see PAD 3). The data from Djadjiling suggests that while new retouching technologies and formalised artefact types (*e.g.*, backed artefacts, tulas, burrens, burins, *etc.*) were adopted over time, they were an addition to the existing technologies and did not fundamentally alter the basic methods for producing non-formalised retouched artefacts.

Grindstones

A lower grindstone fragment was recovered from the surface of the rockshelter. The grindstone, Artefact 1618, is broken, consisting of two conjoining fragments of tabular martite-goethite. The grindstone is not complete, as fragments remain missing. The maximum measurements of the grindstone were taken with the artefact conjoined, and it measures 166.35-x-142.35-x-28.13mm. The lower grindstone bears evidence of abrasion on both surfaces, but it is more pronounced on one surface. Fullagar (2013) analysed this specimen and noted that it is typical of those used for seed grinding.

Artefact Analysis Summary

The Djadjiling assemblage provides an opportunity to examine stone artefact technologies that have been used over the past 41,000 years. Artefacts were discarded at the rockshelter during intermittent visits over this extensive time period. The largest assemblage was deposited during the preglacial period, approximately 41,000 to 38,000 years ago, and it offers a rare, robust sample of stone artefacts from a very early time period. The overall trend shows that there are few differences in the reduction techniques and stone tool technologies discarded during the Pleistocene, which is consistent with findings observed elsewhere in the arid zone (Smith 2006). This observation extends to stone artefacts discarded during the Holocene, and easily recognisable stone tool technologies such as backed artefacts, tulas, or burrens are not present in the rockshelter assemblage.

Our qualitative and quantitative analyses of the cores, flakes, and retouched flakes have not identified any significant temporal changes or trends amongst attributes exhibited by these artefact categories. There is great variability in the size, shape, and form of these specimens throughout time, and prominent, measureable patterns were not observed. The lithic technology shows relative conservatism, with no new technological introductions. Flakes were generally produced using expedient reduction technologies, favouring unidirectional and rotated cores. There is no evidence to suggest that knappers systematically prepared or maintained cores.

There are also changes in raw material use over time at Djadjiling. Quartz was a favoured raw material during the initial occupation of the site, but it soon fell into disuse. The most recognisable change occurs during the LGM, where there is a significant increase in the manufacture of chert artefacts. This increase LGM increase suggests that fine-grained raw materials were specifically targeted during this hyperarid phase, possibly due to their superior knapping qualities or perhaps due to that chert stone tools have long-lasting and resilient use potential.
Possibly the most unique find from Djadjiling is a conjoin set recovered from preglacial AU6. The set consists of core with two conjoining flakes and a retouched flake. The resulting conjoin set provides clear evidence for on-site core reduction a, offers a rare insight of rotated core reduction. The conjoin set demonstrates that the preglacial sediments are undisturbed.

8.7 SPECIALIST STUDIES

A number of specialist studies were commissioned to provide additional context to the archaeological patterns at Djadjiling, including artefact usewear analysis, pollen and sediment analysis, phytolith analysis, archaeomagnetic, and macrobotanical analysis. The results of these specialist studies are presented in separate chapters. The outcomes of these studies are summarised below with consideration of how the data relates to the archaeological materials and chronology.

Artefact Usewear Analysis

A sample of 43 artefacts was selected from various site contexts and submitted to Dr Richard Fullagar (Scarp Archaeology Pty Ltd) for usewear and residue analysis (Fullagar 2012). A summary of his findings can be found in Chapter 15 of this monograph. The objectives of the study were to determine if any evidence of usewear is present and if any residues are preserved on the artefact specimens. Ultimately, this information could be used to infer patterns of past Aboriginal subsistence and tool using behaviours. The following section summarises the results of the usewear analysis and places the study and its results into the broader archaeological context at Djadjiling.

The artefacts submitted for analysis are listed inTable 8-20 , below. Usewear was identified on all but three artefacts (Artefact 30, Artefact 530, and Artefact 1211), and residue (e.g., resin) was observed on 12 specimens. Fullagar (2012) found that the wood working was the predominant use of the artefacts submitted for analysis. Fullagar (2012) also identified that some of the stone tools were used for skin working, soft plant processing, and in one instance, seed grinding. The mode of use for the stone tools was highly varied, including scraping, slicing, cutting, drilling, and boring.

Evidence of hafting was observed on some specimens, and Fullagar (2012) believes that a resin adhesive (*e.g.*, spinifex resin) was the most likely hafting agent. Many of the specimens have evidence of dorsal ridge rounding and resin-like residues, which support Fullagar's resin hypothesis.

As previously mentioned, the specimens sent for analysis come from a variety of site contexts. Admittedly, the majority of the specimens come from AU6, representing a sample of the utilised assemblage discarded on site between 41,000 to 38,000 years ago. Twenty-four specimens were specifically selected from this layer due to their significant antiquity and their potential to provide information on tool use from the early occupational period. Moreover, most of the artefact assemblage comes from AU6; thus, there was a greater sample of artefacts exhibiting usewear from this analytical unit. Artefacts were also selected from AU5, AU4, AU3, AU2, and AU1; however, specimens exhibiting unambiguous usewear from these analytical units are comparatively less. In total, nine specimens were selected from AU5, two specimens were picked from AU4, and one specimen was submitted from AU3. From the terminal Pleistocene and early Holocene period, two specimens were chosen from AU2, and four specimens were analysed from AU1, representing the middle and late Holocene period.

Table 8-20 Usewear and residue analysis results by analytical unit (summarised from Fullagar 2012), Djadjiling rockshelter

AU	Number	Type	Hafting?	Residue?	Mode of Use	Material Worked
Surface	1618	Grindstone	No	No	Grinding	*cf.* seeds
1	10	Retouched/ Utilised Flake	No	Yes	Cutting / Scraping	*cf.* skin/flesh
1	1006	Retouched/ Utilised Flake	No	Yes	Scraping/Graving	Uncertain
1	1030	Retouched/ Utilised Flake	No	No	Graver	Uncertain
1	1342	Core	No	No	Scraping	*cf.* wood
2	30	Retouched/ Utilised Flake	No	No	Not Utilised	NA
2	1470	Retouched/ Utilised Flake	No	No	Scraping	*cf.* wood
3	89	Retouched/ Utilised Flake	No	No	Cutting / Scraping	*cf.* wood
4	126	Retouched/ Utilised Flake	No	No	Scraping	Uncertain
4	1539	Retouched/ Utilised Flake	No	No	Scraping	*cf.* wood
5	159	Retouched/ Utilised Flake	Yes	Yes	Uncertain	*cf.* plant
5	170	Retouched/ Utilised Flake	No	No	Scraping	Uncertain
5	174	Retouched/ Utilised Flake	No	No	Scraping	*cf.* wood
5	178	Retouched/ Utilised Flake	No	No	Uncertain	Uncertain
5	182	Retouched/ Utilised Flake	No	No	Graver	*cf.* wood
5	1401	Retouched/ Utilised Flake	Yes	No	Scraping	*cf.* wood
5	1403	Retouched/ Utilised Flake	No	Yes	Cutting/Slicing	plant
5	1554	Retouched/ Utilised Flake	No	Yes	Scraping	*cf.* wood
5	1617	Retouched/ Utilised Flake	No	No	Scraping	Uncertain
6	225	Retouched/ Utilised Flake	No	No	Possible Scraping	*cf.* wood
6	227	Retouched/ Utilised Flake	Yes	Yes	Uncertain	Uncertain
6	230	Retouched/ Utilised Flake	No	No	Uncertain	Uncertain
6	313	Retouched/ Utilised Flake	No	No	Slicing	*cf.* wood
6	335	Retouched/ Utilised Flake	No	No	Scraping	soft wood
6	408	Retouched/ Utilised Flake	No	No	Uncertain	*cf.* wood
6	471	Retouched/ Utilised Flake	No	No	Scraping	*cf.* wood
6	474	Retouched/ Utilised Flake	Yes	Yes	Uncertain	*cf.* wood
6	498	Core	No	No	Awl/Drilling/Scraping	Uncertain
6	530	Flake	No	No	Not Utilised	NA
6	602	Retouched/ Utilised Flake	Yes	Yes	Scraping	Uncertain
6	604	Retouched/ Utilised Flake	No	No	Uncertain	Uncertain
6	1193	Retouched/ Utilised Flake	No	No	Uncertain	Uncertain
6	1197	Retouched/ Utilised Flake	No	No	Drilling Scraping	*cf.* wood
6	1211	Core	No	Yes	Not Utilised	NA
6	1231	Retouched/ Utilised Flake	No	No	Uncertain	*cf.* wood
6	1324	Retouched/ Utilised Flake	No	No	Uncertain	Uncertain
6	1326	Retouched/Utilised Flake	No	No	Scraping/Slicing	Uncertain
6	1411	Retouched/ Utilised Flake	No	Yes	Scraping	*cf.* wood
6	1452	Retouched/ Utilised Flake	No	No	Cutting/Slicing	Uncertain
6	1459	Retouched/ Utilised Flake	Yes	No	Awl	*cf.* skin
6	1577	Retouched/ Utilised Flake	Possible	Yes	Scraping	*cf.* wood
6	1584	Retouched/ Utilised Flake	Yes	Yes	Scraping	Uncertain
6	1590	Retouched/ Utilised Flake	No	No	Scraping	*cf.* wood

Usewear identified on the AU6 assemblage indicates that wood working is the most common task for which stone tools were used. Approximately half of the AU6 assemblage exhibits usewear consistent with wood working activities. It is uncertain what material was worked with the other half of the assemblage, and there is only one instance in AU6 where skin was worked in an awl-like motion. The mode of stone tool use for wood working is mostly scraping but there are a few examples where the usewear is indicative of slicing a woody material. There are traces of hafting usewear on five specimens from AU6, and residues (most likely resin) are present on seven specimens. It is interesting that there is so much evidence of wood working activities in this early occupational layer, as it demonstrates that wooden items were crafted by preglacial populations, and wooden implements were most likely a significant component of the important part of the preglacial toolkit. The residues also infer that composite tools may have been in use approximately 41,000 years ago. Unfortunately, examples of these ancient wooden items are not preserved in the archaeological record to verify this hypothesis. The apparent simplicity of the Pleistocene stone artefact assemblage does not fairly reflect the complexity of the material cultural items that were produced during this period, and the residues identified in Fullagar's study openly hint at this prospect.

Although the technological attributes of the assemblage are relatively consistent throughout time, there are subtle changes in artefact distribution. For example, artefact discard rates are greatest during the preglacial period, inferring that the site was more regularly inhabited or perhaps more extensively utilised during this time. Discard rates from later periods suggest that site use became more intermittent over time, and site visitation most likely decreased or diminished for lengthy periods during the LGM. Stone artefact discard rates increased slightly during the Holocene, but it is unlikely that rockshelter occupation was ever as extensive as during the preglacial period.

The results are similar for AU5, the analytical unit representing the gradual transition to the LGM. In AU5, four specimens had usewear consistent with wood working, two specimens suggest they were used for plant modification, and it is uncertain what material the remaining three specimens worked. The mode of use for most of the AU5 specimens was scraping, and a couple

of specimens were used for graving, cutting, and slicing. Two specimens have usewear or residues indicative of hafting.

The specimens discarded in AU4 and AU3 were discarded during full onset of hyperarid conditions, during a period when on-site artefact discard decreased. Only two specimens from AU4 were analysed for usewear. In both instances, the retouched flakes were used in a scraping motion. On one specimen, wood is the only material that could be identified as being scraped. It is uncertain what other material was worked. No residues were identified on the AU4 specimens. The single specimen submitted from AU3 also did not have any remaining residues. The mode of use for the specimen was cutting and scraping. The tool was used for wood working.

The propensity to have utilised retouched flakes to work wood continued in the terminal Pleistocene and early Holocene (AU2). Two retouched flakes from AU2 were submitted for usewear analysis. One specimen (Artefact 30) does not appear to have been utilised in any manner. The other specimen was used to scrape wood. No residues or hafting traces were found on either specimen.

The results of the AU1 usewear analysis offer the most recent and varied usewear results from the rockshelter sequence. Artefact 10 (Figure 8-12) is a retouched flake that was refitted together from six potlid and crazed flake fragments, and it is directly associated with the burning of the Feature 2 hearth. Despite the breakage, the specimen refits perfectly, and there are still residues adhering to its surface. Artefact 10 was used to cut or scrape animal skin or flesh just prior to its discard in the fire. Another interesting find is Artefact 1342, a core with usewear consistent with scraping wood. The two remaining retouched flakes from AU1 are consistent with scraping and graving activities; although, it cannot be determined what material was worked using these tools.

The implications of Fullagar's usewear and residue study are far-reaching. His study shows that usewear and residues can be preserved on artefacts of up to 41,000 years old. His results suggest that Aboriginal stone tool use at Djadjiling was heavily geared towards wood working activities. The frequency of artefacts used for wood working is an interesting finding, as it infers cultural items manufactured from wood comprised a significant portion of the toolkit since the earliest period of occupation.

Pollen, Sediment, and Micro-Charcoal Analysis

A series of sediment samples from Djadjiling rockshelter were sent to PalaeoWorks for pollen, sedimentary, and micro-charcoal analysis. PalaeoWorks is the palaeoenvironmental consulting arm of the Department of Archaeology and Natural History at the Australian National University. The analysis is presented in Chapter 13 of this monograph (Haberle *et al.*, this volume). The following section briefly summarises the results of the analysis and presents the data within the broader archaeological context of the site.

Few pollen studies have been conducted in the Pilbara. This study is one of the first for the region, and it was largely commissioned to test and determine if pollen is preserved within Pilbara rockshelter sediments. If pollen is preserved, then the researchers aimed to identify what types of pollen are present, and therefore what plants are represented in the assemblage. The Palaeoworks study further investigated what changes occur over time and attempted to determine if any of the plant species could provide insight on Aboriginal subsistence and/or perhaps climate change. The presence of micro-charcoal in the sediments can provide information regarding the occurrence of bushfires in the past, and it is useful for understanding changes in the vegetation.

The sediment samples submitted for analysis were collected at continuous 5cm increments from Unit 4 (Quad A; Layers 1-40; note U4-L04 and U4-L05 were not excavated as arbitrary excavation layers, but features), beginning at the surface and terminating at bedrock. The study confirms that microscopic pollen, spore and charcoal remains are preserved in the rockshelter sediments, albeit in low concentrations. The pollen concentrations on most of the slides prepared for the study were considered too low for standard percentage pollen analysis to be performed.

Based on the pollen evidence, the main plant families that could be identified are Myrtaceae (*Corymbia* sp., *Eucalyptus* sp., *Melaleuca* sp. and *Calytrix* sp.), Sapindaceae (*Dodonaea* sp.), and Poaceae (Haberle *et al.*, this volume). All of these plants are abundant in the Pilbara environment today; however, due to the low concentrations on the slides, it is unclear to what extent they were present in the past. All of these plants rely on wind-dispersal for pollination, which likely explains their abundance in the pollen record.

Throughout the sedimentary sequence, microscopic charred plant remains were identified as well as the presence of particular pollen taxa, which suggest that regional burning of savannah plants was continuous for the entire period of human occupation at Djadjiling (Haberle *et al.*, this volume). A loss-on-ignition analysis indicates that there is increased carbon content in the sediments from SL3 to SL1 (approximately 24,000 years ago to present-day) and SL6 to SL5 (42,000-28,000 years ago). SL4, which was deposited during the peak of the LGM, has negligible carbon content. Based on the abundance of microscopic charcoal and burned grass phytoliths in the sediments, it is believed that past grass fires continuously contributed to the rockshelter's depositional history. Charcoal fragments are the most common in SL1, representing the past 7000 years, and based on this evidence, Haberle *et al.* (this volume) note that evidence for more frequent local fires are only clearly exhibited in the site's more recent Holocene past.

Perhaps the most unexpected and intriguing find of the study is the identification of dung fungi spores *Podospora* and *Sporormiella* (Haberle *et al.*, this volume). Elsewhere in the world, these spores have been linked to large herbivores, particularly megafauna. These spores are particularly abundant in SL6 and SL7, which are in sediments that pre-date 32,000 years ago. Haberle and Roberts hypothesise that dung fungi may be related to the presence of megafauna in the region, and the absence of fungi spores in younger layers may be due to the widespread extinction of the large herbivores in Australia. The only other layer to have *Podospora* and *Sporormiella* is SL1, which dates to the middle and late Holocene. It is further suggested that the presence of dung fungi in SL1 may be attributed to greater small mammal densities in the rockshelter or perhaps the arrival of the dingo in Australia. Unfortunately, this cannot be corroborated by evince from the faunal assemblage, as only a very small number of specimens were recovered from the excavation and they were restricted to the first several arbitrary excavation layers.

In summary, the study provides some very useful insights on types of vegetation that surrounded Djadjiling rockshelter and suggests that the region has a long history of grass fires. Also, the identification of dung spores offers an exciting prospect for

investigating the history of megafauna in the region. Clearly, the region will benefit from similar pollen studies in the future.

Phytolith Analysis

A vertical succession of sediment samples were submitted to Dr Lynley Wallis for phytolith analysis to determine if phytoliths are present and ascertain what kinds of plants are represented in the assemblage. The study also asked what changes in the plant community can be observed over time, with particular reference to tree/shrub communities and grasses. This research also aimed to provide insights on Aboriginal subsistence, based on the phytolith assemblage. The detailed results of her study are presented in Chapter 12 of this monograph, and a brief overview of the results are summarised below.

Prior to beginning the analysis of the samples from the Djadjiling excavation, Wallis first had to develop a modern reference collection using plant samples collected from the Hope Downs 1 lease. After completing work on the modern reference collection, Wallis began the analysis of the sediment samples collected from Djadjiling, which was carried out as a blind scientific study to preclude sampling bias. In total, 38 sediment samples were submitted. Each sample was collected at 5cm intervals throughout Unit 4 (Quad A; Layers 1-40; note U4-L04 and U4-L05 were not excavated as arbitrary excavation layers, but features), spanning the entire depositional sequence in this unit. Prior to Wallis' analysis, the samples were assigned random numbers to ensure the results are not a product of sequential lab processing. A provenance key was provided to Wallis after analysis, and the samples were interpreted in the order of their real stratigraphic association.

The analysis was successfully identified a suitable sample of phytoliths preserved in the Djadjiling sediments. The study assumes that most phytoliths are introduced to the site sediments via anthropogenic activity, while acknowledging that there will be a relatively consistent background noise of phytoliths deposited throughout time via the *in situ* decay of macropod scat. The relative percentages of phytoliths were examined by stratigraphic layer, and there are some interesting changes in the phytolith abundance over time.

In the lowermost layers of the site (excavation Layers 40-38; SL7), Wallis (this volume) found low quantities of phytoliths. She suggests that they may represent a background phytolith assemblage that accumulated in the rockshelter as the result of macropod occupation. There is an increase in phytoliths between excavation Layers 37 and 34 (SL7), and Wallis (this volume) suggests that this may indicate the first human occupation of the site or increased macropod activity. As no artefacts were recovered from these arbitrary excavation layers, it appears that the increase in phytolith content is due to greater use of the site by macropods. Based on a significant increase in the quantity of phytoliths in the samples, Wallis (this volume) interpreted Layers 30 to 33 (within AU6) to represent the period of most intensive use of the site. During the phytolith analysis, Wallis was not provided with any data regarding the other patterns of archaeological site use, yet her findings independently correspond to the period of greatest artefact discard at Djadjiling, roughly 41,000 to 38,000 years ago.

There is a substantial decrease in phytolith abundance after this time, and from Layers 29 to 21 (beginning in AU6 and continuing through to mid AU4), there is a decrease in the abundance of tree and shrub phytoliths. Again, the phytolith abundance mirrors the relative trends in the artefact density. The phytolith assemblage in excavation Layer 20 (within AU4) was very limited, leading Wallis (this volume) to suggest that the site may have not been occupied at this specific interval. This excavation layer more or less corresponds to the LGM proper, around 24,000 years ago. Artefact density is indeed low in AU4, but there is evidence of limited site use during this time. For example, nine artefacts were recovered from Unit 4, Layer 20 and all were produced from dark grey chert, possibly representing a single knapping event. Within Layers 19 to 13 (AU3 through to mid-AU2), the phytolith assemblage included an increase in the numbers of trees and Panicoid grasses. Wallis (this volume) argued that the phytolith assemblage between Layers 33 and 13 represented a period of intermittent or sporadic site use and suggested that the decreased tree phytoliths may have been a response to the climatic conditions of the LGM. In the terminal Pleistocene and Holocene period, Wallis (this volume) observed that phytolith levels increased, and the assemblage includes tree and shrub species again, with a minor decline in the uppermost layers of the site. Wallis (this volume) interprets the increased phytolith abundance as representing greater site use, and the flaked stone artefact assemblage suggests that there was occasional site use during this time.

Although phytoliths occur throughout the rockshelter sediments, there is an absence of distinctive or diagnostic phytoliths in the assemblage. Due to this limitation, Wallis (this volume) argues that the assemblage is better positioned to provide information on generalised vegetation change over time rather than human use of specific plant species through time. Her assessment of the phytolith data suggest that there is a decline in tree cover around the site between Layers 29 and 13, which she infers as a decline in regional rainfall. Based on the radiocarbon dates and site stratigraphy, these layers roughly correspond to AU5 through mid-AU2, which are estimated to span from 38,000 to 15,000 cal BP. This temporal assessment of tree decline correlates very well with the full duration of the LGM, which has been defined by researchers elsewhere to cover the time span of 35,000 to 14,000 years ago (Williams *et al.* 2009: 2410).

There are other changes observed in the phytolith record, such as a shift in the types of grasses in the site. However, a thorough investigative analysis of these changes was not in the current scope of the project, and Wallis (this volume) recommends further research in this area, as it may be useful in discerning more specific patterns of human plant use in the rockshelter.

Archaeomagnetic Analysis

Forty six sediment samples were submitted to Dr Andrew Herries for archaeomagnetic analysis with the aim of identifying periods of site use through changes in concentrations and grain sizes of the magnetic minerals. Herries' full report is presented in Chapter 11, and the following section summarises his results and places them into context with the other studies from this site. Importantly, this study is the first comprehensive archaeomagnetic analysis of sediments from a site in Australia and it demonstrates the efficacy of this technique for identifying periods of human occupation as well as changes in the environment.

The sediment submitted for analysis includes samples from each of the 38 arbitrary excavation layers within Unit 4 (Quad A; Layers 1-40; note U4-L04 and U4-L05 were not excavated as arbitrary excavation layers, but features). Eight sediment samples collected from features were also submitted for analysis. The samples were assigned random numbers prior to

submission to ensure the results are not a product of sequential lab processing. A provenance key was provided after analysis, and the samples were interpreted in order of their real stratigraphic association.

Based on the magnetic susceptibility results, Herries (this volume) divides the Unit 4 samples into five zones, which roughly correspond to the stratigraphic layers defined in Section 8.3. Herries found variations in the magnetic susceptibility throughout the stratigraphic sequence, with the data suggesting anthropogenically unaltered deposits in Zone 1 (*ca.* SL7). There is a strong signal indicating anthropogenically altered deposits in Zone 2 (*ca.* SL6). There is little evidence of site use in Zone 3 (*ca.* SL5 to mid-SL2) during which there appears to have been a cooler climate. The sediment samples from Zone 4 (*ca.* mid-SL2 to mid-SL1) suggest a transition to a warmer climatic phase, and this stratigraphic layer represents the transition into the early Holocene. The magnetic susceptibility results suggest that there was little human alteration of the sediments during this time. Zone 5 (mid-SL1 to surface) suggests significant site use, with the data indicating heavy anthropogenic alteration during a warm climatic period.

The coercivity studies reveal important information regarding the site formation processes at Djadjiling. Herries found that the mineralogical signature indicates that most sediment in the deposit was derived from a single sedimentary source. The rates of sedimentation from this source were influenced by climatic change, weathering, and paedogenesis (to some extent). During warm and wet phases (*i.e.*, Zone 2, 4, and 5), there were increased rates of erosion, while in cool phases (*i.e.*, Zones 1 and 3), there was slow accumulation of allochthonous (derived from an external source) and increased rates of autochthonous deposits (derived from a source within the shelter).

The patterns identified within the magnetic susceptibility sequence are consistent with the distribution of artefacts through the deposit, as well as with the results of the phytolith analysis. The archaeomagnetic analysis suggests that the most intense period of site use was during the initial occupation of the site, thereafter site use declined until the late Holocene. Moreover, it shows that there were considerable climatic changes over the course of occupation of the site, with a cool climate in Zone 1, followed by slightly warmer conditions in Zone 2. The coolest conditions were experienced at the site in Zone 3, and Zone 3 corresponds to the period between 38,000 to 15,000 cal BP. Wallis (this volume) found that there was a decline in tree phytoliths during this same period, which she suggests may be due to a decline in effective precipitation.

Herries' analysis of the sediment samples collected from hearth features shows that while the site was utilised intermittently between the phases of intense site use, there was minimal alteration of the surrounding sediments. Feature 4 (identified in SL3) had a very prominent archaeomagnetic signature, while there is a lack of a background anthropogenic signal in the surrounding sediments. This suggests that the feature is well preserved and the site was only used briefly, as the surrounding sediments did not become altered. The artefact density supports this interpretation, as AU3 had the lowest artefact density with 80 artefacts deposited over a time span of approximately 7000 years.

Macrobotanical Analysis

Dr Andrew Fairbairn was engaged to carry out a macrobotanical analysis of charcoal samples from Djadjiling, with the aim of determining what woody plant species were used as fuel throughout the sequence, and if there are variations through time (Fairbairn 2012). The study also considered if the macrobotanical evidence could provide information regarding environmental change through the occupation, as well as to determine if any plant remains in the assemblage could provide insight into past subsistence. A brief summary of the results is provided below that incorporates further contextual information.

Charcoal samples were submitted from each hearth feature, and Fairbairn found that samples from eight features (Features 2-6 and 8-10) were suitable for analysis. While there are abundant samples of charcoal recovered from throughout the excavation, Fairbairn (2012) specifically selected the samples from hearth contexts as they are demonstrated to be a result of human activity within the shelter. The samples were submitted without the provenance data and were assigned random sample numbers. Only after the analysis had been completed, did ACHM provide the analyst with the full provenance details for the samples.

While Fairbairn (2012) found that the preservation of the samples generally declined with depth, he was able to identify that the samples contained a limited range of woody plant species, which were dominated by mulga (*Acacia aneura*), wattle (*Acacia* sp.) and gum (*Eucalyptus* spp.). Fragments from the gum family (Myrtaceae) were also identified. Fairbairn (2012) found that Mulga and *Eucalyptus* were the dominant fuel sources throughout the Pleistocene occupation. There is a considerable decline in the proportion of mulga and wattle in Feature 4 (23,813±184 cal BP), and this trend continues into the Holocene with Feature 3, which is argued to be contemporaneous with or slightly older than Feature 2 (2858±45 cal BP). In contrast, Feature 2 shows a similar pattern to the Pleistocene features. The wood charcoals from Feature 6 show that the fuel was sourced from a variety of wood types, including mulga, wattle, gum, Myrtaceae, and an indeterminate type. This was an important finding, as the irregular shape of Feature 6 had brought question to the origin of the feature. It had been previously suggested that Feature 6 may have been a burned branch or log rather than a hearth feature.

Fairbairn (2012) interprets the wood charcoal frequency data to suggest the there was a transition from a mulga-gum woodland in the late Pleistocene to a wattle-gum woodland in the late Holocene. He suggests that the decline in mulga may have occurred because of water stress and shortage. This interpretation is based upon the decline in mulga in Features 4 and 3. However, radiocarbon dates from Features 4 and 5 show similar ages, but their stratigraphic relationship indicates that Feature 4 is slightly more recent than Feature 5. Features 4 and 5 have considerably different wood charcoal compositions, and Fairbairn (2012) cautions that further samples are needed to confirm this pattern. Fairbairn (2012) suggests that drought conditions may have been experienced when Feature 3 was utilised, due to the low proportion of mulga. A regional dry phase dating between 5400 and 3700 cal BP has been indicated through studies of palaeo-tropical cyclone records (Nott 2011), as well as through pollen studies (van der Kaars *et al.* 2006: 887, Figure 4). As Feature 3 remains undated, it is unclear whether these regional arid conditions are responsible for the decline in mulga, or whether there was a later, more localised arid event.

8.8 DISCUSSION

The results of the Djadjiling archaeological investigations and specialist analyses have implications for our understanding of the archaeology of the Pilbara and greater arid zone. Our

attempt to summarise the most significant findings of the Djadjiling study is presented in Table 8-21. Significantly, the radiocarbon age estimates demonstrate that the Hamersley Ranges were occupied as early as 41,000 years ago, extending the known antiquity of Aboriginal occupation in the Pilbara by 10,000 years. Previous archaeological investigations at nearby sites produced radiocarbon determinations that suggested the rangelands of the inland Pilbara were first occupied by approximately 28,000 to 31,000 cal BP, as reported for Newman Rockshelter (30,897±372 cal BP, SUA-1510; Brown 1987) and Mesa J24 Rockshelter (28,317±415 cal BP, Wk-2514; Hughes *et al.* 2011). In addition to these early dates, a number of other Pleistocene sites have been identified in the Hamersley Ranges, but the timing of the initial occupation of these sites is considerably more recent, dating around 23,000 to 25,000 cal BP (*e.g.*, Milly's Cave, Jundaru, Newman Orebody XXIX, Yirra Rockshelter, and Juukan-2; for specific dates see Table 2-3). The newly reported Juukan-1 rockshelter provides further confirmation of the early occupation of the Pilbara uplands with a small assemblage associated with an age estimate of 37,504±373 cal BP (Beta-249759; Slack *et al.* 2009).

This data places the early occupation of the eastern Hamersley Plateau in-line with, or perhaps slightly earlier than, the occupation of other areas of the arid zone, and it suggests that the western interior of the arid zone was occupied earlier than the arid centre of Australia. Nearby in the Little Sandy Desert, a Pleistocene occupation at Serpent's Glen rockshelter occurs slightly before 28,300±186 cal BP (23,550±140 BP; ANSTO-0ZB582; O'Connor *et al.* 1998). Radiocarbon dates from Puritjarra and Kulpi Mara rockshelters suggest that the central Australian ranges were occupied between 35,730±481 cal BP (31,140±470 BP; ANU10013; Smith *et al.* 1997) and 34,178±343 cal BP (29,510±230 BP; Beta-98034; Thorley 1998; Thorley *et al.* 2011). Evidence from the margin of the Great Sandy Desert suggests that the occupation of the shoreline of Lake Gregory may have occurred as early as 45,000 to 50,000 years ago (Veth *et al.* 2009).

The evidence from Djadjiling demonstrates that the site was most intensely utilised during the initial occupation of the site (AU6), which spans the period between 41,000 and 38,000 cal BP (see Table 8-21). Not only is peak site use in AU6 demonstrated by artefact densities, but the results of independent archaeomagnetic (Herries, this volume) and phytolith (Wallis, this volume) analyses also have established the same pattern. The peak in site use occurs during a local phase of warm and wet climatic conditions (Herries, this volume), when trees and shrubs were abundant in the area surrounding the site (Wallis, this volume). At a regional level, there is further evidence in support of warmer and wetter conditions between 50,000 and 35,000 years ago than presently experienced (Magee *et al.* 2004: 1151; Johnson *et al.* 1999; Cohen *et al.* 2011; De Deckker *et al.* 2011). It is during this phase of favourable climatic conditions, that Djadjiling was occupied most frequently and for the greatest durations.

The evidence from Djadjiling demonstrates that the site was most intensely utilised during its initial occupation phase (AU6), which spans the period between 41,000 and 38,000 cal BP (see Table 8-21). Not only is peak site use in AU6 demonstrated by artefact densities, but the results of independent archaeomagnetic (Herries, this volume) and phytolith (Wallis, this volume) analyses also have established the same pattern (Table 8-21). The peak in site use occurs during a local phase of warm and wet climatic conditions (Herries, this volume), when trees and shrubs were abundant in the area surrounding the site (Wallis, this volume). At a regional level, there is further evidence in support of warmer and wetter conditions between 50,000 and 35,000 years ago than presently experienced (Magee *et al.* 2004: 1151; Johnson *et al.* 1999; Cohen *et al.* 2011; De Deckker *et al.* 2011). It is during this phase of favourable climatic conditions, that Djadjiling was occupied most frequently and for the greatest durations.

Subsequent to the initial peak in site use, the data indicates that Djadjiling was only occupied intermittently, likely for only brief periods of time. This decline in site use is roughly contemporary with the onset of cooler and more arid conditions experienced throughout the LGM. In northwest Australia, palaeoclimatic research suggests that the LGM began at approximately 35,000 years ago and persisted until 14,000 years ago (Williams *et al.* 2009: 2410). While the decline in site use begins prior to this regional model for the initiation of the LGM, data from the archaeomagnetic analysis suggests that cooler conditions were experienced at the site by U4-L29 (*ca.* 140-145cmbd; Herries, this volume), and this excavation layer occurs at the transition of AU6 to AU5, or approximately 38,000 years ago (Table 8-21). Similarly, Wallis (this volume) found that there was a corresponding decrease in phytolith abundance and fewer phytoliths belonging to trees and Panicoid grasses beginning in U4-L29, which were interpreted as a response to cooler and more arid conditions.

As indicated in Table 8-21, both the archaeomagnetic and phytolith analyses showed climatic amelioration in by U4-L12 (*ca.* 60-55cmbd; Herries, this volume; Wallis, this volume), and this corresponds to the middle of AU2. This layer has not been directly dated, but a charcoal sample collected at a similar level (58cmbd, U6-QB-L09) dates to 14,907±214 cal BP. The distribution of artefacts throughout the Djadjiling sequence suggests low site use throughout this same period, particularly in AU3. In AU2, the proportion of artefacts begins to increase slowly and peaks between 55 and 45cmbd, with 75 artefacts recovered from between these depths. Thus, it appears that the increase in artefact numbers occurs slightly after the improved climatic conditions.

It is important to clarify that after the initial occupational phase (AU6), artefact numbers are consistently low throughout the deposit. The one exception is a slight rise in artefact numbers between 95 and 85cmbd, which occurs at the transition between AU4 and AU3. This phase of occupation dates to approximately 24,000 years ago and is contemporaneous with a widespread occupation of the Hamersley Ranges at this time (see above), when many sites were occupied for the first time. While there are numerous sites in the Pilbara with occupations dating to this period, most sites have only small artefact assemblages dating to this phase and this suggests that there was a small resident population in the region that only briefly occupied sites and was highly mobile. This occupation occurs during the LGM, but prior to the generally accepted onset of the LGM proper (23,000 to 19,000 cal BP; see Mix *et al.* 2001: 636; Williams *et al.* 2009: 2400). However, the Djadjiling macrobotanic analysis suggests that there may have been less precipitation during this time, as indicated by a decrease in mulga in Feature 4 (Fairbairn 2012). Similarly, pollen recovered from an offshore core indicates that there was a peak in aridity around 25,000 cal BP, followed by a phase of rapid climatic fluctuations (van der Kaars *et al.* 2006: 887, Figure 4, 888).

Table 8-21 Summary of results, Djadjiling rockshelter

AU	Depth (cmbd)	Features with Max Depth Range	Dates (cal BP)	Artefact Count	Palynological Analysis [1]	Macrobot. Analysis [2]	Archaeomag. Analysis [3]	Phytolith Analysis [4]
1	Surface -15			2		↑ *Acacia*	Zone 5 - heavy anthro. alteration during a warm climate phase.	Zone 6b - ↓ phytolith abundance; ↓ trees & shrubs
	15-20	F7 (11-13cmbd) F6 (15-22cmbd)		4				
	20-25	F1 (21-25.5cmbd) F2 (22-37cmbd)		24	Dung fungi			
	25-30	F3 (26-32cmbd)	2858±45 (27cmbd)	43		↓ mulga & wattle	Zone 4 - relatively unaltered deposits formed during a warm climate phase.	Zone 6a - ↑ site use by humans; ↑ phytolith abundance; ↑ trees & shrubs
	30-35			30	→ local fires; higher frequency of charcoal; dung fungi			
	35-40			27				
2	40-45		7024±73 (43cmbd)	28	Dung fungi			
	45-50			35				
	50-55			40				
	55-60		14,907±214 (58cmbd)	21				
	60-65			21			Zone 3 - anthro. unaltered, cold climate deposits with occasional combustion features.	Zone 5 – limited phytolith abundance; ↑ trees and Panicoid and *Eriachne* grasses
	65-70			7				
3	70-75			5				
	75-80			1				
	80-85	F4 (81-84cmbd)	21,436±126 (83cmbd) 23,813±184 (83-85cmbd)	6	↑ carbon content	↓ *Acacia*		
	85-90			68		Mulga and *Eucalyptus* dominant		Zone 4 –↓ tree & shrubs; ↑ spinifex; likely natural
4	90-95	F5 (88-98cmbd)	23,820±185 (88-96cmbd) 23,624±161 (94cmbd)	62				
	95-100			26				
	100-105			19				Zone 3 - ↓ phytolith abundance; ↓ trees & shrubs; ↑ Panicoid grasses
	105-110			32				
	110-115	F8 (113.5-118cmbd)		14				
5	115-120		30,377±235 (117cmbd)	11				
	120-125			9				
	125-130		29,380±212 (128cmbd) *	30				
	130-135	F9 (130-134cmbd)		40				
	135-140			46				
6	140-145			98				
	145-150		40,267±642 (148cmbd)	149			Zone 2 – anthro. altered deposits.	Zone 2 - ↑ phytolith abundance; trees present; ↓ palms
	150-155			200				
	155-160	F10 (155-161cmbd)	40,546±615 (157cmbd) 40,911±580 (159cmbd)	182				
	160-165			35	dung fungi			
7	165-170			0	dung fungi; ↑carbon content			Zone 1b - ↑ phytolith abundance & diversity; ↓spinifex; *Acacia* present
	170-175		32,815±402 (170.5cmbd) [R]	0	↑ carbon content		Zone 1 – anthro. unaltered deposits.	
	175-180			0				
	180-185			0				
	185-190			0				Zone 1a; high proportion of spinifex; palm present
	190-195		38,317±604 (193cmbd) [R]	0				
	195-200			0	dung fungi			

Key: → first instance/beginning of; ↑ general increase; ↓ general decrease; Δ peak; ∇ trough
Source: 1 (Haberle *et al.*, this volume), 2 (Fairbairn 2012), 3 (Herries, this volume), and 4 (Wallis, this volume)

The data from Djadjiling indicates that there was very limited site occupation during the LGM proper, which roughly dates between 23,000 and 19,000 cal BP (Mix *et al.* 2001: 636; Williams *et al.* 2009: 2400). Low artefact densities in AU3 and the transition to AU2, particularly between 85 and 65cmbd, correspond well with this phase, and suggest that there was extremely limited and sporadic use of the site during this interval. The archaeomagnetic analysis showed that the sediments deposited at this time exhibited little evidence of human occupation (Herries, this volume). The one exception was the single hearth feature (Feature 4), which has a strong archaeomagnetic signature against the unaltered background sediments (Herries, this volume).

The occupation of the Pilbara during the LGM is a prominent research topic in arid-zone archaeology, and there are several models that consider the settlement patterns of the arid zone, and the Pilbara in particular, during this period. The Djadjiling data demonstrates that Aboriginal people occupied the Hamersley Ranges during the LGM, but there is only evidence of intermittent occupation, particularly during peak LGM conditions. The applicability of this data to Veth's (1989; 1993) settlement model really lies in the interpretation of the model itself, which predicts that refuges, including the Pilbara, would have had multiple occupations through the LGM and specifically in the LGM proper. Taken in a very literal sense, the data from Djadjiling fits this model because there is evidence of multiple occupations over the course of the LGM; however, the problem is that the term 'occupation' is not quantified.

When the Table 8-21 data is considered more closely, the intermittent use of Djadjiling becomes apparent. For example, only 418 artefacts (including 288 diagnostic artefacts) were recovered from the excavation layers that span the LGM (AU5 through mid-AU2). Thus, over the span of the LGM (*ca.* 21,000 years from 35,000 to 14,000 years ago), the average rate of artefact discard was 19.9 artefacts every thousand years or approximately two artefacts every century. The peak of the LGM coincides with AU3, and in the first arbitrary layer of AU3 (85-90cmbd) there are a considerable number of artefacts (n=68), but only 12 artefacts were recovered in the rest of the layer (70-85cmbd). This shows how infrequently the site was utilised over this period. The low artefact discard rates over the duration of the LGM raise the question as to whether these artefacts represent 'occupations' or brief stops at the site. Hiscock and Wallis (2005: 44-45) identified a similar problem with sites in the sandy deserts and suggest that sites with low artefact densities do not reflect continuing occupation.

Based on the artefact densities, it is evident that site use continued to be infrequent through the Pleistocene-Holocene transition and even into the late Holocene. The low artefact discard rates in the middle and late Holocene are incongruent with the evidence from other Holocene sites throughout the Hope Downs 1 lease, which typically show that there was increased site use from the mid-Holocene onwards (*e.g.*, HD07-1A-07, PAD 3, and PAD 4; Law and Cropper 2011; Cropper 2011). It is possible that the large roof fall event, which blocked off most of the rockshelter entrance, may have made the site less suitable for occupation. The roof fall event occurs at the base of SL1 (*ca.* 7024±73 cal BP), and this is in good agreement with the commencement of more intense occupation of the local area.

Due to the lack of formalised implements in most Pleistocene sites, the assemblages are often regarded as being simple and lacking technological complexity. It is true that there is consistency in the knapping technology throughout the occupation of the site, and this was observed both in the production of flakes as well as in retouched artefact manufacture. The evidence from cores and flakes demonstrates that knapping occurred at the site, and that all artefacts were not produced elsewhere and brought into the rockshelter. The refit core and flakes in AU6 provide the best evidence of on-site reduction and illustrate the excellent preservation of the deposit. Additionally, numerous tiny flakes, typical of retouching flakes, were present in the assemblage and signify the creation or maintenance of retouched artefacts at the site. Over time, there were consistent proportions of retouched and utilised artefacts, and retouching technology is consistent throughout the sequence. Many of the retouched artefacts were produced on chert or fine-grained shale, showing a preference for these high-quality raw materials over more readily available coarser-grained materials or quartz.

Significantly, evidence of hafting was identified on several retouched artefacts from AU6 and AU5. Fullagar (2012) found either resin or usewear consistent with hafting on six of the 24 specimens from AU6 that were submitted for usewear analysis, as well as on two specimens from AU5. The use of hafting and composite tools is not a new technological innovation, as this practice that appears to date back to the initial peopling of Australia (Stern 2009; McConnell 1997). However, evidence of hafting during the Pleistocene remains limited, and the data from Djadjiling is an important addition to our understanding of this technology. While it is easiest to associate hafted tools with the new formalised artefact types that appear in the Holocene assemblages (*e.g.*, tulas and backed artefacts), this evidence demonstrates that at Hope Downs 1, hafting was a long-established practice.

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Chapter 9

Excavations at PAD 3 Rockshelter

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PAD 3 was a large rockshelter in Hope North (Figure 9-2) that was first recorded during a survey undertaken by Gavin Jackson Pty Ltd in 2005 (Jackson *et al.* 2007). The site was recorded as a potential archaeological deposit (PAD), due to a lack of archaeological materials on the ground surface. The location of the site placed it within an area marked for the development of Hope 1 North mine infrastructure, including the primary crusher and run-of-mine (ROM) pad (a flattened compacted area where trucks can dump ore before being sent to the crusher). In accordance with the 2002 Section 18 permit, an application for a Section 16 permit to undertake mitigative salvage at PAD 3 was lodged with the DAA, and Section 16 Permit 416 was granted on 19 March 2007 (Hebron 2007).

A team of ACHM archaeologists conducted excavations at PAD 3 in May and June 2007 as part of the Hope North Stage 1 (MIB25) salvage program. The excavations revealed a series of extremely well-preserved combustion features and recovered a rich assemblage of artefacts, macrobotanics, and faunal remains. The lower-most combustion feature was dated 7730±46 cal BP, suggesting that PAD 3 was initially occupied at the end of the early Holocene. The following chapter provides a summary of ACHM's investigations and results.

9.1 ROCKSHELTER SETTING AND DESCRIPTION

PAD 3 was situated near the mouth of a steep gully (Figure 9-1). Due to the proximity to the ROM pad, the gully was referred to as the 'ROM pad gully'. The small gully drained from the northwest to the southeast before it dissected a wide stony plain and drained into the upper reaches of Weeli Wolli Creek. Hummock grasslands (S1 community; see Table 1-2) surrounded the site, and there were occasional acacias and eucalypts along the adjacent hillslope. Typical creek line vegetation communities began several hundred metres downstream from the site, which consisted of tall acacia shrubland (C3 community).

Within the gully, there were numerous other archaeological sites. Immediately across the gully from PAD 3 was another rockshelter, PAD 4, which had an occupation sequence beginning from the mid-Holocene. Further up the gully were rockshelters PAD 2, PAD 5, and PAD 6. A man-made structure (Hope 1-47) was located near the head of the gully. On the opposite side of the ridge was another gully that drains to the northeast. There were several rockshelters additionally recorded in this gully (Hope 1-39, Hope 1-40, Hope 1-41, and PAD 1).



Figure 9-1 Overview of ROM pad valley and PAD 3 rockshelter, pictured left

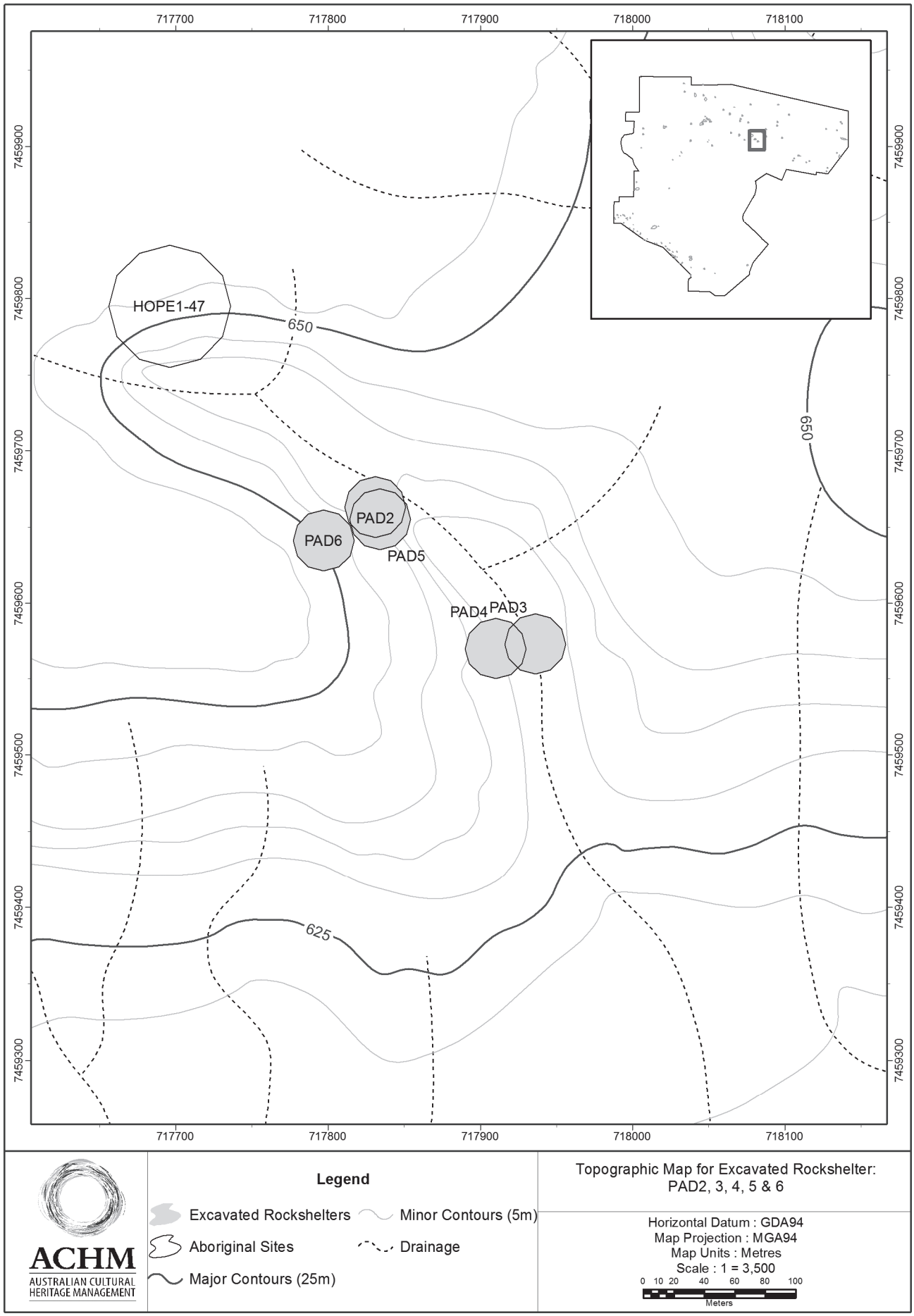

Figure 9-2 Topographic map for PAD 3 rockshelter



Figure 9-3 Photograph of PAD 3 rockshelter

PAD 3 rockshelter was on the east side of the gully, approximately 3m above the gully floor. It had a broad entrance with a southwest aspect. The rockshelter was large, measuring 14.4m wide and 2.2m high at its entrance (Figure 9.4). The average roof height was slightly lower, approximately 1.6m. The depth of the rockshelter extended back 11.9m from the dripline, towards the northeast, and the roof gradually sloped down towards this point. The rock overhang formed at the edge of a geological fold, where the bedrock stratigraphy sloped downward towards the southeast. There was a large accumulation of roof collapse along the entrance of the rockshelter, suggesting the shelter was much larger in its past. The roof collapse may have acted as a natural sediment trap, and it likely is an important factor in the preservation of the deposit.

The rockshelter occupied the Newman Member of the Marra Mamba Iron formation. The rockshelter entrance and floor sloped down from the west to the east, following the geological bedding. Less resistant bands weathered at a faster rate than the more resistant bands of BIF. As a result, most of the rockshelter floor surface was covered by large slabs of roof collapse. The east half of the rockshelter was entirely covered by large weathered slabs of roof collapse. Amongst the rocky surface of the shelter, there was only a small area that was not covered by large blocks of roof collapse. This area occurred in an area of low roof height, and it is presumed that there has been a slower rate of weathering in this area. As a result, there were numerous large BIF ledges that precariously that extended over this area. Smaller fragments of exfoliated rock with powdery silty sediment covered this part of the rockshelter floor. A small amount of leaf litter, a large burned branch, and some macropod scats were observed in this area.

9.2 SUMMARY OF FIELD INVESTIGATIONS

Prior to any archaeological work in the rockshelter, protective scaffolding was installed so the field team could safely excavate the deposits (Figure 9-5). Initially, a 1.0-x-1.0m excavation unit (Unit 1) was opened to determine the nature of the PAD 3 deposit. Ash and charcoal deposits were identified in the first layer excavated, which prompted the team to expand the excavation area to 1.0-x-2.0m (Units 1 and 2). The excavation methodology was also modified to excavate with site stratigraphy (as opposed to 5cm arbitrary excavation layers). Bedrock was exposed across both excavation units.

Based on the variety of preserved organic material, the number of archaeological features, and the quantity of artefacts recovered within a relatively small area, further work was recommended, due to the potential for this rockshelter to yield a unique and significant record of the daily activities of Aboriginal peoples in the Pilbara over at least the last several thousand years (Law and Canning 2007). Before this work could commence, a geotechnical expert deemed the site too unsafe to enter due to the high probability that the overhanging rock could dislodge and cause serious injury. Since no reasonable measure could be found to make the rockshelter safe for work, the archaeological investigations at PAD 3 were terminated. The ROM pad gully was subsequently infilled in July 2007, burying PAD 3 and the neighbouring archaeological sites.



Figure 9-4 PAD 3 rockshelter plan



Figure 9-5 PAD 3 with scaffolding in place; note the overhanging rock that resulted in the termination of the rockshelter excavation

9.3 STRATIGRAPHY

PAD 3 was the most stratigraphically complex rockshelter investigated in the ROM pad valley. In comparison to other ROM pad rockshelters, PAD 3 was assessed as the least likely to have well-preserved or stratified sediments. Prior to excavation, the site was inspected by several archaeologists, and all shared the opinion that the site was likely to have very shallow deposits (<10cm depth), with little or no preservation. This initial, unquantified assessment could not have been more incorrect, and it echoes the adage 'you can't judge a book by looking at its cover'. The PAD 3 investigations highlight the importance of test excavations for potential archaeological deposits.

The average depth of the PAD 3 deposit was approximately 40cm, and the maximum depth in Units 1 and 2 was 50cmbs. The bedrock surface was uneven, but in general, the bedrock gently sloped down from the north of Unit 2 towards the south of Unit 1. The coarse sedimentary fill of PAD 3 rockshelter formed through the spalling and weathering of roof fragments. The fine sediment was loose, and it was derived in part of windblown particulates and the chemical weathering of rockshelter walls and roof fragments. When wet, the fine sediment had the texture of silty loam. A very thin layer of the mineral kaolinite was observed adhering to patches of bedrock at the base of the excavations. The sediments also contained some unidentified fine precipitate mineral content, which may include calcite or some type of salt (*e.g.*, gypsum or halite). These precipitates may have been a contributor to the preservation of organics at this rockshelter; however, this hypothesis requires further testing to be verified.

The PAD 3 deposit consisted of two principal background sedimentary layers that were distinguished by colour (Figure 9-6). The upper layer, defined as SL1, was loose and shallow, and varied in thickness between 5 and 10cm. The SL1 sediment colour was dark brown (7.5YR 3/4), and it was rich with organic matter such as charcoal, grasses, twigs, macropod scats, and other faecal matter. The underlying SL2 was a brown (10YR 4/3) colour and continued to bedrock. This lower layer was also comparatively loose and undifferentiated. Organics, including charcoal, twigs, leaves, and grasses were also preserved throughout SL2, but their concentration in the deposit diminished with depth. Macropod scat was uncommon in SL2.

The most striking element of the PAD 3 deposit was the series of well-preserved combustion features, interpreted as hearths, and a floor clearing event (or hearth-clearing event). The unusual preservation of these features tells the unique story of PAD 3 and provides insight into past subsistence activities. The features also provide a secure, unambiguous context for the mid-Holocene utilisation of backed artefacts, which is earlier than previously documented for the inland Pilbara region.

Each of the PAD 3 combustion features was distinctive, but differentiating the feature sediments from the background site stratigraphy was challenging at times. While some features were extremely well-preserved, others were less well-defined, possibly due to post-depositional disturbance, which created mixing of burned and unburned sediment. The elements that distinguished the combustion features from the surrounding sediments include a darkened sediment colour, the presence of ash and charcoal, fire cracked rock, and underlying reddened sediment.

The excavation team removed the PAD 3 features stratigraphically, with the aim of documenting the *in situ* relationship of artefacts and organics, as well as determining the chronological order of combustion events. The biggest challenge of this exercise was establishing the spatial relationship of the features with the material discarded in the adjacent background sediments. Connecting the artefacts from the background sediments to the features could not be done based on arbitrary levels alone, as the investigations demonstrate that the PAD 3 features were often constructed on undulating or sloping floor surfaces, and oftentimes the occupants excavated into the rockshelter floor to construct basin-shaped hearths. Additionally, combustion features were often built atop of one another, and sometimes only a few millimetres of unburned fine brown sediment separating events. Adding to further complexity, there is a good likelihood that

some hearths were reused or disturbed by general subsistence activities, resulting in the intermixing of feature contexts.

To overcome the complexities of reporting the site stratigraphy, feature relationships, and artefact associations, the research team developed the following diagram to assist with illustrating the temporal and spatial contexts of the excavated materials with the background stratigraphy and features. The resulting diagram, depicted in Figure 9-7, provides a tool to examine the order of archaeological events at PAD 3, and it forms the basis for our temporal interpretation of the rockshelter stratigraphy.

For illustrative and interpretive purposes, the stratigraphic layers, calibrated AMS radiocarbon determinations, and backed artefact contexts for PAD 3 rockshelter are presented in Figure 9-7. These items are included as they will be discussed further in the text. It is also important to acknowledge that Figure 9-7 is a simplified diagram that is used for illustrative purposes to demonstrate the stratigraphic and spatial contexts of the PAD 3 features and surrounding sediments. These key temporal and stratigraphic markers, discussed in further detail below, will be used to guide the PAD 3 analysis and provide the rationale for interpreting the site chronology.

9.4 RADIOMETRIC DATES

Five charcoal samples were submitted to the University of Waikato Radiocarbon Dating Laboratory for AMS radiocarbon dating. The charcoal samples were selected from feature contexts and key matrix locations to try to provide a site chronology for feature events. The radiocarbon results are presented in
Table 9-1 below.

As indicated above, the AMS results are confined to the Holocene period and demonstrate that the PAD 3 sediments accumulated over the past 8,000 years. Charcoal from the earliest combustion feature, Feature 11, yielded a radiocarbon determination of 6899±41 BP (Wk-26737). The calibrated age for Feature 11 is therefore 7833 to 7663 cal BP, suggesting PAD 3 was initially occupied at end of the early Holocene, around 7730±46 cal BP.

Charcoal submitted from Feature 5 and Feature 1 returned radiocarbon determinations of 5621±34 BP (Wk-26737) and 4143±34 BP (Wk-21658) respectively. These two age estimates are important for understanding the antiquity of backed artefact technology because four backed artefact specimens were recovered from within the Feature 1 matrix, a very well preserved hearth. An additional broken backed artefact (Artefact 524) was recovered in the sediments underlying Feature 1. Based on the calibrated age results and the context of these specimens, it is conservatively suggested that backed artefacts have been utilised in the region since at least 4569 cal BP and possibly as early as 4825 cal BP.

Charcoal sample Wk-26736 was selected from a background context overlying Feature 1 and underlying Features 8 and 9. As discussed in the section below, the structure of Features 8 and 9 was slightly diffuse and very little sediment separates these overlapping combustion features. A large fragment of charcoal was collected from the brown sediment underlying these features to estimate the age of the deposit that accumulated between Feature 1 and Features 8 and 9. The charcoal sample provided an age estimate of 3688±30 BP, which corresponds with the Feature 1 result. When calibrated, Sample Wk-26736 infers that Features 8 and 9 once rested upon a surface that formed between 4145 and 3926 cal BP.

The uppermost and most recent hearth from PAD 3 was Feature 2. Charcoal collected from Feature 2 dates to 2417±30 BP (Wk-21659). The hearth was in very good condition, retaining its shape and structure, and an *in situ* heat affected core was recovered from within the feature. The calibrated age suggests that the hearth was constructed sometime between 2696 and 2349 cal BP. No surface artefacts or cultural features were found in overlying sediments, suggesting that late Holocene site use was short-lived or possibly had ceased.

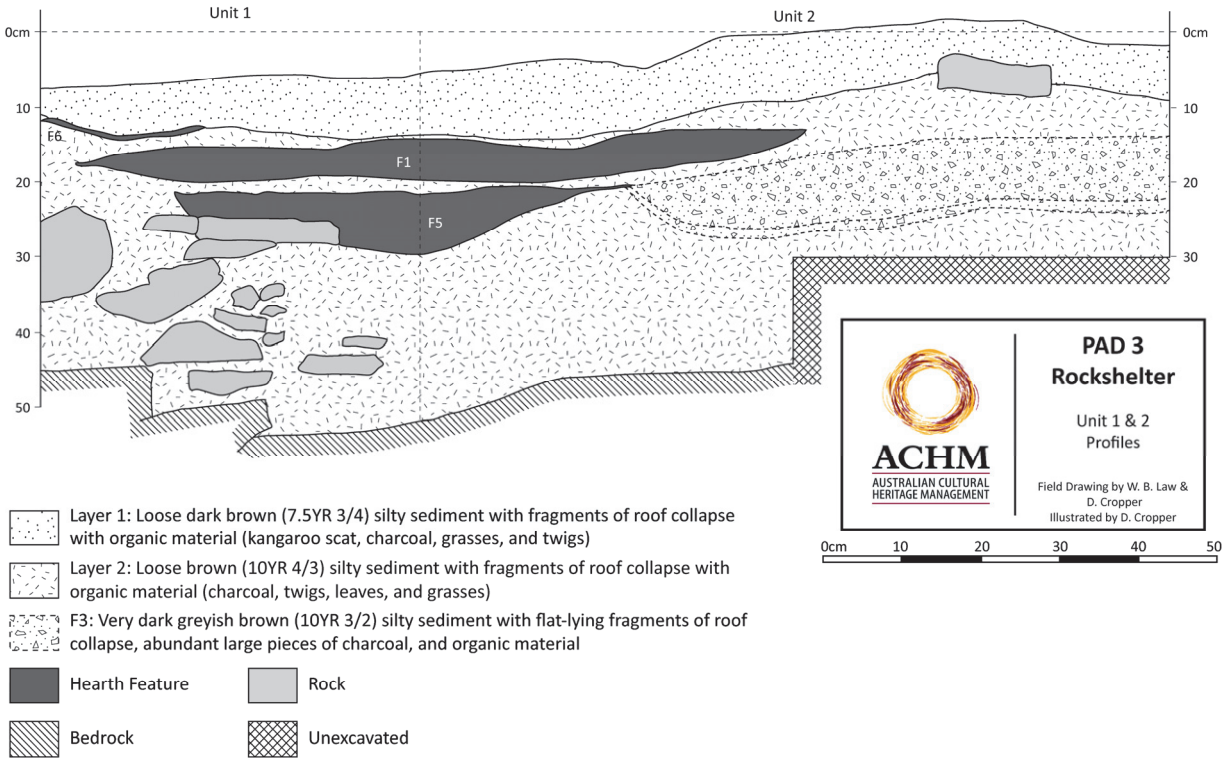

Figure 9-6 West wall section profile, PAD 3 rockshelter

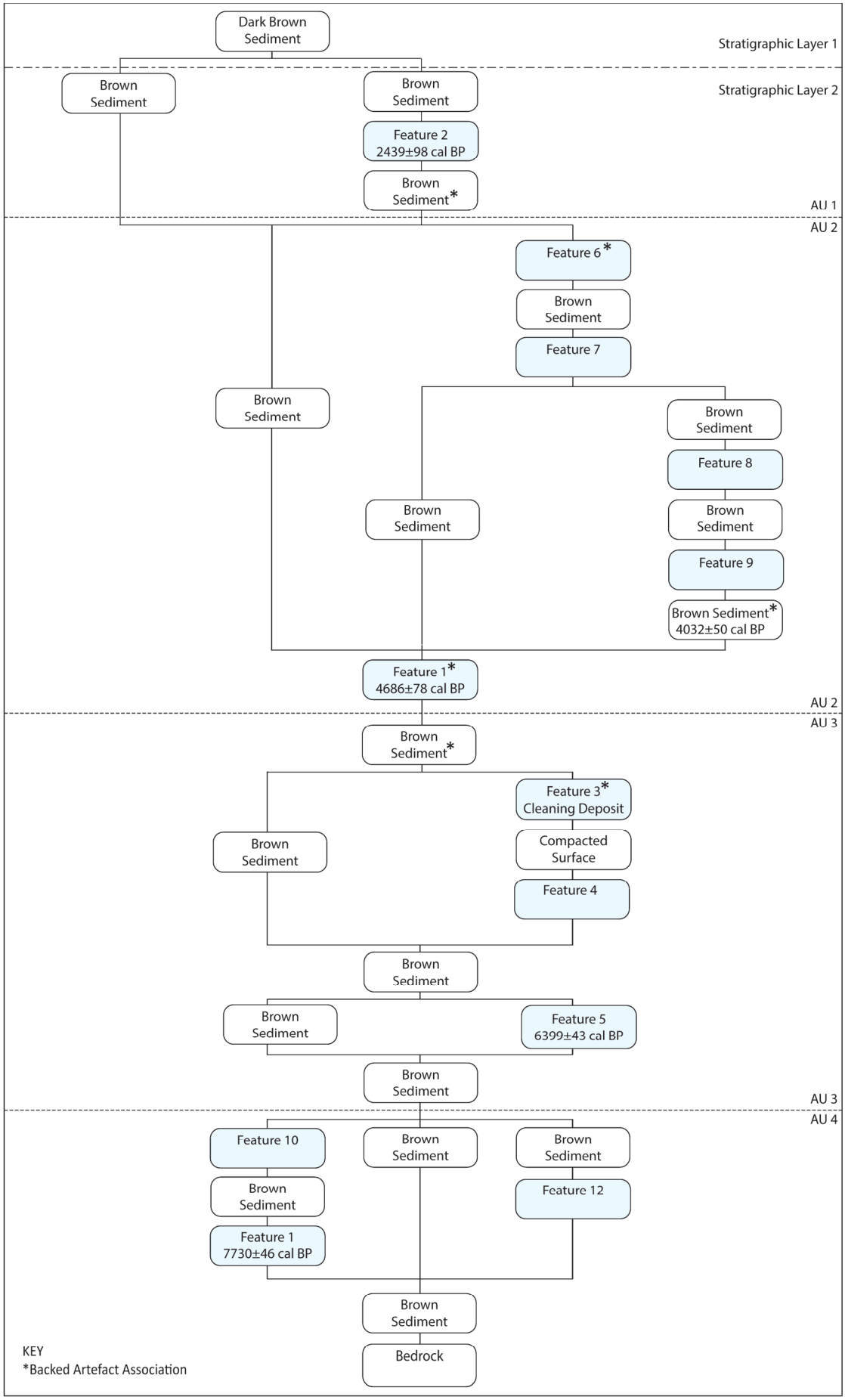

Figure 9-7 Simplified diagram of stratigraphy, archaeological features, and analytical units, PAD 3 rockshelter

Table 9-1 AMS radiocarbon results, PAD 3 rockshelter

Lab Code	Sample No.	Material	Context	Depth (cmbd)	Depth (cmbs)	$\delta^{13}C$	^{14}C Age (BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-21659	C-13	Charcoal	Feature 2	10	5	-24.1±0.2%	2417±30	2696 to 2349	2439±98
Wk-26736	C-25	Charcoal	Beneath Features 8 & 9	17	12	-23.9±0.2%	3688±30	4145 to 3926	4032±50
Wk-21658	C-8	Charcoal	Feature 1	21	16	-22.8±0.2%	4143±34	4825 to 4569	4686±78
Wk-26737	C-35	Charcoal	Feature 5	27.5	22.5	-24.5±0.2%	5621±34	6469 to 6313	6399±43
Wk-21660	C-41	Charcoal	Feature 11	34	29	-25.6±0.2%	6899±41	7833 to 7663	7730±46

9.5 ARCHAEOLOGICAL FEATURES

The excavated site deposit contained 12 archaeological features, which appear to represent 11 combustion features and one floor clearing or sediment clearing event. Each feature was stratigraphically separated by a layer of brown sediment. Many of the combustion features share similar attributes; they generally have a thin lens of ash that is layered atop of dark soil and charcoal. All of the combustion features have been interpreted as campfire hearths. *In situ* charcoal was collected from each feature, and artefacts, burnt bone, seed, and charcoal were recovered in close association with some features.

In many instances, PAD 3 had undisturbed hearths that have maintained their *in situ* artefact associations, shape, and structure. The site also had a secondary feature that has been interpreted as an area of feature cleaning or sediment clearing, whereby the early site residents excavated and redistributed the feature matrix amongst the adjacent rockshelter sediments. Beneath the cleaning deposit, the excavators also encountered a distinct compacted surface that is hypothesised to be associated with a previous occupation.

The PAD 3 features have been numbered arbitrarily, which do not reflect the temporal order of feature events. Feature number assignment is related to the order in which the feature was discovered. Therefore it should not be assumed that features are numbered based upon their temporal-spatial ordering within the site deposit. The spatial relationship between the PAD 3 hearth features is complex. This intricacy is due, in part, to the high number of features within a relatively shallow deposit, where the features closely overlap each other and may only be separated by a few millimetres of brown background sediment. Many of the features were draped over one another and not all were constructed atop of a level floor surface. Based on the angle of some feature sediments, it is likely that some features were constructed on previously undulating or sloping floor surfaces. Furthermore, some hearth features were basin-shaped, suggesting the early inhabitants shallowly excavated an area for the campfire, and this is supported by the identification of the feature cleaning event (Feature 3).

The distribution of the PAD 3 features is presented in Table 9-2 and includes the maximum top and bottom elevations (cmbd) for each feature. All of the feature elevations were recorded as centimetres below datum, and they do not necessarily demonstrate how closely features overlapped one another. For example, Feature 9 appears to be at a higher elevation than Feature 8; however, Feature 9 was actually angled and beneath Feature 8. These two features were separated by a thin layer of sediment that was only a few millimetres thick.

The PAD 3 features are discussed individually below, beginning with the deepest (and oldest) feature and finishing with the most recent (and youngest) feature. The features have been grouped based upon their occurrence in early Holocene, mid-Holocene, or late Holocene aged sediments. When possible, each feature's structure, contents, and *in situ* artefact associations are discussed.

Early Holocene Features

Feature 11 - Stratigraphically, Feature 11 is the oldest archaeological feature and the first cultural event documented for PAD 3. A charcoal sample selected from Feature 11 yielded a date of 6899±41 BP, and it calibrates to 7833 to 7663 cal BP, firmly establishing Feature 11 as an early Holocene event. The median calibrated age for this feature is 7730±46 cal BP, suggesting initial occupation of the rockshelter occurred around this time. The feature was located in Unit 1 (Quads A/C) and Unit 2 (Quads B/D), and it abutted a large slab of roof fall. It was a teardrop-shaped hearth comprised of an ashy layer overlying charcoal and dark reddish brown (5YR 3/2) sediment and fire-cracked rock. The hearth was clearly separated from the overlying organic-rich fine brown background sediment, which rested between it and the overlying Feature 10.

The profile of Feature 11 was plano-convex and measured 0.55-x-0.82m. The top heights of the feature varied between 34 to 35cmbd and the bottom elevations of the feature were between 37 and 39cmbd; thus, the hearth was approximately 4 to 5cm thick. One of the striking differences of this hearth, in comparison with the other features and excavated layers, was the high pH value of 9; the surrounding sediment had pH values that range from 5.5 to 6.

Another interesting aspect of Feature 11 is the comparatively high percentage of *Acacia* spp. charcoal within the feature matrix. Together with Feature 12, these two features contain approximately 20% charcoal from *Acacia* spp., with *Eucalyptus* spp. comprising the remaining macrobotanics burned within the feature (Fairbairn 2011). Feature 12 was possibly contemporaneous with Feature 11, as it was located nearby at a similar elevation and contained a similar macrobotanical matrix.

No faunal remains were found in the Feature 11 matrix; however, two complete flakes (Artefacts 285 and 286) manufactured from BIF were recovered from within the hearth. One flake is technologically a blade, lacking cortex and having parallel sides with a hinge termination. The other specimen is a secondary flake (1-32% cortex), and it expands distally with a feather termination. Neither artefact showed signs of heat damage (*e.g.*, potlids, crazing, or reddening) or usewear.

Feature 12 - Feature 12 was a small hearth that was identified in Unit 2 (Quads A/B). The full extent of the hearth could not be determined as it continued into the east baulk. The excavated portion of Feature 12 measured 0.30-x-0.38m. The cross section of the hearth was lenticular shaped and it was comprised of two layers. The upper layer consisted of light grey ash, while the lower layer was compacted and was comprised of very dark greyish brown sediment (10YR 3/2, pH 6). The top of the feature began 31.5 to 33.5cmbd, and the bottom of the hearth feature rested on a flat compacted layer 37 to 39cmbd.

Table 9-2 Chronology of combustion features presented from oldest to youngest, PAD 3 rockshelter

Feature Number	Excavation Unit(s)	AU	Top Levels (cmbd)	Bottom Levels (cmbd)	pH	Median Calibrated Age (cal BP)	Comments
Feature 11	Unit 2	4	34-35	37-39	9	7730±46	High pH; high proportion of acacia
Feature 12	Unit 2	4	31.5-33.5	32-34.5	6		High proportion of acacia
Feature 10	Unit 1 & 2	4	30	31	6		100% eucalyptus wood charcoals
Feature 5	Unit 1 & 2	3	23-25.5	25-30	5.5	6399±43	
Feature 4	Unit 1 & 2	3	20.5-21.5	21.5-25	6-7		Greasy texture
Feature 3	Unit 2	3	15.5-16	20.5-26	5.5		Possible cleaning deposit?
Feature 1	Unit 1 & 2	2	13.5-14.5	15-22	7	4686±78	Extremely well-preserved layered hearth. Burned paperbark identified.
Feature 9	Unit 2	2	11.5	14	6		Charcoal fragment below feature dated to 4032±50 cal BP
Feature 8	Unit 2	2	13	16	6-7		Charcoal fragment below feature dated to 4032±50 cal BP
Feature 7	Unit 1 & 2	2	11	12.5-14	5		Greasy texture
Feature 6	Unit 1	2	11	14-14.5	4.5		
Feature 2	Unit 2	1	8	11	6	2439±98	Half heat-reddened core.

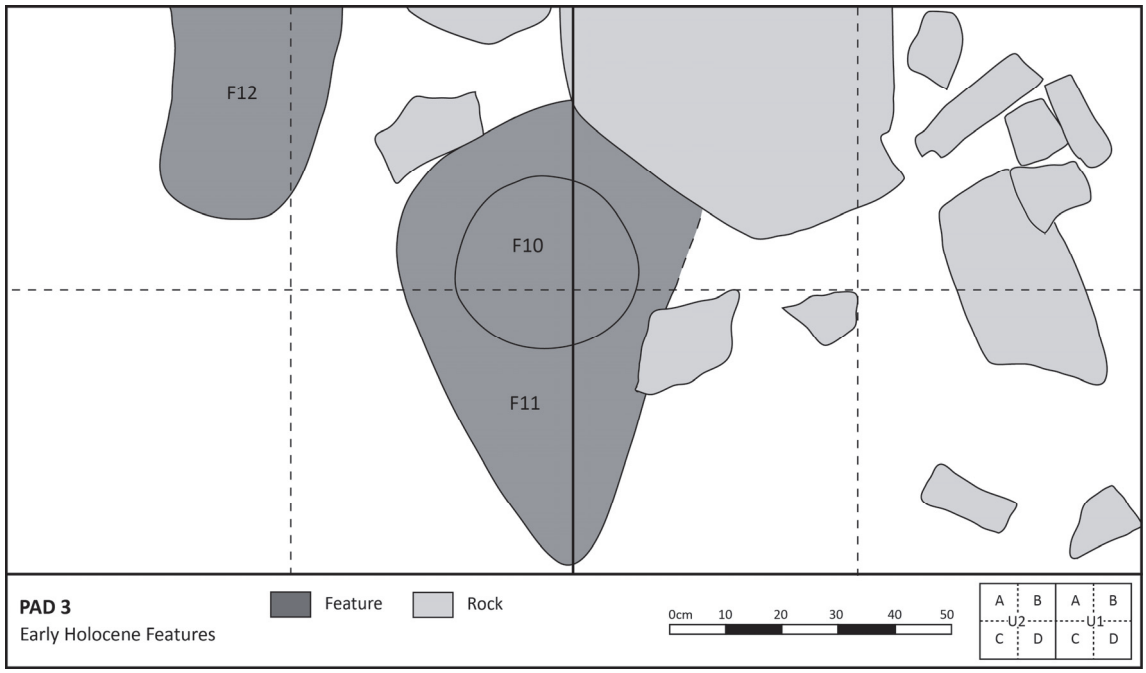

Figure 9-8 Distribution of early Holocene combustion features at PAD 3 rockshelter

Feature 12 may be contemporaneous with Feature 11. Irrespective of this potential association, Feature 12 was clearly an early Holocene feature, feasibly 7833 to 7663 cal BP. The probability that these features are contemporaneous is based on the close spatial context of the features and is supported by the results of the macrobotanical analysis. Feature 12 was near Feature 11 and it occupied a similar spatial elevation. Like Feature 11, the macrobotanical analysis demonstrates that *Acacia* spp. comprise around 20% of the archaeological charcoals, *Eucalyptus* spp. make up the remaining 80% of the macrobotanical contents (Fairbairn 2011). As noted by Fairbairn (2011), *Acacia* spp. were found in higher frequency in the early Holocene hearths, and the decline in *Acacia* spp. in mid-Holocene and late Holocene hearths may reflect a decline in its local availability

A left longitudinally cone split flake manufactured from homogenous BIF was recovered in the Feature 12 matrix. The flake did not exhibit signs of heat damage. Similarly, two unburned mammal bones were recovered from the matrix, suggesting they are not associated with the event.

Feature 10 - Feature 10 was a small circular hearth located in Units 1 (Quads A/C) and Unit 2 (Quads B/D). It was a coherent feature, separated from the overlying Feature 5 and underlying Feature 11 by a thin layer of brown sediment. The shape of the Feature 10 hearth was semicircular and it measured 0.34-x-0.31m. In profile, the hearth was bowl-shaped and 1cm thick, occupying an elevation of 30 to 31cmbd. The feature matrix was comprised of a dark reddish brown layer (5YR 2.5/2, pH 6) with charcoal fragments, approximately 1cm long, abundant throughout the deposit. No artefacts or faunal material were recovered from the feature sediments.

Mid-Holocene Features

Feature 5 - Feature 5 was a large hearth that extended across Unit 1 (Quads A/C) and Unit 2 (Quads B/D). The full extent of the hearth could not be determined because it continued into the

unexcavated east and west baulks, as well as into unexcavated Unit 1 sediments from Quads B and D. The maximum excavated area of the feature matrix measured 0.98-x-1.0m. The hearth had an irregularly shaped outline, but in cross-section, it was basin-shaped, suggesting that a shallow depression was excavated prior to the hearth's construction. The top of the hearth appeared from 23 to 25.5cmbd and the bottom of the hearth terminated at 25 to 30cmbd.

Feature 5 was comprised of two layers; at the top of the feature there was a distinct ashy lens over a layer of very dark brown ashy sediment (10YR 2/2, pH 5.5) with ash pockets and bright red fire-cracked rock. There was an ample amount of charcoal and black staining throughout this feature. Charcoal submitted for dating from this feature returned an AMS radiocarbon age of 5621±30 BP, suggesting the hearth was constructed at the beginning of the mid-Holocene sometime between 6469 to 6313 cal BP, or as the median calibrated age suggests, around 6399±43 cal BP.

The analysis of the macrobotanics indicates that the wood charcoals are 100% *Eucalyptus* spp. (Fairbairn 2011). In addition to charcoal, the feature matrix consists of fine sediment with fire-cracked roof spall, pockets of ash, organics, and bone. The fire cracked roof spall appears to have been heated *in situ*; however, the bone fragments do not exhibit evidence of burning (McDowell, this volume).

McDowell (this volume) identified three specimens from Feature 5 that are possibly cultural. All three fragments are mammal bone. Two have crenulated fractures and one is spirally fractured. Crenulated breaks suggest a predator has eaten the bone and spiral breaks occur only in living or freshly broken green bone.

Feature 5 rested beneath Feature 4 and the two features were separated by an organic-rich brown sediment layer. Feature 5 also appeared to be associated with the layer of compacted sediment beneath Feature 3. It is hypothesised that the compacted layer of sediment was a possible living surface, located directly adjacent to the feature.

The preservation of Feature 5 was affected by an area of bioturbation (fine roots) in the southwest corner of Unit 1 (Quad C). This disturbed area was immediately below a large, boulder-sized overhanging rock. This rock was clearly used as a perch by birds as is evidenced by the bird droppings along the edge of the rock. These droppings may have been an influencing factor in the bioturbation.

Feature 4 - Feature 4 was a small sub-oval hearth that extended over Unit 1 (Quads A/C) and Unit 2 (Quads B/D). The maximum dimensions of the feature were 0.75-x-0.50m. The top of the feature began at 20 to 21cmbd and terminates at 21.5 to 25cmbd. In cross-section, the hearth had a slightly askew basin-shape, measuring 5cm at its maximum thickness.

Feature 4 was beneath Feature 1 and over Feature 5. These features were separated from one another by a thin layer of brown sediment. The spatial context of Feature 4 suggests that the hearth is of mid-Holocene antiquity, and based on the outer calibrated ranges for Feature 1 and 5, it may be approximated that Feature 4 was constructed between 4825 and 6313 years ago.

The excavators noticed that the feature matrix exhibited a moderate degree of internal structure. The upper feature matrix was a thin grey (7.5YR 6/1, pH 6) ashy layer less than 0.5cm thick, which overlaid a thin layer of very dark greyish brown (10YR 3/2, pH 6) consolidated sediment (approximately 0.5cm thick). Mineral deposits with the texture of salt crystals were observed in this layer. The base of the feature was a very thin dark brown layer (7.5YR 3/2, pH 7). Paperbark, bone, fire cracked roof spall, and plant fibres recovered were recovered from the feature matrix. These items were not burned, so it is unlikely that they are related to the feature event. The most unusual attribute of the matrix was the greasy texture of the fine sediment. The cause of the texture remains unknown, but the excavators postulated that the texture could be influenced by the release of *Eucalyptus* oil or animal lipids during burning, decomposing plant matter, microbe activity, or an unknown pedological agent.

The charcoals from Feature 4 are estimated to consist of 12% *Acacia* spp. and 88% *Eucalyptus* spp. (Fairbairn 2011). Two nondescript types of gum tree and a melaleuca were identified in the charcoal, but identification beyond the family and genus taxa was not possible (Fairbairn 2011).

Three reptile and 29 mammal bones were recovered from the feature matrix (McDowell, this volume). The only identifiable remains belong to the *Agamidae* (dragon lizard), *Muridae* (rodent), and *Macropodidae* families. Two non-diagnostic burned mammal bones were identified by McDowell (this volume) as having a possible cultural association.

Eight flaked stone artefacts were recovered from the Feature 4 matrix. Only one flake specimen is unbroken, and seven of the flaked artefacts have been crazed or potlidded from the fire.

Feature 3 - Feature 3 was the only cultural feature from PAD 3 not defined as a hearth. This deposit consisted of a dense concentration of large charcoal fragments (up to 3.5cm long), organic remains (leaves, twigs, and grass), faunal remains materials, artefacts, very dark greyish brown (10YR 3/2, pH 5.5) sediment, and rock. The matrix showed no evidence of *in situ* burning, and it ha a dispersed or intermixed appearance, which led to its interpretation of a secondary cleaning deposit. The deposit contained no heat-affected rock, pockets of ash, or mottled and reddened sediment, and although the feature sediment was slightly greyer than in the surrounding deposits, this difference was subtle at best. The elements that most clearly distinguished the feature from the surrounding sediment were the high density of charcoal fragments amongst unburned rock and organics (including wood, grasses, and seed).

Feature 3 extended across most of Unit 2 (0.95-x-0.90m), but the full extent of the deposit could not be determined as it continued into the north and west baulks. The top of the feature began at 15.5 to 16cmbd, where it was overlain by brown sediment. The base of the feature varied from 21.5 to 26cmbd, and it terminated at a compacted surface of brown sediment hypothesised to be an occupation surface associated with Feature 5.

The macrobotanics from Feature 3 were not investigated due to the likely mixture of the deposit. It is proposed that the Feature 3 sediments were reshuffled when the contents of an adjacent hearth were dug out or pushed to the side. Based on the accumulated deposit, it is possible that this happened several times. Fortunately, since Feature 3 is bounded by good temporal stratigraphic references (Feature 5 and 1), the sediments, although potentially mixed, maintain a relative mid-Holocene age.

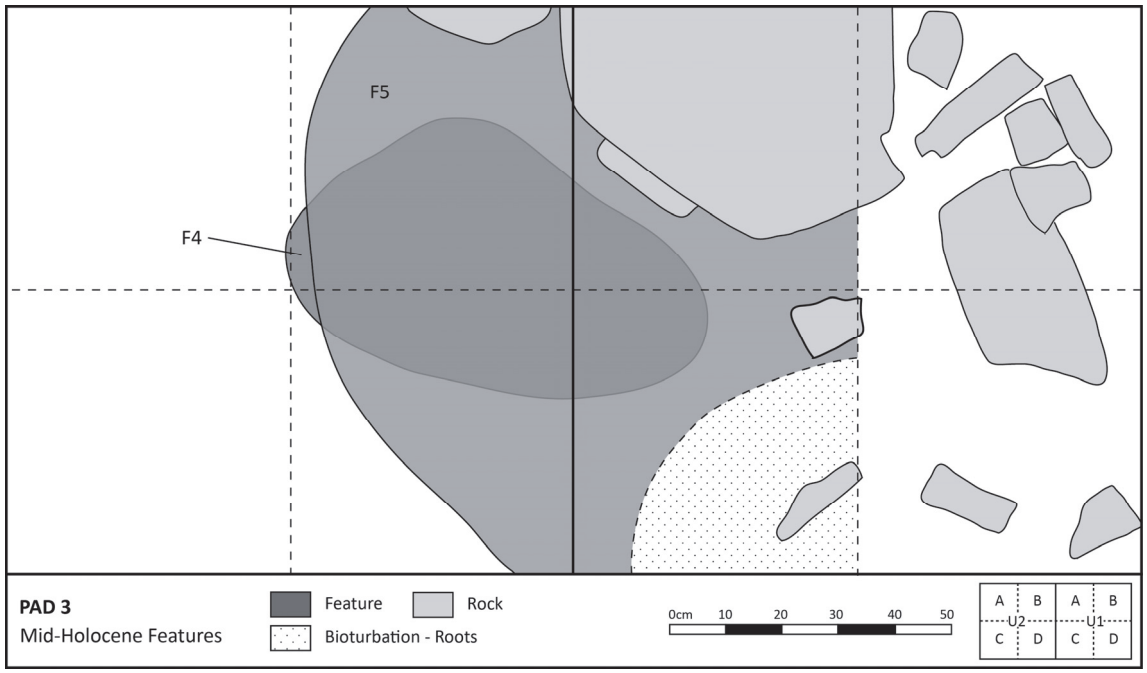

Figure 9-9 Distribution of mid-Holocene combustion features at PAD 3 rockshelter (Features 5 and 4)

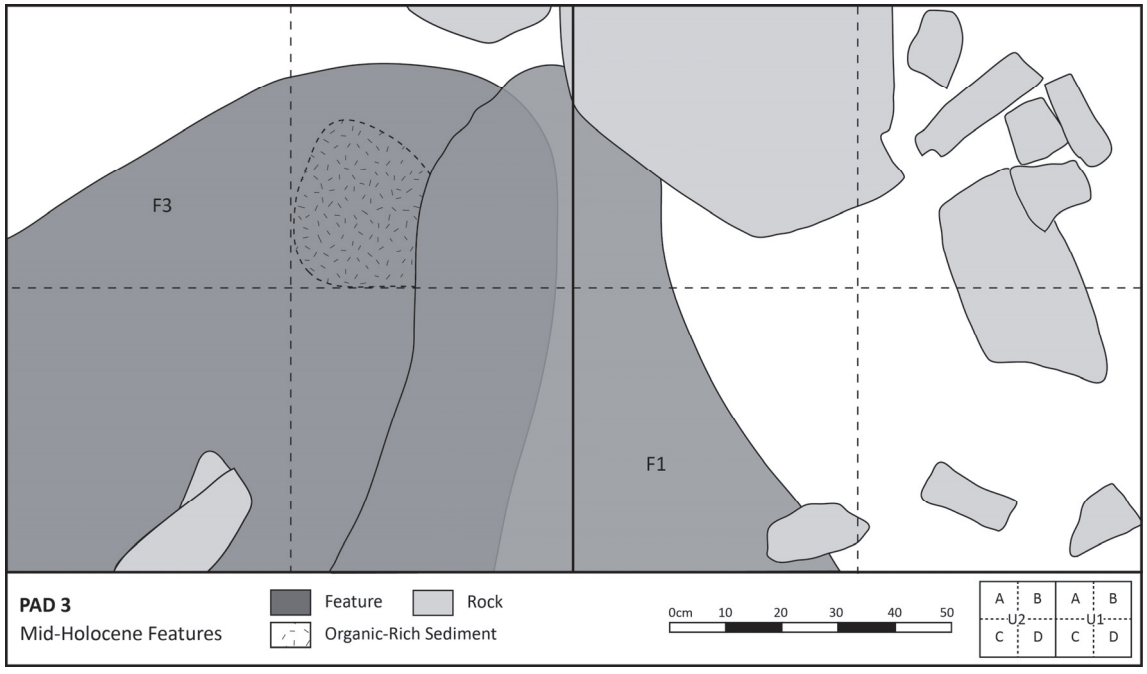

Figure 9-10 Distribution of mid-Holocene combustion features at PAD 3 rockshelter (Features 3 and 1)

Numerous artefacts (n=83) were recovered from the Feature 3 matrix, including a heat-affected flake with a conjoining potlid. Of additional interest is a flake specimen (Artefact 460) that looks to be the result of marginal retouch. The specimen was submitted to Fullagar (2011) for usewear and residue analysis, and he believes the flake has been detached from the working edge of a much larger implement. He also reasons that the presence of dark red plaques and blobs on the surfaces suggest it may have been attached to a hafted stone tool (Fullagar 2011). This is a significant observation, as it implies that composite tool hafting technologies were employed in the mid-Holocene.

MacDowell (this volume) identified 40 fragments of bone in the Feature 3 matrix, including one osteicthyes (bony fish), three reptilian, and 36 mammalian specimens. Only four specimens exhibited attributes that suggest they might be the byproduct of cultural activities. Two mammal fragments were burned and slightly calcined, while another mammal bone fragment exhibited a spiral fracture that is suggestive of a green break (McDowell, this volume). The fish bone was most likely transported to the site by the early inhabitants, as the nearest permanent water source with fish is Weeli Wolli Creek, 20km northeast.

Feature 1 - Feature 1 was the preeminent hearth feature from PAD 3. It was a very well preserved hearth with distinctive shape and internal structure. The hearth measured 0.9-x-0.9m and extended over Unit 1 Quads A/C and Unit 2 Quads B/D; however, the full extent of the feature could not be entirely determined as it continued into the west baulk of Units 1 and 2. The feature sloped towards the northeast and abutted the large slab of rock exposed in Unit 1 Quad A. In cross-section, the

hearth was lenticular, and it contained three distinctive layers (Figure 9-11). The top of the feature began at 13.5 to 14.5cmbd and the base terminated at 15 to 22cmbd. The upper layer of the feature consists of fine, light grey (2.5Y 7/2), ashy sediment. Underlying this layer was a charcoal-rich yellowish brown (10YR 5/4) layer of sediment that rested upon a brown (7.5YR 5/4, pH 7) sedimentary layer, which has become fire-reddened and dense with fire-cracked rock. Based on the good, layered preservation of the feature, it is possible that the feature represents a one-time burning event, as the feature did not exhibit evidence of mixing.

The Feature 1 matrix was very distinct. Visibly, the feature was layered and easily differentiated from the surrounding sediment. The matrix was an extremely fine-grained sediment and was largely devoid of rocks. Like Feature 4, the matrix had a greasy texture that had slightly consolidated the matrix, making it clearly distinguishable from the surrounding loose, powdery, brown sediment. These attributes, together with the colour changes and the presence of charcoal, clearly defined the boundary of the feature. Due to the unusual nature of the sediment, a sample was retained and archived for further analysis. Like Feature 4, the excavators hypothesised that the greasy texture was due to the heating and subsequent release of plant or animal oils, decomposed organics, geomicrobial activity, or another pedological process.

Fairbairn (2011) examined the wood charcoals from Feature 1 and found it to have the most taphonomically diverse *Eucalyptus* spp. from any of the PAD 3 hearths. He estimates that the composition of the Feature 1 charcoals t approximately 4% *Acacia* spp. and 96% *Eucalyptus* spp., which included three types of unidentified gum, an indeterminate species from the Myrtaceae family, and burned paperbark (*cf. Melaleuca* sp.) (Fairbairn 2011). It is significant that Fairbairn's study identified paperbark, as the closest modern source of this tree is Weeli Wolli Creek, which is 2km away. Thus, it is evident that the paperbark was brought to the site with its early inhabitants.

McDowell (this volume) examined the faunal assemblage from Feature 1 and identified four mammal specimens, one reptile specimen, and one bird specimen. Only one non-diagnostic mammal specimen showed evidence of burning, suggesting it may have an archaeological association (McDowell, this volume). The remaining fragments are unburned specimens, and they likely entered the sedimentary record through natural processes. These include the bird and reptile specimen, which could not be identified on a genus species level. The only mammal specimens that could be identified to a family or genus level include the family *Chiroptera* (bat) and the murid *Leggadina* sp. (mouse) (McDowell, this volume).

A number of the Feature 1 charcoal samples were collected *in situ* and provide a well-provenanced date for the age of the feature. One sample collected from the base of the hearth was dated to 4143±34 BP, and when calibrated, this specimen dates to 4825 to 4569 cal BP, with a median calibrated age of 4686±78 cal BP. This date is significant for understanding the antiquity of backed artefact manufacture for the inland Pilbara, as four asymmetrical backed artefacts (Artefacts 171, 224, 572, and 575) were recovered from within the Feature 1 matrix, and one broken specimen (Artefact 524) was recovered beneath the hearth. The context of these specimens conservatively demonstrates that backed artefacts were a component of the Aboriginal tool kit by at least 4569 cal BP, and perhaps as early as 4825 cal BP.

In addition to the backed artefacts, numerous flaked stone artefacts were recovered from the feature matrix (n=55). These artefacts are considered to be part of Analytical Unit 2, and their qualitative and quantitative attributes will be discussed further in the analytical results section.



Figure 9-11 Cross-section of Feature 1 at PAD 3 rockshelter, showing the internal structure of the hearth

Feature 9 - Feature 9 was a small, shallow, circular hearth within Unit 2 Quads C/D. The hearth had a lenticular profile and measured 0.34-x-0.31m. The top elevation for the hearth was 11.5cmbd and the feature terminated at 14cmbd atop of thin layer of unburned brown sediment. A charcoal fragment collected from the brown sediment underlying Feature 9 (and Feature 8) returned a date of 3688±30 BP, or 4145 to 3926 cal BP, indicating that the Feature 9 was constructed after this age estimate.

The Feature 9 matrix consisted of white ashy sediment over a dark greyish brown, charcoal-rich layer (10YR 4/2, pH 6). The white ash was concentrated in the centre of the feature. The wood charcoals from Feature 9 consist of 96% *Eucalyptus* spp. and 4% *Acacia aneura* (Fairbairn 2011). Two eucalypt species could be differentiated in the charcoals, but not beyond a family taxonomic level (Fairbairn 2011).

Based on the small size of the feature, Feature 9 likely represented a one-time, perhaps ephemeral, event. The feature was separated from the overlying Feature 8 matrix by only a couple millimetres of brown sediment. It is thought that the Feature 8 hearth was used shortly after the Feature 9 burning event, and they are probably of very similar antiquity.

No further organic or faunal materials were recovered from within the Feature 9 matrix; however, 29 flaked stone artefacts were found in the sieved sediment. One symmetrical backed artefact (Artefact 561) was recovered from beneath the feature.

Feature 8 - Feature 8 was described as a small hearth within Unit 2 Quad D. The feature was atop Feature 9, with only couple of millimetres of sediment separating the features. Feature 8 was comprised of very dark greyish brown (10YR 3/2, pH 7), ashy sediment. The matrix texture was powdery (presumably from ash), and it contained small fragments of charcoal. In profile, the hearth had a plano-convex shape. The maximum thickness of the deposit was only 3cm thick, beginning at 13cmbd and terminating at 16cmbd.

The feature was fairly non-descript, and the hearth deposit was so thin that it was originally missed when excavating Quad B; thus, the east extent of the feature was truncated between Quads B/D. In area, the extent of the hearth measured 0.31-x-0.25m. Even if the feature had not been truncated in Quad B, it is unlikely that the feature would have been much larger than its noted maximum dimension of 0.31m.

No artefacts or faunal material were recovered from the Feature 8 matrix. The wood charcoals did not lend themselves to analysis as they were very small and fragmented. Temporally, it is likely that Feature 8 was closely related to underlying Feature 9 and overlying Feature 7. These features drape over each other, only separated by a thin layer of brown sediment.

Feature 7 - Feature 7 was a small and thin hearth with a lenticular cross-section. It was identified by its ashy sediment (10YR4/4, pH 5) with small flecks of charcoal. Excavators noted that the Feature 7 sediment had a greasy texture, presumably due to the high ash content.

The hearth was primarily located in Unit 2 Quad D, but a small portion rested within Unit 1 Quad C. The feature sloped with the underlying sediment, but only had a thickness of approximately 1cm. The exposed plan of the feature was semi-circular (0.55-x-0.33m), but it extended into the west baulk so the true extent and shape could not be determined. The feature was overlain and underlain by brown background sediment.

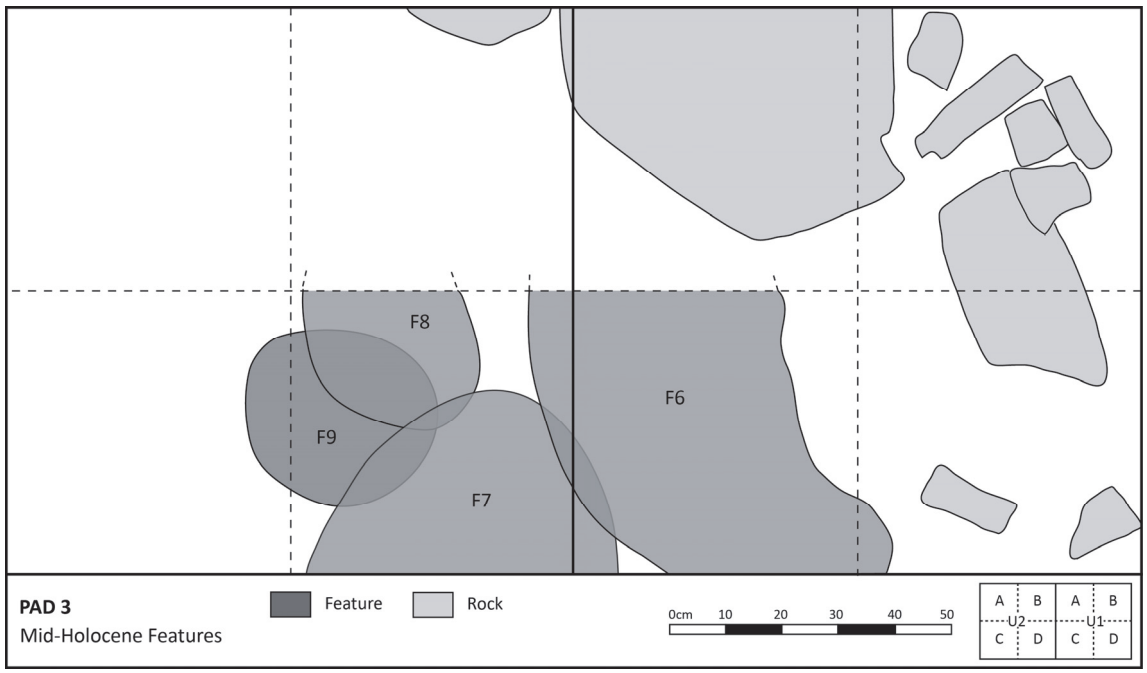

Figure 9-12 Distribution of mid-Holocene combustion features at PAD 3 rockshelter (Features 9, 8 7, and 6)

No faunal remains were recovered from Feature 7; however, 35 flaked artefact specimens were within the matrix. These specimens are grouped with Analytical Unit 2 for the artefact analysis, which is discussed in the artefact analysis section.

Compared to other hearth features, Feature 7 had a dispersed appearance and showed little evidence of structure or layering. It might have been slightly dispersed from previous site activities or perhaps bioturbation. It was difficult to completely distinguish this feature from the surrounding sediments; however, this feature was clearly separated from the underlying Feature 8 by a thin layer of brown sediment.

Feature 6 - Feature 6 was a shallow lenticular hearth consisting of ashy sediment (pH 4.5) and fragments of fire-cracked rock. The feature was first identified while excavating Unit 1 Quad C, when an ashy upper feature layer appeared at 11cmbd. The feature presumably extended across Unit 1 Quad A; however, given the limited area due to the large piece of roof fall, the feature was not identified when Quad A was excavated (prior to Quad C).

The full extent of the hearth is unknown, as it continued into the east baulk, and as mentioned, a portion of the feature was previously removed in Quad A. The maximum extent of the hearth measured 0.46-x-0.50m. The feature had a maximum thickness of 3.5cm, extending from 11 to 14.5cmbd. The upper portion of the hearth consisted mostly of ashy sediment, and the lower part of the feature contained fire reddened and cracked rock, averaging 2 to 3cm in size. A white, ochre-like substance was identified on one of the rocks in the hearth, and the substance is believed to be kaolinite. Patches of this substance occurred throughout the feature.

A vertically-orientated symmetrical backed artefact (Artefact 313) was recovered from the matrix, as well as 12 flaked stone artefacts. The backed artefact was examined by Fullagar (2011), who identified usewear along the lateral margin and the backed margin, confirming its use as a stone tool. Fullagar (2011) also recognised dark red plaques and smears of resin along the backed margin suggesting the tool was hafted during its use life. It is likely that the smears are the result of the specimen moving while in the haft.

Macrobotanical analysis of the wood charcoals from the feature indicates that 95% of the wood charcoals are from gum trees (*Eucalyptus* spp.) and 5% *Acacia* spp (Fairbairn 2011). This study identified three *Eucalyptus* varieties burned in the hearth, as well as *Acacia aneura*.

Ten fragments of mammal and one fragment of reptile bone were recovered from Feature 6. The reptile bone belongs to the skink (*Scinidae*) family. The specimen is not burned and likely found its way into the rockshelter through natural processes. Only one mammal bone fragment could be identified as a macropod, with the remaining listed a non-diagnostic fragments. Two non-diagnostic fragments exhibit evidence of burning, and they may be associated with the Feature 6 fire.

Stratigraphically, Feature 6 was above Feature 7; however, only a thin layer of unburned brown sediment separated these features. Like Features 7, 8, and 9, Feature 6 was constructed sometime between 3688±30 BP and 2417±30 BP, or roughly 3926 and 2696 cal BP. The age of Features 6, 7, 8, and 9 are likely to be similar, as these features share similar structural and spatial contexts. Together, the artefacts and materials recovered from these features and the surrounding sediments are grouped as Analytical Unit 2 for our study.

Late Holocene Features

Feature 2 - Feature 2 was a very well preserved late Holocene hearth that dates to 2417±30 BP. When this age is calibrated, it is estimated that the hearth was constructed between 2696 and 2349 cal BP. This archaeological feature had *in situ* artefacts that directly coincide with feature use. These *in situ* relationships demonstrate that the feature is well preserved and infer there has been minimal site visitation or reuse of the rockshelter since this time.

The outline of the Feature 2 hearth was sub-circular shaped, measuring 0.56-x-0.66m, and the feature was contained entirely in Unit 2 Quads A-D. The top of the feature appeared at 8cmbd, around 5cm below the ground surface. In cross-section, the feature had a plano-convex or basin shape, suggesting that the previous floor surface had been slightly excavated prior to the hearth's construction. The base of Feature 2 terminated at 11cmbd.

The hearth matrix was comprised of very dark brown (10YR 2/2, pH 6), ashy sediment and charcoal, while the edges of the feature were defined by large pieces of charcoal and small local concentrations of charcoal without ash. Large pieces of charcoal, up to 2cm long, were found throughout the deposit. The feature was underlain by unburned brown sediment and a fine layer of organic material (grass). All sediment was collected from the feature.

Feature 2 had two remarkable *in situ* stone artefact associations. A bidirectional core (Artefact 265) manufactured from homogenous BIF was recovered resting atop the hearth matrix. The bottom half of the core is fire reddened, but the top is not heat affected, suggesting that the artefact was placed in the centre of the feature when the coals were still hot. Fullagar (2011) identified usewear polish on the core that is consistent with woodworking.

A large retouched flake (Artefact 273), also manufactured from homogenous BIF, was recovered *in situ* from the hearth matrix. Like the other specimen, the flake was heat reddened, and the overall colour has been darkened due to placement within the hearth while it was hot. Fullagar (2011) identified usewear scars indicative of wood scraping. He also found red plaques of resin along one margin of the specimen, suggesting it may have once had a resin grip along one edge (Fullagar 2011).

Only one additional artefact was found in the Feature 2 sediments. A retouched flake (Artefact 266), manufactured from dark grey chert, was recovered from the sieved matrix. The specimen is a right longitudinal cone split fragment, and it exhibits extensive evidence of heat damage. The retouched flake is crazed and potlidded, and much of the specimen margin is fragmented due to intense exposure to heat. Fullagar (2011) identified striations, edge rounding, and polish along the margin of this specimen, suggesting it was used for scraping soft wood. He also recognises that fire crazing and fine cracks indicate that the artefact has been subject to high temperatures probably in a cooking or warming fire (Fullagar 2011), which is an observation consistent with the archaeological interpretation of Feature 2.

Wood charcoals from the Feature 2 hearth were subject to macrobotanical analysis by Fairbairn (2011), who identified the fire charcoals to be from 100% *Eucalyptus* spp. Only two gum tree types were distinguishable, but not to a genus or species taxa.

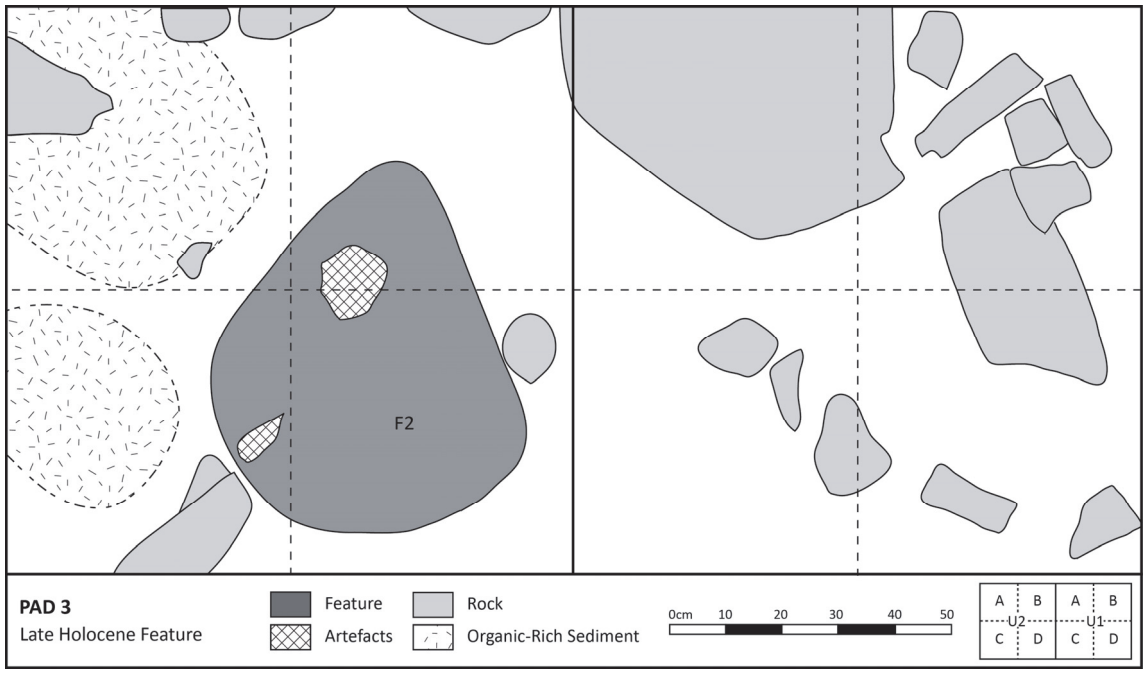

Figure 9-13 Distribution of late Holocene combustion features at PAD 3 rockshelter

One bone fragment was recovered from the hearth matrix. McDowell (this volume) determined that it is a femur or humerus fragment from the Macropodidae family. Although the fragment is unburned, McDowell (this volume) believes it may be cultural due to the usual spiral fracture along the long bone. Since spiral breaks occur only on green bone, there is a good likelihood the break occurred around the time of the animal's death. Based on its context, it is possible that the break is a result of butchering or a similar activity.

Adjacent to Feature 2, the excavators encountered dense patches of spinifex grass mixed with brown sediment. It is not possible to determine if the organic rich patch of sediment is directly associated with the hearth, but it is worth noting as it has been ethnographically observed that spinifex grasses are utilised by Western Desert groups for resin, fire starter, shelter, fibre-work, and sometimes as a source of food areas (Pitman 2010).

9.6 ARTEFACT ANALYSIS

A moderate assemblage of artefacts was recovered PAD 3, including 582 artefacts from the excavation and three artefacts from the surface of the shelter. A full technological analysis of the assemblage was conducted in accordance with the methodology outlined in Chapter 4. The artefact analysis was carried out by Dawn Cropper, W. Boone Law, and Aara Welz. The following sections define the analytical units, consider the distribution of artefacts through the sequence, and present the results of the artefact analysis.

Division of Analytical Units

PAD 3 rockshelter was excavated stratigraphically, and it is dense with cultural features. The complexity of the stratigraphy presented a challenge to excavators in maintaining temporal and spatial relationships between the cultural features and surrounding sediments. In many cases, the features are separated by only millimetres; thus it is impossible to indisputably link the features with cultural materials discarded in surrounding sediments.

Despite this challenge, the researchers are able to divide the PAD 3 sediments into meaningful spatial-temporal analytical units (AU) that are based on a combination of feature stratigraphy, arbitrary excavation surfaces, and mean calibrated radiocarbon dates. It is important to clearly define these units so the analytical and interpretive constraints of the data set are better understood.

Analytical Unit 1 - The upper boundary for AU1 is the modern ground surface of PAD 3 rockshelter. The lower boundary for AU1 is 11cmbd, which coincides with the base of Feature 2. AU1 includes the organic rich, dark brown stratigraphic layer, Feature 2, and the surrounding brown sediments. The brown sediments surrounding and immediately below Feature 2 were arbitrarily levelled at 11cmbd, making this an ideal division for AU1. The median calibrated AMS ages indicate that the base of AU1 dates to approximately 2439±98 cal BP; thus the overlying sediments are of late Holocene antiquity. It is unknown when the site was last utilised by Aboriginal people, but ephemeral site visitation has likely occurred within the past 1000 years.

Analytical Unit 2 - AU2 encompasses many mid-Holocene features (*e.g.*, Features 1, 6, 7, 8, and 9). The top of AU2 begins at 11cmbd and terminates with the removal of Feature 1. Feature 1 was constructed inside a shallow floor depression, and prior to its removal, the area surrounding the feature was carefully excavated to expose the maximum extent of the hearth and determine the associated occupation surface. The entire Feature 1 matrix was then removed from the depression. AU2 includes the Feature 1 matrix and the sediments above the Feature 1 occupation surface. The associated occupation surface varies in depth, but on average it is 16 to 18cmbd. Based on the upper and lower median calibrated ages, AU2 is estimated to date between approximately 4686±78 and 2439±98 cal BP, covering a time range of roughly 2247 years.

Analytical Unit 3 - The upper boundary of AU3 starts below Feature 1 and at an arbitrary 16cmbd excavation surface. The base of AU3 terminates immediately below Feature 5 at 30cmbd. AU3 includes Features 3, 4, and 5. The median calibrated AMS dates suggest that AU3 roughly spans the time

period between 6399±43 and 4686±78 cal BP, reflecting a time span of 1713 years.

Analytical Unit 4 - This is the lowest (and oldest) analytical unit, and it contains Features 10, 11, and 12. AU4 begins below 30cmbd and terminates at bedrock. The calibrated age of Feature 11 indicates that AU4 is early Holocene. Based on the median calibrated dates, it is estimated that the AU4 sediments were deposited over a 1331 year period, between approximately 7730±46 and 6399±43 cal BP.

Artefact Distribution

The PAD 3 investigations resulted in the total recovery of 585 stone artefacts, including three unprovenanced surface stone artefacts collected from non-excavation contexts. All of the specimens were analysed according to the methods outlined in Chapter 4, and a breakdown of the diagnostic and non-diagnostic artefact types is presented in Table 9-3.

The diagnostic stone artefacts include specimens that are indisputable artefacts with unambiguous attributes. Diagnostic specimens include cores, flakes, retouched and utilised flakes, and grindstones. The non-diagnostic artefacts include categories that are affected by breakage or heat fracture, and consequently, their numbers may be anomalously high due to the increased likelihood of fragmentation.

Based on the analysis, diagnostic artefacts comprise roughly 78% of the assemblage. There is a mild degree of variability for the percentage of diagnostic artefacts between analytical units, but the overall trend remains the same: diagnostic specimens comprise the majority of the assemblage. The high frequency of diagnostic artefacts within in each analytical unit unequivocally demonstrates that PAD 3 has been intermittently occupied since the early Holocene.

Flakes are the most common artefact type discarded at the site, representing nearly 72% of the assemblage. They are followed in numbers by flaked pieces, heat shatter, and potlids; however, this result is not surprising as these categories are highly fragmented or heat fractured. Retouched and utilised flakes comprise 4.1% and cores 1.7% of the assemblage. The remaining artefact categories include a top grindstone and two manuports. The grindstone has dubious provenance, as it was found atop the ground surface on the final day of investigations, and it is possible the grindstone was uncovered by scaffolding disturbing the ground. The manuports include a rounded river cobble, presumably collected from the gully floor, and a rose coloured quartz crystal. Neither manuport displays any evidence of usewear.

AU4, which represents the early Holocene deposit (7730-6399 cal BP), has the lowest number of artefacts discarded at the site (n=35). The number of discarded artefacts increases substantially in the mid-Holocene (6399-4686 cal BP), with a total of 287 artefacts recovered from AU3. The number of artefacts decreases to 179 in AU2, estimated to be 4686 to 2439 years old, and it decreases again to 81 artefacts AU1, roughly representing the past 2439 years of deposition. Thus, artefact discard peaks in AU3 and decreases incrementally through AU2 and AU1

Raw Materials

The raw materials selected for artefact manufacture are presented in Table 9-4 and Table 9-5. More specifically, the raw material counts are offered in Table 9-4, and the respective weights are listed in Table 9-5. Determining raw material use based on weight alone can be somewhat misleading, as iron-rich rocks (*e.g.*, BIF, goethitised shale, and martite-goethite) will have higher weight values in comparison to microcrystalline, siliceous raw materials. Due to this situation, raw material comparisons are based on counts rather than weight. However, artefact weight is still a useful variable to report, as it can provide insights into the degree which raw materials were consumed.

Compared to other ROM pad valley sites, the PAD 3 assemblage has been manufactured on a considerable array of raw materials. The majority of the flaked stone artefacts have been manufactured on chert, making up nearly 45% of the assemblage. Based on appearance, the analysts identified nine different varieties of chert in the assemblage, but the most common kinds of chert are dark grey chert and greyish brown chert. The second most abundant raw material selected for artefact manufacture is BIF, and it comprises a little more than 38% of the assemblage. From a technological standpoint, this trend is not unusual because the fine-grained, microcrystalline qualities of chert make it a superior knapping material to the coarser grained BIF.

Quartz was utilised in approximately 7% of instances, making it the third most abundant raw material selected for artefact manufacture. Martite-goethite and shale were each utilised in a little more than 4% of instances. There were negligible amounts of goethitised shale and limonite used for artefact manufacture (<0.5%).

When viewed by analytical unit, some interesting raw material trends can be observed. In the early Holocene (AU4), 82.2% of the artefacts were manufactured from coarse grained BIF. Chert (8.57%), martite goethite (5.71%), and shale (2.86%) represent the remaining raw materials discarded in the early Holocene unit.

There is a significant shift in raw material use in the mid and late Holocene. Chert became the predominant and preferred raw material for artefact manufacture throughout these later analytical units. Its abundance infers its importance or perhaps normalisation to the technological system. Approximately, 45% of the artefact specimens were manufactured from chert in AU3, AU2, and AU1. BIF is still the second most knapped raw material throughout these units, constituting around 33% of the assemblage. The consistent utilisation of BIF throughout these layers suggests that although it is a poorer quality raw material, its abundance was still important for the overall technological system. Quartz and shale were used in artefact manufacture more regularly throughout the mid-Holocene and late Holocene analytical units; however, quartz was selected for knapping less than approximately 14% of the time, and shale was chosen no more than around 7.5% of instances. Martite-goethite, goethitised shale, and limonite, although present, were rarely utilised for artefact manufacture.

Additional raw material trends can also be observed between the diagnostic artefact categories and analytical units. For example, in early Holocene AU4, nearly all of the artefact specimens were manufactured from coarse grained BIF, and no retouched or utilised flakes were found from this analytical unit. Thus, it seems the early occupants engaged a technological system that emphasised the use of locally available stone. The absence of retouched or utilised artefacts from AU4 implies that artefacts were not reused extensively, they were not discarded regularly, or they were taken away from the site.

Table 9-3 Artefact distribution by analytical unit, PAD 3 rockshelter

Artefact Type	Surface		AU1		AU2		AU3		AU4		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Diagnostic Artefacts	*3*	*100*	*65*	*80.25*	*130*	*72.63*	*225*	*78.40*	*33*	*94.29*	*456*	*77.95*
Cores	0	0	2	2.47	2	1.12	5	1.74	1	2.86	10	1.71
Flakes	1	33.33	55	67.90	117	65.36	216	75.26	32	91.43	421	71.97
Retouched / Utilised Flakes	1	33.33	8	9.88	11	6.15	4	1.39	0	0	24	4.10
Grindstone	1	33.33	0	0	0	0	0	0	0	0	1	0.17
Non-diagnostic Artefacts	*0*	*0*	*16*	*19.75*	*49*	*27.37*	*62*	*21.60*	*2*	*5.71*	*129*	*22.05*
Flake Piece	0	0	4	4.94	21	11.73	22	7.67	0	0	47	8.03
Heat Shatter	0	0	8	9.88	13	7.26	24	8.36	1	2.86	46	7.86
Manuport	0	0	1	1.23	1	0.56	0	0	0	0	2	0.34
Potlid	0	0	3	3.70	14	7.82	16	5.57	1	2.86	34	5.81
Total	**3**	**100**	**81**	**100**	**179**	**100**	**287**	**100**	**35**	**100**	**585**	**100**

Table 9-4 Distribution of the number of raw material types by analytical unit, PAD 3 rockshelter

Raw Material Type	Surface		AU1		AU2		AU3		AU4		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
BIF	*1*	*33.33*	*29*	*35.80*	*58*	*32.40*	*106*	*36.93*	*29*	*82.86*	*223*	*38.12*
Homogenous BIF	1	33.33	27	33.33	51	28.49	104	36.24	29	82.86	212	36.24
Laminate BIF	0	0.00	2	2.47	7	3.91	2	0.70		0.00	11	1.88
Chert	*1*	*33.33*	*40*	*49.38*	*75*	*41.90*	*142*	*49.48*	*3*	*8.57*	*261*	*44.62*
Dark Grey	1	33.33	27	33.33	30	16.76	55	19.16	1	2.86	114	19.49
Greyish Brown	0	0.00	11	13.58	32	17.88	75	26.13	1	2.86	119	20.34
Light Green-Grey	0	0.00	1	1.23	1	0.56	1	0.35	0	0.00	3	0.51
Olive	0	0.00	0	0.00	3	1.68	1	0.35	0	0.00	4	0.68
Red	0	0.00	0	0.00	1	0.56	2	0.70	1	2.86	4	0.68
Speckled Black	0	0.00	0	0.00	3	1.68	1	0.35	0	0.00	4	0.68
Sugar	0	0.00	0	0.00	3	1.68	3	1.05	0	0.00	6	1.03
Trans. Green	0	0.00	1	1.23	1	0.56	0	0.00	0	0.00	2	0.34
White & Trans.	0	0.00	0	0.00	1	0.56	4	1.39	0	0.00	5	0.85
Goethitised Shale	*0*	*0.00*	*1*	*1.23*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.17*
Limonite	*0*	*0.00*	*1*	*1.23*	*2*	*1.12*	*1*	*0.35*	*0*	*0.00*	*4*	*0.68*
Martite-goethite	*1*	*33.33*	*1*	*1.23*	*7*	*3.91*	*14*	*4.88*	*2*	*5.71*	*25*	*4.27*
Quartz	*0*	*0.00*	*4*	*4.94*	*15*	*8.38*	*10*	*3.48*	*0*	*0.00*	*29*	*4.96*
Quartz Crystal	*0*	*0.00*	*1*	*1.23*	*9*	*5.03*	*2*	*0.70*	*0*	*0.00*	*12*	*2.05*
Shale	*0*	*0.00*	*4*	*4.94*	*13*	*7.26*	*10*	*3.48*	*1*	*2.86*	*28*	*4.79*
Brown Shale	0	0.00	3	3.70	13	7.26	10	3.48	1	2.86	27	4.62
Green Shale	0	0.00	1	1.23	0	0.00	0	0.00	0	0.00	1	0.17
Indeterminate	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.70*	*0*	*0.00*	*2*	*0.34*
Total	**3**	**100**	**81**	**100**	**179**	**100**	**287**	**100**	**35**	**100**	**585**	**100**

Table 9-5 Distribution of the weight of raw material types by analytical unit, PAD 3 rockshelter

Raw Material	Surface		AU1		AU2		AU3		AU4		Total	
	Sum (g)	%	Sum (g)	%	Sum (g)	%	Sum (g)	%	Sum (g)	%	Sum (g)	%
BIF	*217*	*91.59*	*574.42*	*83.84*	*255.9*	*64.79*	*545.75*	*76.58*	*451.48*	*99.72*	*2044.55*	*82.36*
Homogenous BIF	217	91.59	571.3	83.39	251.76	63.74	543.62	76.29	451.48	99.72	2035.16	81.99
Laminate BIF	0	0.00	3.12	0.46	4.14	1.05	2.13	0.30	0	0.00	9.39	0.38
Chert	*1.82*	*0.77*	*82.51*	*12.04*	*49.87*	*12.63*	*84.99*	*11.93*	*0.92*	*0.20*	*220.11*	*8.87*
Dark Grey	1.82	0.77	71.17	10.39	10.94	2.77	29.04	4.08	0.49	0.11	113.46	4.57
Greyish Brown	0	0.00	9.85	1.44	32.73	8.29	20.54	2.88	0.28	0.06	63.4	2.55
Lt. Green-Grey	0	0.00	1.15	0.17	1.23	0.31	0.01	0.00	0	0.00	2.39	0.10
Olive	0	0.00	0	0.00	0.31	0.08	1.6	0.22	0	0.00	1.91	0.08
Red	0	0.00	0	0.00	0.56	0.14	0.39	0.05	0.15	0.03	1.1	0.04
Speckled Black	0	0.00	0	0.00	1.32	0.33	2.52	0.35	0	0.00	3.84	0.15
Sugar	0	0.00	0	0.00	1.09	0.28	30.66	4.30	0	0.00	31.75	1.28
Trans. Green	0	0.00	0.34	0.05	0.28	0.07	0	0.00	0	0.00	0.62	0.02
White & Trans.	0	0.00	0	0.00	1.41	0.36	0.23	0.03	0	0.00	1.64	0.07
Goethitised Shale	*0*	*0.00*	*11.5*	*1.68*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*11.5*	*0.46*
Limonite	*0*	*0.00*	*0.01*	*0.00*	*2.36*	*0.60*	*0.01*	*0.00*	*0*	*0.00*	*2.38*	*0.10*
Martite-goethite	*18.1*	*7.64*	*1.19*	*0.17*	*54.65*	*13.84*	*51.15*	*7.18*	*0.28*	*0.06*	*125.37*	*5.05*
Quartz	*0*	*0.00*	*2.15*	*0.31*	*3.94*	*1.00*	*13.98*	*1.96*	*0*	*0.00*	*20.07*	*0.81*
Quartz Crystal	*0*	*0.00*	*6*	*0.88*	*2.25*	*0.57*	*0.25*	*0.04*	*0*	*0.00*	*8.5*	*0.34*
Shale Total	*0*	*0.00*	*7.33*	*1.07*	*25.98*	*6.58*	*16.15*	*2.27*	*0.07*	*0.02*	*49.53*	*2.00*
Brown Shale	0	0.00	4.81	0.70	25.98	6.58	16.15	2.27	0.07	0.02	47.01	1.89
Green shale	0	0.00	2.52	0.37	0	0.00	0	0.00	0	0.00	2.52	0.10
Indeterminate	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0.33*	*0.05*	*0*	*0.00*	*0.33*	*0.01*
Total	**236.92**	**100**	**685.11**	**100**	**394.95**	**100**	**712.61**	**100**	**452.75**	**100**	**2482.34**	**100**

Table 9-6 Raw material trends for cores, flakes, and retouched and utilised flakes, PAD 3 rockshelter

Artefact Type	AU1		AU2		AU3		AU4		Total	
Raw Material Type	n	%	n	%	n	%	n	%	n	%
Cores	*2*	*3.08*	*2*	*1.54*	*5*	*2.22*	*1*	*3.03*	*10*	*2.21*
BIF	1	1.54	1	0.77	4	1.78	1	3.03	7	1.55
Chert	1	1.54	1	0.77	0	0.00	0	0.00	2	0.44
Martite-goethite	0	0.00	0	0.00	1	0.44	0	0.00	1	0.22
Flakes	*55*	*84.62*	*117*	*90*	*216*	*95.99*	*32*	*96.97*	*420*	*92.71*
BIF	25	38.46	37	28.46	84	37.33	27	81.82	173	38.19
Chert	24	36.92	50	38.46	108	48.0	3	9.09	185	40.84
Limonite	0	0.00	2	1.54	1	0.44	0	0.00	3	0.66
Martite-goethite	1	1.54	5	3.85	6	2.67	1	3.03	13	2.87
Quartz	2	3.08	15	11.54	11	4.89	0	0.00	28	6.18
Shale	3	4.62	8	6.15	5	2.22	1	3.03	17	3.75
Indeterminate	0	0.00	0	0.00	1	0.44	0	0.00	1	0.22
Retouched / Utilised Flakes	*8*	*12.31*	*11*	*8.46*	*4*	*1.78*	*0*	*0.00*	*23*	*5.08*
BIF	1	1.54	0	0.00	0	0.00	0	0.00	1	0.22
Chert	6	9.23	10	7.69	4	1.78	0	0.00	20	4.42
Shale	1	1.54	1	0.77	0	0.00	0	0.00	2	0.44
Total	**65**	**100**	**130**	**100**	**225**	**100**	**33**	**100**	**453**	**100**

There is a significant shift in the pattern of artefact manufacture and raw material use in the mid and late Holocene analytical units (Table 9-6). In AU3, 48% of flakes were made from chert and 37.33% were manufactured from BIF, showing that chert was a preferred material for flake manufacture, but BIF was still an important raw material. This trend marks a significant change in the selection of raw materials for artefact manufacture, and it is a trend that continues throughout AU2 and AU1. Despite the increase in chert flakes, there were only two chert cores discarded at the rockshelter, compared to seven BIF cores and one martite-goethite core. This suggests that chert flakes were manufactured off site or else chert cores might form part of a mobile toolkit that was carried away from the site.

Cores

Ten cores were recovered during the PAD 3 excavations, including bidirectional, unidirections, and rotated specimens (Figure 9-14). Eight of the cores are considered complete specimens, that is, specimens that are not severely fragmented from incipient fracture lines or heat crazing. Broken core specimens of this nature were not subject to quantitative analysis because they do not exhibit all their attributes.

The complete core specimens were subject to a full metrical analysis and these attributes are presented in Table 9-7. Due to the small sample size, statistically significant temporal trends cannot be identified amongst the quantitative attributes (Table 9-7). There is much variability in the size of the specimens, and presented together, the specimens do not elucidate much information on the patterns of reduction strategies.

The single core that was recovered from AU4 is covered with 66 to 99% cortex and it has been reduced unidirectionally. Despite the high percentage of cortex, nine negative flake scars are on the surface. The scars are all feather terminated, and in the opinion of the analyst, the core was discarded in an exhausted state, with no reasonable potential for further flake removals. The analyst noted that the core is very brittle and fragile as it is heavily heat crazed.

The three complete cores in AU3 were manufactured from coarse-grained BIF. The three specimens were all unidirectionally reduced, and cortex is absent from two of the specimens. The specimens lacking cortex weigh 48.27g and 52.42g, with four and one scar removed respectively. Only 33 to 65% cortex remains on one core that weighs 74.03g. Five flakes have been removed from this specimen. Each of the AU3 cores has feather terminated negative scars, and all three specimens are considered viable and could potentially be reduced further.

The two complete cores in AU2 were produced from greyish brown chert and BIF. The chert core is small, weighing only 6.22g. It has been rotated and has nine negative scars with feather or step terminations. No cortex remains on the specimen. Due to the heavy reduction, the specimen is considered to be in an exhausted state. Contrastingly, the BIF core is large, weighing 104.62g. The specimen has 33 to 65% cortex remaining and it was unidirectionally reduced. Although there are 12 negatives scars on the core, it is considered to have reduction potential.

There are two complete cores made from BIF and dark grey chert in AU1. The chert core is small and completely exhausted. Weighing 40.56g, it has been rotated and four flakes have been removed. Rounded river pebble cortex remains on 66 to 99% of the surface; thus, the raw material was small when it was collected from the gully. The BIF core was likely procured locally and weighs 412g. The core surface is obscured by 66 to 99% cortex and six stepped or hinged flake scar remain. Due to its size, the BIF is considered viable for further reduction.

The qualitative core attributes offer limited information on the systematic reduction of cores at PAD 3. Based on the discussion, it may be argued that fine-grained siliceous materials were more heavily reduced than coarse-grained materials such as BIF. However, such an argument is not entirely valid as the sample size is too small to positively draw such conclusions.

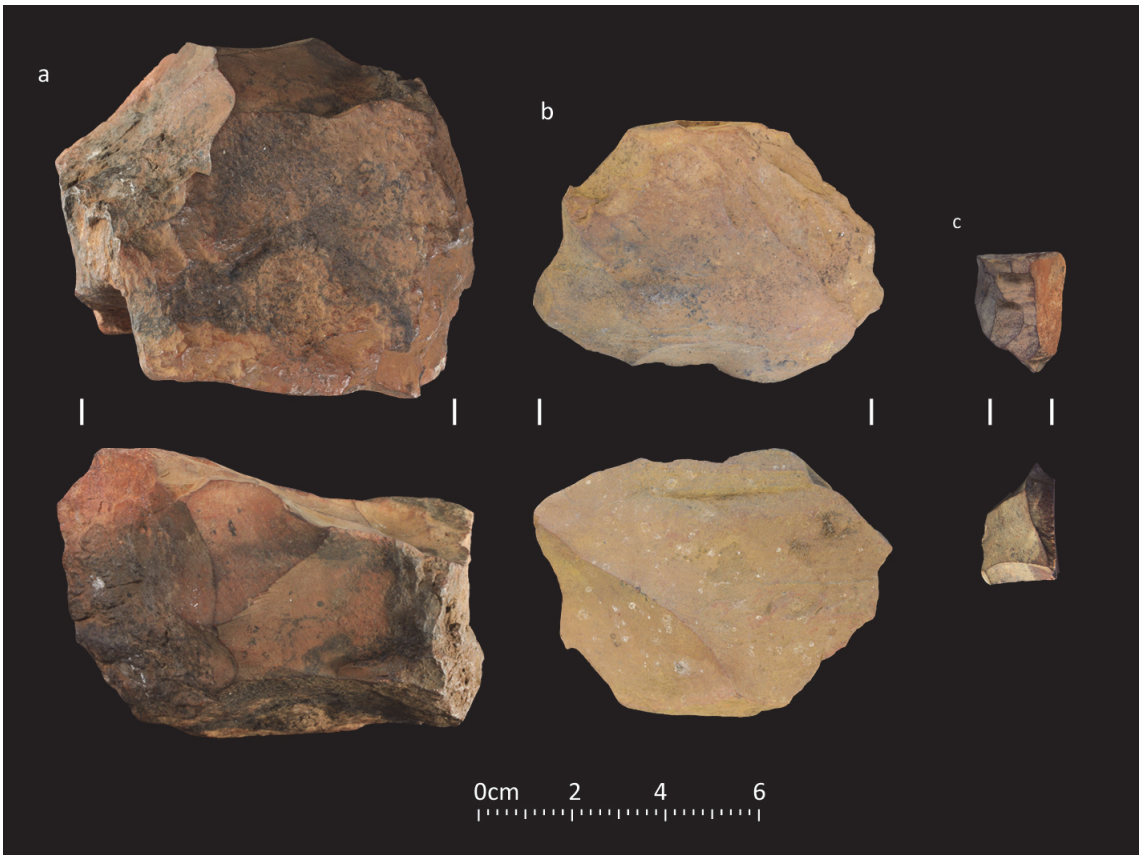

Figure 9-14 PAD 3 cores: a) bidirectional (artefact 265), b) unidirectional (artefact 582), and c) rotated (artefact 502)

Table 9-7 Quantitative attributes for complete cores by analytical unit, PAD 3 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	1	2	72.65	90.0	55.3	24.54
	2	2	25.42	26.11	24.73	0.98
	3	3	40.17	44.3	35.9	4.20
	4	1	89.91	89.91	89.91	-
	Total	8	50.82	90.0	24.73	26.05
B. Max Width (mm)	1	2	63.70	83.9	43.5	28.57
	2	2	45.47	72.69	18.25	38.49
	3	3	34.67	38.6	29.1	4.96
	4	1	71.36	71.36	71.36	-
	Total	8	49.21	83.9	18.25	23.66
C. Max Thickness (mm)	1	2	31.20	40.0	22.4	12.45
	2	2	32.54	53.58	11.5	29.76
	3	3	27.50	32.1	23.8	4.22
	4	1	34.32	34.32	34.32	-
	Total	8	30.54	53.58	11.5	12.69
D. Mass (g)	1	2	226.28	412.0	40.56	262.65
	2	2	55.42	104.62	6.22	69.58
	3	3	58.24	74.03	48.27	13.83
	4	1	404.90	404.9	404.9	-
	Total	8	142.88	412.0	6.22	166.29
Measurement	**AU**	**Count**	**Average**	**SD**	**Average**	**SD**
E. Average Maximum Negative Scar Dimensions	1	2	26.35	7.00	33.35	1.34
	2	2	29.09	4.36	15.39	14.83
	3	3	29.71	7.34	22.81	6.78
	4	1	28.06	-	32.63	-
	Total	8	28.51	5.21	24.82	10.07
F. Average Minimum Negative Scar Dimensions	1	2	17.90	3.82	15.80	12.02
	2	2	6.92	4.78	14.06	2.46
	3	3	20.02	11.69	21.22	10.06
	4	1	13.70	-	14.55	-
	Total	8	15.43	8.73	17.24	7.86

Flakes

In total, 421 flakes and flake fragments were recovered from the PAD 3 excavations (Table 9-8). The assemblage consists of 221 unbroken flakes, including 12 specimens technologically considered to be blades. Utilising Hiscock's (2002) methodology for quantifying the size of flake assemblages, it is estimated that the assemblage is derived from a minimum number of 301 flakes. Based on Table 9-8, it is estimated that 26.6% of the flake assemblage is fragmented (percentage of flake fragmentation = ((MNF-unbroken flakes)/MNF) -x- 100). It is unclear if the fragmentation occurred on site or if particular broken flake fragments were selected and carried to the rockshelter. It does not appear that particular fragments were intentionally selected, as there is negligible difference between the number of proximal (n=48) and distal flake fragments (n=58). Longitudinal breakage is also evenly distributed across distal and proximal categories. Complete medial flake fragments do not outnumber the proximal and distal flake fragments, and with the exception of estimating the MNF, longitudinally broken flake fragments are of little interpretive value to understanding flake fragmentation.

Quantitative Flake Attributes

The PAD 3 flake assemblage was subject to a number of quantitative attribute measurements, and these results are presented by analytical unit in Table 9-9. Complete flakes are used for the calculations in Table 9-9: A-I, while proximal and complete flake platform measurements are reported for the calculations in Table 9-9: J-L.

In general, the quantitative results suggest that the average flake dimensions increase over time from AU4 through AU1; however, the increase in average maximum flake dimensions and axis dimensions are very slight and not statistically significant (Table 9-9). Thus, the size of the average flake remains relatively uniform throughout the history of the site. The average flake axis dimensions are slightly smaller than the maximum flake dimensions, but the overall pattern remains with only a minor increase in average axis length, width, and thickness. Average flake mass is reported in Table 9-9: G; however, interpreting flake mass is dubious in this instance due to the high frequency of iron-rich flakes in the assemblage. The high concentration of iron in these specimens exaggerates the weight of these objects in comparison to their size.

Table 9-8 Flake fragmentation, PAD 3 rockshelter

Longitudinal Fragmentation	Transverse Fragmentation				
	Complete	Distal	Prox.	Medial	Total
Complete	221	58	48	25	352
Left + Left LCS	13	1	2	9	25
Right + Right LCS	13	6	5	6	30
Medial	0	5	0	9	14
Total	**247**	**70**	**55**	**49**	**421**

Trends in flake elongation are reported as the elongation index (Table 9-9). There is slight increase in flake elongation from AU3 through to AU1; however, the increase is not significant, and it does not seem to be influenced by an increased production of blades. As previously mentioned, there are only 12 flakes that meet the definition of a blade. One occurs in AU4, four specimens are in AU3, three blades were recovered from AU2, and four specimens are in AU1. The distribution of these specimens is relatively even across the mid to late Holocene analytical units, and they do not have a significant effect on the elongation index.

Flake platform size remains relatively constant throughout time, with no obvious temporal trends. Among analytical units, the average platform width varies between 8.48mm and 9.43mm. Similarly, the exterior platform angle measured on flakes is relatively constant, varying on average between 72° and 85° amongst the four analytical units.

The expanding, contracting, or parallel morphology of flake margins is measured using the parallel index (Table 9-9: I). The results indicate that from the striking platform, flake margins tend to expand, rather than contract or be parallel. Over time, the analytical unit trend suggests that flake margins became more expansive; however, the slight increase in not statistically significant, as there is large and obvious overlap in the standard deviation of these results.

Qualitative Flake Attributes

The qualitative attributes of complete flakes is recorded in Table 9-10 and provide further insight on flake technology and reduction trends at PAD 3 rockshelter. Qualitative attributes were recorded wherever possible for each flake specimen, and they are reported, as appropriate, for complete, proximal, and distal flakes (Table 9-10: A-K).

Complete flakes provide the best means for studying reduction trends and flake morphology. For example, the amount of dorsal cortex recorded for each specimen provides an interesting pattern in flake reduction between analytical units (Table 9-10: E). In AU4, 3, and 2, approximately 52.94% to 59.42% of the flake assemblage does not exhibit dorsal cortex; however, in AU1 only 25% of the complete flake assemblage is absent of cortex. The increase of cortex on the AU1 flake specimens does not have a direct correlation with an increase in cores discarded on site as only two cores are present in AU1 (Table 9-6). In fact, the site lacks a substantial assemblage of cores, with two recovered from AU2, five in AU3, and one in AU4. The increase in cortex bearing flakes from AU1 may be due an increase in early stage reduction activities occurring on-site, or it could be that more cortex-bearing flakes were transported and discarded in the rockshelter.

To a certain degree, the argument for an increase in early stage core and flake reduction in AU1 is substantiated by looking at the number of dorsal scars recorded for each flake specimen (Table 9-10: F). In AU1 there are no flakes exhibiting more than three dorsal flake scars. In comparison, more than 11% of the complete flake specimens from AU2, 3 and 4 have four or more dorsal flake scars, suggesting latter stage core reduction. The dorsal scar pattern implies that a significant proportion of the AU1 flake assemblage was manufactured on site from relatively fresh cores, and in comparison to earlier analytical units, this marks a significant change in the knapping behaviour previously employed at the rockshelter.

Table 9-9 Quantitative flake attributes by analytical unit, PAD 3 rockshelter

Measurement	Analytical Unit	Count	Average	Max	Min	SD
A. Max Length (mm)	1	28	19.30	36	6.3	8.74
	2	69	14.21	47.8	2.75	10.29
	3	106	15.08	58.76	1.42	11.42
	4	17	16.62	30.1	4	8.40
B. Max Width (mm)	1	28	17.00	36.20	6.10	8.14
	2	69	13.82	43.70	2.60	8.19
	3	106	16.04	62.10	3.20	11.41
	4	17	15.19	35.67	4.20	7.51
C. Max Thickness (mm)	1	28	4.89	13.70	0.90	3.20
	2	69	4.10	17.10	0.50	3.62
	3	106	4.12	18.10	0.23	3.38
	4	17	3.64	9.08	1.02	2.13
D. Axis Length (mm)	1	28	17.50	33.60	6.28	7.70
	2	69	12.48	40.70	2.54	8.61
	3	106	13.46	52.10	1.42	10.19
	4	17	16.16	29.60	4.10	8.01
E. Axis Width (mm)	1	28	14.74	31.90	5.60	6.37
	2	69	12.24	41.90	2.80	7.60
	3	106	14.10	44.40	2.70	9.92
	4	17	13.88	33.38	4.20	7.27
F. Axis Thickness (mm)	1	28	4.34	12.80	0.99	2.76
	2	69	3.46	16.60	0.49	3.10
	3	106	3.52	12.60	0.30	2.92
	4	17	3.42	8.30	0.85	1.91
G. Mass (g)	1	28	2.44	14.09	0.05	3.10
	2	69	2.30	28.80	0.01	5.35
	3	106	3.59	53.01	0.01	8.18
	4	17	1.70	8.70	0.03	2.31
H. Elongation Index	1	28	1.27	2.87	0.53	0.64
	2	69	1.09	2.92	0.30	0.53
	3	106	1.00	2.92	0.19	0.46
	4	17	1.17	2.38	0.63	0.54
I. Parallel Index	1	28	2.08	12.27	0.93	2.14
	2	69	1.91	5.47	0.52	1.08
	3	106	1.81	7.13	0.59	1.06
	4	17	1.94	5.42	0.88	1.16
J. Platform Width (mm)	1	33	9.43	25.70	2.60	5.55
	2	80	8.48	39.80	0.91	6.81
	3	131	9.03	30.63	1.00	6.44
	4	24	8.77	25.25	2.50	5.41
K. Platform Thickness (mm)	1	33	4.36	21.30	0.80	4.09
	2	80	2.87	13.70	0.31	2.86
	3	131	3.54	48.00	0.20	5.32
	4	24	2.54	7.17	0.70	1.67
L. Platform Angle (°)	1	33	85.03	115.00	60.00	13.11
	2	80	79.19	115.00	30.00	13.79
	3	131	72.87	112.00	12.00	15.55
	4	24	80.75	103.00	64.00	10.09

A number of the qualitative attributes listed in Table 9-10 provide a good indication of flake morphology. For example, in Table 9-10: H, the overall shape or form of each complete flake indicates that more than half of the assemblage has distally expanding margins (54.55%). This dominant pattern holds true throughout the site history, and it supports the pattern observed by the parallel index (Table 9-9: I). Contracting distal flake margins are the second most common flake form, accounting for 21.72% of the assemblage. Together, parallel (4.98%) and sub-parallel sided (18.10%) flakes comprise an additional 23.08% of the assemblage. Leaf-shaped (0.45%) flakes are comparatively rare in the assemblage. For the most part, this overall pattern is maintained throughout each analytical unit.

The ventral profile of each complete flake is reported in Table 9-10: I. The majority of the flake assemblage has a straight ventral profile. The second most common profile is concave ventral surfaces, followed closely by convex ventral surfaces. Convex ventral surfaces are presumably caused by pronounced bulbs of percussion, and may be indicative of the force of the blow used to remove the flake. The flakes from AU4 have the highest incidence of convex profiles, which may be related to extra force required to flake local BIF, the dominant raw material utilised in the early Holocene analytical unit. Some ventral profiles exhibit twisted morphology, but this is relatively uncommon.

The morphological cross section of complete flakes is listed in Table 9-10: J. The results are highly varied, and no clear patterns exist. In general, the data shows that nearly all categories of cross section are fairly evenly distributed.

Table 9-10 Qualitative flake attributes by analytical unit, PAD 3 rockshelter

A. Platform Type [cp]	AU1		AU2		AU3		AU4		Total	
	n	%	n	%	n	%	n	%	n	%
Cortical	12	36.36	16	20.0	19	14.50	6	25.0	54	20.07
Dihedral	0	0.00	4	5.00	4	3.05	2	8.33	10	3.72
Linear	0	0.00	4	5.00	1	0.76	0	0.00	5	1.86
Plain	19	57.58	42	52.50	96	73.28	15	62.50	172	63.94
Winged	0	0.00	5	6.25	4	3.05	0	0.00	9	3.35
Crushed	0	0.00	4	5.00	4	3.05	1	4.17	9	3.35
Facetted	2	6.06	5	6.25	3	2.29	0	0.00	10	3.72
Total	**33**	**100**	**80**	**100**	**131**	**100**	**24**	**100**	**269**	**100**
B. Overhang Removal [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
Crushed	1	3.03	3	3.75	3	2.29	0	0.00	7	2.60
Facetting	3	9.09	12	15.00	14	10.69	2	8.33	31	11.52
None	29	87.88	65	81.25	114	87.02	22	91.67	231	85.87
Total	**33**	**100**	**80**	**100**	**131**	**100**	**24**	**100**	**269**	**100**
C. Lipping [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
False	32	96.97	73	91.25	120	91.60	24	100	250	92.94
True	1	3.03	7	8.75	11	8.40	0	0.00	19	7.06
Total	**33**	**100**	**80**	**100**	**131**	**100**	**24**	**100**	**269**	**100**
D. Bulb of Percussion [cp]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
Diffuse	18	54.55	53	66.25	78	59.54	5	20.83	154	57.25
Prominent	15	45.45	27	33.75	53	40.46	19	79.17	115	42.75
Total	**33**	**100**	**80**	**100**	**131**	**100**	**24**	**100**	**269**	**100**
E. Dorsal Cortex [c]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
None	7	25.00	41	59.42	61	57.55	9	52.94	118	53.39
1-32%	9	32.14	9	13.04	26	24.53	3	17.65	47	21.27
33-65%	6	21.43	6	8.70	8	7.55	1	5.88	22	9.95
66-99%	1	3.57	3	4.35	5	4.72	3	17.65	12	5.43
100%	5	17.86	10	14.49	6	5.66	1	5.88	22	9.95
Total	**28**	**100**	**69**	**100**	**106**	**100**	**17**	**100**	**221**	**100**
F. Dorsal Scars [c]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
0	5	17.86	10	14.49	6	5.66	1	5.88	22	9.95
1	8	28.57	20	28.99	28	26.42	5	29.41	61	27.60
2	8	28.57	16	23.19	40	37.74	5	29.41	69	31.22
3	7	25.00	14	20.29	19	17.92	4	23.53	44	19.91
4	0	0.00	8	11.59	11	10.38	2	11.76	22	9.95
5	0	0.00	1	1.45	2	1.89	0	0.00	3	1.36
Total	**28**	**100**	**69**	**100**	**106**	**100**	**17**	**100**	**221**	**100**
G. Scar Orientation [c]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
Bidirectional	1	3.57	0	0.00	6	5.66	1	5.88	8	3.62
Indeterminate	3	10.71	11	15.94	35	33.02	7	41.18	56	25.34
NA	5	17.86	10	14.49	6	5.66	1	5.88	22	9.95
Rotated	5	17.86	13	18.84	13	12.26	3	17.65	35	15.84
Unidirectional	14	50.0	35	50.72	46	43.40	5	29.41	100	45.25
Total	**28**	**100**	**69**	**100**	**106**	**100**	**17**	**100**	**221**	**100**
H. Form [c]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
Contracting Distally	5	17.86	12	17.39	27	25.47	4	23.53	48	21.72
Expanding Distally	15	53.57	37	53.62	58	54.72	10	58.82	118	53.39
Leaf	0	0.00	0	0.00	1	0.94	0	0.00	1	0.45
Parallel-sided	2	7.14	6	8.70	2	1.89	1	5.88	11	4.98
Sub Parallel-sided	6	21.43	14	20.29	18	16.98	2	11.76	40	18.10
Total	**28**	**100**	**69**	**100**	**106**	**100**	**17**	**100**	**221**	**100**
I. Profile [c]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
Concave	4	14.29	13	18.84	26	24.53	3	17.65	46	20.81
Convex	6	21.43	9	13.04	20	18.87	6	35.29	41	18.55
Straight	16	57.14	44	63.77	55	51.89	7	41.18	123	55.66
Twisted	2	7.14	3	4.35	5	4.72	1	5.88	11	4.98
Total	**28**	**100**	**69**	**100**	**106**	**100**	**17**	**100**	**221**	**100**
J. Cross-section [c]	**AU1**		**AU2**		**AU3**		**AU4**		**Total**	
	n	%	n	%	n	%	n	%	n	%
Irregular	3	10.71	5	7.25	22	20.75	5	29.41	36	16.29
Left triangle	5	17.86	14	20.29	11	10.38	2	11.76	32	14.48
Plano-convex	4	14.29	13	18.84	20	18.87	4	23.53	41	18.55
Right triangle	7	25.00	13	18.84	20	18.87	1	5.88	41	18.55
Symmetric Triangle	3	10.71	13	18.84	15	14.15	0	0.00	31	14.03
Trapezoid	6	21.43	11	15.94	18	16.98	5	29.41	40	18.10
Total	**28**	**100**	**69**	**100**	**106**	**100**	**17**	**100**	**221**	**100**

K. Termination [cd]	AU1		AU2		AU3		AU4		Total	
	n	%	n	%	n	%	n	%	n	%
Axial	0	0.00	1	1.14	0	0.00	0	0.00	1	0.36
Cortical - Axial	1	3.03	1	1.14	4	2.96	0	0.00	6	2.15
Feather	24	72.73	67	76.14	96	71.11	17	77.27	205	73.48
Hinge	2	6.06	9	10.23	20	14.81	4	18.18	35	12.54
Inflexed	1	3.03	1	1.14	1	0.74	0	0.00	3	1.08
Plunge	2	6.06	5	5.68	8	5.93	1	4.55	16	5.73
Step	3	9.09	4	4.55	6	4.44	0	0.00	13	4.66
Total	**33**	**100**	**88**	**100**	**135**	**100**	**22**	**100**	**279**	**100**
Key: cp - complete and proximal flakes; c - complete flakes; cd - complete and distal flakes										

Proximal and complete flakes were used to examine qualitative platform attributes (Table 9-10: A-D). In reviewing the platform types, a clear pattern is observed. Throughout time, it is evident that plain platforms were preferred by early flint knappers. At total of 63.94% of all flake platforms are plain, lacking any additional remnant scars or evidence of striking platform preparation. Cortical platforms are the second most common platform type, comprising 20.07% of the complete and proximal flake assemblage. There is no clear pattern in the temporal distribution or range of remaining platform types, as linear, dihedral, winged, crushed, and facetted platforms occur in similar frequency throughout the deposit. There is also little evidence of platform preparation as overhang removal occurs on less than 15% of specimens (Table 9-10: B).

Flakes with diffuse platforms are more common in the assemblage than flakes with prominent bulbs of percussion. This pattern is observed throughout the site record, with the exception of AU4. In the early Holocene AU4, 79.17% of the flakes have prominent bulbs of percussion. A possibility for this pattern may be due to the high proportion of coarse grained BIF used for flake manufacture. More force may have been required to detach BIF flakes, resulting in a higher percentage of prominent bulbs. However, diffuse bulbs are also represented in the BIF assemblage, so this hypothesis is not conclusive.

In the past, archaeologists inferred that platform lipping may be indicative of soft hammer percussion; however, as is discussed in Chapter 4, lipping is not directly related to knapping technique, but is affected by the angle of force. At PAD 3, only 19 (7.06%) of the platforms exhibited lipping, and this attribute is represented equally across coarse and fine-grained raw materials. Therefore lipped platforms do not seem to be related to raw material types. The majority of the specimens with lipped platforms (n=12) are on flakes weighing less than 0.5g, suggesting that lipping tends to occur on small flakes, and it is possible that many of these flakes are the result of marginal retouch where high angles of force would be advantageous.

Feather flake terminations are most common on the complete and distal flake assemblage, accounting for 73.48% of all terminations. They are followed by hinge (12.54%) and plunge (5.73%) terminations. This trend is observed within all analytical units, and no distinctive pattern is observable amongst the remaining termination types (*e.g.*, step, plunge, inflexed, axial, and cortical axial).

Retouched and Utilised Artefacts

Twenty three retouched or utilised artefacts were recovered from the PAD 3 excavations (Table 9-11), including nine formalised retouched artefacts, 12 retouched artefacts, and two utilised artefacts. Of this population, unifacially retouched flakes are the most common, totalling 11 specimens. Only one retouched flake with alternating retouch along the margin was identified. Two utilised artefacts consisting of a flake with unifacial usewear and a flake with alternating usewear are in the assemblage. The following section provides a discussion of the formalised retouched artefacts and the edge modification techniques that are present in the assemblage.

Formalised Retouched Artefacts

A number of stone tool technologies are represented at PAD 3 (Table 9-11). Eight backed artefacts, including four asymmetrical, three symmetrical, and one fragment were found in the assemblage (Figure 9-15). Three of the asymmetrical forms may be considered Bondi types (one specimen has a slight distal tip missing), and one asymmetrical form is irregular-shaped, with backing retouch that has truncated the proximal end of the flake. The three symmetrical backed artefacts have a semicircular or crescent-shaped backed margin. There is one backed artefact fragment that cannot definitively be described as symmetrical or asymmetrical, so it is listed as indeterminate.

Table 9-11 Distribution of retouched and utilised artefacts by analytical unit, PAD 3 rockshelter

Retouched or Utilised Artefact Type	Surface		AU1		AU2		AU3		Total	
Subtype	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*1*	*100*	*5*	*62.50*	*4*	*36.36*	*2*	*66.67*	*12*	*52.18*
Unifacial	1	100	4	50.00	4	36.36	2	66.67	11	47.83
Alternating	0	0.00	1	12.50	0	0.00	0	0.00	1	4.35
Asymmetrical Backed Artefact	*0*	*0.00*	*0*	*0.00*	*4*	*36.36*	*0*	*0.00*	*4*	*17.39*
Bondi	0	0.00	0	0.00	3	27.27	0	0.00	3	13.04
Irregular	0	0.00	0	0.00	1	9.09	0	0.00	1	4.35
Symmetrical Backed Artefact	*0*	*0.00*	*1*	*12.50*	*2*	*18.18*	*0*	*0.00*	*3*	*13.04*
Crescent	0	0.00	1	12.50	2	18.18	0	0.00	3	13.04
Backed Artefact	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*33.33*	*1*	*4.35*
Indeterminate	0	0.00	0	0.00	0	0.00	1	33.33	1	4.35
Scraper	*0*	0.00	*1*	*12.50*	*0*	*0.00*	*0*	*0.00*	*1*	*4.35*
Steep Edge	0	0.00	1	12.50	0	0.00	0	0.00	1	4.35
Utilised Artefact	*0*	*0.00*	*1*	*12.50*	*1*	*9.09*	*0*	*0.00*	*2*	*8.70*
Unifacial	0	0.00	0	0.00	1	9.09	0	0.00	1	4.35
Alternating	0	0.00	1	12.50	0	0.00	0	0.00	1	4.35
Total	**1**	**100**	**8**	**100**	**11**	**100**	**3**	**100**	**23**	**100**

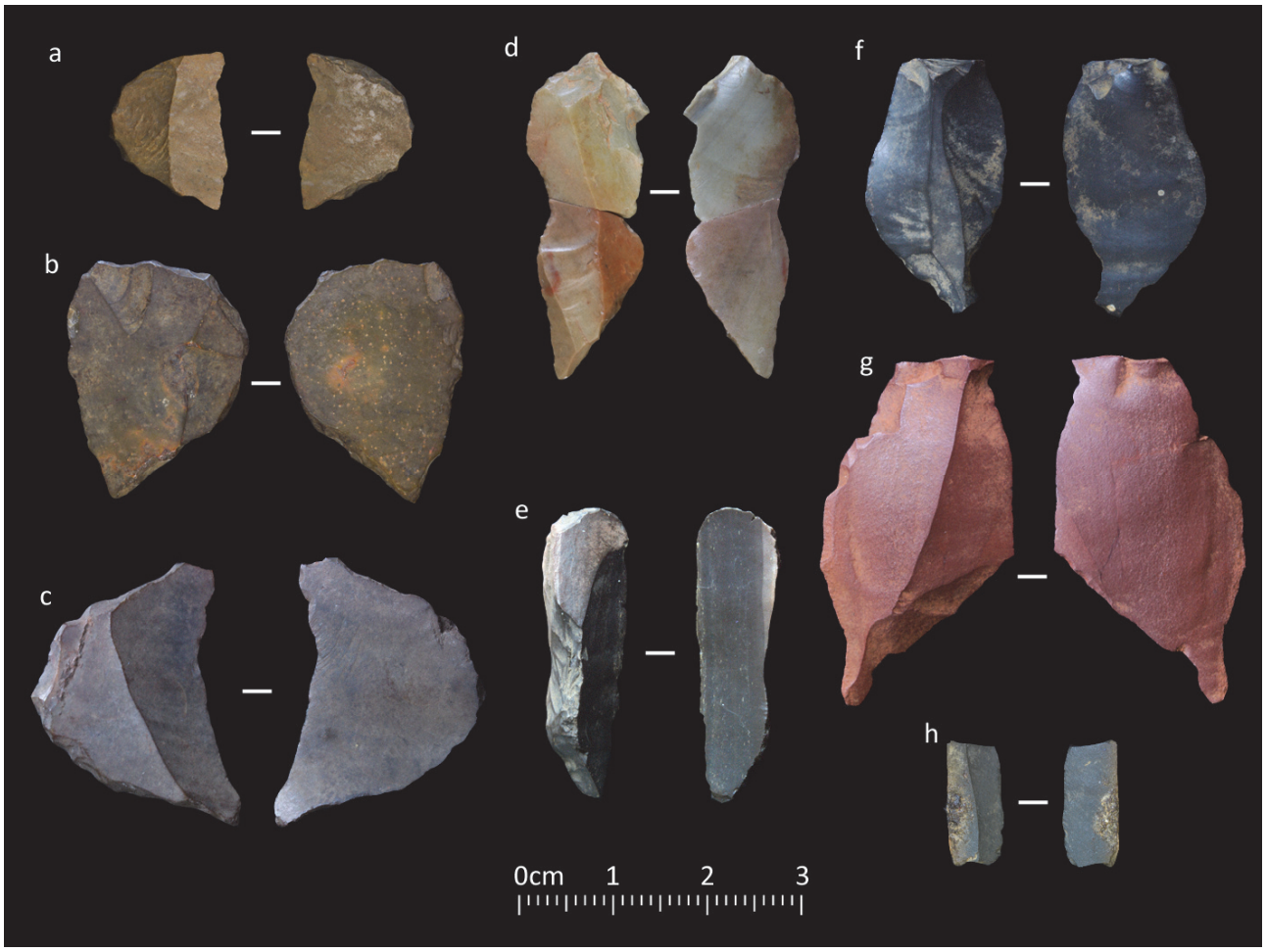

Figure 9-15 retouched and utilised artefacts from PAD 3 rockshelter: symmetrical backed artefacts a) crescent (Artefact 313), b) crescent (Artefact 181), c) crescent with resin (Artefact 561), asymmetrical backed artefacts: d) Bondi (Artefact 171), e) Bondi (Artefact 224), retouched flakes: f) unifacial (Artefact 288), g) unifacial (Artefact 268), and h) utilised flake with resin (Artefact 211)

Backed artefact technology at PAD 3 is presently the oldest documented from the Pilbara. Four asymmetrical specimens and one broken fragment were recovered from within and immediately beneath the Feature 1 matrix. Radiocarbon dates from Feature 1 conservatively suggest that backed artefact technologies were utilised in the Pilbara by at least 4569 cal BP, and possibly as early as 4825 cal BP.

Fullagar (2011) has identified usewear and resin on many of the PAD 3 backed specimens, suggesting that they were hafted as composite tools. He also believes that the usewear on the eight backed artefact specimens is indicative of multifunctional use, including piercing skin, graving wood, and possibly as a projectile tip (Fullagar 2011).

One retouched flake (Artefact 276) has been described as a steep edge scraper due to the regularity of the retouch scars and apparent systematic modification. Most of the original perimeter of the artefact has been retouched, removing the original flake margin at associated attributes. Usewear along the margin of the stone tool indicates it was most likely used for scraping wood (Fullagar 2011).

Two flakes (Artefacts 211 and 268) exhibiting macroscopic usewear were recovered from the assemblage (Figure 9-15). Both specimens were submitted for usewear analysis, and usewear was confirmed (Fullagar 2011). Artefact 211 has alternating usewear and resin plaques, suggesting it was hafted (Fullagar 2011). The specific use of each specimen could not be determined.

Edge Modification Analysis

In total, 25 areas of edge modification were documented on 12 complete retouched artefacts (Table 9-12). The modified areas include 23 areas of retouch and two areas of usewear. The retouched areas provide some insight of early knapping methodologies and reduction techniques. Obviously, all of the backed artefacts have characteristically steep retouch scars along a margin (n=6), as this is the criterion that defines this stone tool category. In addition to the backing, the analysts noted one area or regular retouch along the lateral margin of a symmetrical specimen and macroscopic usewear on another specimen. Fullagar (2011) found additional microscopic usewear on all the backed artefact specimens, indicating their use as stone tools.

The PAD 3 complete retouched flake assemblage exhibits a variable array of edge modification, including six instances of regular retouch, one retouched notch, and three areas of macroscopic usewear. The steep edge scraper found in AU1 displayed evidence of macroscopic usewear and regular retouch. The most common direction of edge modification was towards the dorsal surface, with 44.0% of retouch scars and usewear oriented in this direction. Ventrally directed modification occurs 34.0% of the time with alternating retouch and usewear responsible for the remaining 24.0% of instances.

The angle of the retouched edges is more commonly steep than acute. For the complete retouched flake assemblage, five instances of AAR (<60°) are recorded and there are 13 instances of SAR (>60°). However, along utilised edges on complete retouched and utilised artefacts, AAR is more common, with six areas of usewear reported as being acute compared with only one instance of SAR along an utilised edge.

In accordance with our analytical methodology, each area of macroscopic usewear (<1mm) was recorded, and it accounts for 28% of the instances of edge modification. Sixty four percent of the retouch scars were classified as short. Long retouch scars occurred in only 8% of the instances of edge modification, and no retouched flake specimens were invasively retouched.

The delineation of the retouched areas is variable for the retouched flake assemblage. On complete flakes, regular retouch is the most common type, occurring in 14 instances. Convex retouch, which creates a rounded retouched edge, is the second most common delineation of retouch, occurring in seven cases. Three concave retouch areas were created, while only one instance of rectilinear retouch was recorded.

Upon close examination of the 25 areas of edge modification from the complete retouched flake assemblage, a distinct pattern of retouch emerges (Table 9-13). The highest number of edge modifications occur equally on the right lateral edge (n=8) and left lateral edge (n=8). The distal margin is the second most commonly modified area (n=3). The proximal edge was modified in one instance. On two occasions, modification continued along the right lateral edge and onto the distal or proximal margin. Similarly, modification of the left lateral margin continued onto the distal or proximal margin for two specimens. The overall pattern suggests that the lateral margins of flakes were utilised or retouched more often than the distal or proximal flake margins.

Due to the low sample size of appropriate retouched flakes, the results of reduction indices such as the PRI and GIUR are not valid for PAD 3 rockshelter. Eleven specimens are appropriate for the PRI, and for the entire assemblage, the average PRI is 0.42 (SD=0.22). The PRI varies amongst the analytical units (surface: n=1, Avg=0.24; AU1: n=3, Avg=-0.62, SD=0.16; AU2: n=6, Avg=0.39, SD=22; AU3: n=1, Avg=0.18), with slightly higher PRI values in AU1 and AU2. Given the very limited sample size, the variation is not statistically significant. Amongst the complete retouched artefacts, there are eight artefacts with ten areas of retouch that provide suitable GIUR results. The average GUIR is 0.65 (SD=0.26) and there is a moderate amount of variation amongst the analytical units (surface: n=2, Avg=0.76, SD=0.07; AU1: n=3, Avg-0.60, SD 0.35; AU2: n=5, Avg=0.63, SD 0.28). As with the PRI results, the sample size is too limited to make valid comparisons and interpretations of this data.

Table 9-12 Edge modification areas on complete retouched artefacts by analytical unit, PAD 3 rockshelter

Retouched or Utilised Artefact Type	Surface		AU1		AU2		AU3		Total	
Subtype	Artefacts	EM	Artefacts	EM	Artefacts	EM	Artefacts	EM	Artefacts	EM
Retouched Artefact	*1*	*5*	*1*	*2*	*1*	*2*	*1*	*1*	*4*	*10*
Unifacial	1	5	0	0	1	2	1	1	3	8
Alternating	0	0	1	2	0	0	0	0	1	2
Asymmetrical backed artefact	*0*	*0*	*0*	*0*	*3*	*5*	*0*	*0*	*3*	*5*
Bondi	0	0	0	0	2	4	0	0	2	4
Irregular	0	0	0	0	1	1	0	0	1	1
Symmetrical backed artefact	*0*	*0*	*1*	*2*	*2*	*3*	*0*	*0*	*3*	*5*
Crescent	0	0	1	2	2	3	0	0	3	5
Scraper	*0*	*0*	*1*	*3*	*0*	*0*	*0*	*0*	*1*	*3*
Steep edge	0	0	1	3	0	0	0	0	1	3
Utilised Artefact	*0*	*0*	*0*	*0*	*1*	*2*	*0*	*0*	*1*	*2*
Unifacial	0	0	0	0	1	2	0	0	1	2
Total	1	5	3	7	7	12	1	1	12	25

Table 9-13 Retouch location on complete retouched artefacts by analytical unit, PAD 3 rockshelter

Retouch Location	Surface		AU1		AU2		AU3		Total	
Retouch Type	n	%	n	%	n	%	n	%	n	%
DE	*1*	*20.00*	*1*	*14.29*	*1*	*8.33*	*1*	*100*	*4*	*16.00*
Retouch	1	20.00	1	14.29	1	8.33	1	100	4	16.00
LLE	*2*	*40.00*	*4*	*57.14*	*2*	*16.67*	*0*	*0.00*	*8*	*32.00*
Retouch	0	0.00	3	42.86	0	0.00	0	0.00	3	12.00
Retouched Notch	1	20.00	0	0.00	0	0.00	0	0.00	1	4.00
Usewear	1	20.00	1	14.29	2	16.67	0	0.00	4	16.00
RLE	*2*	*40.00*	*0*	*0.00*	*6*	*50.00*	*0*	*0.00*	*8*	*32.00*
Retouch	1	20.00	0	0.00	1	8.33	0	0.00	2	8.00
Backing	0	0.00	0	0.00	3	25.00	0	0.00	3	12.00
Usewear	1	20.00	0	0.00	2	16.67	0	0.00	3	12.00
PE	*0*	*0.00*	*0*	*0.00*	*1*	*8.33*	*0*	*0.00*	*1*	*4.00*
Backing	0	0.00	0	0.00	1	8.33	0	0.00	1	4.00
LLE + DE or PE	*0*	*0.00*	*0*	*0.00*	*2*	*16.67*	*0*	*0.00*	*2*	*8.00*
Backing	0	0.00	0	0.00	2	16.67	0	0.00	2	8.00
RLE + DE or PE	*0*	*0.00*	*2*	*28.57*	*0*	*0.00*	*0*	*0.00*	*2*	*8.00*
Retouch	0	0.00	1	14.29	0	0.00	0	0.00	1	4.00
Backing	0	0.00	1	14.29	0	0.00	0	0.00	1	4.00
Total	**5**	**100**	**7**	**100**	**12**	**100**	**1**	**100**	**25**	**100**
Key: LLE – Left Lateral Edge, RRL – Right Lateral Edge, DE – Distal Edge, PE – Proximal Edge										

Artefact Analysis Summary

The PAD 3 assemblage demonstrates little differences in the reduction techniques and stone tool technologies represented in the middle and late Holocene analytical units. The overall trend suggests that there is technological continuity amongst the artefacts discarded throughout the middle and late Holocene period, echoing a trend observed nearby at PAD 4. Multifunctional stone tools such as backed artefacts comprise a rare, but unique tool component of middle and late Holocene assemblages, and there appears to be an emphasis on extending the use-life of artefacts, particularly on those manufactured from fine-grained raw materials. Chert was the preferred raw material in the mid to late Holocene; however, locally available BIF continued to be utilised but to a lesser degree than before.

The main temporal and technological differences that can be observed at PAD 3 are between the early Holocene assemblage and later assemblages. In the early Holocene, locally available raw materials such as BIF and shale were utilised more frequently, and retouched flakes are absent from the record. Together, these patterns infer that the overall technological system may have required less planning than later periods, or perhaps economic resources were more readily accessible in the region. It is possible that there may have been less risk in accessing food, water, and raw materials during the early Holocene, so there may have been less need for specialised stone tools during this period.

9.7 SPECIALIST STUDIES

Due to the excellent preservation of hearth features, macrobotanical remains, and faunal remains at PAD 3, specialist studies were commissioned in order to gain a better understanding of the Aboriginal occupation at the site. The results of the macrobotanical and faunal analysis are summarised below. As the results of the artefact usewear analysis have been discussed in the previous section, they are not repeated in the following section.

Macrobotanical Analysis

Organic plant material, including both charred and unburned specimens, was extremely well-preserved within the PAD 3 deposit. In the authors' experience at Hope Downs 1, it is relatively rare to find such a large assemblage of plant remains, particularly within archaeological features. The PAD 3 macrobotanics provided the salvage project with a unique opportunity to investigate the nature of the material and determine if any of the remains could provide further insights into the archaeological record. The macrobotanical materials collected from each feature matrix, as well as other specific site contexts, were submitted to Dr Andrew Fairbairn at the University of Queensland for analysis. The detailed results of this study are presented elsewhere (Fairbairn 2011).

The principle aim of the macrobotanical analysis was to determine what species are present within each hearth and if the plant materials provide information of Aboriginal subsistence. The research also aimed to investigate if there is variability between the plant species represented in each hearth and if there are any temporal changes between the features. Further, if there are temporal changes in the plants burned within the features, then what inferences can be made about past environments in the region?

Fairbairn (2011) determined that the principal charred plant species are *Acacia*, *Eucalyptus*, and *Triodia*, which are within the expected contemporary range of species present in the region today. Fairbairn (2011) interprets this as an indication that hearth fuel was selected from local wood resources, as opposed to materials brought to the site from elsewhere. Fairbairn (this volume) did find evidence of non-local woody species within the deposit, such as paperbark, and the closest source of this material today is several kilometres east of the ROM pad gully, along Weeli Wolli Creek.

Although there are only small differences between the wood taxa identified in the features, Fairbairn (2011) did determine that there is a modest change in the pattern of woody species burned in the hearths. For example, Fairbairn's analysis shows that *Acacia* is more common in the early and early mid-Holocene (AU4 and AU3) hearths than in later period hearths. He argues that the decline in the use of *Acacia* species may be a climatic inference that corresponds with other regional climatic data. Fairbairn (2011) suggests that 'Although the limited taxonomic resolution of the record restricts the scope of climatic inference, the reduction in Acacia species seems to be a robust pattern post-dating approximately 4800 cal BP'. He then points out that this pattern corresponds with a reduction in rainfall evidenced in central Australia's lake level record (Hesse *et al.* 2004) and indirectly with Shulmeister and Lees' (1995) data from northern Australia (Fairbairn 2011). It is also worth pointing out that recent climatic evidence from northwest Australia and central Australia also supports this supposition (Nott 2011; Quigley *et al.* 2010)

Fairbairn's analysis of organics (*e.g.*, seeds, bark and grass) from non-feature contexts yielded mixed results. Like the wood charcoals, his study identified a narrow range of plant species that are typical to the modern Pilbara environment. Fairbairn (2011) surmises that *Acacia* and *Eucalyptus/Melaleuca* seeds are possible bush foods because their ethnographic use is recorded in related anthropological texts. Spinifex grass seed (*Triodia*), another ethnographically documented bush food, is also identified in the assemblage; however, they are less common in the assemblage than the other taxa (Fairbairn 2011).

A major difficulty with interpreting the non-feature matrix organics is determining if the seeds are the result of anthropogenic activity or were subsequently deposited by the animals occupying the rockshelter. Fairbairn (2011) notes that recent contamination is obvious in the upper site layers, as evidenced by goat faeces and the fresh appearance of seeds and fruits. Some, he hypothesises, might be the result of caching by rodents (Fairbairn 2011). Consequently, he questions the integrity of non-wood plant remains in the upper 15cm of the site deposit (Fairbairn 2011).

Fairbairn (2011) contends that the Holocene use of spinifex and paperbark in the rockshelter seems to be well evidenced. Spinifex is known ethnographically to have a number of uses as a source of resin, fire tinder, and food (seeds) amongst others (Pitman 2010). Paperbark is also known to be used as fire tender, matting, containers, and as a bush medicine (Clarke 2007).

Presently there is very little wood charcoal data available for the Pilbara; thus, Fairbairn's PAD 3 analysis is a cornerstone study for the region. Future research in this area will refine our understanding of Aboriginal subsistence and climate change.

Faunal Analysis

Bone, teeth, and other fragmented faunal remains are well-preserved within the PAD 3 assemblage, which prompted

further analysis of the material, which was undertaken by Matthew McDowell. The aim of the faunal study was to identify and investigate the nature of the material, and if possible, determine what archaeological insights can be gathered from the assemblage. The research concentrated on the positive identification of each specimen, as well as recording individual specimen attributes such as breakage, burning, modification, and taphonomy. The detailed results of the analysis are presented in Chapter 14.

McDowell's (this volume) study demonstrates that the PAD 3 assemblage is small and highly fragmented. He contends that the majority of the materials cannot be directly attributed to human activity and that they have most likely been deposited by natural processes (McDowell, this volume). Despite this, McDowell (this volume) did identify a small sample of specimens that provide some insight into the diet and subsistence practices of the PAD 3 occupants.

Only two classes of fauna have contexts and attributes suggesting that they were once on the PAD 3 dinner menu. McDowell (this volume) identified one vertebra belonging to an unidentified class of bony fish (Osteichthyes) and 23 non-diagnostic mammalian bone fragments as having 'likely cultural' affiliation. The fish vertebra fragment is an interesting find, as the nearest source of fish today is at Weeli Wolli Spring, 20km northeast of the site (Figure 9-16). The fish vertebra was recovered from the Feature 3 matrix; thus, the bone was likely discarded prior to 4825 cal BP. Due to the context of this find, it is argued that humans were the most likely agent transporting the fish to PAD 3. This rare find is an interesting subtext to the foraging activities of early populations; however, the overall pattern suggests that mammals were the principal fauna consumed.

None of the likely cultural mammalian remains could be identified to a family, genus, or species level due to their highly fragmented nature. However, in examination of the entire assemblage, many marsupial and reptile remains may subsistence related, including *Lagorchestes* (hare-wallaby), *Macropus* (kangaroo), *Sminthopsis* (dunnart) and *Bettongia* (bettong) spp. Disappointingly, the faunal analysis yields very little evidence to support on site butchering, cooking, and consumption activities. McDowell (this volume) believes some bone breakage may be attributed to humans, but most of the breakage patterns can be explained by erosion and trampling (either animal or human). There is also little evidence to suggest high temperature burning, but there are four instances where bone has clearly been subject to percussion flaking, most likely to access the bone marrow (McDowell, this volume) (Figure 9-16).

Low proportion of burned and calcined bone have been reported at many archaeological sites in the arid zone (*e.g.*, Gould 1996; Edwards *et al.* 2001), and previous research suggests that the amount of burned and calcined bones in the assemblage is not necessarily directly related to the proportion faunal remains deposited by humans. For example, ethnographic observations in the Western Desert demonstrate that Aboriginal cooking methods often do not result in a large amount of burned bone because animals were typically roasted in their skins (*e.g.*, Gould 1996: 78). Gould (1996: 78) noted that fragments of bone were occasionally tossed into the fire for no specific purpose. It is also possible that post-depositional burning may account for some burned and calcined specimens (Walters 1988; Asmussen 2009; Gould 1996)

The reptilian assemblage includes examples of Agamidae (dragon lizard), Elapidae (snake) and Scincidae (skink) (McDowell, this volume). It is possible that these reptiles were consumed, but there is no direct evidence from PAD 3 supporting this hypothesis. Therefore, it is presumed their deposition was through natural processes.

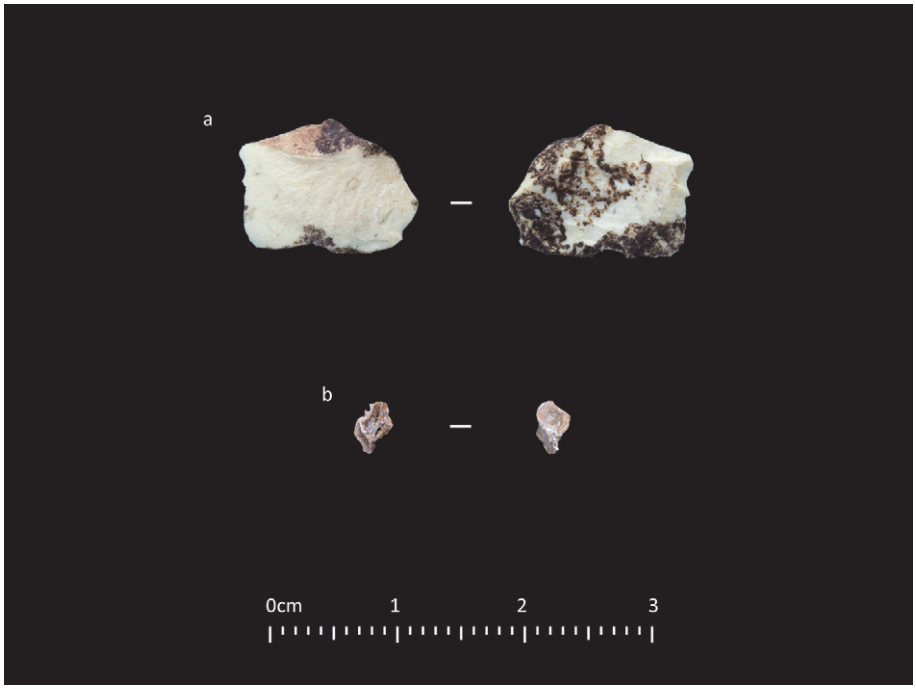

Figure 9-16 PAD 3 rockshelter faunal assemblage photos: a) flaked bone and b) fish vertebra

9.8 DISCUSSION

The PAD 3 investigations elevate our understanding of the Holocene archaeological and palaeoenvironmental record. Possibly the greatest contribution of the PAD 3 investigation is observing that cultural features and organics can be well preserved in a rockshelter deposit. Together, the stratigraphic relationships and radiocarbon chronology of these features increase our resolution and understanding of the site's Holocene record.

In total, 11 hearth features were documented in the PAD 3 excavations, spanning the early, middle and late Holocene period. The radiocarbon dates and site stratigraphy suggest the occupational history of PAD 3 was intermittent. It is argued that PAD 3 was a place that was occupied for very short periods (most likely one or two days), followed by long periods of disuse.

The earliest period of occupation began approximately 7833 to 7663 cal BP. The early residents constructed small hearths and discarded artefacts manufactured from locally available raw materials, primarily BIF. None of the flakes from the early Holocene display macroscopic retouch, and there are comparatively few cores. The predominant use of local raw materials for artefact manufacture and the lack of retouched artefacts suggest that stone tools with extensive use lives or use potential was not a prominent characteristic of the early Holocene technological system. It is hypothesised that perhaps climatic conditions were less risky and opportunities to access resources were more abundant in the early Holocene than in later periods. Evidence for possibly wetter climatic conditions is supported by the macrobotanical analysis, which demonstrates that *Acacia* charcoals are only present in significant abundance from hearths predating Feature 1, 4825 to 4569 cal BP (Fairbairn 2011). The diminished presence of *Acacia* spp. after this time coincides with a decrease in rainfall documented in central Australia (Hesse *et al.* 2004; Quigley *et al.* 2010). Local palaeoclimate data further documents that increased aridity occurred along the mid-north WA coastline 5400 to 3700 cal BP, accompanied by a decrease or cessation of monsoonal activity (Nott 2011: 722).

At the beginning of the mid-Holocene, between approximately 6469 and 4569 cal BP, the artefact assemblage took on characteristics that are more common in the remaining middle and late Holocene record. Fine-grained siliceous raw materials such as chert became more common in the assemblage. Flake retouch, particularly on fine-grained materials, became more normalised, and backed artefact technologies emerged. In fact, PAD 3 has the earliest unequivocal evidence of backed artefacts in the Pilbara, conservatively demonstrating their use by 4569 cal BP, or possibly as early as 4825 cal BP.

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Chapter 10

Excavations at HD07-3A-03 Rockshelter

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HD07-3A-03 is a small rockshelter in Hope South (Figure 10-1) that was excavated as part of the MIB40 project. Excavations were conducted by ACHM in January 2009, as part of the Hope Downs 1 Mitigative Salvage Program (MIB40). This work revealed a sequence of occupation through the mid-Holocene to recent times at HD07-3A-03. The site is unique in that there is an extremely high artefact density, including 5123 artefacts recovered from two 1-x-1m excavation units and 57 artefacts that were distributed across the surface of the shelter. As such, HD07-3A-03 provides an excellent opportunity to study variation in the flaked stone assemblage over the middle and late Holocene. The site has one of the largest sample of tulas from excavated contexts at Hope Downs 1 (second only to Jundaru), as well as a large assemblage of backed artefacts. The following chapter documents the excavations and results for HD07-3A-03.

10.1 SITE SETTING AND DESCRIPTION

HD07-3A-03 is located within the Newman land system, and while the site is situated within an open valley, it is surrounded by the iron-rich ranges on the western periphery of Hope South (Figure 10-2 and Figure 10-3). Within the valley, several ephemeral creeks merge and there are archaeological sites dotted along each of the small tributaries. The high number of sites in the valley suggests that it was an area of repeated use. Immediately across the ephemeral creek to the southwest is HD07-3A-PAD13, which has an occupation sequence dating back to the Pleistocene). Following the ephemeral creek as it bends around the hill to the south is HS-A2, and recent investigations at this rockshelter suggest that it was utilised concurrently with HD07-3A-03. Approximately 160m to the north, a large range forms the northern border of the valley and there are numerous rockshelter sites along the creekline that runs from the west to the east along at the base of the range. On the south face of the range, there is a large exposure of goethitised shale, which was used as a raw material source in the past, as there are numerous flakes and cores at the site. This site has been recorded as a quarry, HS-A3.

The rockshelter is small and has maximum dimensions of 11.2m wide, 5.3m deep, and 2.5m high (Figure 10-4). The rockshelter is broadest at its entrance, and it reduces in size towards the back. The roof of the rockshelter slopes down towards the south, reducing the amount of usable ground surface. The estimated usable ground surface area is 16 square metres. Three large blocks of roof collapse are present in front of the shelter, but the entrance to the shelter remains unrestricted. One of the blocks of roof collapse is over five metres long, nearly two metres wide, and over a metre high. This large boulder stands vertically in front of the shelter as though it simply cracked off of the overhang. This demonstrates that the overhang would have been much more substantial and would have offered more protection from the elements in the past.



Figure 10-1 Photograph of HD07-3A-03 rockshelter

Unlike many rockshelters investigated in the Hope Downs 1 lease, this shelter is very low-lying. The site formation processes were affected to a great degree by the overbank deposits of the ephemeral creek in front of the site. The deposit within the shelter appears to be an extension of the upper terrace, which occurs along both sides of the creek.

According to Williams (this volume), the terrace was once the floodplain of the creek, which has since been incised by subsequent erosional flood events. The surface of the terrace appears to have been stable for several centuries (M. Williams, this volume), as evidenced by the large trees growing upon it and the ironstone gravel pavement. Within the shelter itself, the ground surface is relatively level, but the lower terrace is within seven metres of the rockshelter entrance. Small, angular fragments of exfoliated bedrock cover the surface and silty sediment is observable between the rocks. A shallow depression was noted by the excavation team near the east end of the shelter, and the faecal pellets suggest that it was created by a macropod.

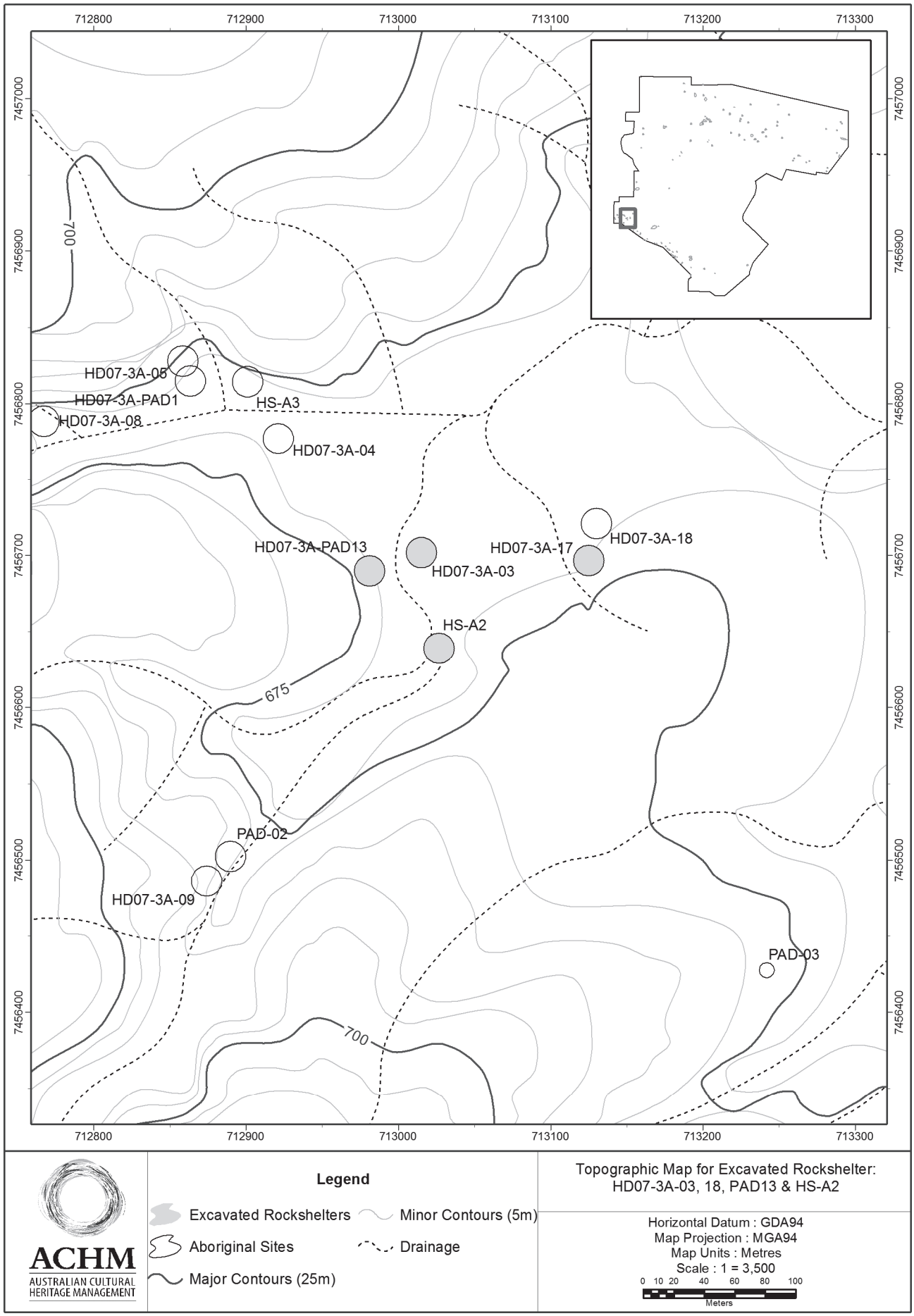

Figure 10-2 Topographic map for HD07-3A-03 rockshelter



Figure 10-3 HD07-3A-03 (lower centre) in its wider setting

The vegetation survey carried out by Mattiske Consulting Pty Ltd (2009) classifies the vegetation within the valley as being tall acacia shrubland (C3 community; see Table 1-2), while hummock grasslands (S1 community) occupy the surrounding uplands. The upper terrace in the valley supports more established vegetation, including mature eucalypts and acacias, while the lower terrace is vegetated by young shrubs (M. Williams, this volume). This suggests that the incision of the lower terrace was a relatively recent erosional event. In the immediate area of the rockshelter and along the banks of the stream in front of the shelter, a wide range of plants were observed, including *Eucalyptus leucophloia* (snappy gum), *Cymbopogon ambiguous* (lemon grass), *Senna venusta, Gossypium robinsonii, Ptilotus calostachyus* (weeping mulla-mulla), and *Cassia* sp. The lemon-scented grass extended up to the dripline of the shelter, and was also observed growing on the bedrock ledge above the shelter along with spinifex. There was a small amount of leaf litter on the shelter surface, and most of the leaf litter had accumulated along the back wall.

10.2 SUMMARY OF FIELD INVESTIGATIONS

HD07-3A-03 was first recorded during the 2007 Hope 1 South Survey by ACHM (see Section 6.1.7; Law *et al.* 2009: 243-245). The survey team observed there were numerous artefacts on the surface of the shelter, as well as charcoal (Law *et al.* 2009: 243). Based on the high number of surface artefacts and the possibility of buried cultural materials, the site was assessed as having medium archaeological significance and further archaeological excavations were recommended (Law *et al.* 2009: 243). In accordance with the 2002 Section 18 permit, a Section 16 permit to undertake mitigative salvage at the site was acquired by the proponent. Section 16 Permit 423 was granted on 25 October 2007 (Thorley 2007).

Between 13 and 19 January 2009, salvage investigations at HD07-3A-03 were completed, revealing an occupation sequence dating back to the mid-Holocene. Prior to excavation, the salvage team created a detailed plan of the rockshelter. The site had the highest density of surface artefacts of any of the rockshelters investigated at Hope Downs 1. In recognition of the importance of the provenance of these artefacts, each specimen was assigned a unique item number, and plotted onto the rockshelter map. Where artefacts were within one centimetre of each other, a central location was plotted and they were collected under the same unique item number. In total, 57 artefacts were recovered from the surface of the rockshelter.

Initially, the excavation team placed a 1-x-1m test unit (Unit 1) near the centre of the rockshelter and approximately one metre beyond the dripline. Because of the high artefact density in the upper layers of this unit, an additional 1-x-1m excavation unit was opened. Unit 2 was positioned adjacent to and east of Unit 1, abutting the east wall of the rockshelter (Figure 10-5). The surface elevations of Unit 1 and Unit 2 varied up to 8.5cm, with the south side of the trench being higher than the northern side. Along the south side of the trench, the elevations of Quads A and B range between 20 and 21cmbd. The deposit slopes up towards the northern edge of the units (along Quads C and D) with elevations of up to 28.5cmbd in Unit 2 and slightly lower in Unit 1 (27.5 to 24.5cmbd).

Because of the considerable slope, the first arbitrary excavation layer was used to level the excavation trench and was terminated at a depth of 30cmbd. Eleven arbitrary layers were excavated in each unit, and the excavation terminated when bedrock was exposed across Units 1 and 2. Throughout most of Unit 1 and Unit 2, the level of bedrock is fairly uniform, ranging between 73 and 76cmbd. Depths of up to 80cmbd occurred only in some small crevices in the bedrock. Along the east side of the trench, the bedrock slopes down from the surface into the trench and forms a ledge. The ledge extends into the excavation trench by approximately 60cm.

A large assemblage of cultural material was recovered during the excavation and through the sorting of the rock fraction. All excavated sediment was weighed and sieved, and the coarse fraction was floated and sorted on-site. The fine rock fraction was collected from the site and stored at the Hope Downs 1 Laboratory. The fine fraction was subject to flotation and sorting between late January and early February 2009. During this process, a large assemblage of flaked stone artefacts was recovered, as well as 5.8kg of floated organic material. A paperbark fragment was recovered *in situ* (U2-L01). Faunal remains were only recovered during the sorting process, and they were identified in 51 separate contexts up to a maximum depth of 60cmbd. The faunal remains have not been submitted for analysis, but they have been archived for future research along with all of the artefacts, macrobotanical remains, and sediment samples.

At the time the excavations were conducted, the site was not intended to be directly affected by the mine; however, HD07-3A-03 is situated on the edge of the Hope South pit and future expansion may affect this site.

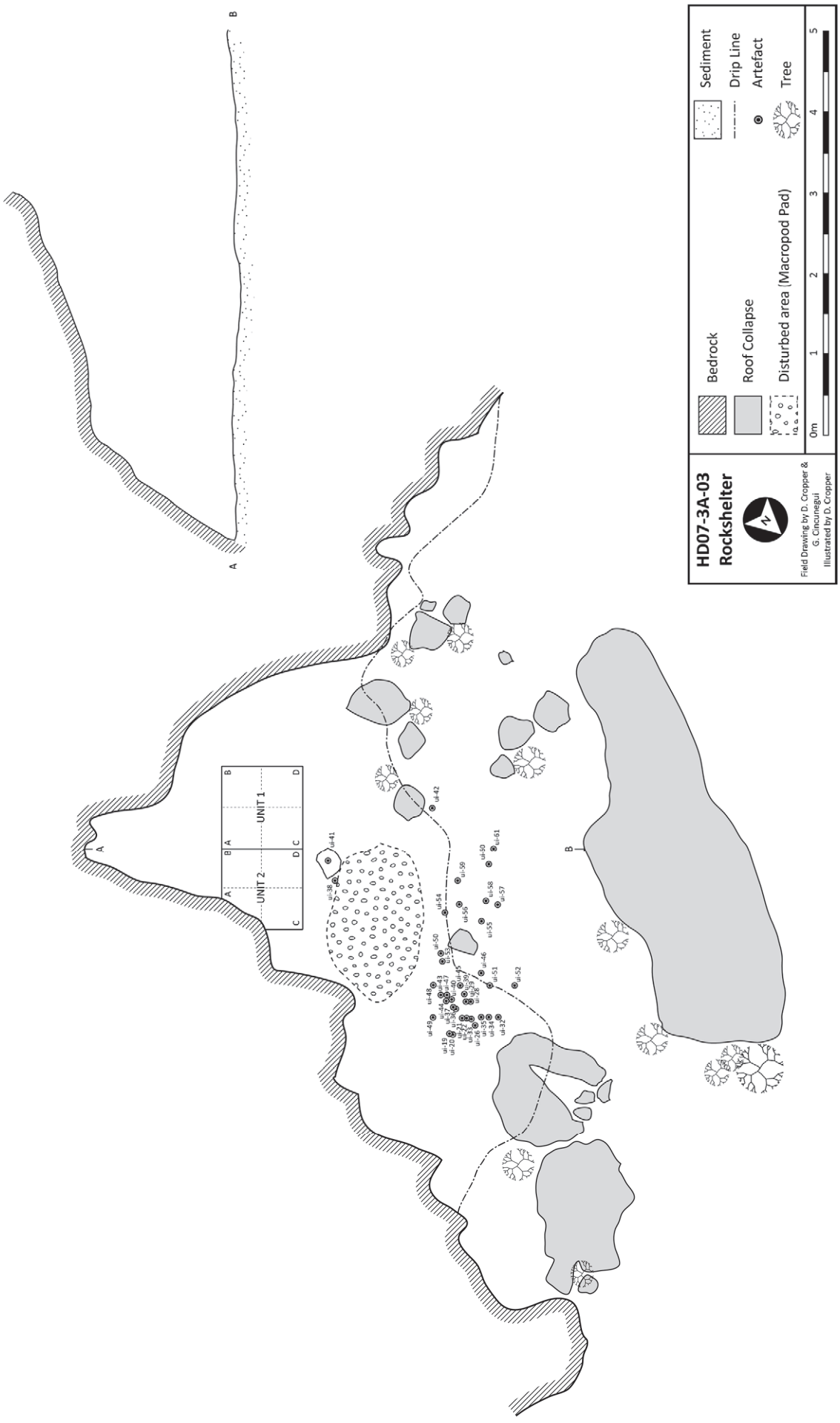

Figure 10-4 HD07-3A-03 rockshelter plan and cross section



Figure 10-5 Units 1 and 2, HD07-3A-03 rockshelter

10.3 STRATIGRAPHY

A deposit with a maximum depth of 60cm was revealed at HD07-3A-03, and the excavation team identified three stratigraphic layers that were defined on the basis of changes in the colour and matrix composition (Figure 10-6). The deposit largely was comprised of fine silty loam that was deposited as the result of flooding of the nearby ephemeral creek. There were subtle differences in the stratigraphic layers, with the surface layer having a higher proportion of organic matter and the basal layer having a greater abundance of weathered bedrock. The deposit is much shallower than the neighbouring rockshelter site, HD07-3A-PAD13, as HD07-3A-03 is situated at a higher elevation, and only in the mid-Holocene was the floodplain at a sufficient level for the overbank deposits to accumulate within the rockshelter. Separate flood events could not be distinguished. While the chronology of the stratigraphic profile is discussed in the following section, it demonstrates that the sediment was not the result of a single flood event, but accumulated through multiple events in which various amounts of sediment were deposited. The lack of stratigraphy relating to the flood events is not unique to this site, but was also noted at HD07-3A-PAD13, where neither the excavation team nor M. Williams (this volume) could identify any microstratigraphy. It is possible that the homogeneity in the source material makes separate events difficult to distinguish. Moreover, if the rockshelter was continuously occupied by both humans and animals, there would have been disturbance to the surface sediment. It is the author's experience that most of the Hope Downs 1 rockshelter deposits are easily disturbed when walked upon, and they become quite powdery when there is concentrated activity within the shelter. Perhaps this disturbance combined with the insect and root bioturbation essentially erased the contact or interruption between depositional events (M. Williams, this volume).

The deposit had a small rock component derived from both autochthonous and allochthonous sources. The source of most of the rock in the deposit was the rockshelter itself; however, the excavators observed some very small rounded pebbles, which must have been washed into the rockshelter during the flood events. The rounded pebbles are allochthonous and the source may be pisolite iron gravels, which form a pavement on the surface of the upper terrace. The flaked stone artefacts show no evidence of rounding, which would imply that they had been washed into the site. It is believed that the artefacts were deposited at the rockshelter and their provenance has not been significantly affected by the low-energy floodwaters. However, the layers with rounded pebbles indicate that some of the flood events had slightly higher energy and were able to transport larger particles, and it is possible that small artefacts may have been moved slightly during these slightly higher energy flood events. A high density of roots extended throughout the entire deposit. A minor amount of insect bioturbation (white ant) was identified, and there were occasional mud wasp brood chambers in the deposit.

No combustion features were identified during the excavation of HD07-3A-03, but the excavation team encountered a number of diffuse ash lens. It is presumed that these lenses may have been small campfires, but they have been disturbed by subsequent occupation (human or animal), taphonomic processes (*e.g.*, roots), or floodwaters. The largest ash lens was observed in Unit 1, Layer 5 (Quads C and D), where it measured over 90cm wide and over 46cm long. Because the ash lens extended into an unexcavated area, its full extent could not be determined. In total, 483 artefacts were recovered from this arbitrary excavation layer alone, including numerous heat-affected artefacts. In the upper 10cm of the deposit, the sediment exhibited a mottled ashy appearance and there was abundant charcoal, but features could not be defined.

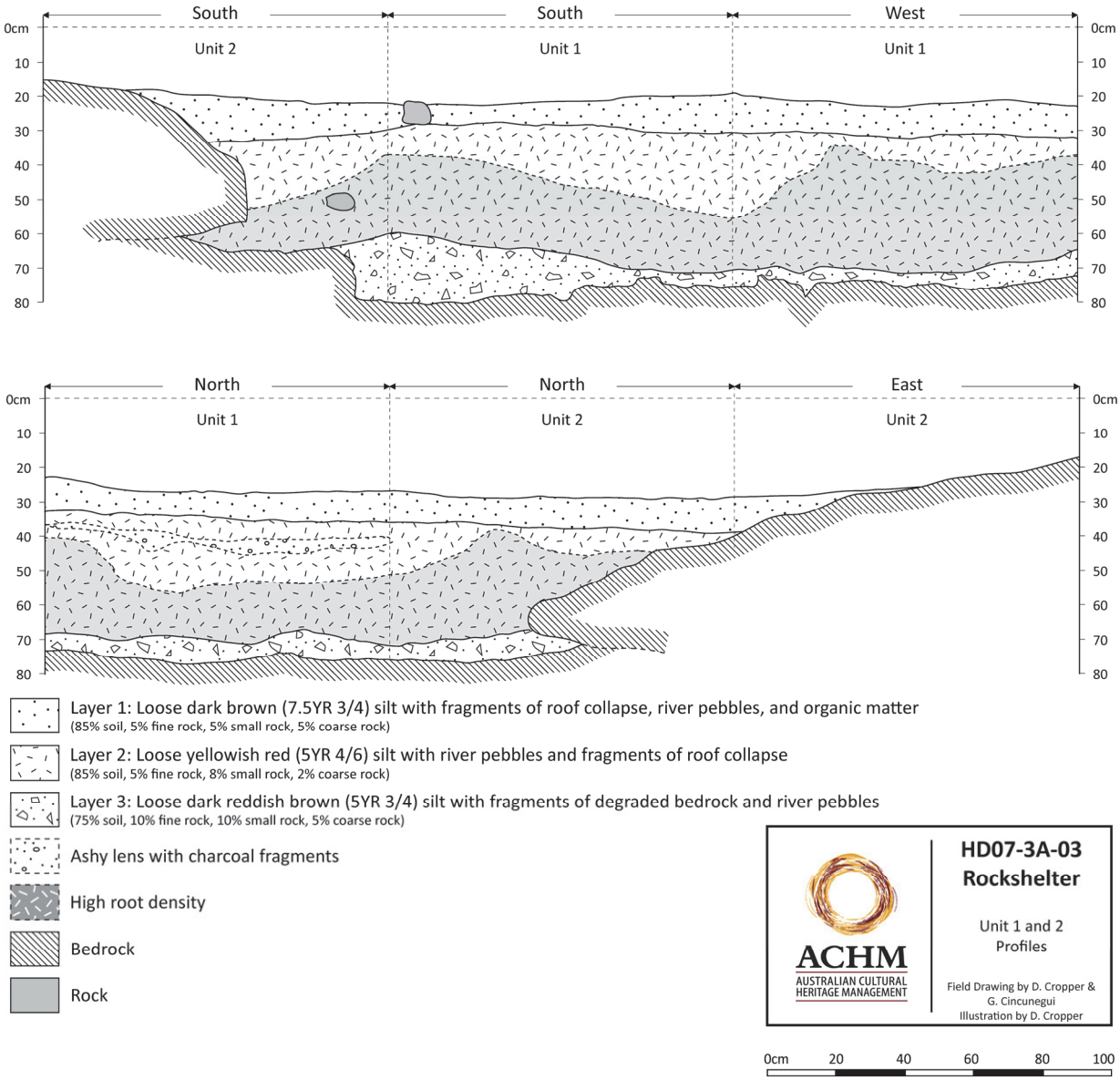

Figure 10-6 Unit 1 and Unit 2 profiles, HD07-3A-03 rockshelter

Stratigraphic Layer 3 - SL3 was a thin layer of dark reddish brown silty sediment with a high proportion of degraded bedrock (75% soil, 10% fine rock, 10% small rock, and 5% coarse rock). The layer was 5 to 8cm thick, with the exception of the south side of Unit 1 and Unit 2, where it was a much more developed layer. Very small rounded pebbles were also present in the deposit, indicating that fluvial deposition continued to be the primary mode of sedimentation. The deposit was slightly darker (5YR 4/3) than the overlying stratigraphic layer, but the colour change was minimal. Fine roots extend through the layer and were concentrated along the bedrock. Many of the roots were growing in the cracks in the bedrock, suggesting that roots played a considerable role in the breakdown of the basal bedrock. Slightly more moisture in the sediment was observed with depth. Occasional mud wasp brood chambers were noted throughout the stratigraphic layer.

Stratigraphic Layer 2 - SL2 was differentiated from the underlying SL3 on the basis of a colour change and the lower proportion of rock (85% soil, 5% fine rock, 8% small rock, and 2% coarse rock). The loam component, which comprises most of the deposit, was slightly lighter than in SL3, possibly due to the lower degree of weathered bedrock. Some rounded pebbles were identified in the layer between 45 and 60cmbd. The lower portion of the layer had an extremely high density of fine roots, which formed a matted layer. Larger roots, up to two centimetres in diameter, were also occasionally encountered. Occasional mud wasp brood chambers were noted throughout the layer, and there were occasional flecks of charcoal and some larger charcoal pieces. The excavators noted a large ashy lens (possibly a hearth that had been disturbed) and a number of other diffuse ashy lenses, but no distinct hearth features could be delineated.

Stratigraphic Layer 1 - SL1 was primarily comprised of very loose, silty loam and has a similar matrix composition to SL2 (85% soil, 5% fine rock, 5% small rock, and 5% coarse rock). The layer included the upper 10cm of the deposit, and it had a much higher organic component in comparison with the other stratigraphic layers. The deposit appears to have been stable for the last several centuries based on the growth of trees on the upper terrace (M. Williams, this volume). Within the deposit at HD07-3A-03 were small rounded pebbles in addition to a small component of exfoliated rock. The sediment colour was brown

rather than the reddish hues in the underlying layers, along with some mottling of grey ashy and reddish sediment. The organic material in the layer was primarily decomposing macropod faecal pellets and leaf litter; however bird feathers, snake skin, insect cocoons, and paperbark were also observed. Kaolinite was observed on one small floating rock.



Figure 10-7 Bedrock exposed in Units 1 and 2 at HD07-3A-03

10.4 RADIOMETRIC DATES

Four charcoal samples were submitted to the Radiocarbon Dating Laboratory at the University of Waikato for AMS radiocarbon dating. While it is ideal to date archaeological sites using charcoal samples from hearth features, this was not possible at HD07-3A-03 because no combustion features were delimited. Therefore, the isolated charcoal samples collected *in situ* remain the best way to provide an associated age estimate for the archaeological remains. The elevation of the samples was recorded in relation to the datum; however, the approximate depth below the surface has also been presented in the table below using the average surface elevations for each excavation unit. The submitted charcoal samples were selected to date the initial, the middle, and the later occupation of the site. Artefacts were recovered from every excavation layer, so samples were simply chosen in the lowest layer (c-22), near the midpoint of the deposit (c-19), and the upper layer (c-02). Additionally, sample c-21 was selected to provide an age estimate for the earliest appearance of backed artefacts at the site.

The radiometric dates indicate that HD07-3A-03 has an occupation sequence that begins approximately 5716±64 cal BP and continues until the recent past. While the results are in good chronological order, one date (177±86 cal BP) does not follow to the linear trend of the three other dates. The most likely explanation is that there were different sedimentation rates over time, but it is also possible that there has been some disturbance to the context of the charcoal during use of the rockshelter by animals (particularly macropods) or humans.

The non-linear trend of the radiocarbon results may indicate that the sedimentation rates at the site were not consistent over time. There was relatively slow and steady sediment accumulation from the beginning of site use until 603±32 cal BP. At some point between 603±32 cal BP and 177±86 cal BP, sedimentation increased dramatically. The jump in sedimentation rates suggests that there was either a single large flood event that deposited a significant quantity of sediment or that there were repeated flood events that quickly built up the deposit over this period. The latter theory seems more plausible, as the energy of a large flood evens may have too great and could have caused erosion, and no small rounded pebbles were identified in these layers. The change in sedimentation rates is the best explanation for the non-linear relationship between the age of the charcoal samples and their depth. If the sedimentation rates continued at the same rate prior to 603±32 cal BP, it is estimated that the surface of the excavation unit would have been at least ten centimetres lower than its actual recorded depth.

The timing of the appearance of backed artefacts in the Hamersley Range is a prominent research question. To provide further data for this research, a charcoal sample selected immediately below the lowermost backed artefact at the site was selected. A symmetrical backed artefact (triangle) and a backed artefact fragment were recovered from U1-L08 (60-65cmbd; Quad A). The charcoal sample was recovered *in situ* from Quad A of the same layer, and it provides a good estimate of the first use of backing at this site at approximately 3241±52 cal BP. Earlier evidence of backing has been established for PAD 3, where backed artefacts were found in good association with a hearth dating to 4686±78 cal BP (Law and Cropper 2011: 173). Backed artefacts were also found below this hearth, suggesting even earlier use (Law and Cropper 2011: 173).

Table 10-1 AMS radiocarbon results, HD07-3A-03 rockshelter

Lab Code	Sample No.	Material	Context	AU	Depth (cmbd)	Depth (cmbs)	$\delta^{13}C$	^{14}C Age (BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
Wk-26733	c-02	Charcoal	U1-L01-QA	1	23.5	~2	-23.3±0.2	165±30	289 to -3	177±86
Wk-26734	c-19	Charcoal	U2-L05-QC	3	46.5	~18	-22.9±0.2	601±30	665 to 542	603±32
Wk-32635	c-21	Charcoal	U1-L08-QA	4	61.5	~40	-25.2±0.2	3023±25	3337 to 3159	3241±52
Wk-26735	c-22	Charcoal	U1-L11-QA	5	76.5	~55	-24.7±0.2	4994±30	5887 to 5645	5716±64

10.5 ARTEFACT ANALYSIS

An assemblage of 5180 artefacts was recovered from HD07-3A-03, including 5123 artefacts from the excavation and 57 surface artefacts that were distributed across the shelter floor. Each artefact has been subject to a full technological analysis by Ben Anderson and Anne-Marie Beavis using the methodology outlined in Chapter 4. The assemblage was deposited at the site over a considerable period of time, ranging from the mid-Holocene to the recent past. For this reason, the assemblage has not been treated as a single entity, but has been divided into discrete analytical units so that changes over time can be explored.

Division of Analytical Units

Because of the high number of flaked stone artefacts at HD07-3A-03, the excavated assemblage was divided into five analytical units based on the arbitrary excavation layers. The arbitrary excavation layers also generally conform to the stratigraphy at the site. The radiocarbon dates provide chronological context for the analytical units and their associated artefacts. A linear trend between the age and depth of the lower three radiometric dates, age estimates for the analytical units are offered with the caveat that they should be treated cautiously and not considered definitive. The artefacts in AU5 were deposited during the mid-Holocene and those in AU4 represent repeated occupations at the site during the transition between the mid-Holocene and the late Holocene. Artefacts within AU3, AU2, and AU1 represent the late Holocene occupation, which is also the most intense period of site activity.

Analytical Unit 5 – AU5 is the lowermost occupational phase at the site, including all artefacts recovered from bedrock (maximum depth of 80cmbd) to 65cmbd. While all of the other analytical units are comprised of two excavation layers, AU5 includes excavation Layers 9, 10, and 11. A radiocarbon date of 5716±64 cal BP recovered from 76.5cmbd provides a good estimate for the initial occupation of the site. One *in situ* artefact was recovered below this date at a depth of 79cmbd; hence, it is possible that the occupation may slightly predate 5716±64 cal BP. Based on the age-depth trend of samples c-19, c-21, and c-22, it is estimated that AU5 terminates around the transition from the middle to late Holocene (*ca.* 3800 cal BP).

Analytical Unit 4 – AU4 is comprised of arbitrary excavation Layers 8 and 7, which have depths between 65 and 55cmbd. Charcoal sample c-21 provides a date for the midpoint of this analytical unit (at a depth of 61.5cmbd), indicating that the associated artefacts are approximately 3241 years old. The age-depth trend of samples c-19, c-21, and c-22 suggests that AU4 spans the period from approximately 3800 to 2000 years ago.

Analytical Unit 3 – AU3 includes all artefacts recovered between 55 and 45cmbd and is equivalent to arbitrary excavation Layers 5 and 6. The age-depth trend of samples c-19, c-21, and c-22 suggests that this phase of occupation began around 2000 years ago. A date of 603±32 cal BP was determined for a charcoal sample recovered just below the top of this analytical unit. It is estimated that this analytical unit represents approximately 1400 years of site use.

Analytical Unit 2 – AU2 includes arbitrary excavation Layers 4 and 3, which lie between 45 and 35cmbd. There are no radiocarbon dates for this analytical unit, but it is reasonable to assume that AU2 represents several centuries of occupation, beginning slightly prior to 603±32 cal BP. As discussed previously, there appears to have been a period of increased sedimentation shortly after 603±32 cal BP

Analytical Unit 1 – AU1 extends from 35cmbd to the surface of the excavation unit, encompassing arbitrary excavation Layers 1 and 2. A charcoal sample recovered from just below the surface yielded a date of 177±86 cal BP, suggesting that the most recent occupation of the site occurred within the last two centuries.

Artefact Distribution

The density of artefacts at HD07-3A-03 is unparalleled at any other site investigated at Hope Downs 1. In total, 5180 artefacts were recovered from the site, including 5123 artefacts from the two excavation units. An additional 57 artefacts were collected from the surface of the rockshelter. The depth of accumulated sediment in Units 1 and 2 was slightly less than 60cm, and if the excavation units were perfectly square, the volume of excavated sediment would be equal to 1.2 cubic metres. Using this estimated volume of sediment, the average artefact density would be an estimated artefact density of 4269 artefacts per cubic metre of sediment. However, true artefact density is much higher because the large bedrock ledge in Unit 2 significantly reduces the volume of sediment excavated.

Table 10-2 presents the distribution of artefacts at HD07-3A-03 by analytical unit. The HD07-3A-03 assemblage is comprised of 86.02% diagnostic artefacts, while non-diagnostic artefacts are relatively rare. In comparison to other Hope Downs 1 rockshelter assemblages, the frequency of non-diagnostic artefacts is low. The assemblage is primarily comprised of flakes, which account for over 93% of the diagnostic artefacts. Flaked pieces and heat shatter are only a small component of the assemblage, and the flaked pieces may be indicative of on-site reduction. While no definite hearth features were identified at the site, the presence of ash lenses and heat shattered artefacts suggests that the past occupants had built campfires at the site.

Based on the density of artefacts, the site appears to have been more regularly and intensely used in the recent past (Figure 10-8; Table 10-2). AU5 and AU4 have fairly low numbers of artefacts in comparison to the overlying analytical units. However, the artefact density during the lowest period of site use at HD07-3A-03 is greater than most other sites. For example, only 585 artefacts were recovered from PAD 3 (Law and Cropper 2011: 186). In AU3, the proportion of artefacts increases considerably; however, it is only in arbitrary Layer 5 that artefact numbers increase considerably. This pattern continues through AU2 and AU1, with the greatest number of artefacts recovered from the uppermost arbitrary excavation layer. The period of most intense site use occurred in AU1, and radiocarbon dates suggest that this phase of occupation ended less than two centuries ago. Considering that AU3 through AU1 represent less than a millennia of site use, the artefact density is particularly high.

Raw Materials

A broad range of raw material types is represented in the assemblage (for specific descriptions of each raw material type see Chapter 4). The distribution of raw material types throughout the assemblage is presented in Table 10-3 and Table 10-4. The two tables present the data in different ways, by count (Table 10-3) and by weight (Table 10-4). This discussion focuses on the number of artefacts within each raw material type, rather than their combined weight, as there are significant differences in the weight of each type. The iron-rich raw

materials, such as BIF and martite-goethite, are very heavy, while other raw materials are relatively light (*e.g.*, chert, quartz, and goethitised shale). Because of the different weights, similar sized artefacts produced on chert and martite-goethite would have significantly different weights. Because this discrepancy exists, patterns of raw material use are discussed in terms of their abundance. The data for the mass of each raw material type has been included, as it could be useful for inter-site or regional comparisons.

Over the course of the occupation at HD07-3A-03, there are observable patterns in the raw materials that were selected for artefact manufacture. In the earliest phases of site use (AU5 and AU4), there were moderate proportions of chert use (39.08% to 48.39%), and most other artefacts were produced from BIF and shale. In AU5, a number of quartz artefacts were also produced, but the use of this raw material declined in AU4. Other raw material types were seldom utilised throughout AU5 and AU4. In AU3, the raw material preferences changed and chert use increased considerably. There was a concomitant decline in the manufacture of BIF artefacts, while the use of shale remained relatively constant. The data from AU2 shows strikingly similar raw material frequencies to AU3. The pattern is repeated with AU1, albeit with a slightly lower proportion of chert artefacts and equivalent increase of shale artefacts. The artefacts collected from the surface of the rockshelter show a different trend to that observed for the excavated assemblage from AU1. The small sample size and the different recovery methods may mean that the data for the surface artefacts is not directly comparable with that of the excavated assemblage.

Chert is a fine-grained material and it is easy to understand why knappers would prefer this raw material. However, the coarser grained raw material types have much greater availability and could have easily been procured around the site. A goethitised shale quarry (HS-A3) is located 160m from the rockshelter, yet only 22 goethitised shale artefacts were recovered from HD07-3A-03. While goethitised shale has a similar appearance to chert, it is brittle and often has flaws that would have made knapping more difficult. The data suggests that the knappers at HD07-3A-03 preferred chert, particularly in the later stage of the occupation, even though it was less abundant and therefore a more 'expensive' resource.

Table 10-2 Artefact distribution by analytical unit, HD07-3A-03 rockshelter

Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diagnostic Artefacts	*57*	*100*	*1861*	*84.40*	*1405*	*88.42*	*674*	*84.57*	*210*	*84.68*	*249*	*87.68*	*4456*	*86.02*
Core	4	7.02	10	0.45	8	0.50	3	0.38	6	2.42	8	2.82	39	0.75
Flake	34	59.65	1719	77.96	1321	83.13	645	80.93	197	79.44	237	83.45	4153	80.17
Retouched / Utilised Flake	16	28.07	131	5.94	76	4.78	26	3.26	6	2.42	4	1.41	259	5.00
Grindstone	3	5.26	1	0.05	0	0.00	0	0.00	1	0.40	0	0.00	5	0.10
Non-Diagnostic Artefacts	*0*	*0.00*	*344*	*15.60*	*184*	*11.58*	*123*	*15.43*	*38*	*15.32*	*35*	*12.32*	*724*	*13.98*
Flaked Piece	0	0.00	239	10.84	100	6.29	54	6.78	20	8.06	24	8.45	437	8.44
Heat Shatter & Potlid	0	0.00	105	4.76	84	5.29	69	8.66	18	7.26	10	3.52	286	5.52
Manuport	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.35	1	0.02
Total	**57**	**100**	**2205**	**100**	**1589**	**100**	**797**	**100**	**248**	**100**	**284**	**100**	**5180**	**100**

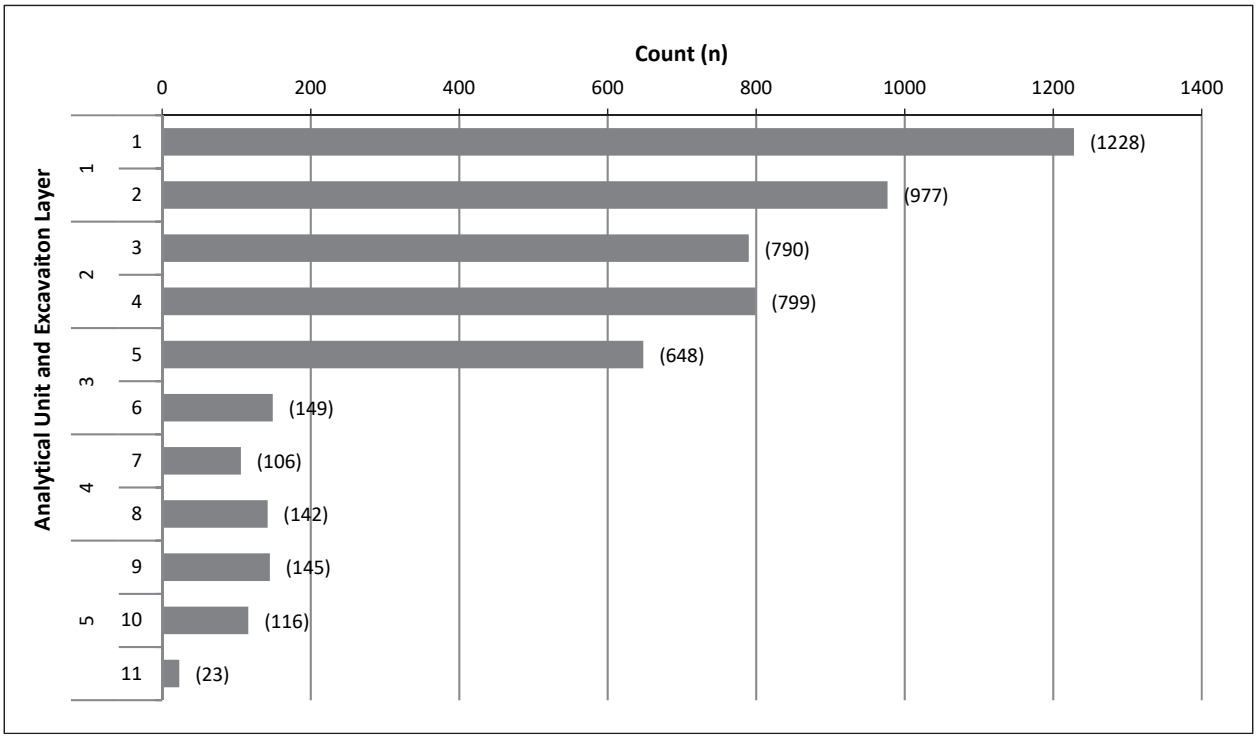

Figure 10-8 Distribution of artefacts by analytical unit and arbitrary excavation layer for HD07-3A-03 rockshelter

Table 10-3 Distribution of raw material types by count and analytical unit, HD07-3A-03 rockshelter

Raw Material Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
BIF	*14*	*24.56*	*198*	*8.98*	*130*	*8.18*	*67*	*8.41*	*64*	*25.81*	*62*	*21.83*	*535*	*10.33*
Homogenous BIF	14	24.56	198	8.98	128	8.06	65	8.16	64	25.81	53	18.66	522	10.08
Laminate BIF	0	0.00	0	0.00	2	0.13	2	0.25	0	0.00	9	3.17	13	0.25
Chert	*23*	*40.35*	*1339*	*60.73*	*1110*	*69.86*	*566*	*71.02*	*120*	*48.39*	*111*	*39.08*	*3269*	*63.11*
Creamy Grey	0	0.00	37	1.68	53	3.34	31	3.89	5	2.02	5	1.76	131	2.53
Dark Grey	1	1.75	258	11.70	252	15.86	129	16.19	24	9.68	39	13.73	703	13.57
Dashed Black	0	0.00	3	0.14	5	0.31	0	0.00	1	0.40	0	0.00	9	0.17
Greyish Brown	2	3.51	79	3.58	89	5.60	54	6.78	6	2.42	4	1.41	234	4.52
Light Green-Grey	3	5.26	71	3.22	77	4.85	28	3.51	6	2.42	3	1.06	188	3.63
Moss Agate	0	0.00	1	0.05	3	0.19	0	0.00	0	0.00	0	0.00	4	0.08
Olive	1	1.75	168	7.62	82	5.16	59	7.40	15	6.05	9	3.17	334	6.45
Pink and Green	2	3.51	12	0.54	9	0.57	4	0.50	0	0.00	1	0.35	28	0.54
Red	6	10.53	415	18.82	246	15.48	114	14.30	21	8.47	18	6.34	820	15.83
Speckled Black	0	0.00	34	1.54	36	2.27	20	2.51	7	2.82	0	0.00	97	1.87
Sugar	1	1.75	29	1.32	30	1.89	13	1.63	5	2.02	8	2.82	86	1.66
Thylo	0	0.00	5	0.23	1	0.06	0	0.00	0	0.00	0	0.00	6	0.12
Trans. Dark Grey	2	3.51	48	2.18	47	2.96	18	2.26	8	3.23	5	1.76	128	2.47
Trans. Green	2	3.51	99	4.49	127	7.99	73	9.16	16	6.45	14	4.93	331	6.39
White & Trans.	3	5.26	16	0.73	5	0.31	4	0.50	0	0.00	1	0.35	29	0.56
Yellow Trans.	0	0.00	64	2.90	48	3.02	19	2.38	6	2.42	4	1.41	141	2.72
Goethitised Shale	*1*	*1.75*	*2*	*0.09*	*1*	*0.06*	*8*	*1.00*	*6*	*2.42*	*4*	*1.41*	*22*	*0.42*
Martite-Goethite	*0*	*0.00*	*6*	*0.27*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*6*	*0.12*
Quartz	*5*	*8.77*	*150*	*6.80*	*80*	*5.03*	*28*	*3.51*	*15*	*6.05*	*47*	*16.55*	*325*	*6.27*
Quartz	5	8.77	138	6.26	63	3.96	22	2.76	15	6.05	47	16.55	290	5.60
Quartz Crystal	0	0.00	12	0.54	17	1.07	6	0.75	0	0.00	0	0.00	35	0.68
Shale	*13*	*22.81*	*481*	*21.81*	*244*	*15.36*	*126*	*15.81*	*41*	*16.53*	*58*	*20.42*	*963*	*18.59*
Brown Shale	13	22.81	468	21.22	232	14.60	123	15.43	39	15.73	58	20.42	933	18.01
Green Shale	0	0.00	13	0.59	12	0.76	3	0.38	2	0.81	0	0.00	30	0.58
Indeterminate	*1*	*1.75*	*2*	*0.09*	*4*	*0.25*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*7*	*0.14*
Dragonsblood	0	0.00	0	0.00	4	0.25	0	0.00	0	0.00	0	0.00	4	0.08
Indeterminate	1	1.75	2	0.09	0	0.00	0	0.00	0	0.00	0	0.00	3	0.06
Vitreous Goethite	*0*	*0.00*	*27*	*1.22*	*20*	*1.26*	*2*	*0.25*	*2*	*0.81*	*2*	*0.70*	*53*	*1.02*
Total	**57**	**100**	**2205**	**100**	**1589**	**100**	**797**	**100**	**248**	**100**	**284**	**100**	**5180**	**100**

There are 16 varieties of chert present in the assemblage, and each type is differentiated on the basis of unique colours, patterns, or textures. Red chert and dark grey chert are the two most common varieties, and this is consistent throughout the occupation of the site. The high proportion of red chert (25.11% of the chert artefacts) is surprising, as it is less common in most other excavated assemblages from Hope Downs 1. Red chert occurs naturally, but other chert varieties can also become reddened through heating. Thus, it is possible that some of the red chert artefacts in the assemblage are other varieties that have been heat altered. Olive chert with darker laminae accounts for over 10% of the chert artefacts, and this variety tends to be very high-quality with few flaws and a fine-grained texture. Use of this material is slightly lower in AU5 and AU2. Translucent green chert also accounts for over a tenth of the chert artefacts, but this variety is seldom represented amongst other assemblages. The proportion of translucent green chert shows a slight decrease in its use during AU1 (7.4% of chert artefacts), while it ranges between 11.47% and 13.33% of the chert artefacts in the underlying analytical units. Greyish brown chert, which is a fairly common chert variety in most large assemblages, only accounts for 7.17% of the chert artefacts at HD07-3A-03.

Quartz is a fine-grained raw material, but unlike chert it often has flaws and is more difficult to knap. Quartz use at HD07-3A-03 was at its greatest during the initial occupation of the site (AU5). In this phase of site occupation, the 47 quartz artefacts represent 16.55% of the assemblage. In subsequent occupations, quartz was used much less frequently for artefact manufacture. Quartz cobbles continue to be abundant in the ephemeral creek near the site, and this was a probable source of the raw material.

While the raw materials at HD07-3A-03 are dominated by chert, coarser-grained raw materials were an important component of the raw material procurement strategies. Brown shale was consistently procured for artefact manufacture at HD07-3A-03. It was most commonly utilised in AU5 and AU1, but the knappers also made considerable use of this material in AU4 through AU2. Brown shale is slightly coarser-grained than chert, but most specimens exhibit excellent knapping potential. Artefacts were only occasionally produced from green shale, which tends to be coarser-grained and has more flaws than brown shale. BIF was used for artefact manufacture throughout the occupation, but it was much more commonly utilised during the earlier phases of site use. In AU3, there was a dramatic decline in BIF use at the site. Even though BIF was locally abundant, the knappers deliberately chose to use a less widely available raw material, chert.

The data indicates that in the early phases of site occupation, locally abundant raw materials were moderately used. In the more recent occupation of the site, the knappers appear to have preferred fine grained materials, which would have been more difficult to procure, as they are less abundant throughout the region. BIF, shale, and quartz account for over half of the artefacts in AU5. In AU4, there was a slight decline in the use of quartz and shale, and an increase in the proportion of chert. AU3 shows the first sharp rise in the frequency of chert, with 71.02% of the artefacts having been produced from a variety of chert. Chert use continued to be predominant in AU2 and AU2, and it was primarily supplemented by brown shale. Many cores that retain cortical surfaces exhibit rolled and smoothed surfaces, typical of river cobbles. This suggests that the ephemeral creek near the site was a likely source of raw materials. At least one artefact (Artefact 1597;Figure 10-9: c)

appears to be an older artefact that was collected and re-used as a core. The red chert core has a thick patinated rind that has a lighter colour than the freshly knapped surface.

The patterns of raw material use for the main types of diagnostic artefacts: cores, flakes, and retouched (or utilised) artefacts are presented in Table 10-5. The data suggests that chert cores are under-represented at the site. Despite the high frequency of chert flakes, only seven chert cores were recovered from HD07-3A-03. The 32 remaining cores were produced from shale, quartz, and BIF, which are all materials that are easily obtained throughout the region. The low incidence of chert cores suggests that as people moved from site to site, they took their chert cores with them, but left behind cores of other raw materials knowing that they could be easily replaced. This interpretation suggests that the knappers were very familiar with the available resources in the region.

The raw material trends for flakes show the same general patterns as the assemblage as a whole. As flakes are the largest artefact category in the assemblage, this is expected. The retouched and utilised artefacts show quite interesting patterns of raw material use through time. Unfortunately, there are only small numbers of retouched and utilised artefacts in AU5 and AU4. Nevertheless, no retouched or utilised chert artefacts were identified in AU5. The pattern of raw material use amongst the six retouched and utilised artefacts in AU4 is nearly identical to that of flakes. In AU3, chert and shale is slightly over-represented amongst the retouched and utilised flakes, while BIF flakes are less commonly selected for secondary modification. The retouched and utilised flakes in AU2 show a slightly different pattern, with a slight over-representation of BIF specimens and a lower proportion of chert artefacts (as compared to the assemblage average). There are slightly elevated proportions of retouched and utilised shale artefacts in AU1.

Thermal alteration is evidenced by indicators such as reddened or glossed appearance, crazing, and potlidding. Over a third of the artefacts exhibit signs of thermal alteration (n=1939, 37.43%). Thermal alteration is least prevalent in AU5 (20.07%) and AU4 (28.23%), while there are consistent proportions in AU3 (38.90%) through AU1 (39.91%). Throughout the entire sequence, chert is the most common raw material type to exhibit evidence of heating, and shale is a distant second. Evidence of heating is quite easy to identify on these raw materials in comparison with BIF. The thermal alteration of the artefacts in the HD07-3A-03 assemblage does not appear to be consistent with deliberate heat treatment of raw materials to improve their knapping qualities. Instead, many of the artefacts show signs of being severely burned, with 69.57% of the heat-affected artefacts exhibiting either crazing or potlidding. Specimens with reddening (and gloss in some cases) account for 29.40% of the heated artefacts. The high incidence of crazing and potlidding indicates that the vast proportion of thermally altered artefacts were burned, rather than heated in a controlled manner. Of the 40 cores, 17 specimens show signs of heating. None of the heated cores exhibited double patinas (or glossy negative scars), which are produced when a core is heated prior to the removal of a flake. This is further evidence against the deliberate use of thermal alteration by the knappers at HD07-3A-03. It is probable that most artefacts were inadvertently burned in campfires at the site. As vegetation extended up to the dripline of the shelter, it is also possible that bushfires may have caused the thermal alteration of some artefacts.

Table 10-4 Distribution of raw material types by mass and analytical unit, HD07-3A-03 rockshelter

Raw Material Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%	sum (g)	%
BIF	*852.71*	*78.70*	*607.94*	*41.97*	*882.15*	*60.07*	*548.42*	*56.65*	*827.74*	*87.06*	*933.17*	*75.76*	*4652.13*	*65.06*
Homogenous BIF	852.71	78.70	607.94	41.97	787.27	53.61	539.34	55.71	827.74	87.06	919.97	74.69	4534.97	63.42
Laminate BIF	0	0.00	0	0.00	94.88	6.46	9.08	0.94	0	0.00	13.2	1.07	117.16	1.64
Chert	*131.13*	*12.10*	*396.52*	*27.38*	*398.36*	*27.13*	*300.51*	*31.04*	*36.94*	*3.89*	*36.41*	*2.96*	*1299.87*	*18.18*
Creamy Grey	0	0.00	9.55	0.66	31.24	2.13	27.01	2.79	0.25	0.03	0.24	0.02	68.29	0.95
Dark Grey	14.2	1.31	62.67	4.33	76.24	5.19	68.52	7.08	5.59	0.59	10.04	0.82	237.26	3.32
Dashed Black	0	0.00	1.75	0.12	2.06	0.14	0	0.00	0.07	0.01	0	0.00	3.88	0.05
Greyish Brown	8.92	0.82	60.61	4.18	42.48	2.89	40.52	4.19	0.87	0.09	0.59	0.05	153.99	2.15
Light Green-Grey	11.27	1.04	10.29	0.71	27.67	1.88	22.18	2.29	4.71	0.50	0.54	0.04	76.66	1.07
Moss Agate	0	0.00	0.13	0.01	1.14	0.08	0	0.00	0	0.00	0	0.00	1.27	0.02
Olive	1.76	0.16	35.84	2.47	40.39	2.75	29.66	3.06	5.16	0.54	5.11	0.41	117.92	1.65
Pink and Green	8.6	0.79	14.3	0.99	4	0.27	1.54	0.16	0	0.00	0.02	0.00	28.46	0.40
Red	31.11	2.87	111.16	7.67	64.64	4.40	40.78	4.21	1.56	0.16	2.68	0.22	251.93	3.52
Speckled Black	0	0.00	20.37	1.41	13.31	0.91	20.86	2.15	12.01	1.26	0	0.00	66.55	0.93
Sugar	3.46	0.32	8.26	0.57	3.44	0.23	2.63	0.27	0.8	0.08	5.68	0.46	24.27	0.34
Thylo	0	0.00	0.8	0.06	0.1	0.01	0	0.00	0	0.00	0	0.00	0.9	0.01
Trans. Dark Grey	22.32	2.06	16.27	1.12	2.18	0.15	2.2	0.23	0.37	0.04	0.36	0.03	43.7	0.61
Trans. Green	10.73	0.99	27.1	1.87	67.7	4.61	39.74	4.11	4.94	0.52	10.72	0.87	160.93	2.25
White & Trans.	18.76	1.73	5.75	0.40	4.71	0.32	1.1	0.11	0	0.00	0.03	0.00	30.35	0.42
Yellow Trans.	0	0.00	11.67	0.81	17.06	1.16	3.77	0.39	0.61	0.06	0.4	0.03	33.51	0.47
Goethitised Shale	*6.11*	*0.56*	*4.33*	*0.30*	*0.34*	*0.02*	*15.43*	*1.59*	*0.54*	*0.06*	*15.82*	*1.28*	*42.57*	*0.60*
Martite-Goethite	*0*	*0.00*	*7.64*	*0.53*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*7.64*	*0.11*
Quartz	*25.4*	*2.34*	*57.1*	*3.94*	*16.6*	*1.13*	*5.53*	*0.57*	*45.12*	*4.75*	*225.8*	*18.33*	*375.55*	*5.25*
Quartz	25.4	2.34	53.4	3.69	15.5	1.06	5.29	0.55	45.12	4.75	225.8	18.33	370.51	5.18
Quartz Crystal	0	0.00	3.7	0.26	1.1	0.07	0.24	0.02	0	0.00	0	0.00	5.04	0.07
Shale	*66*	*6.09*	*313.15*	*21.62*	*147.18*	*10.02*	*97.2*	*10.04*	*40.02*	*4.21*	*17.23*	*1.40*	*680.786*	*9.52*
Brown Shale	66	6.09	306.71	21.18	136.67	9.31	96.38	9.96	34.14	3.59	17.23	1.40	657.136	9.19
Green Shale	0	0.00	6.44	0.44	10.51	0.72	0.82	0.08	5.88	0.62	0	0.00	23.65	0.33
Indeterminate	*2.15*	*0.20*	*0.42*	*0.03*	*0.35*	*0.02*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2.92*	*0.04*
Dragonsblood	0	0.00	0	0.00	0.35	0.02	0	0.00	0	0.00	0	0.00	0.35	0.00
Indeterminate	2.15	0.20	0.42	0.03	0	0.00	0	0.00	0	0.00	0	0.00	2.57	0.04
Vitreous Goethite	*0*	*0.00*	*61.33*	*4.23*	*23.57*	*1.60*	*0.95*	*0.10*	*0.42*	*0.04*	*3.3*	*0.27*	*89.57*	*1.25*
Total	**1083.5**	**100**	**1448.4**	**100**	**1468.5**	**100**	**968.04**	**100**	**950.78**	**100**	**1231.7**	**100**	**7151.036**	**100**

Table 10-5 Raw material trends for cores, flakes, and retouched and utilised flakes, HD07-3A-03 rockshelter

Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
Raw Material Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cores	*4*	*100*	*10*	*100*	*8*	*100*	*3*	*100*	*6*	*100*	*8*	*100*	*39*	*100*
BIF	0	0.00	0	0.00	3	37.50	1	33.33	1	16.67	4	50.00	9	23.08
Chert	3	75.00	0	0.00	3	37.50	1	33.33	0	0.00	0	0.00	7	17.95
Quartz	1	25.00	2	20.00	0	0.00	0	0.00	4	66.67	4	50.00	11	28.21
Shale	0	0.00	8	80.00	2	25.00	1	33.33	1	16.67	0	0.00	12	30.77
Flakes	*34*	*100*	*1719*	*100*	*1321*	*100*	*645*	*100*	*197*	*100*	*237*	*100*	*4153*	*100*
BIF	9	26.47	153	8.90	100	7.57	54	8.37	57	28.93	55	23.21	428	10.31
Chert	11	32.35	1064	61.90	930	70.40	455	70.54	93	47.21	91	38.40	2644	63.66
Goethitised Shale	1	2.94	2	0.12	1	0.08	7	1.09	6	3.05	2	0.84	19	0.46
Martite-Goethite	0	0.00	5	0.29	0	0.00	0	0.00	0	0.00	0	0.00	5	0.12
Quartz	4	11.76	122	7.10	71	5.37	26	4.03	10	5.08	36	15.19	269	6.48
Shale	8	23.53	356	20.71	197	14.91	101	15.66	30	15.23	51	21.52	743	17.89
Vitreous Goethite	0	0.00	15	0.87	19	1.44	2	0.31	1	0.51	2	0.84	39	0.94
Indeterminate	1	2.94	2	0.12	3	0.23	0	0.00	0	0.00	0	0.00	6	0.14
Retouched/Utilised Flakes	*16*	*100*	*131*	*100*	*76*	*100*	*26*	*100*	*6*	*100*	*4*	*100*	*259*	*100*
BIF	2	12.50	11	8.40	11	14.47	1	3.85	2	33.33	2	50.00	29	11.20
Chert	9	56.25	76	58.02	48	63.16	19	73.08	3	50.00	0	0.00	155	59.85
Goethitised Shale	0	0.00	0	0.00	0	0.00	1	3.85	0	0.00	2	50.00	3	1.16
Quartz	0	0.00	1	0.76	0	0.00	0	0.00	0	0.00	0	0.00	1	0.39
Shale	5	31.25	38	29.01	16	21.05	5	19.23	1	16.67	0	0.00	65	25.10
Vitreous Goethite	0	0.00	5	3.82	1	1.32	0	0.00	0	0.00	0	0.00	6	2.32
Total	**54**	**-**	**1860**	**-**	**1405**	**-**	**674**	**-**	**210**	**-**	**249**	**-**	**4452**	**-**

Cores

In total, 39 cores were recovered from HD07-3A-03, including four specimens from the surface of the rockshelter. Cores were recovered in each of the five analytical units of HD07-3A-03. Based on the high proportion of chert flakes at the site, it was anticipated that chert cores would be abundant. As is discussed above, chert cores are under-represented in the assemblage, and the cores are predominantly brown shale, quartz, and BIF. This suggests that many of the chert cores were taken from the site. This theory is supported by the core to flake ratio, where there are between 39 and 65 flakes per core (using complete flakes and the MNF index). Taking this into account, it is possible that the cores discarded at the site do not represent the full range of reduction methods employed by the knappers. While all of the Hope Downs 1 lithic analyses incorporate the technological information from cores and flakes, this assemblage highlights the necessity for considering the data from both sources.

Qualitative Core Attributes

Rotated cores are predominant in the assemblage, with six cores identified having only unidirectional negative scars (Table 10-6: A). As with all of the Hope Downs 1 assemblages, core rotation appears to have been used as a method of extending the use-life of a core. There is almost no evidence to suggest that knappers routinely prepared cores prior to flake production. Similarly, cores do not appear to have been maintained throughout their reduction. When raw material is widely available, as it was at HD07-3A-03, there was no need to try and conserve materials and ensure the longevity of a core.

The vast majority of the cores throughout the occupation have plain platforms (Table 10-6: B), and this is due to the high number of rotated cores in the assemblage. In the case of plain platforms, the knapper makes use of a previously knapped surface or a naturally exfoliated surface for the striking platform. Only five of the complete cores exhibit cortical striking platforms. The low incidence of cortical striking platforms may indicate that the knappers preferred plain to cortical surfaces. Cortex can often be uneven, which may make it more difficult to cleanly strike the core. If a core has chalky cortex, this may absorb some of the force of the blow. The two cores with 'other' platforms simply exhibit both cortical and plain platforms on the same specimen.

Cores can also be identified based on the morphology of their negative flake scars (Table 10-6: C). Most of the cores showed only flake scars, but seven specimens had a combination of flake and blade scars. The mixed flake and blade cores were produced from a variety of different raw material types. The range of materials does not suggest that one material type was targeted for blade production.

The number of scars on a core can provide an indicator of how intensely it was reduced (Table 10-6: D); however, this is a very broad measure of reduction intensity as larger raw materials will be able to produce more flakes. The number of scars per core ranges from one to 19, with an average of 7.8 flakes per core. On average, shale cores have the greatest number of negative scars and quartz cores appear to have been the least reduced. The chert cores fall into the middle of the range, but again, many of the chert cores could have been taken from the site. This attribute can also provide the minimum number of flakes produced by the cores; although, it certainly underestimates the total number of flakes produced by a core as later negative scars can remove the traces of earlier scars. For the complete cores, the total number of negative scars is calculated to be 226. This highlights the incredible gap between the number of flakes in the assemblage and the number of flakes that could have been produced by the complete cores in the assemblage.



Figure 10-9 Cores from HD07-3A-03 rockshelter: a) Artefact 359 from the AU1, b) Artefact 25 from the surface, c) Artefact 1597 from AU2, and d) Artefact 35 from the surface

Of the 30 complete cores in the assemblage, the analysts assessed 22 as being discarded in an exhausted state. In most instances, the exhausted cores had large or numerous step and hinge terminations, which would have made further reduction difficult. Small size, raw material flaws, and heat damage are also cited as possible reasons for core discard. For example, Artefact 25 (Figure 8-14: b) has crushing along the overhang of one platform and a small hinge termination, and these factors added to its diminutive size likely made it difficult to further reduce. Similarly, Artefact 359 (Figure 8-14: a) has severe stepping and hinge terminations along several core faces, as well as at least one crushed platform. This core demonstrates the challenge of reducing a core once it has a problematic termination. Artefact 1597 also shows crushing along the overhang of the primary platform, and perhaps the core became too thin to be manageable. The knapper rotated the core and attempted to knap another surface; however, this overhang also became crushed, probably due to the obtuse angle.

Quantitative Core Attributes

Table 10-8 provides the quantitative data for the complete cores in the assemblage. For all complete cores, the average size is fairly small, measuring 37.17mm long (SD=23.72), 36.49mm wide (SD=22.25), and 21.69mm thick (SD=9.51). The high standard deviation values indicate that there are considerable variations within the data. Within each analytical unit, the cores from the surface and AU1 show the lowest degree of variation, and these were also the smallest cores in the assemblage. With small sample sizes, one anomalous specimen can affect the data.

Table 10-6 Qualitative attributes for cores by analytical unit, HD07-3A-03 rockshelter

A. Core Type*	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Rotated	4	100	9	90.00	7	87.50	3	100	4	66.67	7	87.50	34	87.18
Unidirectional	0	0.00	1	10.00	1	12.50	0	0.00	2	33.33	1	12.50	5	12.82
Total	**4**	**100**	**10**	**100**	**8**	**100**	**3**	**100**	**6**	**100**	**8**	**100**	**40**	**100**
B. Platform Type	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cortex	0	0.00	1	20.00	1	14.29	0	0.00	1	25.00	2	25.00	5	17.24
Other	0	0.00	0	0.00	1	14.29	0	0.00	0	0.00	1	12.50	2	6.90
Plain	2	100	4	80.00	5	71.43	3	100	3	75.00	5	62.50	23	75.86
Total	**2**	**100**	**5**	**100**	**7**	**100**	**3**	**100**	**4**	**100**	**8**	**100**	**29**	**100**
C. Scar Type	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Flake	2	100	4	80.00	4	57.14	1	33.33	3	75.00	8	100	22	75.86
Mixed flake/blade	0	0.00	1	20.00	3	42.86	2	66.67	1	25.00	0	0.00	7	24.14
Total	**2**	**100**	**5**	**100**	**7**	**100**	**3**	**100**	**4**	**100**	**8**	**100**	**29**	**100**
D. Avg. No. Scars	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg	n	avg
BIF	0	0.00	0	0.00	3	7.33	1	14.00	0	0.00	4	8.75	8	8.88
Chert	1	2.00	0	0.00	2	6.50	1	19.00	0	0.00	0	0.00	4	8.50
Quartz	1	3.00	2	4.50	0	0.00	0	0.00	3	4.67	4	3.50	10	4.00
Shale	0	0.00	3	16.00	2	7.00	1	16.00	1	3.00	0	0.00	7	11.57
Total	**2**	**2.50**	**5**	**11.40**	**7**	**7.00**	**3**	**16.33**	**4**	**4.40**	**8**	**6.13**	**29**	**7.79**
E. Reduction Potential	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Exhausted	1	50.00	4	80.00	4	57.14	2	66.67	4	100	7	87.50	22	75.86
Viable	1	50.00	1	20.00	3	42.86	1	33.33	0	0.00	1	12.50	7	24.14
Total	**2**	**100**	**5**	**100**	**7**	**100**	**3**	**100**	**4**	**100**	**8**	**100**	**29**	**100**

* Note: core type is presented for all cores, while all other attributes are presented for complete cores

While there are only 29 complete cores, it is possible to consider changes in core dimensions over time. The data shows that cores recovered from the surface, as well as in AU1 and AU4 are relatively small. The cores in AU4 through AU2 have greater degrees of variation in both their size and shapes. The slightly larger cores in AU5 may be due to the greater use of BIF and shale. These raw material types would have been available as larger cobbles in comparison with chert. The large average size of the cores in AU3 is due to one overly large BIF core, measuring 108.19-x-83.42-x-38.88mm. The other two cores from AU3 have dimensions that fall within the average range.

On each complete core, the dimensions of the largest and smallest negative flake scars were recorded to provide an estimate of the size range of flakes produced by the cores in the assemblage. As expected, the average maximum flake dimensions increase with increasing core size (Table 10-8: E). When the data is plotted, it shows an exponential relationship between the length of the core and the length of the largest negative flake scar. The data from AU2 through AU5 fall directly on the trend line, but amongst the smallest cores, the relationship is less consistent. According to the exponential trend line, the scars on the surface cores should be slightly larger and those in AU1 should be slightly smaller than they actually measure. In contrast, the measurements for the smallest negative scars (Table 10-8: F) have no relationship to the core size. The average dimensions of the smallest negative scars are consistent, and this may represent the threshold for the minimum size of flakes that knappers wanted to produce. The data demonstrates that the maximum flake size is constrained by core size, with larger cores having the potential to produce larger flakes.

Flakes

Flakes comprise 80.17% of the assemblage, and this large sample of flakes provides an excellent opportunity to examine the technological strategies that were used in their production. The assemblage includes 1522 complete flakes as well as 2631 flake fragments. Because a flake can be broken into a number of fragments that are still recognisable as flakes (in contrast to flaked pieces), assemblages with high frequencies of incomplete flakes can artificially inflate the artefact counts and misrepresent the intensity of occupation. Using the MNF index, it is possible to estimate the minimum number of flakes present in an assemblage (Hiscock 2002). Using the calculation MNF = C + T + CL + BL, it is estimated that the 4153 flakes and flake fragments represent at least 2526 flakes (MNF = 1522 + 658 + 192 + 157; Table 10-7).

Table 10-7 Flake fragmentation, HD07-3A-03 rockshelter

Longitudinal Fragmentation	Transverse Fragmentation				
	Complete	Distal	Prox.	Medial	Total
Complete	1522	658	508	245	1522
Left + Left LCS	192	154	90	76	192
Right + Right LCS	183	148	99	83	183
Medial	24	82	29	60	24
Total	**1921**	**1042**	**726**	**464**	**1921**

The percentage of broken flakes at the site is calculated to be 39.75% (percentage of broken flakes = (MNF - complete flakes) / MNF x 100), and this is a fairly high result for an excavated assemblage. Flakes can break both longitudinally (with left, medial, and right fragments) and transversely (with proximal, medial, and distal fragments), and flake fragmentation can be caused by a number of factors. They can be broken during flake production, and these breaks tend to be longitudinal. Transverse fragmentation is more likely to occur as the result of trampling (Hiscock 1985: 87).

Table 10-8 Quantitative attributes for complete cores by analytical unit, HD07-3A-03 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	Surface	2	15.69	16.04	15.34	0.49
	1	5	23.48	34.63	13.05	8.28
	2	7	36.95	71.14	15.08	22.73
	3	3	61.10	108.19	29.13	41.64
	4	4	29.53	57.32	16.40	18.87
	5	8	46.14	77.29	23.4	22.01
B. Max Width (mm)	Surface	2	23.56	26.48	20.64	4.13
	1	5	26.81	46.02	11.59	12.71
	2	7	44.09	86.39	17.31	29.75
	3	3	49.86	83.42	25.66	29.99
	4	4	24.00	28.38	16.56	5.22
	5	8	40.35	76.02	14.85	22.44
C. Max Thickness (mm)	Surface	2	15.61	16.56	14.65	1.35
	1	5	19.51	27.26	16.38	4.42
	2	7	21.81	38.62	9.19	12.54
	3	3	22.66	38.88	12.47	14.20
	4	4	16.89	19.14	14.91	1.83
	5	8	26.51	45.17	14.34	10.12
D. Mass (g)	Surface	2	7.61	7.98	7.24	0.52
	1	5	13.60	28.05	7.54	8.67
	2	7	83.69	312.53	2.15	126.10
	3	3	95.68	245.29	11.12	129.93
	4	4	14.19	27.22	6.94	9.50
	5	8	83.80	239.89	6.33	89.87
Measurement	**AU**	**Count**	**Average Length (mm)**	**SD**	**Average Width (mm)**	**SD**
E. Average Maximum Negative Scar Dimensions	Surface	2	12.34	1.02	15.56	6.89
	1	5	20.87	5.90	19.14	10.20
	2	7	24.43	20.93	23.49	15.12
	3	3	47.62	40.33	24.05	11.61
	4	4	16.89	19.14	14.91	1.83
	5	8	31.50	16.96	24.00	12.19
F. Average Minimum Negative Scar Dimensions	Surface	2	10.60	2.02	8.41	1.09
	1	5	6.41	2.73	6.35	2.88
	2	7	10.05	9.21	12.28	8.72
	3	3	12.90	5.53	12.13	6.69
	4	4	10.84	5.57	8.90	5.91
	5	8	13.21	9.57	12.95	5.98

At HD07-3A-03, there are much higher numbers of transversely fragmented flakes than longitudinally fragmented flakes. It is reasonable to assume that at a site with such high artefact density, there would have been considerable human activity, which would have increased the likelihood of trampled artefacts. The numbers of left and right longitudinal fragments are remarkably similar. This may be related to how these artefacts break. If longitudinal fractures occur during knapping, it is probable that both fragments will be discarded. The proportions of distal and proximal flake fragments are not quite as consistent, with a greater number of distal fragments. This pattern is repeated in most excavated assemblages.

Flake Subtypes

In the assemblage, there are a small number of specific flake types that are characterised by particular reduction techniques or unique morphological features. Blades, or flakes that are at least twice as long as they are wide, are by far the most common of these specific flake types. In the assemblage, there are 104 complete flakes that are twice as long as they are wide, accounting for 6.83% of the assemblage. Eight of the blades can be further classified as spalls (n=6) and ridge blades (n=2). Spalls are flakes produced through a reduction technique called burination. There are three burins in the assemblage; thus, it is natural that spalls are a small component of the assemblage. One burin was identified in each the surface assemblage, AU1, and AU2, while the spalls were recovered from AU1 (n=1), AU2 (n=2), and AU3 (n=3). Ridge blades are typically associated with the preparation of blade cores. The knapper would have created a ridge on the core by removing a series of flakes, then the blade was struck in line with the ridge and the force of the blow would have followed the ridge. The arrises of the negative scar on the core would then be used to guide subsequent removals. The fact that two ridge blades are present in the assemblage demonstrates that this technique was known to the knappers. One ridge blade was identified in each AU1 and AU3. One bipolar flake was also identified, which exhibited a bulb of force on both the proximal and distal ends of the flake.

Quantitative Flake Attributes

Table 10-9 presents the quantitative data for the flakes in the assemblage by analytical unit. The dimensions of the complete flakes indicate that there is a general trend towards decreasing average flake size over time. The surface artefacts do not fit the general pattern observed throughout the excavated assemblage, as they are the largest group of artefacts. This discrepancy may be due to the different recovery methods used for the surface collected artefacts and the excavated assemblage. Like an open artefact scatter, the artefacts distributed across the ground surface of the rockshelter were simply collected as they were identified. Therefore, there is a natural bias against very small artefacts that are more difficult to identify. The large gap in the

minimum sizes of the flakes between the surface assemblage and the excavated assemblage demonstrates that small flakes are routinely missed through surface collection methods. Many of the smallest artefacts may have settled amongst the angular rock fragments that cover the surface of the rockshelter, making their identification through surface collection methods even less likely. In contrast, the artefacts from the excavated assemblage were recovered during the excavation as well as through the systematic sorting of the fine and coarse rock fraction. The difference in the recovery methods is best exemplified by the fact that over half of the artefacts in the assemblage (n=3166) were recovered from the fine rock fraction.

The average maximum length of the flakes in AU5 is nearly double that of the artefacts in AU1. One possible explanation for the difference in flake size between the analytical units is that the proportion of retouched artefacts increases with more recent time, with the small retouching flakes lowering the average size. The larger samples in the upper analytical units may be less affected by outliers in the data (*e.g.*, particularly large flakes). Throughout all of the analytical units, there is considerable variation in the flake size, and this is demonstrated by range between the maximum and minimum dimensions and the high standard deviation values. In most cases, the standard deviation values are nearly equal to that of the average values. This indicates that the data is not normally distributed, as there are many artefacts that clustered at the maximum and minimum size ranges. The average axis measurements are slightly less than the average maximum measurements.

The shape of flakes can be explored through quantitative attributes, and in particular, the elongation index (Table 10-9: H) and the parallel index (Table 10-9: I). The elongation index is a measure that determines the tendency towards flake elongation through a calculation of the maximum width to the maximum length. There is relative consistency throughout all of the analytical units, with the index showing that flake length is generally only slightly greater than the flake width. AU3 and AU5 have higher elongation index values, indicating that there was a greater tendency for somewhat elongated flakes during these phases of occupation. Throughout the entire occupation, there are only 104 flakes that meet true blade proportions (being at least twice as long as they are wide), accounting for 6.83% of the complete flakes. The greatest number of blades were recovered from AU1 (n=35), but AU3 (10.84%) and AU5 (10.99%) had the greatest relative frequencies of blades. This data supports the evidence from the cores, which suggests that blade production was not major component of the technological system at HD07-3A-03. Most blades in the assemblage likely were not deliberately produced, and their proportions were incidental.

The parallel index is a metric evaluation of flake form that compares the platform width to the axis width. As such, it provides information regarding the shape of the flake form from its platform to its midpoint. The average parallel index values indicate that most flakes in the assemblage expand from their platforms towards their midpoints. The data indicates that 12.48% of the complete flakes contract from the platform, while 87.52% of the sample had expanding forms. This quantitative measure is a good complement to the qualitative observations of flake form, which are discussed below.

The striking platform is one of the key areas on a flake that can provide information regarding the methods that the knapper used in its manufacture. Quantitative attributes, such as the platform dimensions (Table 10-9: J-K) and the exterior striking platform angle (Table 10-9: L) have been show in experimental research to affect flake morphology and size (Dibble and Rezek 2009; Pelcin 1997b). Because the platform dimensions vary with the size of the artefacts, it is not unexpected that the surface artefacts have the largest platform dimensions. A ratio of the striking platform width to the maximum flake width removes the variable of the size. Amongst the complete flakes, the average ratios are similar throughout the analytical units, ranging between 2.12 (AU5) and 2.51 (AU3). While the platform widths remain relatively consistent, there is greater variation within the ratio of the striking platform thickness to the flake thickness. The ratios suggest slightly thicker striking platforms in the most recent occupation of the site (surface, 1.44; AU1, 1.64), while the platforms are thinner in AU2 (1.84), AU3 (1.93), and AU4 (2.00). In AU5, the platforms are slightly thicker, with a ratio of 1.72. According to Dibble and Rezek (2009), thicker platforms tend to produce larger artefacts, particularly when coupled with lower exterior platform angles. The HD07-3A-03 data shows that AU3 and AU5 have slightly elongated flakes in comparison with the rest of the assemblage, while the surface artefacts are considerably larger.

The average exterior platform angles are consistent between AU4 and AU1, while AU5 has a slightly lower average value. The surface artefacts have considerably more acute platform angles, and perhaps when this was combined with a thick platform, it resulted in the large artefacts that typify the surface sample. The average exterior platform angles for AU4 through AU1 range between 78° and 76.26°, which shows strong parallels with data from other rockshelter sites.

Qualitative Flake Attributes

The majority of flakes in the assemblage have plain striking platforms, followed by linear platforms in a distant second (Table 10-10: A). Linear platforms are essentially plain platforms that are exceptionally thin. It is surprising that cortical platforms are so rare in the assemblage, but this may reflect the prevalence of rotated cores. Cortical platforms were most common on quartz (n=10) and BIF (n=8) flakes, while amongst the other raw material varieties they are less common. An assortment of other platform types were recorded in the assemblage, but their small numbers suggests that they are not indicative of particular reduction strategies. Instead, these platforms may have incidentally occurred (*e.g.*, winged platforms and dihedral), or they may be isolated examples techniques or technical procedures have been applied (*e.g.*, facetted and ground platforms). The presence of 62 crushed platforms suggests that cores were not being routinely maintained, leading to failure of the platform.

Modification of the overhang of a core prior to the detachment of a flake can provide a more stable platform and reduce the likelihood of platform and overhang crushing. Facetted overhangs occur on 3.55% of the complete and proximal flakes, and two specimens had abraded overhangs (Table 10-10: B). The low incidence of overhang modification suggests that this technical procedure was not commonly utilised among the knappers at HD07-3A-03. A further 257 flakes had crushed overhangs, and this is typically due to the lack of overhang modification. The majority of flakes showed no crushing or modification of the overhang.

Table 10-9 Quantitative flake attributes by analytical unit, HD07-3A-03 rockshelter

Measurement	AU	Count	Average	Max	Min	SD
A. Max Length (mm)	Surface	13	24.43	43.49	7.61	10.48
	1	642	8.01	54.74	2.24	5.41
	2	439	9.52	67.04	1.7	8.33
	3	249	12.98	63.58	2.03	11.74
	4	88	14.58	59.96	3.3	12.58
	5	91	15.60	72.15	2.48	12.96
B. Max Width (mm)	Surface	13	22.85	37.68	12.77	6.88
	1	642	8.34	36.59	2.47	4.65
	2	439	9.38	59.74	1.64	6.17
	3	249	11.17	45.61	2.75	8.06
	4	88	13.96	49.91	3.49	11.38
	5	91	14.40	48.30	2.62	10.32
C. Max Thickness (mm)	Surface	13	7.32	16.04	2.11	3.45
	1	642	2.05	11.00	0.37	1.65
	2	439	2.30	18.16	0.40	2.29
	3	249	2.74	20.34	0.40	2.85
	4	88	3.55	15.11	0.48	3.35
	5	91	4.50	17.81	0.48	4.55
D. Axis Length (mm)	Surface	13	23.51	35.59	8.29	8.56
	1	642	7.23	52.64	1.98	5.07
	2	439	8.70	65.75	2.35	7.37
	3	249	11.62	61.31	1.67	10.38
	4	88	13.37	58.37	2.39	11.83
	5	91	14.18	61.00	2.46	11.62
E. Axis Width (mm)	Surface	13	19.91	36.28	11.30	6.86
	1	642	7.32	31.08	2.57	4.07
	2	439	8.12	56.90	2.25	5.28
	3	249	9.68	42.56	2.61	7.18
	4	88	12.17	48.69	3.19	9.94
	5	91	12.40	40.84	2.34	9.00
F. Axis Thickness (mm)	Surface	13	6.26	8.55	1.97	2.19
	1	642	1.66	10.16	0.23	1.36
	2	439	1.76	14.63	0.24	1.64
	3	249	2.29	19.18	0.36	2.44
	4	88	2.90	10.04	0.36	2.57
	5	91	3.73	16.89	0.43	3.68
G. Mass (g)	Surface	13	5.35	17.21	0.29	4.56
	1	642	0.35	22.49	0.01	1.54
	2	439	0.62	63.18	0.01	3.40
	3	249	1.34	45.29	0.01	4.41
	4	88	2.74	36.71	0.01	6.26
	5	91	3.04	59.01	0.01	7.41
H. Elongation Index	Surface	13	1.06	1.48	0.41	0.35
	1	642	1.04	4.10	0.23	0.55
	2	439	1.08	6.85	0.21	0.67
	3	249	1.20	7.45	0.18	0.81
	4	88	1.08	3.04	0.42	0.50
	5	91	1.15	3.62	0.30	0.65
I. Parallel Index	Surface	13	2.05	3.78	0.66	0.92
	1	642	1.93	11.22	0.48	1.14
	2	439	1.99	9.32	0.52	1.30
	3	249	2.16	7.97	0.52	1.23
	4	88	1.97	10.43	0.68	1.39
	5	91	1.82	6.62	0.74	1.23
J. Platform Width (mm)	Surface	16	12.66	25.25	4.33	5.92
	1	840	4.87	35.53	0.43	3.60
	2	612	5.25	31.77	0.87	4.10
	3	321	5.90	32.95	0.65	5.13
	4	116	7.05	40.86	1.17	6.69
	5	125	8.34	37.26	0.86	6.82
K. Platform Thickness (mm)	Surface	16	5.76	15.82	1.73	3.33
	1	840	1.60	16.35	0.02	1.48
	2	612	1.60	14.64	0.17	1.78
	3	321	1.80	16.01	0.23	1.97
	4	116	2.19	11.49	0.26	2.33
	5	125	3.00	16.89	0.27	3.10

Measurement	AU	Count	Average	Max	Min	SD
L. Platform Angle (°)	Surface	16	65.94	89.00	40.00	13.81
	1	840	77.77	120.00	27.00	14.69
	2	612	78.00	121.00	25.00	14.84
	3	321	77.90	114.00	24.00	14.51
	4	116	76.26	120.00	34.00	15.90
	5	125	72.32	104.00	27.00	16.01

Note: Measurements A-I are for complete flakes. Platform measurements (J-L) include all complete flakes and all proximal flakes that are longitudinally complete.

Proximal attributes on the ventral surface of the flake can reveal information regarding how the flakes in the assemblage were produced. Contrary to longstanding beliefs, lipping occurs on flakes produced through both hard-hammer and soft-hammer techniques (Pelcin 1997a). In this assemblage, over half of the flakes exhibit no lipping and it is present on 863 of the proximal and complete flakes (Table 10-10: C). Lipping is present in all of the raw material types, apart from martite-goethite. Quartz and quartz crystal flakes have fairly low frequencies of lipping. BIF, green shale, and goethitised shale are the only raw materials where lipping occurs on at least half of the flakes. The bulb of percussion was assessed for the 2030 complete and proximal flakes and there is a fairly even division between diffuse and prominent bulbs (Table 10-10: D). In three instances, heat damage to part of the ventral surface prevented accurate assessment of the bulb type. Additionally, one flake had a large éraillure scar that removed most of the bulb. Some raw material types have a greater tendency towards diffuse bulbs of percussion, including quartz, BIF, green shale, and goethitised shale. This may indicate that the raw material type affects the formation of the bulb of percussion.

The dorsal surface of complete flakes yields information regarding the proportion of dorsal cortex remaining on flakes (Table 10-10: E), the number of dorsal scars (Table 10-10: F), and the orientation of previous removals (Table 10-10: G). These attributes help to reconstruct the stages of reduction that occurred at the site, provide a measure of reduction intensity, and reveal the general preferences for core orientation. Most of the complete flakes are completely non-cortical, and 11.63% of the flakes retain some cortex. As the amount of dorsal cortex decreases amongst the cortical flakes, the number of flakes in each category increases exponentially. The majority of chert (91.82%) and shale (90.57%) flakes exhibit no cortex, suggesting these materials were more intensively reduced than lower quality raw material types (*e.g.*, BIF and quartz), which have a higher frequency of cortical flakes. The low number of completely cortical flakes within each of the analytical units may indicate that there is some off-site reduction of the cores. When raw materials were initially sourced, the knappers may have removed several cortical flakes in order to test the quality of the raw material. Alternatively, knappers may have carried cores with them as they moved from site to site. In such a scenario, only the site where the core was initially sourced would have cortical flakes. It is possible that a combination of these factors may have contributed to the low numbers of cortical flakes in the assemblage. The data from HD07-3A-03 suggests that knappers were transporting cores, particularly those of high-quality chert and possibly shale.

The number of dorsal flake scars can provide a broad measure of the reduction intensity. Most flakes exhibit between two and four dorsal flake scars, but some flakes have up to 15 scars. The 14 cortical flakes in the assemblage have no flake scars. In addition, two specimens had heat damage to the dorsal surface that prevented accurate recording of this attribute; thus, a value of zero was recorded. The average maximum length is similar (*ca.* 8-9mm) for flakes with one to three scars, and it increases slightly for flakes with four to five scars (*ca.* 11mm). Flakes with six or more scars are marginally larger. This indicates that larger flakes generally will have a greater number of flake scars than smaller flakes. Amongst the raw material types, quartz and vitreous goethite have the lowest average number of flake scars (2.69 and 2.4 respectively). This pattern does not appear to reflect the size of the flakes, as they have larger average dimensions than most of the other material types. Quartz cores are similar in size to chert cores. The number of dorsal scars on flakes of other raw material types is consistent, ranging between an average of 3.4 and 3.5 scars per flake. When the average number of scars per flake are considered over the occupation of the site, AU3 has the highest value (3.94 scars per flake) and the lowest value is in AU1 (3.11 scars per flake) and the surface assemblage (2.62 scars per flake). This may indicate that there was a slightly higher degree of core reduction in AU3, but the differences are minimal.

The orientation of the scars shows a strong preference towards unidirectional core reduction. While rotated cores are most common in the assemblage, this data demonstrates that the knappers did not alternate between these platforms. Instead, the knappers unidirectionally reduced a single platform at a time. When the knapper encountered a problem with a platform or core face, they would have rotated the core. In doing so, they created a relatively small number of flakes that exhibit rotated flake scars. Only ten flakes have bidirectional flake scars, but this too could be the result of core rotation rather than indicative of true bidirectional core reduction.

The complete flakes in the assemblage also provide the opportunity to consider patterns in flake form (Table 10-10: H), profile (Table 10-10: I), and cross-section Table 10-10: J). In contrast to the parallel index, flake form considers the shape from the platform to the distal tip. The flakes were found to be primarily either distally expanding or distally contracting, while other flake forms were rare. The blades show different patterns to the rest of the assemblage, with 50% classified as distally contracting, followed by sub-parallel-sided (23.08%) and distally expanding (20.19%) forms. Even parallel-sided blades are rare, further suggesting that they generally were not produced through technological blade production. Flakes with concave profiles are most common, representing 42.58% of the sample. Convex profiles were also regularly identified, but flakes with straight profiles are not common. Twisted profiles are rare in the assemblage as a whole, but are more common among the blades (36.54%). The blades also show a lower incidence of convex profiles. Flakes with trapezoid, left triangle, and right triangle cross-sections are most common. Blades show a higher frequency of symmetric triangle cross-sections than the rest of the assemblage. The knappers may have deliberately or unintentionally struck the core in line with an arris, and the force of the blow would have followed this ridge and promoted the formation of an elongated flake.

Table 10-10 Qualitative flake attributes by analytical unit, HD07-3A-03 rockshelter

A. Platform Type [cp]	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cortical	1	6.25	11	1.31	17	2.78	11	3.43	1	0.86	7	5.60	48	2.36
Crushed	0	0.00	36	4.29	13	2.12	8	2.49	2	1.72	3	2.40	62	3.05
Dihedral	1	6.25	14	1.67	16	2.61	10	3.12	1	0.86	4	3.20	46	2.27
Facetted	0	0.00	18	2.14	7	1.14	8	2.49	0	0.00	1	0.80	34	1.67
Ground	0	0.00	1	0.12	0	0.00	0	0.00	0	0.00	0	0.00	1	0.05
Linear	0	0.00	231	27.50	188	30.72	99	30.84	38	32.76	21	16.80	577	28.42
Plain	14	87.50	527	62.74	371	60.62	185	57.63	74	63.79	89	71.20	1260	62.07
Winged	0	0.00	2	0.24	0	0.00	0	0.00	0	0.00	0	0.00	2	0.10
Total	**16**	**100**	**840**	**100**	**612**	**100**	**321**	**100**	**116**	**100**	**125**	**100**	**2030**	**100**
B. Overhang Removal [cp]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Abraded	0	0.00	0	0.00	1	0.16	0	0.00	0	0.00	1	0.80	2	0.10
Crushed	0	0.00	71	8.45	96	15.69	54	16.82	15	12.93	21	16.80	257	12.66
Facetted	0	0.00	38	4.52	21	3.43	11	3.43	1	0.86	1	0.80	72	3.55
None	16	100	731	87.02	494	80.72	256	79.75	100	86.21	102	81.60	1699	83.69
Total	**16**	**100**	**840**	**100**	**612**	**100**	**321**	**100**	**116**	**100**	**125**	**100**	**2030**	**100**
C. Lipping [cp]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
No	10	62.50	597	71.07	285	46.57	166	51.71	57	49.14	52	41.60	1167	57.49
Yes	6	37.50	243	28.93	327	53.43	155	48.29	59	50.86	73	58.40	863	42.51
Total	**16**	**100**	**840**	**100**	**612**	**100**	**321**	**100**	**116**	**100**	**125**	**100**	**2030**	**100**
D. Bulb of Percussion [cp]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Diffuse	3	18.75	381	45.36	359	58.66	213	66.36	94	81.03	102	81.60	1152	56.75
Prominent	13	81.25	457	54.40	253	41.34	108	33.64	21	18.10	22	17.60	874	43.05
Missing	0	0.00	2	0.24	0	0.00	0	0.00	1	0.86	1	0.80	4	0.20
Total	**16**	**100**	**840**	**100**	**612**	**100**	**321**	**100**	**116**	**100**	**125**	**100**	**2030**	**100**
E. Dorsal Cortex [c]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
None	7	53.85	557	86.76	397	90.43	234	93.98	74	84.09	76	83.52	1345	88.37
1-32%	5	38.46	49	7.63	20	4.56	7	2.81	8	9.09	7	7.69	96	6.31
33-65%	1	7.69	21	3.27	17	3.87	1	0.40	2	2.27	6	6.59	48	3.15
66-99%	0	0.00	11	1.71	2	0.46	2	0.80	3	3.41	1	1.10	19	1.25
100%	0	0.00	4	0.62	3	0.68	5	2.01	1	1.14	1	1.10	14	0.92
Total	**13**	**100**	**642**	**100**	**439**	**100**	**249**	**100**	**88**	**100**	**91**	**100**	**1522**	**100**
F. Dorsal Scars [c]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0	0	0.00	6	0.93	3	0.68	5	2.01	1	1.14	1	1.10	16	1.05
1	2	15.38	59	9.19	31	7.06	15	6.02	12	13.64	11	12.09	130	8.54
2	3	23.08	166	25.86	82	18.68	33	13.25	15	17.05	21	23.08	320	21.02
3	6	46.15	198	30.84	121	27.56	67	26.91	25	28.41	22	24.18	439	28.84
4	2	15.38	116	18.07	100	22.78	53	21.29	19	21.59	17	18.68	307	20.17
5	0	0.00	49	7.63	60	13.67	32	12.85	9	10.23	11	12.09	161	10.58
6	0	0.00	36	5.61	21	4.78	19	7.63	3	3.41	1	1.10	80	5.26
7	0	0.00	9	1.40	15	3.42	10	4.02	1	1.14	5	5.49	40	2.63
8	0	0.00	3	0.47	3	0.68	6	2.41	1	1.14	2	2.20	15	0.99
9	0	0.00	0	0.00	1	0.23	4	1.61	1	1.14	0	0.00	6	0.39
10+	0	0.00	0	0.00	2	0.46	5	2.01	1	1.14	0	0.00	8	0.53
Total	**13**	**100**	**642**	**100**	**439**	**100**	**249**	**100**	**88**	**100**	**91**	**100**	**1522**	**100**
G. Scar Orientation [c]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Unidirectional	12	92.31	517	80.53	268	61.05	151	60.64	65	73.86	64	70.33	1077	70.76
Bidirectional	0	0.00	4	0.62	1	0.23	1	0.40	1	1.14	3	3.30	10	0.66
Rotated	1	7.69	105	16.36	164	37.36	90	36.14	21	23.86	22	24.18	403	26.48
NA	0	0.00	4	0.62	3	0.68	5	2.01	1	1.14	1	1.10	14	0.92
Indeterminate	0	0.00	12	1.87	3	0.68	2	0.80	0	0.00	1	1.10	18	1.18
Total	**13**	**100**	**642**	**100**	**439**	**100**	**249**	**100**	**88**	**100**	**91**	**100**	**1522**	**100**
H. Form [c]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Dist. Contracting	4	30.77	221	34.42	202	46.01	111	44.58	56	63.64	49	53.85	643	42.25
Dist. Expanding	6	46.15	359	55.92	211	48.06	110	44.18	27	30.68	26	28.57	739	48.55
Leaf	0	0.00	12	1.87	2	0.46	4	1.61	0	0.00	0	0.00	18	1.18
Parallel-Sided	3	23.08	9	1.40	9	2.05	7	2.81	4	4.55	6	6.59	38	2.50
Sub Parallel	0	0.00	41	6.39	15	3.42	17	6.83	1	1.14	10	10.99	84	5.52
Total	**13**	**100**	**642**	**100**	**439**	**100**	**249**	**100**	**88**	**100**	**91**	**100**	**1522**	**100**

I. Profile [c]	Surface		AU1		AU2		AU3		AU4		AU5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Concave	3	23.08	302	47.04	196	44.65	87	34.94	26	29.55	34	37.36	648	42.58
Convex	9	69.23	209	32.55	133	30.30	89	35.74	39	44.32	33	36.26	512	33.64
Straight	1	7.69	98	15.26	62	14.12	32	12.85	13	14.77	11	12.09	217	14.26
Twisted	0	0.00	33	5.14	48	10.93	41	16.47	10	11.36	13	14.29	145	9.53
Total	**13**	**100**	**642**	**100**	**439**	**100**	**249**	**100**	**88**	**100**	**91**	**100**	**1522**	**100**
J. Cross-section [c]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Left Triangle	2	15.38	160	24.92	122	27.79	53	21.29	24	27.27	24	26.37	385	25.30
Right Triangle	2	15.38	138	21.50	72	16.40	58	23.29	22	25.00	16	17.58	308	20.24
Plano-convex	0	0.00	10	1.56	9	2.05	5	2.01	4	4.55	7	7.69	35	2.30
Symmetric Triangle	0	0.00	63	9.81	67	15.26	27	10.84	7	7.95	15	16.48	179	11.76
Trapezoid	7	53.85	169	26.32	101	23.01	70	28.11	18	20.45	22	24.18	387	25.43
Irregular	2	15.38	100	15.58	68	15.49	36	14.46	13	14.77	7	7.69	226	14.85
Indeterminate	0	0.00	2	0.31	0	0.00	0	0.00	0	0.00	0	0.00	2	0.13
Total	**13**	**100**	**642**	**100**	**439**	**100**	**249**	**100**	**88**	**100**	**91**	**100**	**1522**	**100**
K. Termination [cd]	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Axial	2	11.11	6	0.66	38	5.80	15	4.30	2	1.67	8	6.15	71	3.26
Cortical Axial	0	0.00	0	0.00	0	0.00	3	0.86	0	0.00	2	1.54	5	0.23
Feather	10	55.56	721	79.41	459	70.08	263	75.36	107	89.17	104	80.00	1664	76.33
Hinge	3	16.67	123	13.55	120	18.32	56	16.05	10	8.33	11	8.46	323	14.82
Inflexed	1	5.56	13	1.43	5	0.76	5	1.43	1	0.83	0	0.00	25	1.15
Plunge	1	5.56	18	1.98	23	3.51	5	1.43	0	0.00	4	3.08	51	2.34
Step	1	5.56	27	2.97	10	1.53	2	0.57	0	0.00	1	0.77	41	1.88
Total	**18**	**100**	**908**	**100**	**655**	**100**	**349**	**100**	**120**	**100**	**130**	**100**	**2180**	**100**

Key: cp - complete and proximal flakes; c - complete flakes; cd - complete and distal flakes

The termination is the final portion of the flake that forms before it detaches from the core and the termination type can be affected by a number of variables. Over three-quarters of the distal and complete flakes have classic v-shaped feather terminations, which are generally considered to be the ideal termination type. Hinge terminations are fairly common in the assemblage, particularly in AU2 and AU3. Hinge terminations are often considered to be knapping errors; although, Kamminga (1985: 11) notes that large flakes with hinge terminations may be ideal blanks for the production of pirri gravers. Many of the HD07-3A-03 cores appear to have been discarded due to numerous hinge and step terminations, which have made subsequent removals more and more difficult. Some researchers suggest that the use of flat knapping surfaces (*i.e.*, high exterior platform angles) may promote the formation of hinge terminations, but the average exterior platform angles for complete flakes with hinge (76.6°) and feather (77.1°) terminations is similar. There are a number of flakes with axial and cortical axial terminations, where the force of the flake has gone straight through the core and removed part of the base of the core with the flake. These termination types are often associated with bipolar reduction techniques (Odell 2004: 58), which are particularly useful for reducing small cores. Complete flakes with axial and cortical axial terminations have high striking platform angles (79.2° and 79° respectively). Only 51 plunging terminations were recorded in the assemblage. In experimental research, Dibble and Whittaker (1981) found that there is an increased chance of plunge terminations with higher exterior platform angles. This appears to agree with the data from HD07-3A-03, as the complete flakes with plunging terminations have an average exterior striking platform angle of 79.4°. Of all termination types, the complete flakes with step terminations have the greatest exterior striking platform angle (82.6°), suggesting that this attribute may also contribute to the formation of step terminations.

Retouched and Utilised Artefacts

Retouched and utilised artefacts comprise 5% of the total assemblage recovered from HD07-3A-03. Table 10-11 presents the distribution of retouched and utilised artefacts throughout the site, and it shows that sample is dominated by non-formalised retouched artefacts and utilised artefacts. The formalised retouched artefacts are briefly described before considering the patterns of edge modification for all complete retouched and utilised artefacts.

Formalised Retouched Artefacts

A small proportion of the retouched artefacts can be further classified based on specific retouching technologies used in their manufacture (*e.g.*, backing and burination) or according to their distinctive forms (*e.g.*, tulas, endscrapers, burrens, and backed artefacts). Of these formalised retouched artefact types, symmetrical backed artefacts (n=25) and backed artefact fragments (n=19) are most common. HD07-3A-03 has one of the largest samples of tulas from excavated contexts at Hope Downs 1, and all eight specimens were recovered from AU1 and AU2. Burins, endscrapers, and burrens are a small but important component of the retouched artefact assemblage.

Symmetrical Backed Artefacts – Symmetrical backed artefacts are the most common formalised retouched artefact type in the assemblage, with 25 specimens recovered from AU4 through AU1. Additionally, 19 backed artefact fragments were also identified with the lowest specimen recovered from AU4. The distribution of backed artefacts at HD07-3A-03 suggests that they were deposited as early as 3800 years ago (based on the age-depth trend). These fragments include pieces that have unmistakable backing, but are too fragmentary to be further classified as having either symmetrical or asymmetrical forms. There are five forms of symmetrical backed artefacts in the assemblage: crescent, elongated crescent, trapeze, trapeze with no lateral backing, and triangle.

Table 10-11 Distribution of retouched and utilised artefacts by analytical unit, HD07-3A-03 rockshelter

Retouched Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
Subtype	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Retouched Artefact	*14*	*87.50*	*71*	*54.20*	*33*	*43.42*	*13*	*50.00*	*2*	*33.33*	*3*	*75.00*	*136*	*52.51*
Alternate Edge	0	0.00	2	1.53	0	0.00	0	0.00	0	0.00	0	0.00	2	0.77
Alternating	3	18.75	9	6.87	2	2.63	1	3.85	0	0.00	0	0.00	15	5.79
Unifacial	11	68.75	60	45.80	31	40.79	12	46.15	2	33.33	3	75.00	119	45.95
Utilised Artefact	*1*	*6.25*	*36*	*27.48*	*24*	*31.58*	*1*	*3.85*	*2*	*33.33*	*1*	*25.00*	*65*	*25.10*
Alternating	0	0.00	16	12.21	7	9.21	1	3.85	2	33.33	1	25.00	27	10.42
Unifacial	1	6.25	20	15.27	17	22.37	0	0.00	0	0.00	0	0.00	38	14.67
Symmetrical Backed Artefact	*0*	*0.00*	*7*	*5.34*	*10*	*13.16*	*7*	*26.92*	*1*	*16.67*	*0*	*0.00*	*25*	*9.65*
Crescent	0	0.00	2	1.53	4	5.26	1	3.85	0	0.00	0	0.00	7	2.70
Crescent - E	0	0.00	0	0.00	1	1.32	0	0.00	0	0.00	0	0.00	1	0.39
Trapeze	0	0.00	1	0.76	0	0.00	0	0.00	0	0.00	0	0.00	1	0.39
Trapeze - NLB	0	0.00	3	2.29	2	2.63	3	11.54	0	0.00	0	0.00	8	3.09
Triangle	0	0.00	1	0.76	3	3.95	3	11.54	1	16.67	0	0.00	8	3.09
Backed Artefact - Indeterminate	*0*	*0.00*	*10*	*7.63*	*4*	*5.26*	*4*	*15.38*	*1*	*16.67*	*0*	*0.00*	*19*	*7.34*
Tula (Slug)	*0*	*0.00*	*5*	*3.83*	*3*	*3.95*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*8*	*3.09*
Burin	*1*	*6.25*	*1*	*0.76*	*1*	*1.32*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*1.16*
On Truncation	1	6.25	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.39
Opposed on Break	0	0.00	0	0.00	1	1.32	0	0.00	0	0.00	0	0.00	1	0.39
Simple	0	0.00	1	0.76	0	0.00	0	0.00	0	0.00	0	0.00	1	0.39
Scraper (Endscraper)	*0*	*0.00*	*0*	*0*	*1*	*1.32*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.39*
Burren (Slug)	*0*	*0.00*	*1*	*0.76*	*0*	*0.00*	*1*	*3.85*	*0*	*0.00*	*0*	*0.00*	*2*	*0.77*
Total	**16**	**100**	**131**	**100**	**76**	**100**	**26**	**100**	**6**	**100**	**4**	**100**	**259**	**100**

Unlike typical crescents that have a 'D' shape, elongated crescents are long and needle-like. The backed edge remains slightly convex and it has a symmetrical shape, but the form of these specimens is very different from non-elongated crescents. Artefact 1717 is a distal portion of an elongated crescent, which has dorsal stepped and scaled backing along the left lateral margin. While the red chert artefact is fragmentary, it measures 23.58mm long, 6.49mm wide, and 3.45mm wide. The specimen was heated and it exhibits crazing.

There are seven crescents in the assemblage, including six complete specimens. The complete specimens cluster quite closely in terms of length, ranging between 23.36 and 17.3mm. The shortest specimen looks to have had some edge damage at the proximal end, as it is slightly rectilinear. The sample is evenly divided into two groups when their widths are compared: wide and narrow. The wide group have maximum widths approaching or greater than their lengths, while the artefacts in the other group are much narrower. There are four specimens with backing along the right lateral edge and three examples with backing on the left edge (Figure 10-10: h).

Most of the trapezes in the assemblage do not have backing along the lateral margins, but were formed by two oblique truncations. Artefact 970 is the single exception; it is a trapeze that has continuous, alternating backing from the truncations along the right lateral margin. With the exception of the two atypical specimens (Artefacts 688 and 5215), the width of the trapezes (including those with no lateral backing) is very consistent, ranging between 15.24 and 11.87mm. The length of the trapezes varies considerably, with a range of 29.03mm to 16.96mm.

There are eight trapezes in the assemblage that do not exhibit backing on the lateral margin. Six of the specimens are complete and there is one distal fragment (Artefact 1730) as well as one specimen that has a small fragment missing from the distal end (Artefact 1173). The complete artefacts all have truncations at their distal and proximal ends except for Artefact 688, which only has backing along the distal edge. It is possible that this may be an artefact that was discarded during manufacture, or perhaps it was utilised in this state. In most cases, the truncations are oblique and are angled either to the left or right edge, and there is a relatively even split between the left and right trapezes. Artefact 5215 (Figure 10-10: k) is an atypical specimen because it has an oblique truncation at the distal end and a straight truncation at the proximal end. While this artefact does not have a truly symmetrical form, it is possible that this artefact was repaired, resulting in its unusual shape. The two retouch areas on this artefact exhibit slightly different backing techniques. The retouch along the distal right edge was formed through alternating scaled retouch, while the retouch on the proximal edge is bifacial, sub-parallel. It is also possible that the piece was intentionally shaped in this manner to fit into a pre-existing haft.

Eight triangles were identified in the assemblage, including six that are complete. The size of the triangles varies more than the other backed artefact types, both in terms of their length and width. Five of the specimens exhibited backing on the left lateral margin, and three specimens were backed on the right margin. The slight preference for backing on the left margin is not significant due to the small sample size. Artefact 2650 (Figure 10-10: j) is not typical, as it has backing along the left proximal margin to the midpoint, but form the midpoint towards the distal end, the unmodified inflexed termination was left. It is possible that this artefact was not completed, but the traces of usewear along the right lateral edge suggest otherwise. It is most probable that the knapper simply took advantage of the natural shape of this flake and decided not to back the distal edge.



Figure 10-10 Retouched artefacts from HD07-3A-03 rockshelter. Tulas: a) Artefact 60, b) Artefact 1750, c) Artefact 1605, d) Artefact 5004, e) Artefact 5752; burrens: f) Artefact 104, g) Artefact 2899; and symmetrical backed artefacts: h) Artefact 5050, i) Artefact 3176, j) Artefact 2192, and k) Artefact 5215

Tulas – Eight tulas were recovered during the excavation of HD07-3A-03 (Figure 10-10: a-e), and despite the much smaller excavation area, one less tula was recovered from this site than from Jundaru. The tulas were restricted to AU1 and AU2, and the three lowermost specimens were recovered from between 40 to 35cmbd. AU2 and AU1 represent the occupation of the site over the last 600 years; hence, this suggests that tula use was greatest in the relatively recent past. Seven of the tulas are complete, and there is one specimen that has slight damage along the proximal left edge rendering it incomplete. All of the tulas were discarded in slug form and have oblique working edges created through greater reduction on one side of the flake. Slightly more of the tulas are longer on the left lateral edge (*e.g.*, Artefacts 59, 1605, 5004, 5752), while Artefacts 60, 1141, and 1531 are longer on the right lateral edge. The working edges are fairly straight with only slight concavities or convexities. Artefact 5004 (Figure 10-10: d) has the most pronounced convex edge of the sample. The retouch along the working edge is generally on the dorsal edge, but there are a few instances of alternating retouch (*e.g.*, Figure 10-10: e). The retouch varies from invasive to short and from scaled to stepped. In most cases the overhang of the flake appears to have been facetted; however it is possible that this was done after the flake was detached in order to thin the platform for hafting. The flakes selected for tula manufacture were produced from a variety of raw material types, including brown shale (n=3), speckled black chert (n=2), olive chert, and translucent green chert. While the sample is small, there appears to be a selection of small tulas (*e.g.*, Figure 10-10: b-c) and larger tulas (*e.g.*, Figure 10-10: a, d-e). The size of the tula may have been dependent on the haft, or perhaps it was constrained by the maximum size of the flake that could be produced at that particular moment.

Burrens – Two burrens are present in the assemblage, including one specimen from AU1 (Artefact 104; U1-L01) and one from AU3 (Artefact 2899; U1-L05; *in situ* 48cmbd). While the second specimen is from AU3, its depth places it within the top of the analytical unit and just below the radiocarbon date of 603±32 cal BP (46.5cmbd). Hence, it is likely that burrens only first occurred in the archaeological record at HD07-3A-03 only slightly earlier than 600 years ago. Artefact 104 (Figure 10-10: f) was discarded in a highly reduced state (*i.e.*, slug form), while Artefact 2899 (Figure 10-10: g) exhibits a lesser degree of reduction, remaining functional. Artefact 104 has invasive, stepped and scaled, dorsal SAR along the entire left lateral edge, which has a rectilinear delineation.

The artefact also has retouch along the distal, proximal, and right lateral edges. There are extensive residues along the ventral and dorsal surface of the burren. There are also linear residue smears on the proximal ventral surface. Along the distal end of the artefact, the edges of the artefact have a crushed appearance, suggestive of considerable use. The second burren in the assemblage has a very different appearance. Unfortunately, Artefact 2899 has a minor break along the proximal edge and is therefore incomplete. The artefact was backed along the distal left lateral edge, and there is short retouch and usewear along the proximal half. Along the right lateral edge, there is invasive, scaled SAR. The retouch on the right lateral edge appears to have occurred in at least two separate instances, as indicated by the lack of patina on the scars on the upper two-thirds of the flake. The scars on the distal third of the edge have a darker appearance. There is also dorsal retouch along the hinge termination. There are no clear residue traces on Artefact 2899.

Burins – There are three burins in the assemblage, a burin on truncation, an opposed burin on break, and a simple burin. Artefact 5034 is a distal fragment of a simple burin. At least two spalls were struck from the distal right edge, terminating at a retouch flake scar. Artefact 1716 is an opposed burin on break that shows extensive retouching. The flake was first snapped at the distal and proximal ends, producing two plain striking platforms from which the spalls could be removed. At least three spalls were struck from the right distal edge (including one leaving a hinge termination), and up to seven spalls were removed from the right proximal edge. Based on the negative scars, it appears that spalls were removed from the two platforms alternately, and the proximal edge was probably utilised last. The burin edges appear to have been used, while the facet edges do not have usewear. The left lateral edge also exhibits usewear. Artefact 49 is a burin on truncation, with at least two spalls struck from a prepared platform at the proximal end. The proximal end was truncated using stepped and scaled, dorsal SAR. The knapper used this prepared surface as the striking platform to remove at least two spalls. One of the spalls had an axial termination, while the other had a large hinge termination. While the distal end of the artefact is not retouched, it has a polished and rounded appearance, suggestive of extensive use.

Scrapers – A single specimen was classified as a scraper. Artefact 2453 is a distal fragment of an endscraper that was produced on a BIF flake. The distal edge of this flake has long, scaled, dorsal SAR. There is also dorsal scaled SAR on the right lateral edge. A small dark blob of residue is present on the ventral surface near the centre of the artefact. There are also some white residues on the dorsal surface. The artefact has similar proportions to the larger tulas in the assemblage, and its working edge is similar to that of the tulas. What differentiates this artefact from the tulas in the assemblage is the fact that it lacks the large, pronounced bulb of percussion. Just because this artefact does not have the classic tula shape, does not mean that it was not used in the same manner as a tulas. Usewear analysis would be useful for investigating this theory.

Edge Modification Analysis

While there are 259 retouched and utilised artefacts in the assemblage, only 103 specimens are considered to be complete. There are 209 areas of edge modification on the complete retouched and utilised artefacts, and Table 10-12 provides a breakdown of the number edge modification areas for each of the retouched artefact types and subtypes. The burin and burren have the greatest number of edge modification areas per specimen, but there is only an individual specimen of each. The non-formalised retouched artefacts have a similar average number of edge modification areas to the symmetrical backed artefacts. The quantitative and qualitative edge modification attributes can be used to help reconstruct patterns in the manufacture and use amongst retouched and utilised artefacts.

The qualitative attributes for edge modification are presented in Table 10-13 through Table 10-18. Table 10-13 explores the edge modification types that occur on each retouched and utilised artefact type. By far, regular retouch and usewear are the predominant edge modification types, and combined, they account for 83.25% of the edge modification areas. When utilised artefacts are removed from the sample, usewear is still the second most common edge modification area recorded on the retouched artefacts, with 47 instances identified on the 80 retouched artefacts. Backing is the third most common form of edge modification. Other forms of edge modification, such as burination, truncation, and retouched notches are rare.

Table 10-12 Number of edge modification areas on complete artefacts by analytical unit, HD07-3A-03 rockshelter

Retouched Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
Subtype	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM	n	EM
Retouched Artefact	*4*	*10*	*25*	*56*	*13*	*26*	*6*	*14*	*2*	*2*	*1*	*2*	*51*	*110*
Alternating	1	3	2	9	1	2	0	0	0	0	0	0	4	14
Unifacial	3	7	23	47	12	24	6	14	2	2	1	2	47	96
Utilised Artefact	*1*	*1*	*12*	*23*	*9*	*11*	*0*	*0*	*1*	*2*	*0*	*0*	*23*	*37*
Alternating	0	0	5	11	1	3	0	0	1	2	0	0	7	16
Unifacial	1	1	7	12	8	8	0	0	0	0	0	0	16	21
Symmetrical Backed Artefact	*0*	*0*	*5*	*8*	*7*	*14*	*6*	*16*	*1*	*2*	*0*	*0*	*19*	*40*
Crescent	0	0	2	4	3	4	1	3	0	0	0	0	6	11
Crescent – E	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Trapeze	0	0	2	3	1	2	3	9	0	0	0	0	6	14
Trapeze – NLB	0	0	0	0	3	8	2	4	1	2	0	0	6	14
Triangle	0	0	2	4	3	4	1	3	0	0	0	0	6	11
Tula	*0*	*0*	*4*	*7*	*3*	*6*	*0*	*0*	*0*	*0*	*0*	*0*	*7*	*13*
Burin	*0*	*0*	*0*	*0*	*1*	*3*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*3*
Burren	*0*	*0*	*1*	*4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*4*
Total	**6**	**13**	**47**	**98**	**33**	**60**	**12**	**30**	**4**	**6**	**1**	**2**	**103**	**209**

Table 10-13 Edge modification types for complete specimens by analytical unit, HD07-3A-03 rockshelter

Retouched Artefact Type	Surface		AU1		AU2		AU3		AU4		AU5		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Burin	*2*	*15.38*	*0*	*0.00*	*3*	*5.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*5*	*2.39*
Burin Edge	1	7.69	0	0.00	2	3.33	0	0.00	0	0.00	0	0.00	3	1.44
Truncation	1	7.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.48
Usewear	0	0.00	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00	1	0.48
Burren	*0*	*0.00*	*4*	*4.30*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*4*	*1.98*
Retouch	0	0.00	4	4.30	0	0.00	0	0.00	0	0.00	0	0.00	4	1.98
Retouched Artefact	*10*	*90.91*	*56*	*60.22*	*26*	*43.33*	*14*	*46.67*	*2*	*33.33*	*2*	*100*	*110*	*54.46*
Retouch	9	81.82	36	38.71	18	30.00	7	23.33	2	33.33	1	50.00	73	36.14
Retouched Notch	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.50
Truncation	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.50
Usewear	1	9.09	20	21.51	8	13.33	5	16.67	0	0.00	1	50.00	35	17.33
Symmetrical Backed Artefact	*0*	*0.00*	*8*	*8.60*	*14*	*23.33*	*16*	*53.33*	*2*	*33.33*	*0*	*0.00*	*40*	*19.80*
Backing	0	0.00	5	5.38	9	15.00	13	43.33	2	33.33	0	0.00	29	14.36
Retouch	0	0.00	2	2.15	0	0.00	0	0.00	0	0.00	0	0.00	2	0.99
Usewear	0	0.00	1	1.08	5	8.33	3	10.00	0	0.00	0	0.00	9	4.46
Tula	*0*	*0.00*	*7*	*7.14*	*6*	*10.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*13*	*6.22*
Retouch	0	0.00	6	6.12	5	8.33	0	0.00	0	0.00	0	0.00	11	5.26
Usewear	0	0.00	1	1.02	1	1.67	0	0.00	0	0.00	0	0.00	2	0.96
Utilised Artefact	*1*	*9.09*	*23*	*24.73*	*11*	*18.33*	*0*	*0.00*	*2*	*33.33*	*0*	*0.00*	*37*	*18.32*
Usewear	1	9.09	23	24.73	11	18.33	0	0.00	2	33.33	0	0.00	37	18.32
Total	**13**	**100**	**98**	**100**	**60**	**100**	**30**	**100**	**6**	**100**	**2**	**100**	**209**	**100**

Table 10-14 documents the edge modification position in the assemblage. The position of the retouch refers to whether the retouch scars occur on the dorsal or ventral surfaces, if they alternate, or if they are bifacial. Overwhelmingly, the knappers at HD07-3A-03 preferred dorsal edge modification, which includes a variety of edge modification types. The predominance of dorsal edge modification is consistent through time, with the exception of AU5. As there are only two complete retouched artefacts from AU5, and this pattern is not statistically significant. Alternating edge modification accounts for nearly a fifth of the sample; however, most of the alternating edge modification occurs as usewear and there are only nine instances of alternating retouch (including backing). Ventrally retouched artefacts are more common than those with alternating retouch, but there are only ten instances of ventral usewear. There were five instances of bifacial retouch and each was further classified as backing. While the position of backing varies in the assemblage, dorsal backing is most common.

The retouch angle for each area of edge modification was assessed as being AAR, SAR, or not applicable (for burin edges), and this data is presented in Table 10-15. While quantitative measures, like the GIUR, are suited to a limited number of specimens, this attribute can be assessed for every instance of retouch or usewear. In most instances, angles of over 60° were reported and this is fairly evenly distributed between the retouch and the usewear. All instances of backing were recorded as SAR. Among the edge modification areas assessed as having angles less than 60°, there are slightly more instances of usewear than retouch. These patterns are consistent over time, with the exception of the surface artefacts, which have a much greater occurrence of AAR.

The extent of the edge modification is presented in Table 10-16, and by definition, all scars less than 1mm long were classified as usewear. When the usewear is excluded from the sample, the data shows that short (52.80%) and long (31.20%) retouch are predominant, while invasive retouch (12.08%) is less common. Covering retouch is particularly rare, with one instance recorded. This pattern remains relatively constant over time, with a slight decrease in the amount of short retouch in AU1 and in the surface assemblage. Within these analytical units, there is a concomitant increase in long retouch. AU1 also has the greatest number of invasive edge modification areas and these occur both on formalised tools (like burrens and tulas) as well as on non-formalised retouched artefacts.

Table 10-14 Retouch and/or usewear position and modification type by analytical unit, HD07-3A-03 rockshelter

Scar Position	Surface		AU1		AU2		AU3		AU4		AU5		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Alternating	*0*	*0.00*	*22*	*22.45*	*12*	*20.00*	*3*	*10.00*	*2*	*33.33*	*0*	*0.00*	*39*	*18.66*
Backing	0	0.00	2	2.04	1	1.67	1	3.33	0	0.00	0	0.00	4	1.91
Retouch	0	0.00	4	4.08	1	1.67	0	0.00	0	0.00	0	0.00	5	2.39
Usewear	0	0.00	16	16.33	10	16.67	2	6.67	2	33.33	0	0.00	30	14.35
Dorsal	*6*	*46.15*	*55*	*56.12*	*41*	*68.33*	*22*	*73.33*	*1*	*16.67*	*1*	*50.00*	*126*	*60.29*
Backing	0	0.00	1	1.02	7	11.67	11	36.67	0	0.00	0	0.00	19	9.09
Retouch	3	23.08	33	33.67	18	30.00	5	16.67	1	16.67	0	0.00	60	28.71
Retouched Notch	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Truncation	1	7.69	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	2	0.96
Usewear	2	15.38	21	21.43	16	26.67	4	13.33	0	0.00	1	50.00	44	21.05
Ventral	*6*	*46.15*	*19*	*19.39*	*5*	*8.33*	*4*	*13.33*	*1*	*16.67*	*1*	*50.00*	*36*	*17.22*
Backing	0	0.00	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00	1	0.48
Retouch	6	46.15	11	11.22	4	6.67	2	6.67	1	16.67	1	50.00	25	11.96
Usewear	0	0.00	8	8.16	0	0.00	2	6.67	0	0.00	0	0.00	10	4.78
Bifacial	*0*	*0.00*	*2*	*2.04*	*0*	*0.00*	*1*	*3.33*	*2*	*33.33*	*0*	*0.00*	*5*	*2.39*
Backing	0	0.00	2	2.04	0	0.00	1	3.33	2	33.33	0	0.00	5	2.39
Burin Edge	*1*	*7.69*	*0*	*0.00*	*2*	*3.33*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*1.44*
Burin	1	7.69	0	0.00	2	3.33	0	0.00	0	0.00	0	0.00	3	1.44
Total	**13**	**100**	**98**	**100**	**60**	**100**	**30**	**100**	**6**	**100**	**2**	**100**	**209**	**100**

Table 10-15 Incidence of acute angle retouch (AAR) and steep angle retouch (SAR) by analytical unit, HD07-3A-03 rockshelter

Retouch Angle	Surface		AU1		AU2		AU3		AU4		AU5		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
AAR (<60°)	*9*	*69.23*	*24*	*24.49*	*18*	*30.00*	*6*	*20.00*	*3*	*50.00*	*1*	*50.00*	*61*	*29.19*
Retouch	8	61.54	6	6.12	8	13.33	2	6.67	1	16.67	0	0.00	25	11.96
Usewear	1	7.69	18	18.37	10	16.67	4	13.33	2	33.33	1	50.00	36	17.22
SAR (>60°)	*4*	*30.77*	*74*	*75.51*	*40*	*66.67*	*24*	*80.00*	*3*	*50.00*	*1*	*50.00*	*146*	*69.86*
Retouch	1	7.69	42	42.86	15	25.00	5	16.67	1	16.67	1	50.00	65	31.10
Retouched notch	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Backing	0	0.00	5	5.10	9	15.00	13	43.33	2	33.33	0	0.00	29	13.88
Truncation	1	7.69	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	2	0.96
Usewear	1	7.69	27	27.55	16	26.67	4	13.33	0	0.00	0	0.00	48	22.97
NA	*0*	*0.00*	*0*	*0.00*	*2*	*3.33*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.96*
Burin	0	0.00	0	0.00	2	3.33	0	0.00	0	0.00	0	0.00	2	0.96
Total	**13**	**100**	**98**	**100**	**60**	**100**	**30**	**100**	**6**	**100**	**2**	**100**	**209**	**100**

Table 10-16 Edge modification extent analytical unit, , HD07-3A-03 rockshelter

Retouch Extent	Surface		AU1		AU2		AU3		AU4		AU5		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
<1mm	*2*	*15.38*	*45*	*45.92*	*26*	*43.33*	*8*	*26.67*	*2*	*33.33*	*1*	*50.00*	*84*	*40.19*
Usewear	2	15.38	45	45.92	26	43.33	8	26.67	2	33.33	1	50.00	84	40.19
Short	*4*	*30.77*	*21*	*21.43*	*21*	*35.00*	*17*	*56.67*	*2*	*33.33*	*1*	*50.00*	*66*	*31.58*
Retouch	4	30.77	16	16.33	12	20.00	3	10.00	0	0.00	1	50.00	36	17.22
Backing	0	0.00	5	5.10	9	15.00	13	43.33	2	33.33	0	0.00	29	13.88
Truncation	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Long	*5*	*38.46*	*20*	*20.41*	*8*	*13.33*	*4*	*13.33*	*2*	*33.33*	*0*	*0.00*	*39*	*18.66*
Retouch	4	30.77	20	20.41	8	13.33	3	10.00	2	33.33	0	0.00	37	17.70
Retouched notch	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Backing	1	7.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.48
Invasive	*0*	*0.00*	*12*	*12.24*	*3*	*5.00*	*1*	*3.33*	*0*	*0.00*	*0*	*0.00*	*16*	*7.66*
Retouch	0	0.00	12	12.24	3	5.00	1	3.33	0	0.00	0	0.00	16	7.66
Covering	*1*	*7.69*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*0.48*
Retouch	1	7.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.48
NA	*1*	*7.69*	*0*	*0.00*	*2*	*3.33*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*1.44*
Burin	1	7.69	0	0.00	2	3.33	0	0.00	0	0.00	0	0.00	3	1.44
Total	**13**	**100**	**98**	**100**	**60**	**100**	**30**	**100**	**6**	**100**	**2**	**100**	**209**	**100**

The delineation of the retouch records if the retouch alters the plan of the flake's edge (*e.g.*, concave, rectilinear, sinusoidal, nosed, denticulate, *etc.*) or if it remains largely unaltered (*i.e.*, regular). Table 10-17 presents the edge modification delineation by analytical unit. As expected, all instances of usewear did not modify the general plan of the flake edge; however, the majority of retouch (including all subtypes) also did not change the shape of the edge. This attests to the low intensity of retouch. Rectilinear edge modification follows at a distant second to regular delineation. Most of the rectilinear retouch was classified as backing, and this shows a deliberate desire to create straight backed edges on those particular artefacts. Both concave and convex backing was also identified, but it was much less common. Other types of delineation are relatively uncommon.

The location of each area of edge modification was recorded using the retouch location map (see Figure 4-6), and the results for HD07-3A-03 are presented in Table 10-18. There are slightly more instances of edge modification along the right than left lateral edge, and the proportions of retouch and usewear are consistent. AU3 shows the only strong deviation from this pattern, with a lower frequency of left edge modification than in the other analytical units. When the retouch from the lateral edge continues onto either the proximal or distal margin, there are fairly equal proportions on the left and right sides. Distal edge modification is more common than proximal retouch, and this is particularly true of usewear. The data shows that backing occurs in various configurations. There are greater numbers of backed areas on the right margin that continue to either the distal or proximal edge. However, when the lateral edge backing is combined with the instances that continue to either the distal or proximal edge, there are near equal proportions of right (n=13) and left backing (n=12). The location of the edge modification areas shows that there were not marked preferences for one lateral edge over the other. Like most datasets, the distal edge was more commonly utilised than the proximal edge.

The quantitative edge modification attributes are presented in Table 10-19, including the average retouch length, GIUR, and PRI. The average retouch length was determined for 121 edge modification areas. All instances of usewear were excluded from this calculation, as many of the usewear scars were likely created through the use of the artefact rather than from deliberate edge modification. Burins were also excluded from the sample, as they were produced using a different retouch technique that is not suited to the same types of measurements as retouch that is perpendicular to the flake edge. As the data indicates, there is slight variation in the average retouch length amongst the analytical units, with AU3 having the lowest and AU2 having the greatest average retouch length. However, there are high standard deviation values for the entire sample (AU2 in particular) that outweigh the minor variation in retouch length over time.

The GIUR is a method of exploring the degree of dorsal lateral edge retouch through a ratio of the retouch thickness to the flake thickness. Because the GIUR is limited to dorsal, lateral retouch, there are only 46 areas of retouch suitable for this index. The average GIUR values suggest that there was little difference in the degree of dorsal lateral retouch over time, with values ranging between 0.44 and 0.61. The moderate GIUR values suggest that when knappers discarded their retouched artefacts, many still had the potential for further reduction.

Table 10-17 Delineation of edge modification by analytical unit, HD07-3A-03 rockshelter

Delineation	**Surface**		**AU1**		**AU2**		**AU3**		**AU4**		**AU5**		**Total**	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Regular	*11*	*84.62*	*79*	*80.61*	*42*	*70.00*	*15*	*50.00*	*4*	*66.67*	*2*	*100*	*153*	*73.21*
Retouch	9	69.23	34	34.69	16	26.67	7	23.33	2	33.33	1	50.00	69	33.01
Usewear	2	15.38	45	45.92	26	43.33	8	26.67	2	33.33	1	50.00	84	40.19
Rectilinear	*2*	*15.38*	*5*	*5.10*	*10*	*16.67*	*9*	*30.00*	*2*	*33.33*	*0*	*0.00*	*28*	*13.40*
Retouch	0	0.00	2	2.04	1	1.67	0	0.00	0	0.00	0	0.00	3	1.44
Backing	0	0.00	3	3.06	7	11.67	8	26.67	2	33.33	0	0.00	20	9.57
Truncation	1	7.69	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	2	0.96
Burin	1	7.69	0	0.00	2	3.33	0	0.00	0	0.00	0	0.00	3	1.44
Concave	*0*	*0.00*	*7*	*7.14*	*2*	*3.33*	*4*	*13.33*	*0*	*0.00*	*0*	*0.00*	*13*	*6.22*
Retouch	0	0.00	6	6.12	1	1.67	0	0.00	0	0.00	0	0.00	7	3.35
Retouched Notch	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Backing	0	0.00	1	1.02	1	1.67	3	10.00	0	0.00	0	0.00	5	2.39
Convex	*0*	*0.00*	*5*	*5.10*	*4*	*6.67*	*2*	*6.67*	*0*	*0.00*	*0*	*0.00*	*11*	*5.26*
Retouch	0	0.00	4	4.08	3	5.00	0	0.00	0	0.00	0	0.00	7	3.35
Backing	0	0.00	1	1.02	1	1.67	2	6.67	0	0.00	0	0.00	4	1.91
Sinusoidal	*0*	*0.00*	*1*	*1.02*	*1*	*1.67*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.96*
Retouch	0	0.00	1	1.02	1	1.67	0	0.00	0	0.00	0	0.00	2	0.96
Shouldered	*0*	*0.00*	*1*	*1.02*	*1*	*1.67*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*2*	*0.96*
Retouch	0	0.00	1	1.02	1	1.67	0	0.00	0	0.00	0	0.00	2	0.96
Total	**13**	**100**	**98**	**100**	**60**	**100**	**30**	**100**	**6**	**100**	**2**	**100**	**209**	**100**

Table 10-18 Location and type of edge modification in the complete retouched and utilised flake assemblage, HD07-3A-03 rockshelter

Location	Surface		AU1		AU2		AU3		AU4		AU5		Total	
EM Type	n	%	n	%	n	%	n	%	n	%	n	%	n	%
RLE	*5*	*38.46*	*35*	*35.71*	*14*	*23.33*	*12*	*40.00*	*2*	*33.33*	*0*	*0.00*	*68*	*32.54*
Backing	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Retouch	4	30.77	15	15.31	8	13.33	6	20.00	1	16.67	0	0.00	34	16.27
Usewear	1	7.69	20	20.41	6	10.00	5	16.67	1	16.67	0	0.00	33	15.79
LLE	*5*	*38.46*	*25*	*25.51*	*17*	*28.33*	*5*	*16.67*	*1*	*16.67*	*1*	*50.00*	*54*	*25.84*
Backing	0	0.00	1	1.02	1	1.67	1	3.33	1	16.67	0	0.00	4	1.91
Retouch	4	30.77	11	11.22	9	15.00	1	3.33	0	0.00	0	0.00	25	11.96
Usewear	1	7.69	13	13.27	7	11.67	3	10.00	0	0.00	1	50.00	25	11.96
LLE + DE or PE	*2*	*15.38*	*7*	*7.14*	*9*	*15.00*	*5*	*16.67*	*2*	*33.33*	*1*	*50.00*	*26*	*12.44*
Backing	0	0.00	0	0.00	3	5.00	5	16.67	0	0.00	0	0.00	8	3.83
Burin	1	7.69	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00	2	0.96
Retouch	1	7.69	4	4.08	3	5.00	0	0.00	1	16.67	1	50.00	10	4.78
Usewear	0	0.00	3	3.06	2	3.33	0	0.00	1	16.67	0	0.00	6	2.87
RLE + DE or PE	*0*	*0.00*	*7*	*7.14*	*10*	*16.67*	*5*	*16.67*	*1*	*16.67*	*0*	*0.00*	*23*	*11.00*
Backing	0	0.00	2	2.04	4	6.67	5	16.67	1	16.67	0	0.00	12	5.74
Burin	0	0.00	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00	1	0.48
Retouch	0	0.00	3	3.06	1	1.67	0	0.00	0	0.00	0	0.00	4	1.91
Usewear	0	0.00	2	2.04	4	6.67	0	0.00	0	0.00	0	0.00	6	2.87
DE	*0*	*0.00*	*14*	*14.29*	*7*	*11.67*	*1*	*3.33*	*0*	*0.00*	*0*	*0.00*	*22*	*10.53*
Backing	0	0.00	1	1.02	0	0.00	0	0.00	0	0.00	0	0.00	1	0.48
Retouch	0	0.00	8	8.16	2	3.33	0	0.00	0	0.00	0	0.00	10	4.78
Truncation	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Usewear	0	0.00	5	5.10	5	8.33	0	0.00	0	0.00	0	0.00	10	4.78
PE	*1*	*7.69*	*9*	*9.18*	*1*	*1.67*	*2*	*6.67*	*0*	*0.00*	*0*	*0.00*	*13*	*6.22*
Backing	0	0.00	1	1.02	0	0.00	1	3.33	0	0.00	0	0.00	2	0.96
Retouch	0	0.00	6	6.12	0	0.00	0	0.00	0	0.00	0	0.00	6	2.87
Retouched Notch	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	0	0.00	1	0.48
Truncation	1	7.69	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.48
Usewear	0	0.00	2	2.04	1	1.67	0	0.00	0	0.00	0	0.00	3	1.44
DE + LLE + RLE	*0*	*0.00*	*1*	*1.02*	*2*	*3.33*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*3*	*1.44*
Backing	0	0.00	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00	1	0.48
Retouch	0	0.00	1	1.02	0	0.00	0	0.00	0	0.00	0	0.00	1	0.48
Usewear	0	0.00	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00	1	0.48
Total	**13**	**100**	**98**	**100**	**60**	**100**	**30**	**100**	**6**	**100**	**2**	**100**	**209**	**100**

Key: LLE – Left Lateral Edge, RRL – Right Lateral Edge, DE – Distal Edge, PE – Proximal Edge

The PRI is a measure of how much of an artefact's perimeter has been retouched, and it compares the length of the retouched edge to the perimeter length of the artefact. This index was determined for 78 complete retouched artefacts, and it shows that retouch occurs only on a small proportion of the total edge length on most artefacts. Discounting the single specimen in AU5, the results are fairly consistent for the other analytical units, with the average results ranging from 0.20 to 0.31. No artefacts have retouch along their entire perimeter. The high standard deviation values (which in the case of AU4 are greater than the average value) suggest that the data is not normally distributed, but is clustered around either the minimum and maximum values. After examining the data, it is obvious that most artefacts have limited retouch. The greatest number of artefacts had PRI values less than 0.25 (n=40), meaning that less than a quarter of the perimeter was retouched. Artefacts with PRI values between 0.26 and 0.50 were second in abundance (n=25), while there are 11 artefacts with PRI values between 0.51 and 0.75. Only two specimens exhibited retouch along over 76% of the perimeter.

When the PRI statistics are considered by raw material type, both chert and shale artefacts show a higher degree of retouch in comparison with BIF artefacts. Once again, there are high standard deviations within these samples. Larger samples would be required to further investigate if this pattern is a true reflection of the behaviours of the past knappers at Hope Downs 1.

The 103 complete retouched and utilised artefacts in the assemblage show an interesting pattern of decreasing size over time, and this parallels the data from the flake analysis. In AU5, the single retouched artefact is the largest in the sample (36.81-x-33.00mm), and the average values for each analytical unit decrease steadily to AU1, where the average specimen is 19.83mm long and 18.18mm wide. As with the flake data, the artefacts from the surface are slightly larger, measuring 26.00mm long and 20.06mm wide. The data appears to follow the general pattern of flake manufacture at the site; however, it is interesting to note that the average size of complete retouched artefacts is considerably larger than the average size of flakes in the assemblage.

Table 10-19 Summary statistics for the retouch length, GIUR, and PRI, HD07-3A-03 rockshelter

Measurement	AU	Average	Min	Max	SD	EM
A. Retouch Length (mm) by AU	Surface	9.90	2.87	28.74	8.33	9
	AU1	13.75	0.79	45.66	10.43	53
	AU2	13.68	1.18	47.6	12.77	32
	AU3	9.26	1.44	21.26	5.42	22
	AU4	12.18	4.83	16.62	5.32	4
	AU5	9.35	9.35	9.35	-	1
	Total	12.54	0.79	47.6	10.17	121
B. GIUR Statistics by AU	Surface	0.44	0.32	0.69	0.22	3
	AU1	0.63	0.20	1.00	0.29	23
	AU2	0.53	0.21	1.00	0.26	12
	AU3	0.61	0.25	0.95	0.22	7
	AU4	0.49	0.49	0.49	-	1
	Total	0.58	0.20	1.0	0.26	46
Measurement	**AU**	**Average**	**Min**	**Max**	**SD**	**n**
C. PRI Statistics by AU	Surface	0.20	0.11	0.31	0.09	4
	AU1	0.31	0.01	0.93	0.24	35
	AU2	0.28	0.02	0.73	0.22	23
	AU3	0.27	0.03	0.61	0.21	12
	AU4	0.21	0.03	0.49	0.24	3
	AU5	0.08	0.08	0.08	-	1
	Total	0.28	0.01	0.93	0.22	78
Measurement	**RM**	**Average**	**Min**	**Max**	**SD**	**n**
D. PRI Statistics by Raw Material	BIF	0.15	0.03	0.49	0.13	14
	Chert	0.31	0.01	0.93	0.24	43
	Shale	0.32	0.02	0.64	0.22	20
	Vitreous Goethite	0.26	0.26	0.26	-	1
	Total	0.28	0.01	0.93	0.22	78

Key: n – number of artefacts; EM – number of edge modification areas; RM – raw material type

Grindstones

Five artefacts in the assemblage have been classified as grindstones. Artefact 6262 (Figure 10-11) is a large grindstone produced on a tabular piece of BIF that was recovered from AU4. This artefact has at least five negative scars that were removed from one edge, which may have been removed in order to shape the artefact. Similar trimmed or dressed grindstones have been identified throughout Australia (*e.g.*, Smith *et al.* 2010; McCarthy 1976: 59). Only one surface (opposite the striking platform) appears to have been used as grindstone, with high areas exhibiting polishing and smoothing. The negative flake scars are worn where they meet this surface, indicating that the grinding occurred subsequently to the removal of the flakes. This artefact is similar to a grindstone fragment recovered from Jundaru (Artefact 17,795) that also has flakes removed from one edge and grinding on the surface opposite that used as the striking platform.

Artefact 717 is a small grindstone, which was possibly used as a muller. The grindstone was produced on a BIF river cobble that has a number of apparently natural fractures. The D-shaped grindstone has a plano-convex profile, with the underside retaining the natural, abraded surface of the river cobble. The flat side of the grindstone was created by a natural fracture, and it is this surface that exhibits evidence of grinding. Along the natural fracture, the coarse texture of the raw material can be seen. All of the high points on the ground surface have a polished and worn appearance. Artefact 54 is the largest grindstone recovered from the site, measuring 68.67mm long, 38.03mm wide, and 33.49mm thick.

Artefact 56 is a small (58.76-x-55.44-x-22.08mm) triangular, lower grindstone that was produced on a flat BIF slab. The grindstone was utilised on only one surface, which has a very smooth and polished appearance. Red pigment is embedded within the ground surface, and it is particularly noticeable around the perimeter.

Artefact 54 is the largest grindstone recovered from the site, measuring 111.24mm long, 88.53mm wide, and 31.88mm thick and weighing 487.4g. As with the other BIF grindstones, only one surface was utilised. The grindstone has a sub-rounded shape and a lenticular profile. Artefact 55 was classified as a possible lower grindstone, as it exhibits a smoothed surface, which is unusual for BIF. The artefact does not have clear evidence of grinding like the other specimens. Usewear analysis would be required to confirm the classification of this artefact.

Artefact Analysis Summary

The assemblage from HD07-3A-03 provides an excellent opportunity to study technological changes in artefact manufacture from the mid-Holocene through to the recent past. While two 1-x-1m units were excavated, the assemblage from HD07-3A-03 is the second largest of any of the excavated sites investigated as part of the Hope Downs 1 Mitigative Salvage Project. In total, 5180 artefacts were recovered from the site, including 57 artefacts that were collected from the surface of the rockshelter. Moreover, the overwhelming majority of the artefacts are considered to be diagnostic, including cores, flakes, retouched and utilised flakes, and grindstones. Non-diagnostic artefacts comprise only a small proportion of the assemblage.

The patterns of raw material procurement show that during the initial occupation (AU5 and AU4) chert was used moderately, while most other artefacts were manufactured from coarser-grained and widely available materials, such as BIF and shale. In AU3 (between approximately 2000 and 600 years ago), the knappers increased their use of chert and artefacts were less commonly produced from BIF. Shale use remained relatively consistent from the previous occupational phase. This pattern

continues with AU2 and AU1; although, there is a slightly lower frequency of chert artefacts in AU1.

There are 39 cores in the assemblage, making this one of the largest samples of cores from any excavated site at Hope Downs 1. The cores were primarily produced from coarser-grained raw materials and chert cores are under-represented in the assemblage. The low number of chert cores is incongruent with the high proportion of chert flakes, and it seems likely that many chert cores were taken from the site by the knappers. Throughout the entire occupation, the reduction strategies appear to remain consistent. Most cores are rotated, but there are also a small number of unidirectional cores. As with all of the Hope Downs 1 assemblages, core rotation appears to have been used as a method for prolonging the use-life of the core. Based on the pattern of the negative removals, it appears that the knappers removed flakes in a unidirectional manner from a single striking platform, only rotating the core once a problem was encountered (*e.g.*, problematic termination, crushed platform, poor angle on the platform, *etc.*). Most of the cores exhibit plain striking platforms and there is little evidence of modification or platform preparation. Most cores were discarded with cortex remaining on the surface, despite the fact that most were discarded in an exhausted state (due to problematic terminations, small size, raw material flaws, *etc.*). The cores were used predominantly to manufacture flakes, but seven cores exhibit both flake and blade scars. Taken together with the low proportion of blades in the assemblage, the data indicates that the knappers did not systematically manufacture blades. It is more plausible that many of the blades and blade scars were fortuitous.

The assemblage has a large number of flakes and flake fragments (n=4153), which are estimated to have been derived from a minimum of 2526 flakes (using the MNF index). Many of the flakes in the assemblage are broken transversely, and it is possible that the intensity of the occupation at HD07-3A-03 led to the trampling of many artefacts, resulting in this type of flake fragmentation. The assemblage included a small number of specific flake types, such as blades, spalls, and ridge blades. The dimensions of the complete flakes show that there is a general trend from slightly larger flakes in the earliest occupation to smaller flakes in the most recent phase of site use (AU1). This may be related to the increased use of chert (normally only available as small cobbles) or the slightly higher proportion of retouching flakes in the later phases of site use (as suggested by higher frequencies of retouched artefacts). Alternatively, the small sample sizes in the earlier analytical units may be affected by outliers in the data. As with the analysis of the cores, most flakes exhibit plain striking platforms and have no overhang modification, suggesting expedient reduction methods. In most cases, unidirectional scar patterns were observed, indicating that the knappers favoured unidirectional knapping. Most flakes have feather terminations, but there are a range of problematic terminations, such as hinge, step, and plunge. Axial terminations are relatively uncommon. As axial terminations can be produced through bipolar reduction, their presence in the assemblage may indicate that this reduction technique was used in some instances.

The retouched artefact assemblage includes a rare, large sample of backed artefacts and tulas, in addition to a range of other formalised retouched artefacts and non-formalised specimens. A variety of symmetrical backed artefacts were identified in the assemblage, including crescents, elongated crescents, trapezes, trapezes with no lateral backing, and triangles. Amongst the backed artefacts are a number of atypical specimens, that appear to have been re-shaped after a break or are in various states of manufacture. This suggests that while there was a template for backed artefact manufacture, resulting in the many classic forms, knappers did not feel limited to strict forms and adapted artefacts to suit their needs (*i.e.*, function over form). All of the tulas were discarded in an exhausted state, with one lateral edge slightly longer than the other lateral edge. While the sample is small, there appears to be a group of slightly larger tulas and a group of smaller specimens. Whether these sizes reflect deliberate choices or were irrelevant to the knappers remains unclear.



Figure 10-11 Grindstone from HD07-3A-03 rockshelter (Artefact 6262)

The analysis of the edge modification areas shows that similar techniques were utilised throughout the occupation history of HD07-3A-03. While there are some minor variations (*e.g.*, AU5 shows a lower degree of dorsal retouch than any other analytical unit), these are largely due to the small sample sizes in the earlier phases of occupation. In general, most retouch was steep and short, and it was predominantly created on the dorsal surface of the artefact. In most instances, the retouch did not alter the shape of the flake's edge (*i.e.*, regular delineation). There are similar instances of right and left lateral retouch, but distal retouch is more common than proximal retouch.

10.6 SPECIALIST STUDIES

Due to the significant flaked stone assemblage from the site, it was important to gain a better understanding of the site through the sedimentary, charcoal, and palynological analysis. This analysis also provides an important comparative dataset for the assemblage from HD07-3A-PAD13. Macrobotanical analysis was not conducted for this site due to the lack of combustion features, which are the preferred source of charcoal as it can be directly linked to the past human occupation of the site.

Sedimentary, Charcoal and Palynological Analysis

A series of sediment samples from Unit 1 (Layers 1-11) was submitted to PalaeoWorks for sedimentary, micro-charcoal, and palynological analysis. PalaeoWorks is the consulting arm of the Department of Archaeology and Natural History at the Australian National University. The analysis was carried out by Simon Haberle, Feli Hopf, and Phil Roberts, and their full report is presented as Chapter 13 of, this volume. The following paragraphs summarise their results and correlate them with the archaeological patterns and chronology for the site.

Within the sequence, there is a peak in burned grass phytoliths in Layer 8 (approximately 3241±52 cal BP), which occurs in AU4. Haberle *et al.* (this volume) interpret this peak as indicative of a very local fire event in contrast to the regional fires that continuous throughout the deposit, as evidenced by the presence of micro-charcoal. Fires became more common after Layer 5 (*ca.* 603±32 cal BP), and this period comprises AU2 and AU1.

Above Layer 5, the preservation and concentration of pollen was high (Haberle *et al.*, this volume), and this may be due to the relative young age of these deposits. There appears to have been a very recent shift to an increase in grasses. The pollen in Layer 4 documents the presence a range of woodland species (*Corymbia* sp., *Eucalyptus* sp., *Melalueca* sp., *Calytrix* sp., and *Acacia* sp.), which have a reduced presence in Layer 1 (Haberle *et al.*, this volume).

10.7 DISCUSSION

HD07-3A-03 is a small rockshelter in Hope South that has evidence of occupation from the mid-Holocene until the recent past. In the middle of AU3, which is estimated to date between 2000 and 600 years ago, there was a sharp rise in site use, as indicated by high artefact densities. This pattern of concentrated site use continued and intensified until the recent past. This site has one of the greatest artefact densities recorded of any excavated site at Hope Downs 1, second only to Jundaru. HD07-3A-03 is considered to have a moderate archaeological significance due to the abundance of flaked stone artefacts and the diversity of the artefact assemblage. The large assemblage provides important evidence regarding the timing of key retouched artefact types, particularly tulas, burins, and burrens.

The timing of the appearance of formalised retouched artefacts, such as backed artefacts and tulas, remains an important theme of archaeological research in the Pilbara. The lowermost backed artefact at the site occurred in AU4 (*ca.* 3800 to 2000 years ago); hence, PAD 3 continues to provide the best evidence for the introduction of backing technology in the local area (see Law and Cropper 2011: 173). No backed artefacts were recovered from the surface of the rockshelter, but seven symmetrical backed artefacts and ten backed artefact fragments were identified in AU1. Many of these specimens were recovered from the first arbitrary excavation layer, demonstrating that backed artefacts continued to be an important component of the tool kit at least until the last two to three centuries.

The tulas were restricted to AU1 and AU2, which represent the occupation of the site over the last 600 years, suggesting that tula use at HD07-3A-03 was restricted to the relatively recent past. This is consistent with the identification of a tula on the surface of rockshelter HD07-1A-02 (Cropper 2012). A tula was also found during the excavation of HD07-1A-07, and while the chronological context of the tula at HD07-1A-07 is not absolutely certain, it was argued that it may be contemporaneous with Feature 1 (866±46 cal BP) or slightly older (Cropper and Law 2012: 200).

The abundance and diversity of artefacts suggest the people who occupied the site carried out a wide range of tasks. Not only were a large quantity of flakes produced at the site, but many were utilised or retouched. Amongst the retouched artefacts are backed artefacts, tulas, burins, scrapers, and burrens. Ethnographic evidence indicates that burrens and tulas were typically used as adzes for woodworking (Sheridan 1979; Moore 2004; Tindale 1965; Horne and Aiston 1924). The usewear analysis of burins from Jundaru (see Fullagar, this volume) also showed that these artefacts were utilised for woodworking, but they may have been used for fine work, such as graving. The presence of tulas, burrens, and burins at the site provide good evidence to suggest that wooden artefacts were produced or maintained at the site. The fact that the tulas and burrens were discarded in slug form may also indicate that they had been de-hafted and replaced with new tools that could have been produced on-site. The assemblage also includes a large number of backed artefacts and three grindstones. These artefacts may have been utilised in food procurement and processing; although, this would need to be confirmed through usewear analysis.

Because no clear hearth features were identified at the site, the floated macrobotanical remains were not submitted for analysis; however, they have been archived for future research. One fragment of paperbark was recovered from Unit 2 (Layer 1, 26.5cmbd), and presently, paperbarks do not grow in the area around the site and are restricted to the riverine environments surrounding Weeli Wolli Creek to the east of the mining lease (Mattiske Consulting Pty Ltd 2009). Fragments of paperbark were also recovered at PAD 3 rockshelter. As a resource in the past, paperbark could have been utilised in a variety of ways, such as fire tinder, matting, containers, and bush medicine (Clarke 2007). A small faunal assemblage was also recovered from the site, primarily while sorting through the fine rock fraction. The faunal material has not been submitted for analysis, but it has been archived for future research.

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PART 3: SPECIALIST STUDIES

Chapter 11

Archaeomagnetic Analysis of Sediments from Djadjiling Rockshelter (HD07-1A-04), Pilbara, Western Australia

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11.1 INTRODUCTION TO ARCHAEOMAGNETISM

When thinking of the use of magnetic methods of analysis in archaeology, most researchers would perhaps think in terms of the palaeomagnetic analysis and magnetostratigraphic dating of earlier Pleistocene archaeological or hominin bearing sites (Herries *et al.* 2006; Braun *et al.* 2010; Dirks *et al.* 2010) by identifying 180° changes or reversals in the Earth's magnetic field fossilised in sediments and comparing this record against the known changes and ages of reversals as established in the Geomagnetic Polarity Timescale (GPT; Ogg 2012). More recently this research has also focused on identifying shorter magnetic events and excursions in the Earth's magnetic field that allow a more precise dating of archaeological and fossil deposits (Pickering *et al.* 2011; Herries and Shaw 2011; Herries *et al.* 2013). The term archaeomagnetism is most often used to describe the technique of archaeomagnetic dating of much more recent Neolithic to historic archaeological sites by looking at small palaeodirectional and palaeointensity variation of the Earth's magnetic field within a normal field state that is fossilised in burnt structures and pottery when they are baked and cool (Herries *et al.* 2007; Herries *et al.* 2008). However, archaeomagnetism in its broader sense (the use of mineral magnetic and palaeomagnetic analysis on archaeological sites and materials) has much broader implications and uses and can elucidate many different aspects of archaeological materials and sites (Herries 2009; Herries 2006; Brown *et al.* 2009; Herries and Fisher 2010). However, the integration of archaeomagnetism into excavations and post-excavation analysis as a standard technique is very rare, despite its cheap cost and ubiquitous use.

Archaeomagnetic analysis in this modern sense can be roughly divided into two types of analysis. Firstly, palaeomagnetic analysis to look at the direction and intensity of magnetic minerals fossilised in rocks, sediments or artefacts. The palaeomagnetic analysis of burnt artefacts and hearth rocks can help understand the heating histories of material from archaeological sites (palaeotemperature estimations) and behavioural activities such as the heat treatment of stone to make more refined stone tools (Brown *et al.* 2009). Secondly, mineral magnetic analysis (also known as Rock Magnetism or Environmental Magnetism; Walden *et al.* 1999) can be used to define the concentration and grain size of magnetic minerals present in sediments. To begin with this method aims to identify the presence of stronger ferrimagnetic phases (*e.g.*, magnetite and maghaemite) versus weaker anti-ferromagnetic phases (*i.e.,* haematite and goethite). Mineral magnetic analysis can be used to help characterize and source sediments and ochre (Mooney *et al.* 2003; Herries 2006), reconstruct palaeoclimatic signatures and identify combustion features, and spatial patterning in archaeological sites (Herries and Latham 2003; Herries and Fisher 2010; Herries 2009; Herries 2006). However, the formation history of the deposit and secondary anthropogenic alteration will define if or what information can be recovered from an individual site. If vastly different magnetic minerals are noted in different parts of a cave section, then this could relate to sediments being derived from different source rocks at different periods due to changes in hydrology if fluvial in origin or wind direction or strength if deposited by aeolian action (*i.e.,* soils formed on volcanic rock will be different from soils formed on limestone). In many cases this sediment source change is in itself driven by climatic factors and such changes are often noted between glacial and interglacial periods (Herries 2006). If sediments throughout the cave sequence are derived from a single rock type, then changes in climate related to changes in pedogenic enhancement outside the cave can also be detected. During warm, wet phases more strongly magnetic material is created (normally magnetite and maghaemite), while during cold, dry phases less magnetic material is created by pedogenesis in the open landscape and by weathering and erosion. In these cases the mineralogy is dominated by magnetic material derived from roof spall. This signature is preserved when sediments are deposited in caves or lake sequences. If pedogenic in origin, the change in the magnetic mineralogy can be used as a proxy for rainfall, while other signatures may relate to temperature or even such things as deforestation (Maher and Thompson 1999).

In archaeological cave sites any sedimentary or climatic signal will often be partly overprinted by an anthropogenic signal from the use of fire by humans. Heating sediments causes the conversion of weaker magnetic phases to stronger magnetic phases in a similar way to pedogenesis (Herries and Fisher 2010). However, different magnetic minerals will be formed and altered depending on whether the environment of heating is more oxidising or reducing. In reducing environments larger single domain magnetite is often formed and haematite formation is inhibited, while in oxidising environments finer grained, superparamagentic to single domain magnetite and maghaemite are formed and the sediments redden due to the formation of haematite, often from the conversion of maghaemite or goethite (Herries *et al.* 2007; Brown *et al.* 2009). In most Palaeolithic campfires a more mixed environment of heating occurs, although material around the edges and on the surface will be more oxidising, while material that has become buried under coals or is beneath the fire will be in a more reducing environment of heating. As such, the reddening of sediments under a campfire is not that common (Canti and Linford 2000). Moreover, heat transfer through deposits under campfires and so the alteration of older deposits is minimal, meaning that anthropogenic alteration has only a localised effect (Herries and Fisher 2010). Heating causes the formation of a distinct ultra-fine grain size of magnetite that is finer grained than that produced by pedogenesis in soils and so this helps the

effects of natural and anthropogenic processes to be distinguished (Herries and Fisher 2010). However, all this will all vary depending on the rock into which the cave is eroded and local climatic conditions as well as the temperature of heating in antiquity and so it is important to not overgeneralise between different sites and regions of the world and magnetic mineral variation is best interpreted on a case by case basis taking local factors into account.

11.2 RESEARCH AIMS

While archaeomagnetic studies to look at the effects outlined above has been conducted on Eurasian and South African caves and rockshelters (Ellwood *et al.* 1997; Herries 2006; Herries and Fisher 2010; Curnoe *et al.* 2012; Ji *et al.* 2013) this has never been attempted on Australian sites, or cave sites formed in banded ironstone. The aim of this study was to test such caves by undertaking an archaeomagnetic study of sediments from the Djadjiling (HD07-1A-04) rockshelter in the Pilbara region of Western Australia. The research presented in this paper is the first detailed magnetic mineralogical analysis of an Australian archaeological site and aims to show some of the information that is recoverable post-excavation from bulk sediment samples taken during excavation. In particular, the aim was to see if Australian rockshelters and in this instance, rockshelters in banded ironstone were suitable for archaeomagnetic analysis and recorded climatic or anthropogenic signals. Magnetic enhancement due to climate or anthropogenic effects is often more marked on rock types that contain weak magnetic phases. Banded ironstone contains large quantities of iron and so it was assumed that magnetic enhancement was likely to be limited, or potentially undetectable, when compared to sediments derived from other rock types. In general the greatest magnetic enhancement is often seen in deposits from less magnetic host rocks and in well-drained, poorly-acidic soils in a climate that produces wetting/drying cycles (Maher and Thompson 1999). Work on Middle Stone Age fireplaces in South Africa has identified a distinct character for burnt sediments (Herries and Fisher 2010). If an anthropogenic signal was recoverable from the Australian sites, another question was whether a similar pattern holds for burnt material. Other questions include whether there is a direct correlation between any anthropogenic or climatic signal and other indicators of occupation intensity such a lithic numbers. In other words, can the magnetic signal be used as an indicator of the intensity or longevity of the occupation of the rockshelter by humans. In South Africa it has been shown that short intensity occupation will only enhance the sediments marginally. It takes the reuse of a fire around four times for the sediments to be significantly enhanced (Herries and Fisher 2010). As such, minimal or single occupations of sites will have only minimal enhancement and heavily used sites will have greater enhancement, if fire use is associated with the occupation. Trends in mineralogy can therefore potentially show changes in site use and areas of use through time (Herries and Fisher 2010). A build-up of wood ash will cause the most significant magnetic enhancement and it is the ash, rather than burnt sediments that is the most magnetic due to the high proportion of ultra-fine superparamagnetic magnetite grains (Peters *et al.* 2002; Herries and Fisher 2010). Different fuel sources used for fires can also be characterised by their different magnetic signature (Church *et al.* 2007). However, the magnetic character of the ash is also in part dependent on the part of the tree that is burnt. Experimental tests have shown that in South African and Australian species that ash formed from the bark of trees or thick barked species is very magnetic, while ash from the core of the tree or from thin barked species is non-magnetic to only slightly magnetic. Thus while multiple fires producing thick ash beds will show up as magnetic hot spots, raked out hearths or hearths in environments where the ash is blown away or does not survive will not necessarily show the same magnetic enhancement. While fire always causes greater enhancement of the magnetic signal either due to burnt sediment or ash the combustion features overall value and degree of change is dependent on the base mineralogy of the deposits that are being burnt. Burnt deposits within glacial layers will have much less overall values than burnt deposits in interglacial layers because sediments formed during warmer periods are more magnetically enhanced due to increased pedogenesis. The magnetic signal, particularly magnetic susceptibility values which are most often used as a proxy for either fire use or climate effects in sediments sequences, can be a complex mixture of overprinting signals that need to be isolated to understand the factors driving the variation. The aim here was to see what processes are mainly driving any signals seen in the Pilbara caves and on a banded ironstone lithology.

11.3 SAMPLING AND METHODS

The benefit of mineral magnetic analysis is that samples can often be taken from reference samples after excavations have taken place and initial analysis is very cheap and quick. Although it is generally best if independent samples are taken using non-ferrous tools if the sites were excavated using iron trowels and sieves, especially old rusty ones that can cause iron contamination. If bulk reference samples are taken from every unit and feature excavated at a site, a multi-dimensional model can be built for the site to look at variation in both space and time (Herries and Fisher 2010). Only palaeomagnetic analysis requires the orientation of samples in the field during excavation so that oriented palaeodirectional date can be obtained. Such data if from a well dated site or feature can then be used to provide a reference point for the Australian Archaeomagnetic Curve (AAC) that is being developed by the Australian Archaeomagnetism Laboratory at La Trobe University. However, even without orientation the palaeointensity of the earth's magnetic field when that sample was burnt may be obtained and added to the AAC. Once fully developed the AAC will enable the dating of archaeological sites where conventional methods are not available or even surface scatters heat retainers or other baked material. Moreover, an analysis of the palaeotemperature of fire modified rocks and artefacts can also be obtained from such non-oriented samples be they deliberately or accidentally burnt.

Thirty eight samples for archaeomagnetic analysis were taken from sieved bulk samples taken from all stratigraphic layers at Djadjiling, with an additional 8 samples taken from potential combustion features. Samples were sieved of large clasts, ground, air dried and packed into standard Bartington plastic sample tubs (2.5cm diameter, 10cc). Stratigraphic layers were defined by subtle changes in sediment colour and matrix composition during archaeological excavation. Because the sediments have extremely strong magnetic susceptibility values the standard 10cc (10g) samples had values too large to measure on Bartington MS2 meter. Samples were thus packed into containers holding roughly 5g of sediment. Samples were then subjected to a suit of mineral magnetic tests as per Herries and Fisher (Herries and Fisher 2010; SOM also see Walden *et al.* 1999 for methodology of magnetic tests). This included dual frequency and low temperature magnetic susceptibility measurements using the Bartington MS2 equipment and IRM (isothermal remanent magnetization) acquisition curves and backfields, hysteresis loops and thermomagnetic curves using a Magnetic Measurements variable field translation balance (VFTB).

The sediment samples were first subjected to dual frequency (low and high; χ_{LF} and χ_{HF}) magnetic susceptibility (MS is taken to be χ_{LF} throughout; $x10^{-6}$ m^3/kg^{-1}) measurements. MS gives an idea of the bulk iron content as well as the percentage of fine to ultra-fine ferrimagnetic grains (magnetite/maghaemite) by working out the frequency dependence of magnetic susceptibility (χ_{FD}%). The samples were then processed on a Magnetic Measurements Variable Field Translation Balance (VFTB) to provide isothermal remanent magnetisation (IRM) acquisition curves and backfields, hysteresis loops, and thermomagnetic curves. This analysis provides detailed information of the magnetic minerals, grain sizes, and concentrations of the various magnetic minerals present in the sediments. This is primarily done by a comparison of the coercivity of the samples (how easily they acquire a remanence in and out of field) and analysis of the Curie or Néel point of minerals in the sample (*i.e.,* the temperature at which a samples magnetisation is randomised [paramagnetic]; ~585ºC for magnetite and ~680ºC for haematite). Magnetically strong ferrimagnetic minerals such as magnetite and maghaemite have a low coercivity and are magnetically soft, saturating in fields below 300 mT and weak anti-ferromagnetic minerals such as haematite or goethite are magnetically hard and have a higher coercivity and will not saturate in fields of 1T. Thermomagnetic curves will also identify the magnetic alterations that occur when the sample is heated which is due to a range of different minerals with different Curie Points existing in many samples. Where alteration is identified in the samples hysteresis loops and thermomagnetic curves were run after the first heating had been undertaken in the sample. Low temperature magnetic susceptibility measurements (χ_{LT}; x10-5 SI) were also undertaken on sister specimens. This is a good way of differentiating between lower coercivity minerals magnetic grain size and has been used as a way of characterising burnt deposits (Herries 2009; Peters *et al.* 2002).

11.4 RESULTS AND DISCUSSION

13.4.1 Magnetic susceptibility (MS)

The magnetic susceptibility (MS) sequence shows a distinct fluctuating signal consisting of relatively low MS in Layers 7, 5, 4, and 3 and high MS in Layers 6, 1, and 2 (Figure 11-1). Fluctuating MS values roughly correlate to specific layers. Because of the iron-stone host rock, the MS signal is much higher than seen in karstic caves or pseudo-karst weathered on sandstone where such studied have been done previously (Ellwood *et al.* 1997; Herries and Fisher 2010; Herries 2006). The high iron content is shown by the dark brown to reddish-brown colour of the sediments. χ_{FD}% values (2-5%) are relatively consistent throughout the sequence and low compared to temperate European and tropical cave sequences (Ellwood *et al.* 1997; Ji *et al.* 2013; Curnoe *et al.* 2012) where the primary deposition is due to an influx of eroded local soil (Figure 11-2). These values suggest an admixture of superparamagnetic and single domain grains likely forming in a relatively dry climate. In contrast χ_{FD}% values for tropical sediments can be close to the maximum expected for natural samples (~15%; Figure 11-2; Walden *et al.* 1999). The sediments therefore have ferrimagnetic material likely derived from a combination of erosion of externally derived soils from outside the rockshelter as well as a major component from weathering and erosion of the local bedrock.

Law *et al.* (2010) note that the majority of the deposit consists of angular rock fragments produced through spalling and exfoliation of the rockshelter roof and walls, while the remainder of the deposit is comprised of silt derived through chemical weathering of the rockshelter host rock and aeolian deposition. Host rock material from erosion outside the rockshelter will be more heavily altered and enhanced than that that eroded from the walls as roof spall and this also accounts for the variation in the magnetic signal with phases where more sediment is derived internally than externally. Higher χ_{FD}% values suggest warmer, slightly wetter phases when pedogenesis causes magnetic enhancement, while lower χ_{FD}% values reflect colder phases or when in conjunction with high χ_{LF} values, anthropogenic overprinting. Herries (2006)and Herries and Fisher (2010) have noted that *in-situ* hearths have a distinct character of high χ_{LF} and lower χ_{FD}% than surrounding deposits due to the very high percentage of ultra-fine grained, superparamagnetic (SP) grains that are smaller than those detected by the Bartington Dual Frequency measurements, which preferentially measure SD-SP boundary grains. Higher χ_{FD}% values are particularly noted in the Holocene Layers 2 and the top of Layer 1. An overall decrease in χ_{FD}% occurs from layer 5 through to Layer 3 showing a cooling in climate from MIS 3 through to the LGM in Layer 3. In a comparison of χ_{LF} versus χ_{FD}% a number of different zones can be identified:

- ZONE 1 (200-175cmbd) Layer 7: low χ_{LF} and medium χ_{FD}% anthropogenically unaltered deposits.
- ZONE 2 (175-150cmbd) Layer 6: high χ_{LF} and medium to low χ_{FD}% anthropogenically altered deposits.
- ZONE 3 (145-60cmbd) Layer 5-3: Low χ_{LF} and high χ_{FD}% with occasional low χ_{FD}%, high χ_{LF} layers. Colder, drier climate deposits with occasional anthropogenic combustion features.
- ZONE 4 (60-25cmbd) Layer 2: High χ_{LF} and high χ_{FD}% relatively unaltered deposits formed during a warm climate phase.
- ZONE 5 (25-10cmbd) Layer 1: High χ_{LF} and low χ_{FD}% suggesting heavy anthropogenic alteration during a warm climate phase.

13.4.2. Coercivity Measurements

Coercivity studies suggest there is generally only very subtle variation in the ferrimagnetic mineralogy of the deposits which is dominated by low coercivity ferrimagnetic material (Figure 11-3 and Figure 11-4). Domain state plots (Figure 11-4) lie in the pseudo-single domain grain size range. PSD grains are larger grains that act like smaller single domain (SD) grains rather than larger multi-domain (MD) grains. Low MS glacial deposits plot further towards the MD grain size, which is produced by weathering of the rockshelter walls. Low temperature magnetic susceptibility data (χ_{LT}) of similar glacial sediments show a mixed SD, MD, and SP signature. This is because the samples, like most natural samples, contain a mixture of grain sizes and mineralogies. These grains have undergone maghaematization due to low temperature oxidization and weathering of exterior grain surfaces. This may indicate that the PSD character is due to a complex mixture of all of these grain sizes from weathering of the rockshelter walls, erosion and weathering of ironstone, and reduced pedogenesis. Interglacial deposits have little evidence of this MD character from the χ_{LT} curves. IRM20mT indicates the total ferrimagnetic component in the samples. High IRM20mT values occur in Layer 6 and 1 and are lowest for Layer 3, 4, 5, and 7 showing a good correlation with MS and suggesting it is primarily driven by the variation in ferromagnetic minerals. However, the Layer 3 LGM deposits have a much higher anti-ferromagnetic content that reflects a change in the weathering regime and input into the rockshelter deposits. If only ferrimagnetic material (magnetite and maghaemite) exists, then the isothermal remanent magnetization curve (IRM; Figure 11-3) will saturate

at an induced field of 300mT. However, if anti-ferromagnetic material also exists, then the curve will not saturate and continue to increase after 300mT is applied. As can be seen Figure 11-3, samples from glacial Layers 3 and 4 have a much lower ferromagnetic component and higher anti-ferromagnetic component than the interglacial deposits from Layers 1 and 2 as shown by their non-saturation in fields of 300mT. Hysteresis loops of the Layer 3 and 4 Layers have a slightly wasp waisted appearance, while those from Layers 1, 2, and 6 are pot-bellied again indicating the mixed ferrimagnetic/anti-ferromagnetic nature of the glacial sediments.

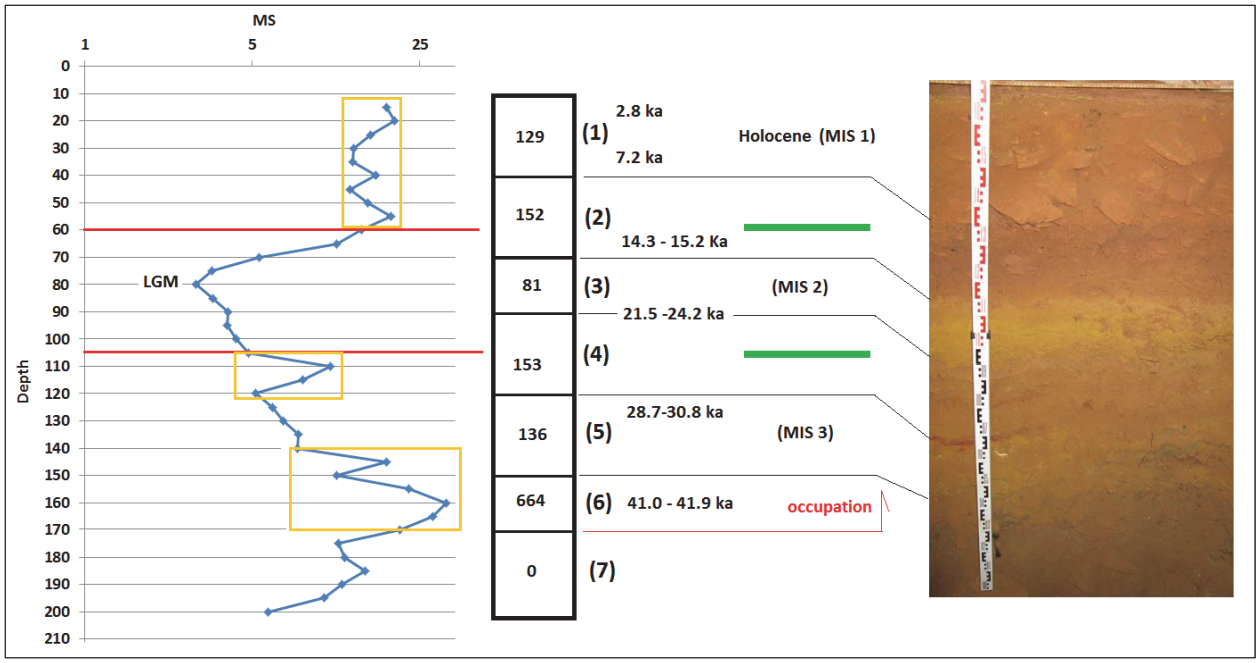

Figure 11-1 Magnetic susceptibility (MS) measurements (not including excavated combustion features) versus layers of stratigraphy (Layers 1-7), artefact numbers (in box from Law *et al.* 2010), radiocarbon chronology (ka cal BP) and marine isotope stages (MIS 1-3)

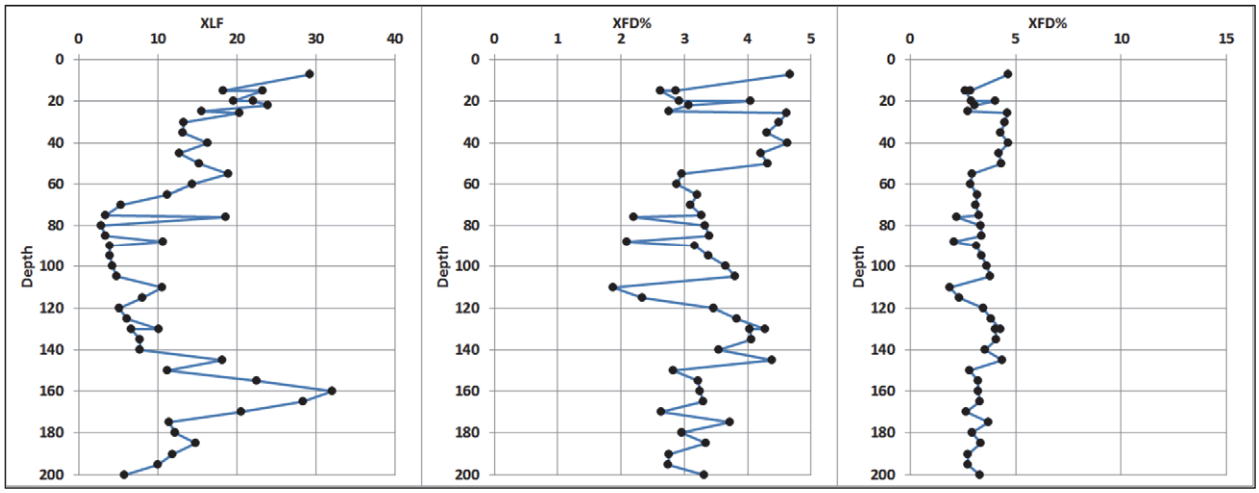

Figure 11-2 χ_{LF} and χ_{FD}% values for column samples and excavated features

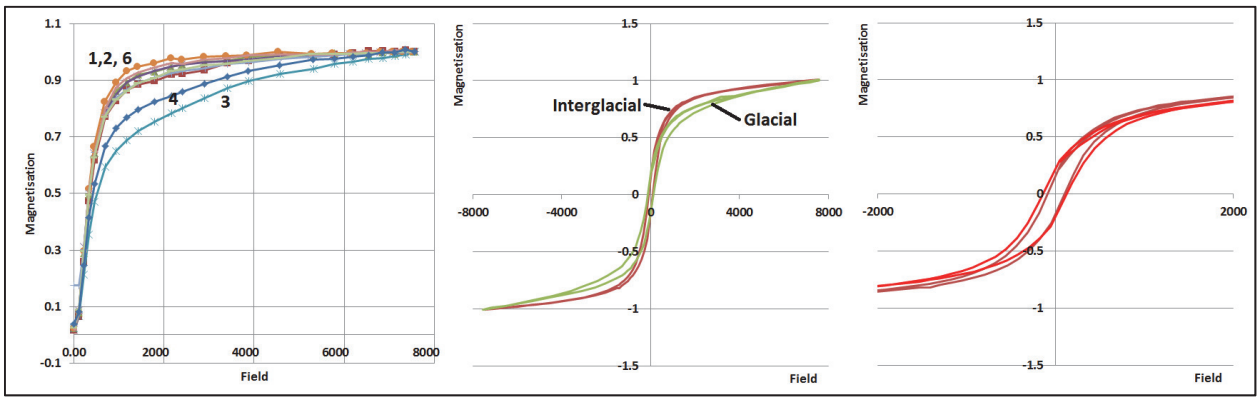

Figure 11-3 a) IRM acquisition curves for the various layers; b) Hysteresis loops for glacial and interglacial deposits; c) hysteresis loops for deposits before and after heating in the laboratory. Field units are presented in oesteds and the plots are normalised.

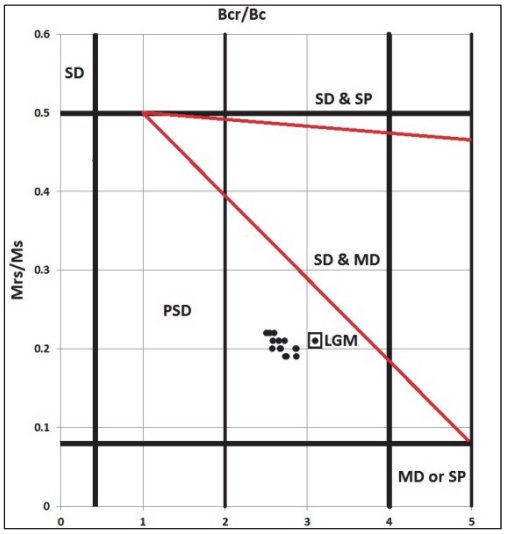

Figure 11-4 Domain state plot for the sediments. the samples all cluster at the SP end of the pseudo-single domain (PSD) grain size range and indicate little difference in the ferromagnetic grain size throughout the section. only the low MS sediments representing the LGM separate from the main group

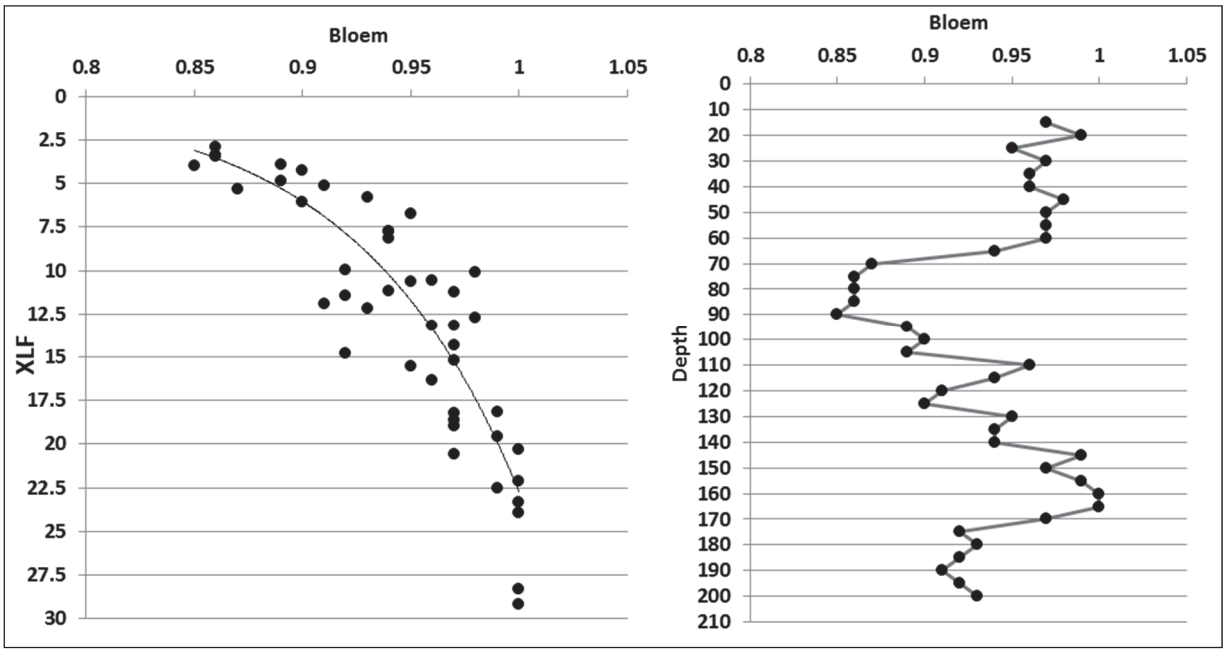

Figure 11-5 a) Plot of the exponential correlation between magnetic susceptibility and the bloemendal parameter; b) bloemendal parameter versus depth (cmbd; excluding excavated combustion features)

The Bloemendal parameter (Bloem) can be used to distinguish between a dominance between ferrimagnetic and antiferromagnetic minerals (Walden *et al.* 1999). If the samples are completely dominated by ferrimagnetic minerals they will have values close to 1, the closer they are to 0, the more antiferromagnetic material exists. Figure 11-5 compares MS and Bloem and shows an exponential relationship between the two with a very similar trend in Bloem when compared to the stratigraphic trend of MS (Figure 11-1). Bloem values peak in MIS 3 Layer 6 and interglacial Layers 1 and 2 and are lowest during LGM Layer 3. Again this suggests that the ratio of ferrimagnetic material to antiferromagnetic material is changing in the coldest layers. This indicates the sequence is dominated by the input and concentration of ferrimagnetic minerals, likely through aeolian action, as well as changes in the weathering regime of the rockshelter. This mineralogical signature suggests the MS sequence is primarily being dominated by a single sedimentary source input that is controlled by climatic fluctuations outside the rockshelter due to erosion, weathering as well as some change in pedogenesis.

MS change in this circumstance is most often influenced by changes in both temperature and more importantly precipitation. During warm, wet phases larger amounts of ferrimagnetic material are formed, while during cold, dry phases fewer ferrimagnetic phases are formed and there is less chemical alteration of anti-ferromagnetic phases formed by weathering of the host rock. Moreover, there appears to be increased erosion rates during these warm phases. The MS signal indicates a cold climate signal in Layer 7, a slightly warmer phase during Layer 6 and then an increasing cold signal from Layer 5 through to the coldest period in Layer 3. The pattern in Layers 5 to 3 suggests gradual, slow sedimentation of externally derived deposits from a single sediment source augmented by increased weathering of the rockshelter walls. The climate warms significantly during Layer 2 and plateaus in Layer 1. Based on the radiocarbon dating of this sequence (Law *et al.* 2010), Layers 7 to 4 represent marine isotope stage 3 (MIS 3) and the low MS Layer 3 represent the LGM. Layer 2 represents the end of MIS 2 and the Pleistocene to Holocene transition (16-11 ka cal BP). Layer 1 is dated to the mid to late Holocene.

The mineralogical change also suggests there is a degree of secondary anthropogenic alteration once the material has been deposited in the rockshelter. Figure 11-6 shows plots of MS and Bloem versus depth including combustion features identified during excavation. Both MS and Bloem easily identify the Layer 3-5 combustion features that have baked the weaker glacial sediments with high values for both that approach the values seen for Layers 1-2 and 6. This is due to the transformation of weaker magnetic phases to stronger magnetic phases (magnetic enhancement) during heating that causes an increase in both Bloem and MS. Studies have shown that the use of fire causes the magnetic enhancement of sediments due to heat (Herries *et al.* 2007; Herries and Fisher 2010; Herries 2009), where weak antiferromagnetic phases and amorphous iron are transformed to magnetically stronger ferrimagnetic phases. Studies suggest that the transformation of magnetic minerals is greater if the deposit is heated to above 300°C (Brown *et al.* 2009) and so deposits where significant thermomagnetic enhancement is identified have likely been heated to above 300°C. However, if a reducing environment exists during heating and cooling then magnetite may be formed but if an oxidizing environment exists then the weaker maghaemite phase will primarily be formed. Purely reducing conditions as seen in an oven can actually create larger stable single domain grains and inhibit pigmentary haematite formation (SSD; Herries *et al.* 2007), while more oxidising and mixed conditions preferentially form ultra-fine grained, superparamagnetic phases. As the atmosphere of campfires will be highly variable it is likely that a mixture will result. However, a situation where the coals are undisturbed during cooling is likely to result in a greater proportion of magnetite.

Because the magnetic susceptibility of the LGM Layer 2 sediments is so low (mean MS 4.0) compared to those from the overlying Holocene Layer 1 (mean MS 15.7), the degree of enhancement seen in *in situ* combustion features is far more marked in the LGM Layers (5 times the background MS value with an increase in MS from 4.0 to 18.6). Overall, thermomagnetic enhancement is most noticeable in the MS and Bloem parameters during cold phases because there are greater quantities of weaker magnetic material to alter to stronger phases than in warmer phases where the sediments outside the rockshelter have already been enhanced before deposition. This is, as in Africa, likely more so in Australia where not just pedogenesis, but perhaps more importantly natural bushfires will help the formation of fine top ultra-fine grained ferrimagnetic phases. The grain size of pedogenically enhanced material versus thermally enhanced is subtle with thermally altered material being much finer grained. However, as shown above the use of χ_{FD}% easily identifies anthropogenic combustion features in warmer periods.

In the Holocene layers the increase from background values of 15.7 to enhanced values of 29.2 is slightly less than a twofold increase (Figure 11-7). The high magnetic susceptibility values in Layer 6 are due to a complicated signal where a slight warmer phase occurred during MIS 3 and the MS has been further enhanced by anthropogenic alteration and spread of this material throughout the deposit. This is shown by the slightly lower χ_{FD}% values for this layer. This suggests intense occupation of the rockshelter at this time period. In contrast combustion Feature 4 from the LGM Layer 3 is by far the most prominent and most magnetically enhanced deposit in the rockshelter; however, the lack of a background anthropogenic signal suggests this occupation was very minimal, especially as this hearth is from the same excavation unit (4) as the column sample. Combustion Feature 9 is the least prominent and suggests minimal alteration of the deposits. Combustion Feature 8 occurs in Layer 4 close to where the magnetic susceptibility signal also picks up evidence of anthropogenic alteration in the sampled section. The base of Layer 5 also has an anthropogenic signal. Layer 7 shows no evidence of anthropogenic alteration. During the terminal Pleistocene to Holocene Layers 1 and 2, the Holocene Layer 1 has the strongest anthropogenic signal and all the combustion Features have a maximum Bloem value of 1. Combustion Feature 7 is particularly noticeable in the magnetic susceptibility curve, but Features 1, 2, 5, and 6 all stand out from the background sediments from the same level as can be seen from Figure 11-5.

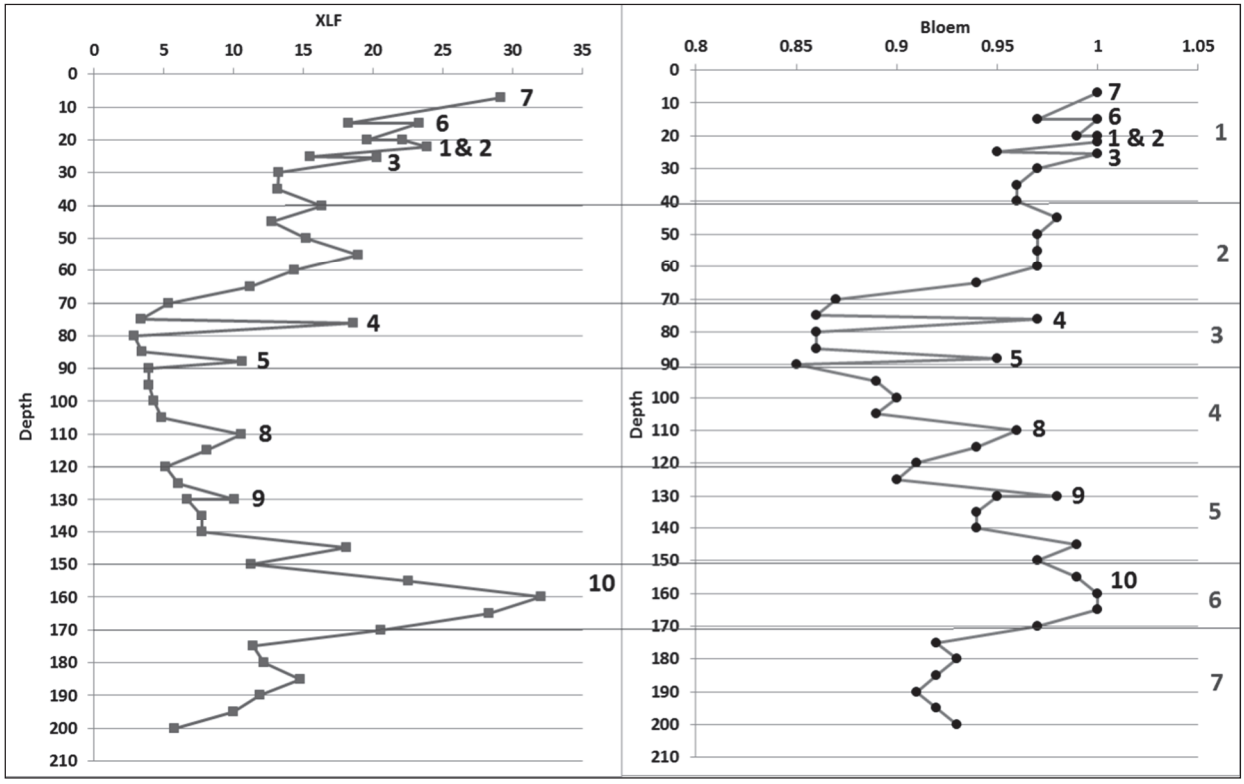

Figure 11-6 a) Plot of magnetic susceptibility (χ_{LF}) including combustion features identified during excavation (Features 1-10) and b) bloemendal parameter including excavated combustion features (Features 1-10) versus depth (cmbd)

13.4.3 Thermomagnetic Curves

To further identify the mineralogical changes through the section as well as the degree of alteration of burnt versus unburnt deposits thermomagnetic curves were undertaken on the samples. Thermomagnetic curves are particularly useful for understanding the exact minerals present in a sample by identifying their Curie point or Néel temperature, the temperature at which magnetic ordering is lost (*e.g.*, pure magnetite has a Curie point of 585°C). Figure 11-8 shows thermomagnetic curves from the various stratigraphic layers at Djadjiling. These indicate a complex ferrimagnetic mineralogy for many of the deposits. There is a noticeable difference in the ferromagnetic fraction for glacial versus interglacial deposits, but most sediments indicate a mixture of grain sizes of magnetite and maghaemite. The Holocene deposits (Figure 11-8: c) show a large increase in magnetization on cooling with Curie points of slightly less than 600°C, suggestive of magnetite. On cooling a distinct phase transition occurs around 500°C where the ferrimagnetic phase formed during the initial heating run is further transformed to greater amounts of ferrimagnetic material. A second heating of this Holocene sample suggests the phase being formed is thermally stable maghaemite (Curie point ~620ºC) as shown by a Curie point for the second run just above 600°C and a drop in magnetization on cooling due to the formation of haematite. Based on hysteresis loop data (Figure 11-3: c) there is little suggestion of a change in the coercivity of the ferrimagnetic phases before and after heating. Hearths from the Holocene layer have a Curie point suggestive of maghaemite, just above 620ºC, but with a phase transition on cooling that suggests magnetite is also partially formed. This phases transition and the increase in magnetization on cooling suggests the deposits had not been entirely thermally altered in antiquity and heating to a temperature less than ~500°C.

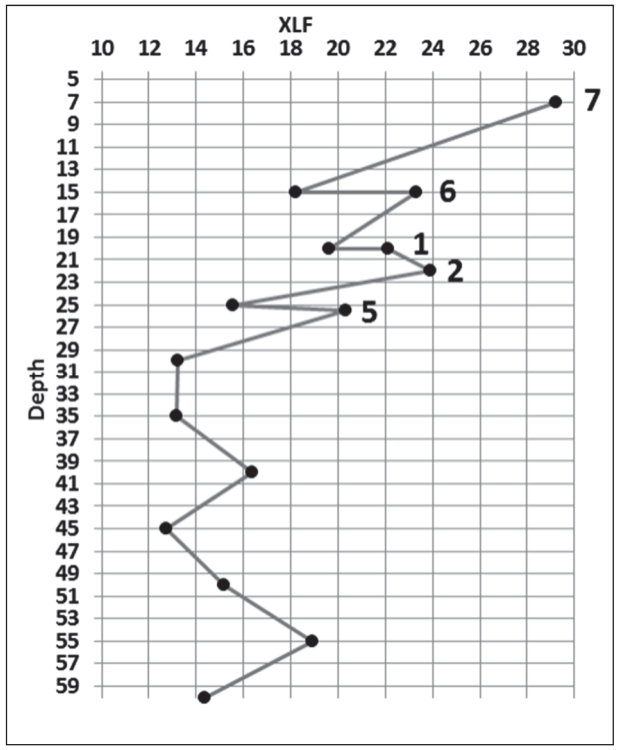

Figure 11-7 Magnetic susceptibility (χ_{LF}) versus depth (cmbd) for the Holocene layers including combustion features (Features 1, 2, 5-7) identified during excavation

The Holocene, interglacial sediments have a much higher magnetization than samples from the preceding glacial periods (MIS 2-3). This is due to the overall lower amount of ferrimagnetic material versus antiferromagnetic material in the glacial deposits, as shown by Bloem. LGM samples (Figure 11-8: c) have a distinctly different mineralogy to the Holocene layers. A number of magnetic phase transitions are noted during heating at approximately 200°C, 400°C, and 550°C with the final Curie point being just above 600°C, and indicating thermally stable maghaemite as also shown by the drop in magnetization on cooling with the formation of haematite. Haematite is also formed due to the dehydration of goethite between 200 and 400°C. These deposits therefore have a complex mineralogy with goethite, haematite, magnetite, and maghaemite being represented. This mixture is related to weathering during this cold phase as well as some minimal influence from human occupation. *In situ* weathering of the ironstone produces goethite within the rockshelter and accounts for the yellow colouration of the Layer 3 LGM layers. Outside the rockshelter this goethite will be transformed to haematite due to low temperature dehydration in arid climates as well as due to wildfire burning of the landscape. Burnt deposits that have been identified in these LGM Layers have a mineralogy that is extremely similar to the unaltered Holocene Layers although with a larger increase in magnetization on heating due to the less altered state of the LGM deposits. The phase transition at ~500°C is also less well defined. The increase in magnetization on heating is even greater in these samples because less antiferromagnetic material has been previously altered by increased pedogenesis in the exterior environment, as is the case in the Holocene.

The Layer 6 deposits (Figure 11-8: e) have a character more similar to the Holocene sediments with a large increase in magnetization on heating and a Curie point of slightly less than 600°C, suggesting magnetite. A phase transition occurs around 200°C, which could also suggest low temperature maghaemite. After heating, the Layer 6 deposit also has a curve similar to the secondary heating curve for the Holocene deposits, except that there is less of a drop in magnetization on heating. This curve lacks the goethite signature seen in other glacial sediments and indicates this phase has already been transformed due to heating. This mineralogical character suggests that the Layer 6 deposits have been, altered by anthropogenic processes, but there is a suggestion that this occurs on top of a signal caused by a slight warming in the climate during this period. Samples from glacial Layer 7 (Figure 11-8: f) have a similar character to the LGM sediments, but the various phase transitions, while still present, are less well defined. This is because a larger ferrimagnetic component already exists in the samples due to the deposits having formed in a warmer, likely early MIS 3 climate. In comparison the base of Layer 7 has much less ferrimagnetic material and might represent cold climates at the very end of MIS 4. Sediments during the transition from the Upper Pleistocene to Holocene have an overall character similar to the Holocene layers; however, there is less of an increase in magnetisation on cooling. This difference purely represents a difference in the concentration of ferrimagnetic minerals related to warming climate during this period.

13.5. Discussion And Conclusions

While the sedimentary source for the deposits seems to be the same throughout deposition of the sequence at Djadjiling, the influence exerted by internally derived and externally derived sediment differs significantly through the section and the anthropogenic alteration of those sediments before and after they were deposited in the rockshelter is also different in different Layers. These differences are primarily influenced by climatic factors and their effect on weathering, erosion, and pedogenesis, which is in itself a reflection of temperature and moisture changes. The externally derived aeolian component is dominated by strong ferromagnetic phases, maghaemite, and magnetite, while the weathering component is dominated by antiferromagnetic phases notably goethite and haematite. During warm, wet phases ferrimagnetic material dominates, while during cold, dry phases ferrimagnetic input is more limited and an increase in weaker antiferromagnetic phases from weathering are present. During cold phases this internally weathered component is dominated by goethite, while during warm phases weathered goethite is altered to haematite. Overprinting this climatically determined signal is an anthropogenic signal where fire use converts the weaker phases into stronger ferrimagnetic phases. This is most evident in Layers 1, 6 and the lower part of 4. Again, how the fire converts the deposits is dependent on whether the unburnt deposits are glacial or interglacial in origin and as such how much ferrimagnetic enhancement and alteration they have already undergone. In cold, glacial phases goethite is converted to haematite and other strong ultra-fine ferrimagnetic phases are also created. During these glacial periods combustion features should be obvious as red-orange lenses within the goethite rich, yellow unaltered sediments. Layer 6 has the greatest anthropogenic overprint and suggests more intense occupation of the rockshelter during this period. This is confirmed by a high density of artefacts at this time (see Figure 8-13 and Table 8-6, Chapter 8 - this volume). The Holocene layers also show significant anthropogenic alteration in the form of discrete combustion features but these deposits have also been ferrimagnetically enhanced and altered due to natural processes. Artefact density for this layer is not particularly high compared to the other layers in the sequence and this may reflect a short, intense occupation, rather than a more sustained Layer 6 (~42-41 ka occupation). A more limited occupation is also suggested in the base of Layer 4 and the base of Layer 5. Combustion features are also noted in Layers 3 and the top of Layer 5 but there is little evidence for heavy alteration of the background deposits, which suggests little disturbance of the hearths occurred after their use, suggesting little reuse of the hearths and a sporadic use of the rockshelter. Hence, while the rockshelter was occupied during the coldest phase of the last glacial cycle this consisted of very short, ephemeral visits,

In conclusion, the Djadjiling sequence suggests the following. The low MS in the base of Layer 7 is perhaps suggestive of a terminal MIS 4 age, perhaps around 58 ka, although a colder phase during MIS 3 could also account for this. An intense occupation of the rockshelter is suggested during Layer 6, MIS 3 times ~42-41 ka. Occupation continues through to early Layer 5 MIS 3 times. As the climate declines through Layer 4and into Layer 3 during the cold, dry LGM period there is not an intense and regular use of the rockshelter, but sporadic occupation events still occur throughout this period with distinct, undisturbed fire events. As the climate warms into the Holocene the shelter is still used sporadically and a short intense occupation then occurs in the Middle to Late Holocene. This sequence establishes for the first time that caves on iron rich substrate, such as banded ironstone, is suitable for this analysis. It also shows how archaeomagnetic analysis can be used both to understand climate change through time at a site and if a climatic sequence such as this exists it could be used as a course dating proxy. Moreover, the effect of human occupation on such a signal and how archaeomagnetism can be used to identify the presence of human fire use in a cave sequence and the intensity of that occupation can be established. If sediment samples are taken from every quad and unit of an excavation then more complex multi-dimensional models of site use through time can

be attempted as per Herries and Fisher (2010). When combined with the palaeomagnetic analysis of burnt rocks (Herries, 2009; Brown *et al.*, 2009) an even more powerful tool for understanding the thermal history of sites and artefacts can be established for a site. Such work could be used to help resolve whether occupations of caves and rockshelters definitely occurred when only a few artefacts exist at the site with dubious context, as has been a matter of debate at some northern Australian sites (Hiscock 2008). Given these benefits, the cheapness and ease of the analysis, at least with regards the base magnetic susceptibility measurements is something that should be incorporated into every archaeological analysis.

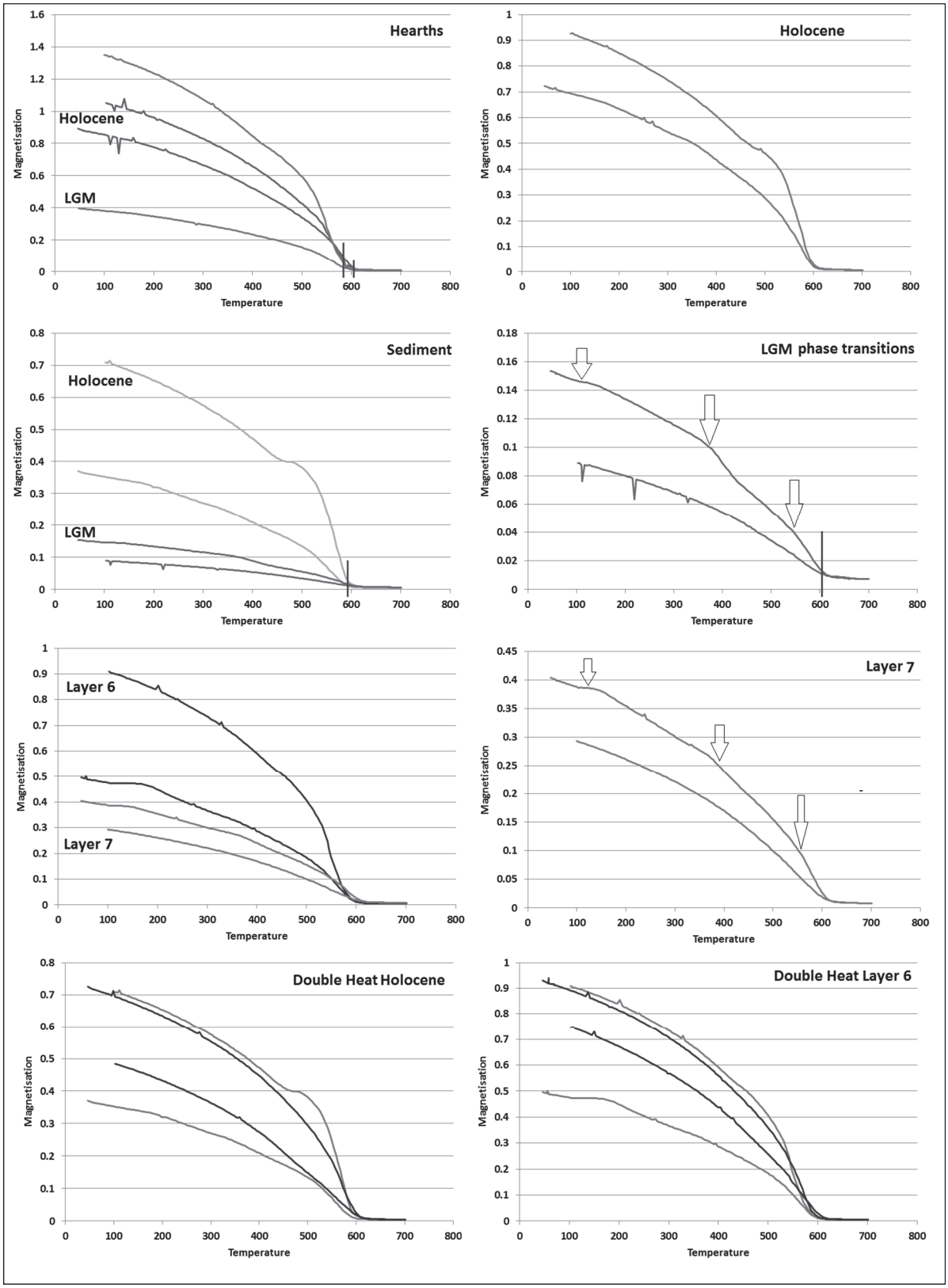

Figure 11-8 Thermomagnetic curves for Djadjiling deposits (left to right from top: a and b, second row: c and d, third row: e and f, and bottom: g and h)

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Chapter 12

Phytolith Analysis of Sediment Samples from Djadjiling (HD07-1A-04), Jundaru (HN-A9) and HD07-3A-PAD13, Pilbara, Western Australia

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12.1 INTRODUCTION AND AIMS

UniQuest Pty Limited was engaged by ACHM to undertake a specialist phytolith analysis relating to the archaeological rockshelter sites of Djadjiling (HD07-1A-04), Jundaru (HN-A9 and formerly known as Malea Rockshelter), and HD07-3A-PAD13. Jundaru is in the area of the Hope North Mine Pit, while Djadjiling and HD07-3A-PAD13 are in the area of the Hope South Mine Pit, within the Hope Downs 1 Mine in the Pilbara region of Western Australia. Geologically all three sites lie are situated in the Marra Mamba Iron Formation.

Sediment samples from Djadjiling, Jundaru, and HD07-3A-PAD13 were provided for phytolith analysis in order to address the following research questions:

1. What kinds of phytoliths are preserved, and what plants are therefore represented in the assemblage?
2. What changes occur over time?
3. Do any of the plant species provide insight on Aboriginal subsistence?

In addition to the archaeological sediment samples, plant specimens were collected from the Hope Downs 1 Mine in order to allow a modern phytolith reference collection for the Pilbara to begin to be developed. The study of phytolith production patterns in living plants is a fundamental precursor to the analysis and interpretation of fossil phytolith assemblages. Without such modern baseline data, fossil phytoliths cannot be related to particular types of plant; they exist simply as shapes without meaning. In other words, without an understanding of phytolith production patterns in modern plants, when attempting to interpret phytoliths recovered from archaeological assemblages no any interpretive value can be assigned to observations.

Preparatory processing for phytolith analysis of the sediments by Ms Lydia McKenzie commenced under the guidance of Dr Lynley Wallis in September 2010 and continued through January 2011. Laboratory and microscopy facilities in the School of Social Science (Michie Building), and the School of Geography, Planning and Environmental Management (Chamberlain and Steele Buildings) at the University of Queensland were utilised for the sample preparation and analysis.

Two preliminary reports provided initial information about the abundance of phytoliths recovered from the Jundaru and HD07-3A-PAD13 archaeological sediment samples (Wallis 2010a; Wallis 2010b); results were sufficiently positive at both sites to justify continuing with full analyses. The current report expands on the initial reports and provides a complete account of the phytolith analyses for both Jundaru and HD07-3A-PAD13. Some information from the preliminary reports (*i.e.*, Wallis 2010a; Wallis 2010b) is repeated herein so as to allow this final report to stand alone without readers needing to refer to the earlier reports. Multivariate analysis was conducted for the initial consulting reports, and these results can be found elsewhere (Wallis 2012; Wallis 2013).

12.2 OVERVIEW OF THE SAMPLES EXAMINED

Modern Plant Specimens

There have been few studies of phytolith production patterns amongst modern Australian flora, with those of Bowdery (1998; Bowdery 1996) in central Australia and Wallis (2002; Wallis 2003) in the Kimberley of north Western Australia standing out as the most comprehensive. To date there have been no studies of phytoliths in plants specific to the Pilbara, although it is reasonable to expect that some of the species and families examined in the aforementioned studies are likely to have geographical ranges that extend into the Pilbara.

The abundance of plant species in the Pilbara, absence of readily available botanical collections, and logistical constraints prevented a complete phytolith survey of the flora being undertaken. Instead, focus was placed on collecting a representative sample of plant species growing in the vicinity of Djadjiling today (though it is acknowledged that local vegetation is likely to have varied considerably with shifting rainfall and temperature conditions through time). Accordingly, a total of 55 modern plant specimen samples, deriving from a minimum of 17 families, were provided by ACHM for phytolith analysis (see Table 12-3). Note that formal identification of these specimens has not been undertaken by a botanist nor verified by the WA Herbarium; hence all species identifications shown in Table 12-3 are regarded as tentative and some remain unidentified even to family level.

Djadjiling Sediment Specimens

A total of 38 sediment samples recovered during excavation of Djadjiling were provided to the author for analysis. The samples were selected from each arbitrary excavation layer of Unit 4; sediment from features U4-L04 and U4-L05 was not submitted for analysis. Upon specific request, sediment samples were provided labelled with a random sample number; only after processing and phytolith counting was complete were the actual stratigraphic assignations provided to the author. The purpose behind this randomisation was to ensure patterning was not inadvertently introduced merely as an effect of samples being processed and analysed in order of their increasing depth below surface or age.

Jundaru Sediment Specimens

A total of 36 sediment samples recovered during the 2008 excavation of Jundaru were provided to the author for analysis. Of these samples, 32 were taken from each of the 5cm excavation layers in Quadrant A in Square D6; in addition, four surface sediment samples were collected from locations outside the excavation trench. Again, all sediment samples were initially provided to the author with randomised labelling that was corrected after processing and phytolith counting was complete.

HD07-3A-PAD13 Sediment Specimens

A total of 38 sediment samples recovered during excavation of Quadrant C in Unit 3 of HD07-3A-PAD13 were provided to the author for analysis. As with other samples, these too were provided to the author labelled with randomised labelling that was corrected after processing and phytolith counting was complete.

12.3 METHODS

Sediment Sample Preparation

All 38 samples from Djadjiling, 36 samples from Jundaru, and 38 samples from HD07-3A-PAD13 were processed using a sodium polytungstate heavy liquid extraction process based on that used with success for a previous study of phytoliths from the Carpenter's Gap 1 rockshelter in the Kimberley region (Wallis 2000; Wallis 2001). Minor modifications to the basic protocol included (a) the addition of an initial combustion step to aid in the removal of organics and thus accelerate processing for the Jundaru and HD07-3A-PAD13 samples, and (b) the inclusion of extra organic and clay removal stages, made necessary by the specific site sediment characteristics.

Sediments were initially sieved through a 1mm mesh to remove larger particles, after which a ~7g sub-sample was weighed into a lidded porcelain crucible and placed in a muffle furnace at 400°C for approximately 24 hours. After cooling the sample was reweighed, thereby providing an estimate of the Loss on Ignition (LOI) value. Approximately 5g of the remaining sample was then weighed into a clean lidded plastic vial. Clay-sized particles were removed using gravity settling out (4 hours over 10cm); the number of settling out steps required varied depending on the specific nature of individual samples. Residual organics were then removed by adding hydrogen peroxide and placing the sample in a water bath at 70°C; where necessary the hydrogen peroxide was refreshed until the reaction ceased. Owing to the presence of iron oxides in the samples this reaction was often extremely vigorous and care had to be taken to ensure the sample did not 'explode'. The next processing phased involved the removal of carbonates using a weak solution of hydrochloric acid, as well as a second hydrogen peroxide wash. The phytoliths were then separated from other material by flotation in sodium polytungstate (a 'heavy' liquid with specific gravity 2.3). Owing to the extremely high iron and clay content of the samples, the separated phytolith fraction was then subjected to another round of gravity settling out and hydrogen peroxide to ensure the samples were as 'pure' as possible. The detailed protocol outlining the complete procedure for the extraction of phytoliths from the various site sediments is provided as
Table 12-1 below.

Table 12-1 Protocol for phytolith extraction from sediment samples

Stage	Step	Directions	Other comments
Initial combustion to remove organics	1	Sieve sample through a 1mm sieve to remove extraneous material.	To minimize contamination throughout all steps of the entire procedure, ensure that all items used (*e.g.* beakers, tweezers, rods *etc.*) are cleaned with distilled water before use or between samples.
	2	Weigh out ~7g of sediment into a clean, lidded porcelain crucible and record the weight to 4 decimal places.	
	3	Place the samples into a muffle furnace for 24 hours at 400°C.	
	4	Remove samples from muffle furnace, allow to cool and reweigh. Use measurements to calculate LOI value.	
Removal of clays	5	Weigh out remaining sediment (~5g) into a clean, labelled 10cm high plastic vial and record the sediment weight to 4 decimal places.	
	6	Add ~100mL of distilled water, stir thoroughly and place in ultrasonic bath for 30 minutes to aid dispersion.	
	7	Remove vial from ultrasonic bath and allow sample to settle for 4 hours before siphoning off the supernatant.	
	8	Repeat steps 3 and 4 until supernatant is clear of clay particles.	
Clean samples	9	Using distilled water, wash residual material into clean, labelled 50mL centrifuge tube.	
	10	Refresh all samples with distilled water to same level.	
	11	Centrifuge at 3000rpm for 10 minutes.	
	12	Decant H_2O_2 from sample.	
Primary removal of organics	13	Add 20mL of H_2O_2 and stir.	These steps must be carried out wearing lab coat, gloves and safety glasses to minimise risk of chemical burns.
	14	Place sample in a waterbath at 70°C for 6 days. Refresh with extra H_2O_2 if necessary. Stir occasionally.	
	15	Remove from waterbath and allow to cool.	
	16	Centrifuge at 3000rpm for 10 minutes.	
	17	Decant H_2O_2 from sample.	
Clean samples	18	Add 30mL of distilled water to all samples, replace lid and shake.	
	19	Centrifuge at 3000rpm for 10 minutes.	
	20	Decant liquid from sample.	
Removal of carbonates	21	Add 30mL 15% hydrochloric acid to tube and stir.	These steps should be carried out in a fume-hood.
	22	Place in waterbath at 70°C for at least one hour, or until reaction stops.	
	23	Remove from waterbath and allow to cool.	
	24	Refresh all samples with distilled water to the same level.	
	25	Centrifuge at 3000rpm for 10 minutes.	
	26	Decant liquid from sample.	

Stage	Step	Directions	Other comments
Secondary removal of organics	27	Add 20mL of H_2O_2 and stir.	
	28	Place sample in a waterbath at 70°C until reaction ceases. Top up with extra H_2O_2 if necessary. Stir occasionally.	
	29	Remove from waterbath and allow to cool.	
	30	Centrifuge at 3000rpm for 10 minutes.	
	31	Decant H_2O_2 from sample.	
Sieving	32	Wash sample through a 300µm sieve into a clean, labelled 50mL centrifuge tube using distilled water.	
	33	Top up all samples with distilled water to the same level.	
	34	Centrifuge at 3000rpm for 10 minutes.	
	35	Decant liquid from sample.	
	36	Residual material in sieve can be dried and weighed if required, or simply discarded.	
Clean samples	37	Using 100% ethanol, wash sediment into clean, labelled 15mL centrifuge tube.	
	38	Top up all samples to the same level with ethanol.	
	39	Centrifuge at 3000rpm for 10 minutes.	
	40	Decant liquid from sample.	
Heavy liquid flotation	41	Add 8mL sodium polytungstate to tube, replace lid, and mix well.	
	42	Centrifuge at 3000rpm for 20 minutes.	
	43	Pipette supernatant and interface off into clean, labelled 15mL centrifuge tubes (this material is the concentrated phytoliths).	
	44	Repeat steps 42 and 43 as many times as necessary until all supernatant and interface has been removed. Add additional sodium polytungstate as required so there is always 8mL present when centrifuging.	
	45	Refresh all phytolith samples with distilled water to the same level (make sure there is at least 5mL distilled water in each sample).	
	46	Centrifuge at 3000rpm for 10 minutes.	
	47	Decant polytungstate into a clean beaker and set aside for recovery.	
	48	Repeat steps 45, 46 and 47 for the non-phytolith/polytungstate mixture. After sodium polytungstate has been recovered, this sediment can be discarded. If for some reason you wish to keep it, follow steps 45, 46 and 47 for it as well.	
Clean samples	49	Add 10mL 50% ethanol to the phytolith tube and mix well.	
	50	Centrifuge at 3000rpm for 10 minutes.	
	51	Decant.	
Clean samples	52	Add 10mL 100% ethanol to the phytolith tube and mix well.	
	53	Centrifuge at 3000rpm for 10 minutes.	
	54	Decant.	
Second phase removal of clays	55	Transfer phytolith fraction to a clean, labelled 10cm plastic vial	
	56	Add ~100mL of distilled water, stir thoroughly and place in ultrasonic bath for 2 minutes to aid dispersion.	
	57	Remove vial from ultrasonic bath and allow sample to settle for 4 hours before siphoning off the supernatant.	
	58	Repeat steps 3 and 4 as many times as necessary.	
Clean samples	59	Using distilled water, wash phytolith material into clean, labelled 50mL centrifuge tube.	
	60	Top up all samples with distilled water to same level.	
	61	Centrifuge at 3000rpm for 10 minutes.	
	62	Decant.	
Second phase removal of clays	63	Add 30mL of H2O2 and stir.	These steps must be carried out wearing lab coat, gloves and safety glasses to minimise risk of chemical burns.
	64	Place sample in a waterbath at 70°C for 5 days. Refresh with extra H2O2 if necessary. Stir occasionally.	
	65	Remove from waterbath and allow to cool.	
	66	Centrifuge at 3000rpm for 10 minutes.	
	67	Decant H2O2 from sample.	
Clean samples	68	Add 40mL distilled water to all samples.	
	69	Centrifuge at 3000rpm for 10 minutes.	
	70	Decant.	
Clean samples	71	Add 10mL 100% ethanol to the phytolith tube and mix well.	
	72	Centrifuge at 3000rpm for 10 minutes.	
	73	Decant.	
Final sample preparation	74	Weigh and label clean storage vials.	
	75	Using 100% ethanol, transfer phytoliths from tube to storage vial.	
	76	Place phytoliths in ethanol in fume-hood or drying oven and allow ethanol to evaporate. Ensure samples are covered in some fashion to minimise the risk of airborne contamination.	
	77	Weigh the now-dried phytolith sample and calculate the percentage of phytoliths by dry weight by subtracting the vial weight (stage 74) from the vial and sample weight. Sample can be stored dry or in ethanol.	

Microscopy

All extracted phytolith fractions were prepared for light microscopy using the same basic procedure, as detailed in Table 12-2. A few millilitres of 100% ethanol were added to the storage vial containing the dried phytolith residue and the sample mixed. Between 10 and 20µL of the sample were then pipetted out and placed on a labelled, standard 1mm thick glass slide. The slide was then warmed on a slide warmer until the ethanol had evaporated. After the sample had dried, a few drops of mountant were applied to the slide and a glass coverslip (22 by 50mm; size '0' thickness) was carefully lowered onto the sample, which was then placed in a drying oven at 60°C for 48 hours.

Though Depex had been used successfully for the slide mounting of phytoliths from Djadjiling and the initial Jundaru extractions (Wallis 2010a; Wallis 2012), the passage of time revealed a tendency for increasing quantities of air bubbles to appear in the Depex mountant. So as to avoid this problem Euparal (Refractive Index = 1.485) was used for the permanent mounting of the phytoliths from Jundaru and HD07-3A-PAD13. Like Depex, Euparal dries to a solid mount and therefore phytoliths cannot be rotated to determine their overall three-dimensional morphology. The advantages of a permanent solid mount are that individual phytolith co-ordinates can be recorded for easy referral at a later date and there is no chance that phytoliths will migrate across the slide during examination, thereby affecting counts. It was considered that these factors outweighed the disadvantages of using a permanent mount. Furthermore, slides can be archived in an upright or horizontal position. If required, three-dimensionality of phytoliths can be determined via scanning electron microscopy (SEM) using a replicate sample mounted on a stub.

After mounting, slides were examined with transmitted light using a Leica DM1000 stereo-microscope at 400x magnification. Where appropriate, photomicrographs were taken using a high resolution digital camera DFC295 attachment, and saved as *.tiff files.

Classification Scheme

In the late twentieth century it was noted that the absence of a universally applicable key for the description, identification, and classification of phytoliths impeded the discipline, causing the proliferation of keys and a lack of standardised terminology with which to describe phytolith morphologies (Bowdery *et al.* 2001). Accordingly, the International Committee on Phytolith Nomenclature (ICPN) working group was formed to address the problem; the terminology used in this report follows Madella *et al.* (2005).

Calculating Phytolith Abundances

The means of estimating the abundance of phytoliths present in each sediment sample was through the calculation of a 'percentage by dry weight' value. As described in Section 12.3 and
Table 12-1, at the beginning of phytolith processing the dry weight of the sediment sample was recorded. The dry weight of the phytolith residue remaining upon completion of extraction was also recorded and the percentage of phytoliths thereby calculated by comparing the values. This method was not entirely accurate, however, since in some cases the residue remaining was not pure silica, but also contained other inorganic particles (such as undigested charcoal and aggregated clays that remained despite the deflocculation procedures). As noted in Section 12.3, attempts were made after extracting the phytolith fraction to further 'purify' the sample, removing as much extraneous organic, clay and iron rich material as possible; however, in several cases this was not especially successful. Such cases are indicated by the presence of a 'less than' sign (<) before the numerical phytolith abundance value and each of these should be considered an over-estimate. While affecting some percentage by weight values, such extraneous material did not impinge on the ability to view or count the slide-mounted phytoliths.

It is noted that the percentage of phytoliths by dry weight values presented herein for Jundaru and HD07-3A-PAD13 are sometimes substantially less than those provided in the initial site reports (Wallis 2010a; Wallis 2010b). This is because initial rapid processing (undertaken in order to meet deadlines for initial reporting) failed to remove much of the clay and iron rich sediments from the samples Following the initial assessment of samples to confirm that phytoliths were present (and therefore that full analysis was worth pursuing), and after initial reporting, additional processing of samples was undertaken in order to remove as much as possible as the extraneous material. As such, the percentage by dry weight values presented in this report should be used in preference to those presented in the preliminary reports (Wallis 2010a; Wallis 2010b).

Table 12-2 Protocol for phytolith slide preparation

Stage	Step	Directions	Other comments
Slide preparation	1	If sample is stored dry, add a small quantity of ethanol to sample.	Slide preparation should be carried out in a laminar-flow unit if possible to prevent air-borne contamination of samples during mounting.
	2	Appropriately label a clean, dry glass slide.	
	3	Using a pipette, add 5-20µL of phytoliths in ethanol solution to the centre of the slide.	
	4	Place slide on slide warmer (~70°C) until ethanol evaporates.	
	5	Add a few drops of Euparal (or Depex) to the centre of the slide and smear to mix in the phytolith residue.	
	6	Place a 32x50mm glass coverslip over the mixture. Wipe any excess mountant from the coverslip edges.	
	7	Place slides in drying oven for 48 hours at 60°C or until fixed.	

Statistical Methods

A total of 400 phytoliths were counted for each sediment sample (excluding morphologically indistinct siliceous material). Owing to the complexity of the final phytolith count data, multivariate statistical analyses were undertaken to allow for its easier interpretation. Ordination using Principal Components Analysis (PCA) reduces the dimensionality of complex assemblage data, enabling the most salient features of each sample to be quantified and expressed spatially as graphs (Digby and Kempton 1987). As such, points located close to one another on a graph can be interpreted as having similar phytolith assemblages, whereas points distantly separated in space can be interpreted as having different phytolith assemblages. Plots of the major phytolith types that generate the variability and define the spatial patterning of the ordination graphs were also constructed. The pollen plotting and analysis software package C2 (Juggins 2007) was used to perform the PCA statistical analyses.

The results for phytolith presence/absence and abundances in the leaves of the 55 specimens of modern Pilbara plants are shown in Table 12-3; phytolith presence is presented as a percentage dry weight value and a descriptive assessment. As shown, 33 of the samples (60%) examined did not produce any phytoliths at all, 11 (20%) produced trace quantities, six (*ca.* 11%) produced common amounts of phytoliths, and the remaining four samples (*ca.* 7%) were abundant producers.

Table 12-4 summarises the phytolith production patterns recorded on a family basis. As can be seen, when the data are considered in this fashion, of the 17 families surveyed, 41% (n=7) are characterised as usually containing species that are non-producers of phytoliths. A further three families—Caesalpinaceae, Chenopodiaceae, and Malvaeae—contain a combination of non-producing and trace producing species. These results are in line with those presented from other Australian regions. For example, of the 53 families Wallis (2000; Wallis 2003) examined from the Kimberley region, 56% (n=30) were characterised as typically being non-phytolith producers. Internationally, 58% (n=42) of 72 plant families summarised by Piperno (1988: 21) fell into the categories of non- or uncommon to rare phytolith producers. Similarly, Runge (1997) found that 53% of East African plant specimens examined did not accumulate silica. Kealhofer and Piperno (1998) also reported that 54% (n=41) of Southeast Asian families examined for their phytolith content did not produce phytoliths or produced only non-diagnostic forms.

Table 12-3 Summary of phytolith production measures for leaf samples from modern Pilbara plant specimens

ID Number	Family Name	Species	Plant Weight (g)	Phytolith Weight (g)	% Phytoliths	Phytolith Production Status
1	Mimosaceae	*Acacia coriacea*	2.419	0.001	0.0	Non-producer
2	Solanaceae	*Solanum phlomoides*	1.283	0.001	0.0	Non-producer
3	Mimosaceae	*Acacia aneura*	1.544	0.095	<6.1	Non-producer
4	Poaceae	*Triodia pungens*	0.872	0.047	5.4	Abundant
5	Myoporaceae	*Eremophila coacta*	0.646	0.001	<0.2	Non-producer
6	Malvaceae	*Sida* sp. (?)	0.648	0.009	<1.5	Trace
7		Unidentified specimen 2	0.408	0.008	2.0	Trace
8	Proteaceae	*Hakea lorea*	1.975	0.001	0.0	Non-producer
9	Caesalpinaceae	*Cassia* sp. (?)	1.076	0.059	<5.5	Trace
10	Fabaceae	*Indigofera cuspidata* (?)	0.546	0.001	<0.2	Non-producer
11	Poaceae	*Eragrostis eriopoda* (?)	0.702	0.094	13.4	Common
12	Poaceae	*Triodia basedowii*	0.841	0.096	<11.4	Abundant
14	Convolvulaceae	*Polymeria ambigua*	0.687	0.024	3.6	Trace
15		Unidentified specimen 6	0.945	0.104	<11.0	Non-producer
16	Mimosaceae	*Acacia* sp.	2.272	0.348	<15.3	Non-producer
17	Convolvulaceae	*Evolvulus alsinoides* (?)	0.152	0.001	0.5	Trace
18	Mimosaceae	*Acacia pyrifolia*	1.001	0.251	<25.0	Non-producer
19		Unidentified specimen 8	0.103	0.001	<0.5	Non-producer
20	Fabaceae	*Sesbania formosa* (?)	0.519	0.027	<5.3	Non-producer
21	Malvaceae	*Gossypium robinsonii*	1.271	0.246	<19.3	Non-producer
22	Chenopodiaceae	*Atriplex* sp. (?)	0.580	0.034	5.8	Trace
23	Poaceae	Unidentified specimen 11	0.813	0.082	<10.0	Common
24	Goodeniaceae	*Scaevola tomentosa* (?)	0.693	0.015	<2.1	Trace
25	Myoporaceae	*Eremophila caespitosa*	0.830	0.047	<5.6	Non-producer
26		Unidentified specimen 13	0.897	0.004	<0.4	Non-producer
27	Fabaceae	*Swainsona formosa*	0.949	0.177	<18.7	Non-producer
28	Portulaceae	*Portulaca oleracea*	0.088	0.000	<0.3	Non-producer
29	Poaceae	*Eriachne helmsii* (?)	0.378	0.016	4.2	Abundant
30		Unidentified specimen 15	0.443	0.003	0.8	Trace
31	Myrtaceae	*Eucalyptus* sp.	1.452	0.679	<46.8	Non-producer
32	Malvaceae	*Hibiscus sturtii* var. *truncatus Fryxell*	0.553	0.005	<0.8	Non-producer
33	Chenopodiaceae	*Salsola* sp. (likely *kali)*	0.658	0.012	<1.8	Non-producer
34		Unidentified specimen 18	1.087	0.169	15.5	Non-producer
35	Boraginaceae	*Heliotropium* sp. (likely *pachyphyllum*) (?)	0.856	0.067	<7.8	Common
36	Myrtaceae	*Eucalyptus* sp.	3.701	0.001	0.0	Non-producer
37	Fabaceae	*Lotus cruentus* (?)	1.134	0.001	<0.1	Non-producer
38	Fabaceae	*Tephrosia gardneri*	0.992	0.000	0.0	Non-producer
39		Unidentified specimen 21	1.715	0.004	<0.3	Trace

ID Number	Family Name	Species	Plant Weight (g)	Phytolith Weight (g)	% Phytoliths	Phytolith Production Status
40	Caesalpinaceae	*Senna* sp. (?)	0.634	0.001	<0.1	Non-producer
41	Boraginaceae	*Heliotropium* sp. (likely *pachyphyllum*) (?)	0.189	0.001	0.3	Common
42	Myrtaceae	*Melaleuca* sp.	1.702	0.001	0.0	Non-producer
43	Cyperaceae	Cyperaceae (?)	0.331	0.019	5.6	Common
44	Myoporaceae	*Eremophilia fraserii*	3.231	0.015	<0.5	Non-producer
45	Malvaceae	*Abutilon dioicum*	0.653	0.001	0.1	Non-producer
46	Scrophulariaceae	*Stemodia grassa*	0.776	0.018	2.3	Trace
47	Mimosaceae	*Acacia hamersleyensis*	1.684	0.001	0.0	Non-producer
48	Poaceae	*Cymbopogon ambiguus*	0.532	0.019	3.6	Abundant
49	Cyperaceae (?)	Unidentified specimen 26	0.257	0.012	4.7	Common
50	Myrtaceae	*Eucalyptus* sp.	3.262	0.001	0.0	Non-producer
51		Unidentified specimen 27	4.439	0.018	0.4	Non-producer
52	Myrtaceae	*Aluta quadrata*	1.497	0.001	0.0	Non-producer
53	Amaranthaceae	*Ptilotus mollis*	0.491	0.006	<1.2	Non-producer
54	Amaranthaceae	*Ptilotus calsstachyus*	0.511	0.001	0.1	Non-producer
55	Caesalpinaceae	*Senna venusia*	1.258	0.000	0.0	Non-producer
56	Malvaceae	*Gossypium robinsonii* (?)	1.520	0.004	0.2	Trace

Note: Figures in the 'Phytolith Weight (g)' column may not be absolute, since samples often contain quantities of non-siliceous materials (*e.g.*, undigested charcoal – this is especially the case with woodier samples); hence, values provided in the 'Phytolith %' column typically over-estimate the proportion of phytoliths present. In cases where visual examination revealed the presence of non-siliceous residual material, this is indicated by a '<' symbol being placed in front of the value given in the 'Phytolith %' column and in the comments column. Of greater value for determining the presence of phytoliths in any particular sample is the final 'Phytolith Production Status' column, which provides a descriptive measure based on visual observations.

Table 12-4 Summary of phytolith production patterns across families examined in this study

Non-Producer	Trace Producer	Common Producer	Abundant Producer
Amaranthaceae			
Caesalpinaceae	----------	Boraginaceae	
Chenopodiaceae	----------		
	Convolvulaceae		
		Cyperaceae	
Fabaceae			
	Goodeniaceae		
Malvaceae	----------		
Mimosaceae			
Myoporaceae			
Myrtaceae			
		----------	Poaceae
Portulaceae			
Proteaceae			
	Scrophulariaceae		
Solanaceae			
Unidentified 6	Unidentified 2		
Unidentified 8	Unidentified 15		
Unidentified 13	Unidentified 21		
Unidentified 18			
Unidentified 27			

Note: A line of dashes (----------) indicates phytolith production is variable across these categories, with the most typical pattern indicated by the category in which the family name has been located. Note the unidentified samples may belong to Families that are listed elsewhere in the table.

Three families in the Pilbara were comprised predominantly of trace producers of phytoliths: Convolvulaceae, Goodeniaceae, and Scrophulariaceae. These first two families were found by Wallis (2000: 185) to often be non-producers of phytoliths, so the finding in this study that at least some members of this family will produced phytoliths is of interest. Wallis (2000: 185) also found that members of Scrophulariaceae were typically trace or non-producers of phytoliths.

Two families contained species that were typically common producers of distinctively shaped phytoliths: Boraginaceae (ornamented hair cells) and Cyperaceae (flat rectangular plate with low cones and nodular protuberances). Both of these families were found by Wallis (2000: 185) to be abundant producers of phytoliths, and thus this finding is in line with current understandings of familial silica accumulation tendencies.

Only species from the Poaceae family (*i.e.,* grasses) examined in this study typically produced abundant quantities of phytoliths; this is in line with what was to be expected based on our current knowledge of phytolith production in plant families globally.

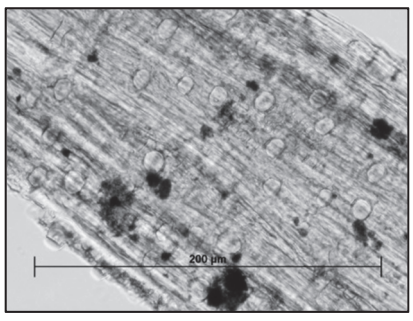
These results are discussed further in Section 12.7 later in this chapter.

Phytolith Morphologies

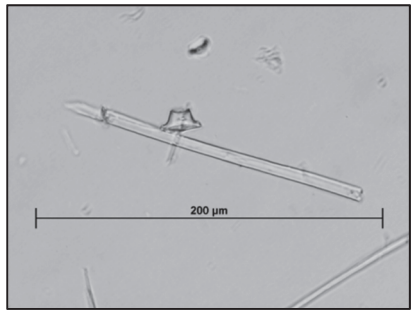
Plant samples which were found to produce at least trace quantities of phytoliths were subject to detailed microscopic examination to determine the range of phytolith morphologies present. As summarised in Table 12-5, all samples produced non-diagnostic forms (these being non-repetitive shapes that are of no interpretive value). Further, samples 7, 9, 17, 22, and 56 only produced non-diagnostic forms. All other samples produced at least some distinctive forms, though those forms were often 'redundant' (*i.e.,* the same shapes were observed in different species and so they have limited interpretive value). As is usual, most specimens produced multiple, different phytolith forms; this phenomenon is referred to as 'multiplicity'. Photomicrographs of typical forms observed in various samples are shown in Figure 12-1 to Figure 12-3.

Table 12-5 Summary of phytolith morphologies present in modern plant specimens indicated as producing at least trace quantities of phytoliths

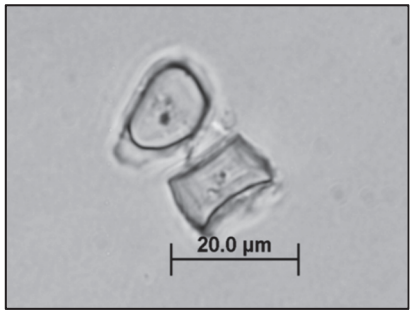
Plant Specimen ID Number	Species	Bilobate	Long shanked bilobate	Saddle	Rondel	Angular quadrilateral	Eriachne type (bilobate on a base)	Unilobate	Quadralobate	Polylobate	Ovoid prickle base	Conical	Hair cell	Parallelepipedal	Oblong	Dendritic	Elongate echinate long cell	Elongate psilate long cell	Elongate sinuous long cell	Flat sinuous	Flat rectangular	Flat rectangular with nodular protuberances	Very large rondel	Cyperaceae type (low cone on a flat plate)	Undiagnostic
4	*Triodia pungens*			*	*	*							*					*	*	*	*				*
6	*Sida* sp. (?)												*				*								*
7	Unidentified 2																								*
9	*Cassia* sp. (?)																								*
11	*Eragrostis eriopoda* (?)	*	*										*	*				*	*	*					*
12	*Triodia basedowii*	*		*	*	*							*					*		*	*	*			*
14	*Polymeria ambigua*				*												*	*							*
17	*Evolvulus alsinoides* (?)																								*
22	*Atriplex* sp. (?)																								*
23	Unidentified 11	*		*	*	*							*			*	*	*	*		*		*		*
24	*Scaevola tomentosa* (?)																*		*						*
29	*Eriachne helmsii* (?)					*	*						*				*	*	*	*	*				*
30	Unidentified 15												*												*
35	*Heliotropium* sp.												*								*				*
39	Unidentified 21																				*				*
41	*Heliotropium* sp.												*					*			*				*
43	Cyperaceae (?)													*			*	*			*			*	*
46	*Stemodia grassa*																*								*
48	*Cymbopogon ambiguus*	*				*		*	*	*	*	*	*				*	*		*	*				*
49	Unidentified 26																	*		*				*	*
56	*Gossypium robinsonii* (?)																								*



Articulated phytoliths from *Triodia pungens* (Sample 4)

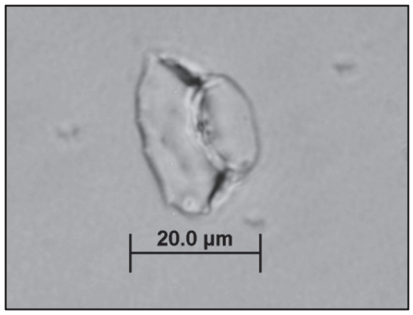


Rondel and elongate psilate long cell from *Triodia pungens* (Sample 4)

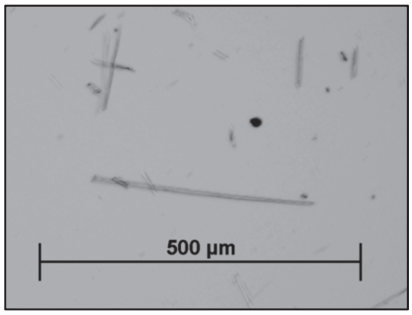


Plan and profile views of rondels from *Triodia pungens* (Sample 4)

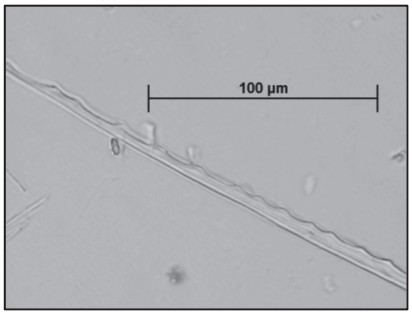
Figure 12-1 Plate 1 - photomicrographs of typical forms observed in various modern samples



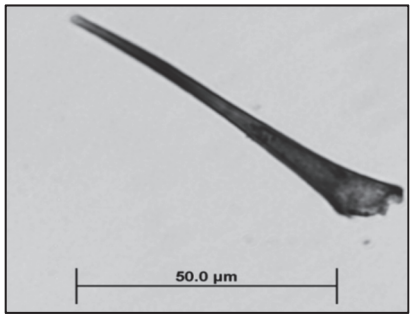
Semi-profile view of rondel from *Triodia pungens* (Sample 4)



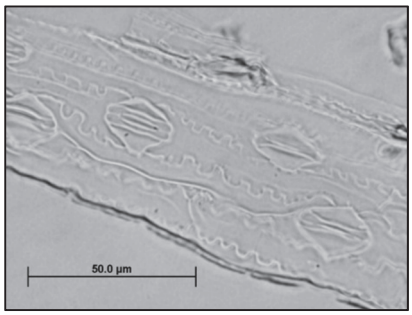
Elongated psilate long cells from *Triodia pungens* (Sample 4)



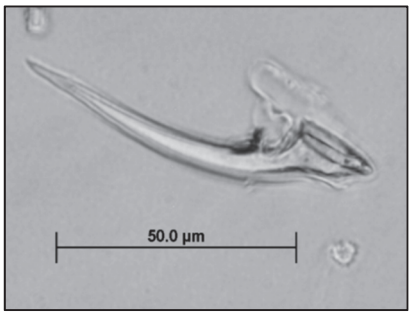
Elongated sinuous long cell from *Triodia pungens* (Sample 4)



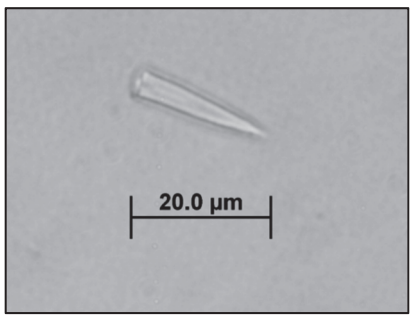
Hair cell from *Sida* sp. (Sample 6)



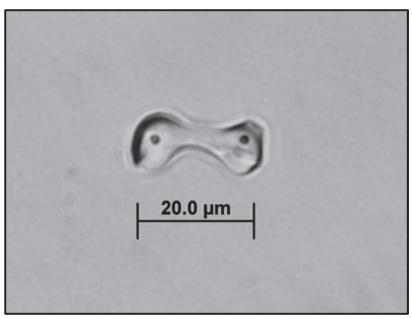
Stomata and flat sinuous phytoliths from *Eragrostis eriopoda* (Sample 11)



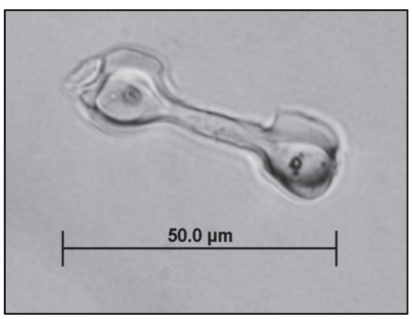
Hair cell from *Eragrostis eriopoda* (Sample 11)



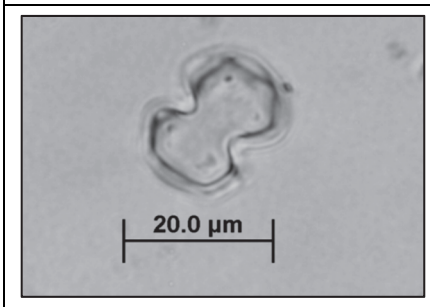
Hair cell from *Eragrostis eriopoda* (Sample 11)



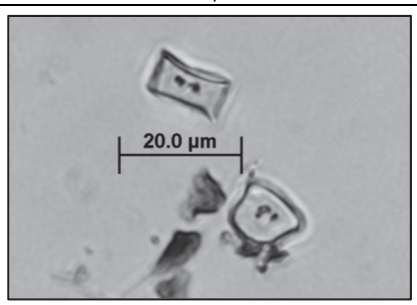
Bilobate from *Eragrostis eriopoda* (Sample 11)



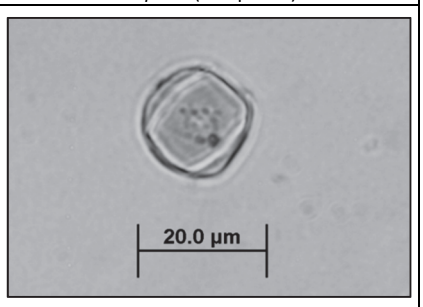
Long shanked bilobate from *Eragrostis eriopoda* (Sample 11)



Bilobate from *Triodia basedowii* (Sample 11)



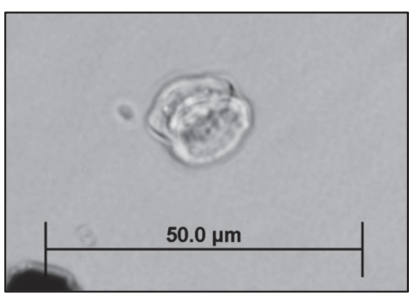
Angular quadrilateral and saddle from *Triodia basedowii* (Sample 11)



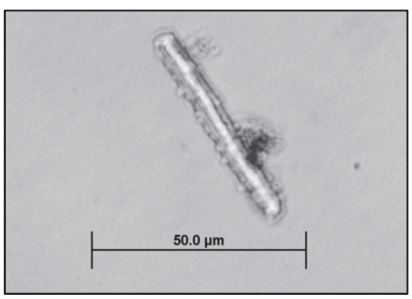
Rondel from *Triodia basedowii* (Sample 11



Hair cell from *Triodia basedowii* (Sample 11)

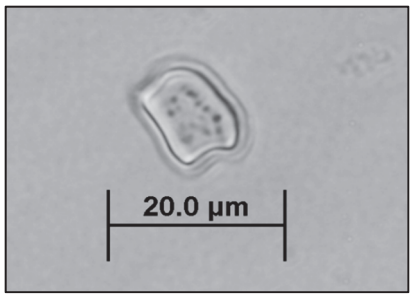


Rondel from *Polymeria ambigua* (Sample 14

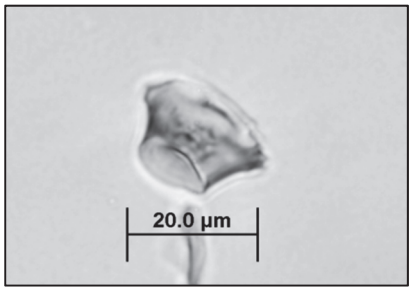


Elongate echinate long cell from *Polymeria ambigua* (Sample 14)

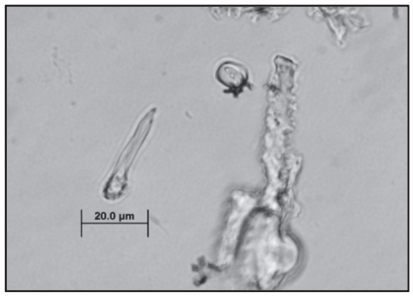
Figure 12-2 Plate 2 - photomicrographs of typical forms observed in various modern samples



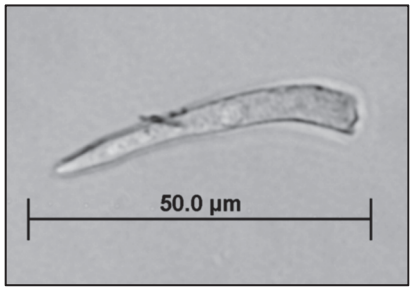
Saddle from unidentified Sample 23



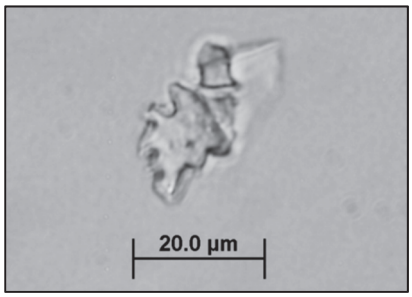
Rondel from unidentified Sample 23



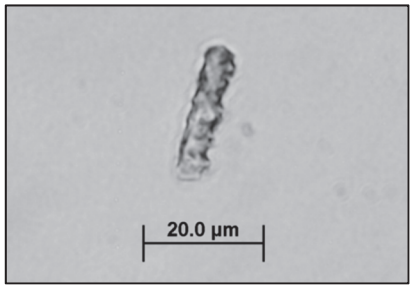
Hair cell, saddle and elongate echinate long cells from unidentified Sample 23



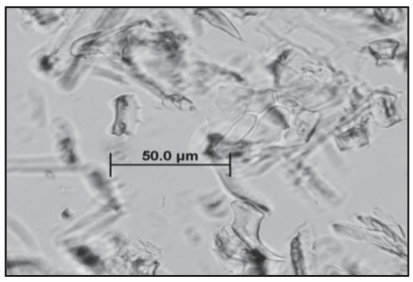
Hair cell from unidentified Sample 23



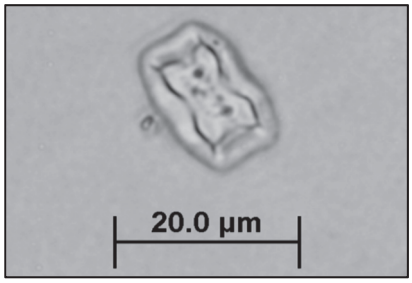
Elongate sinuous long cell from *Scaevola tomentosa* (Sample 24)



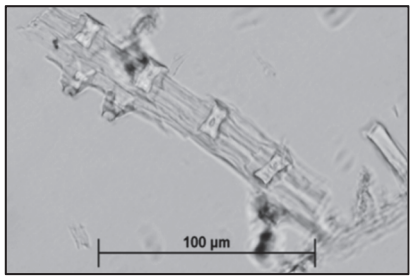
Elongate sinuous long cell from Scaevola tomentosa (Sample 24)



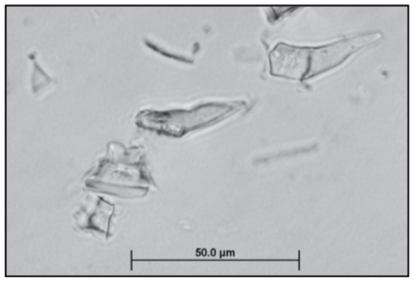
Range of phytolith morphologies from *Eriachne helmsii* (Sample 29)



Typical eriachne form ('Bilobate on a Base') from *Eriachne helmsii* (Sample 29)



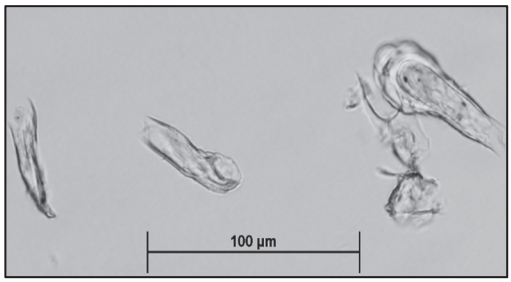
Eriachne form and elongate psilate long cells from *Eriachne helmsii* (Sample 29)



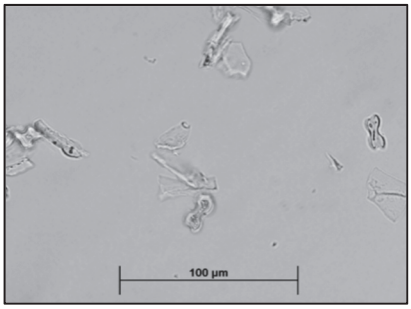
Eriachne form and hair cells from *Eriachne helmsii* (Sample 29)



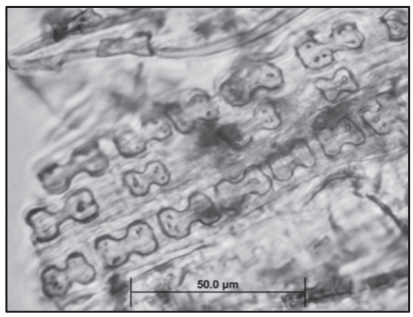
Ornamented hair cell from *Heliotropium* sp. (Sample 35)



Ornamented hair cells from *Heliotropium* sp. (Sample 41)



Bilobates, flat plate and flat sinuous forms from *Cymbopogon ambiguus* (Sample 48)



Bilobates and hair cell forms from *Cymbopogon ambiguus* (Sample 48)

Figure 12-3 Plate 3 - photomicrographs of typical forms observed in various modern samples

12.4 DJADJILING RESULTS

Djadjiling Phytolith Abundance

Phytolith abundances in the Djadjiling sediment samples are shown in Table 12-6. As shown, phytolith abundances range from a low of 0.14% in sample U4-L40 (the basal spit), to a high of 9.19% in sample U4-L32. There are four main peaks in phytolith abundance (from top to bottom): (1) U4-L07 to U4-L12; (2) U4-L15 to U4-L17; (3) U4-L24 to U4-L26; and (4) U4-L31 to U4-L33. Without knowing further details about the radiocarbon chronology, stratigraphy or patterning of other cultural remains for this site, it is difficult to say more about the significance of this patterning, though it will be interesting to ascertain whether it is correlated with peaks in other categories of archaeological remains. The interpretation of these results is discussed further in Section 12.7.

Djadjiling Phytolith Morphologies

A total of 30 phytolith types were encountered regularly throughout the Djadjiling sediments. In addition, several other rare types whose plant origins were unknown were also encountered; for the sake of reporting these are graphed collectively under the heading *'Other'*. Raw counts of the phytoliths from the Djadjiling sediments are presented in Table 12-6 and Figure 12-4. Zones have been indicated on these diagrams based on the patterning observed and the results of the multivariate statistical analyses, and should be considered only tentative until other site data are also taken into account. These results are discussed in Section 12.7.

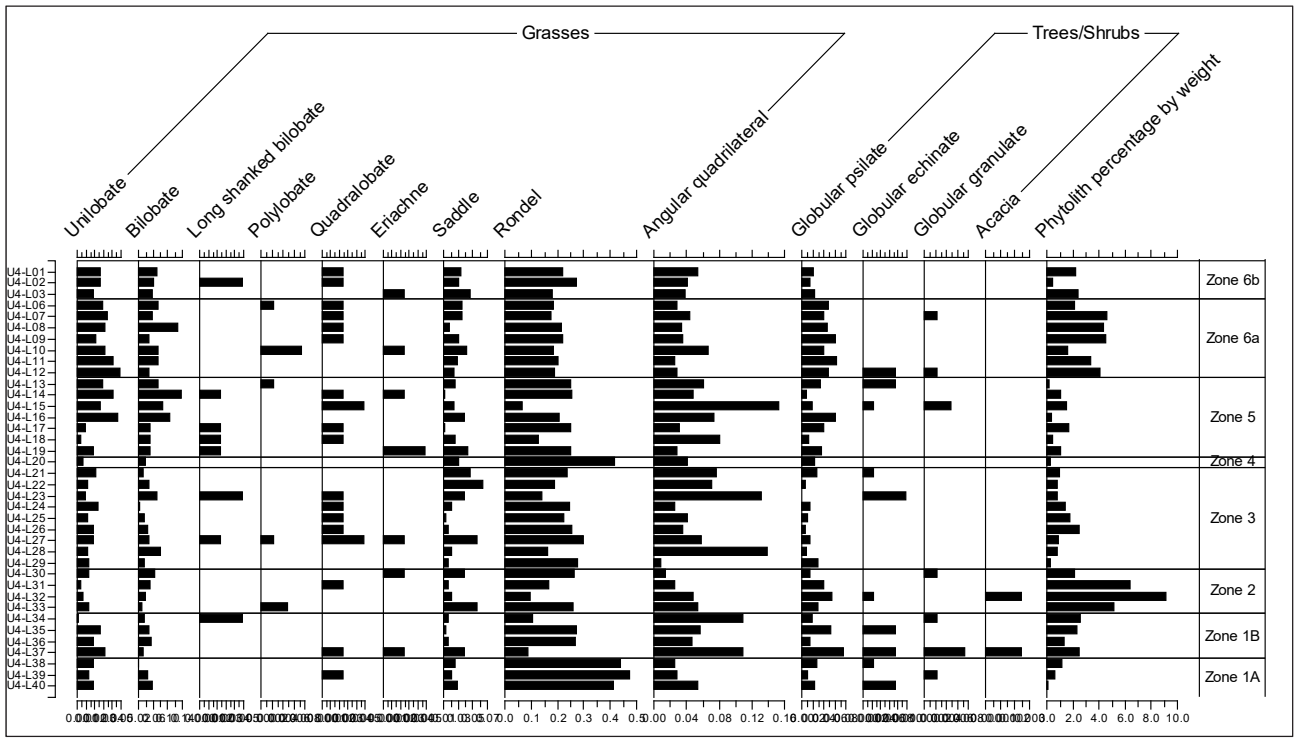


Figure 12-4 Diagram showing percentage values of grass versus tree/shrub phytolith types in Djadjiling sediments. An A3 version of this figure can be found online with the supplementary information.

Table 12-6 Raw counts of the phytoliths from the Djadjiling sediments

Unit-Layer Code	Phytolith % by Dry Weight	Bilobate	Long shanked bilobate	Rondel	Saddle	Eriachne	Unilobate	Quadralobate	Polylobate	Angular quadrilateral	Prickle	Ovoid prickle base	Conical	Hair cell	Parallelepipidal	Oblong	Dendritic	Elongate echinate long cell	Elongate psilate long cell	Elongate sinuous long cell	Flat jigsaw	Flat sinuous	Flat rectangular	Flat rectangular with nodular protuberances	Large rondel	Globular psilate	Globular echinate	Globular granulate	Cuneiform bulliform	Acacia	Other	Elongate lobate long cell
U4-L01	2.26	29	0	89	14	0	11	1	0	22	4	2	1	5	6	0	0	72	91	3	0	11	28	1	0	9	0	0	0	0	1	0
U4-L02	0.55	26	2	111	13	0	11	1	0	17	4	2	0	5	5	2	1	55	99	8	0	10	13	7	0	7	0	0	1	0	0	0
U4-L03	2.47	24	0	73	19	1	8	0	0	16	2	2	0	12	8	0	0	66	110	0	0	26	14	9	0	10	0	0	0	0	0	0
U4-L06	2.22	31	0	75	15	0	12	1	1	12	12	2	0	1	6	1	0	48	114	8	0	15	10	14	0	20	0	0	0	0	1	1
U4-L07	4.69	25	0	72	15	0	14	1	0	18	4	3	0	7	11	3	0	66	98	9	0	14	16	5	0	17	0	1	1	0	0	0
U4-L8	4.39	52	0	88	8	0	13	1	0	14	9	3	0	6	15	1	0	68	68	3	0	13	13	3	0	19	0	0	2	0	1	0
U4-L09	4.64	21	0	89	13	0	9	1	0	15	6	2	0	11	10	1	0	57	96	8	0	19	15	1	0	25	0	0	1	0	0	0
U4-L10	1.71	31	0	76	17	1	13	0	3	27	4	2	0	10	16	0	3	55	95	2	0	12	14	2	0	17	0	0	0	0	0	0
U4-L11	3.41	31	0	82	12	0	17	0	0	11	12	1	0	10	4	0	0	52	102	9	0	4	20	4	2	26	0	0	1	0	0	0
U4-L12	4.14	20	0	77	10	0	20	0	0	12	11	1	0	5	18	0	4	49	101	5	0	16	17	6	0	20	3	1	2	0	2	0
U4-L13	0.24	31	0	102	11	0	12	0	1	25	15	1	0	2	6	0	0	72	69	8	0	10	11	6	0	14	3	0	1	0	0	0
U4-L14	1.13	56	1	104	5	1	17	1	0	20	19	3	0	0	20	4	15	28	72	9	0	6	4	3	1	4	0	0	4	0	0	3
U4-L15	1.55	36	0	28	10	0	11	2	0	62	7	6	1	5	28	0	20	23	96	10	0	20	8	12	3	8	1	2	0	0	0	1
U4-L16	0.48	43	0	85	16	0	19	0	0	30	16	4	1	2	5	1	0	42	71	6	0	11	13	7	0	25	0	0	1	0	2	0
U4-L17	1.76	22	1	102	5	0	4	1	0	13	6	4	0	2	12	1	12	29	89	3	0	38	12	18	3	17	0	0	4	0	1	1
U4-L18	0.54	22	1	52	11	0	2	1	0	33	12	8	2	12	19	1	36	27	76	12	0	32	11	10	4	6	0	0	1	0	8	1
U4-L19	1.14	22	1	102	18	2	8	0	0	12	4	3	0	5	5	0	10	60	95	7	0	17	7	3	0	15	0	0	0	0	2	2
U4-L20	0.36	17	0	168	13	0	3	0	0	17	1	6	0	3	11	2	11	42	75	5	0	5	5	1	0	10	0	0	0	0	3	2
U4-L21	1.04	14	0	96	19	0	9	0	0	31	5	1	0	5	3	1	3	77	75	4	0	26	11	4	0	12	1	0	2	0	0	1
U4-L22	0.90	21	0	78	26	0	5	0	0	29	9	5	0	3	17	4	33	27	66	7	0	33	13	8	4	3	0	0	0	0	7	2
U4-L23	0.89	29	2	58	16	0	4	1	0	53	11	5	2	3	38	2	39	10	66	7	0	16	14	7	2	0	4	0	0	0	6	5
U4-L24	1.52	11	0	100	9	0	10	1	0	11	5	0	0	3	3	0	2	64	78	4	0	60	17	10	0	7	0	0	2	0	1	2
U4-L25	1.87	15	0	91	6	0	5	1	0	17	8	1	0	2	9	2	21	37	124	2	0	30	17	3	0	5	0	0	2	0	1	1
U4-L26	2.53	19	0	104	7	0	8	1	0	15	2	5	0	6	7	1	10	39	73	5	0	56	22	6	0	3	0	0	7	0	3	1
U4-L27	0.97	21	1	121	23	1	8	2	1	24	8	2	0	1	3	0	4	73	53	6	0	28	4	5	1	7	0	0	1	0	1	1
U4-L28	0.89	33	0	66	9	0	5	0	0	56	4	3	2	7	27	2	30	24	65	9	0	20	13	8	3	4	0	0	0	0	6	4
U4-L29	0.35	16	0	112	7	0	6	0	0	4	5	2	0	1	17	0	19	34	79	4	0	46	23	2	1	13	0	0	2	0	6	1
U4-L30	2.18	27	0	107	16	1	6	0	0	6	6	1	0	5	12	1	12	70	54	5	0	33	20	8	0	7	0	1	0	0	0	2
U4-L31	6.50	22	0	69	7	0	2	1	0	11	8	2	3	8	11	5	6	45	114	9	0	26	21	6	1	17	0	0	5	0	1	0
U4-L32	9.19	17	0	41	9	0	3	0	0	20	4	0	0	7	13	3	12	31	143	11	2	8	37	1	0	23	1	0	6	1	6	1
U4-L33	5.21	13	0	106	23	0	6	0	2	22	11	3	1	3	3	1	0	48	72	3	0	26	37	6	0	13	0	0	0	0	1	0
U4-L34	2.62	15	2	43	7	0	1	0	0	44	4	2	4	8	28	1	33	19	112	7	0	22	29	4	2	8	0	1	0	0	4	0
U4-L35	2.36	20	0	110	6	0	11	0	0	23	7	1	0	4	12	0	4	53	70	3	0	17	23	0	3	22	3	0	5	0	2	1
U4-L36	1.38	23	0	109	7	0	8	0	0	19	5	3	0	2	7	2	18	52	79	7	0	32	8	8	1	7	0	0	1	0	2	0
U4-L37	2.56	14	0	36	16	1	13	1	0	44	8	7	0	14	6	1	24	30	86	9	0	17	29	3	2	31	3	3	0	1	1	0
U4-L38	1.22	9	0	177	11	0	8	0	0	11	9	1	0	1	8	4	19	28	46	7	0	28	8	4	0	12	1	0	4	0	4	0
U4-L39	0.70	19	0	191	9	0	6	1	0	12	1	1	0	3	5	0	0	64	43	3	0	12	20	4	0	5	0	1	0	0	0	0
U4-L40	0.14	24	0	166	12	0	8	0	0	22	5	1	0	1	10	2	1	54	46	5	0	10	13	0	2	10	3	0	3	0	2	0

12.5 JUNDARU RESULTS

Jundaru LOI Values

While this analysis was focused on the phytolith component of the Jundaru sediments, as described in Section 12.3, the method of phytolith extraction used involved a high temperature combustion step to remove organics. This method is akin to that used for determining LOI values and, as such, the recorded LOI data are reported herein.

The Jundaru LOI values are presented in Table 12-7, ranging from a high of 20% in a near surface sample (U1-L02), to a low of 7.2% in a sample at depth (U1-L23), with an average LOI value of 11.2%. The usual trend with LOI data is for there to be a general decrease with depth, reflecting increasingly poor preservation of organic materials through time. The Jundaru sediments conform with this overall pattern, though there are some minor peaks at depth, such as between U1-L13 and U1-L19, and again from U1-L24 to U1-L28. There appear to be three general groupings of LOI values: (1) the up*per se*diments, comprising the surface and three uppermost samples (U1-L01 to U1-L03) which, as expected given their more recent deposition, have the highest organic content (average = 16.2%; (2) sediments from U1-L04 to U1-L19 which have (in comparison to the upper unit) reduced organic content (average = 12.4%); and (3) sediments from U1-L20 to the base of the deposit (U1-L32) which have the lowest values in the site (average = 8.8%).

Assuming organic content of the sediments is somehow positively related to human presence and use of the site (in that greater organics would be expected to be deposited during periods when people are utilising they site than compared to when they are not), these results indicate fluctuations in the intensity of site use at different times, and are interesting when compared with the phytolith results presented in the following section. These results should also be compared against trends in categories of other cultural remains (*e.g.*, stone artefacts, bone, and especially macroscopic organics) and also correlated with the available chronology for the site in the main body of the overall report in order to produce a more meaningful interpretation of their significance.

Jundaru Phytolith Abundance

Phytolith abundance for the Jundaru sediment sample results are shown in Table 12-7. As noted in Table 12-7, five samples are substantial over-estimates (owing to the presence of large quantities of non-siliceous remains that could not be easily removed from the phytolith fraction). Note that the values presented here are more accurate than those presented in Wallis (2010a), as samples were subject to additional processing in the intervening period between production of the initial Wallis (2010a) report and this one.

Phytoliths were well preserved throughout the Jundaru sequence, with limited signs of chemical or physical weathering. As can be seen Table 12-7, they range from a low of 2.46% in sample U1-L25, to a high of 10.76% in sample U1-L27 (note that for the purpose of discussing ranges and averages, the five over-estimates are excluded from consideration so as to avoid over-inflating values). Average phytolith abundance is a little over 7%.

Phytolith abundance at Jundaru is surprising consistent through time. At the time of initial sediment deposition in the site, phytolith abundance is around 8% and thereafter generally increases until U1-27 (possibly U1-L26), which has the highest abundance in the entire sequence, before falling dramatically to its lowest level in the whole sequence immediately thereafter in U1-L25. Phytolith abundance recovers in the immediately adjacent level (U1-L24), though not to the extreme abundance seen in U1-L27 and, with the exception of declines in U1-L16 and U1-L13, remains reasonably consistent until near the surface of the site, after U1-L04, when it falls slightly. The phytolith abundance values for the four surface samples (collected at specific locations across the excavation trench area) show a small degree of variability, ranging between 4.39 and 7.33%, with an average of 5.8% which is reassuringly similar to the value of 5.47% for the surface sediment sample from U1-L01.

Table 12-6 Loss on ignition (LOI) data and percentage of phytoliths through time (based on raw weights) for Jundaru sediments

Unit-Layer Code	LOI Value (Percentage by Weight)	Phytolith Percentage by Weight
NW Surface	11.0	4.39
SE Surface	17.5	7.33
E Surface	12.6	6.85
NE Surface	17.7	4.61
U1-L01	19.0	5.47
U1-L02	20.0	4.85
U1-L03	15.9	7.47
U1-L04	13.6	7.93
U1-L05	14.7	7.44
U1-L06	13.2	<11.62
U1-L07	13.6	7.67
U1-L08	11.7	6.96
U1-L09	11.2	<12.19
U1-L10	10.2	7.56
U1-L11	11.2	7.12
U1-L12	11.2	6.81
U1-L13	12.1	5.42
U1-L14	11.9	<13.29
U1-L15	11.5	8.81
U1-L16	12.7	4.47
U1-L17	12.8	6.96
U1-L18	12.2	9.75
U1-L19	13.9	9.82
U1-L20	10.0	7.34
U1-L21	7.7	5.85
U1-L22	8.0	6.06
U1-L23	7.2	6.56
U1-L24	8.2	6.48
U1-L25	8.5	2.46
U1-L26	8.8	<18.58
U1-L27	9.6	10.76
U1-L28	11.1	<18.59
U1-L29	9.9	9.99
U1-L30	7.9	8.57
U1-L31	8.3	9.32
U1-L32	9.0	6.96
Samples with '<' before them are over-estimates owing to the inability during processing to remove all extraneous non-phytolith materials from these samples		

Without knowing further details about the radiocarbon chronology, stratigraphy or patterning of other cultural remains for this site, it is difficult to say more in this chapter about the significance of the general phytolith abundance patterning, though it will be interesting to ascertain whether it correlates with results derived from other categories of archaeological

remains; such comparison is discussed in the main body of the report. The initially quite high levels of phytolith abundance in the lower levels of Jundaru can be interpreted as indicating either that (1) background levels of phytoliths in the site are high (due to non-human agents such as macropods contributing substantial quantities of organic plant materials via faeces to the sediments) and therefore that humanly introduced phytoliths later in the sequence represent a thin veneer over an essentially natural signal, or (2), that human occupation of the site essentially commences concurrently with the accumulation of sediment and that the bulk of phytoliths in the site are related to human activities. Determining which of these is the more appropriate interpretation will depend on an understanding of when the first definitively cultural materials (*i.e.*, stone artefacts) appear in the Jundaru sequence. Further discussion of these results is presented in Section 12.7.

Jundaru Phytolith Morphologies

A total of 33 phytolith types were encountered regularly in the Jundaru sediments. In addition, several other rare types whose plant origins were unknown were also encountered; for the sake of reporting these are graphed collectively under the heading 'Other'. Raw counts of the phytoliths from the Jundaru sediments are presented in Table 12-8 and Figure 12-7. Zones have been indicated on these diagrams based on the patterning observed and the results of the multivariate statistical analyses (see next section), however should be considered only tentative until other site data are also taken into account.

Many of the phytoliths observed are of morphologies diagnostic of grasses, though rarely beyond the Family level. Bilobates and quadralobates are typically characteristic of the Panicoid grasses, and these vary considerably through time in the Jundaru sequence. While initially high in the lowest level of the site, they soon after decline, reaching their lowest levels in U1-L27, before generally rising to reach their highest levels in U1-L7. Saddles are characteristic of the Chloridoid grasses, and these too vary considerably through time in the Jundaru sequence. Long shanked bilobates are indicators of members of the *Aristida* genus and, though these only make very occasional appearances, they seem to be slightly more common in the upper half of the assemblage. Eriachne phytoliths (which have an upper surface shaped like a bilobate and a basal scalloped shaped surface – see Figure 12-5 and Figure 12-6) are another grass morphology that is distinctive at the genus level. While present throughout the sequence in only low numbers, they do appear more consistently and abundantly in levels U1-L1 through to U1-L18.

Several variants of long cell and flat phytolith forms derive from both grasses and trees (Piperno 1988, 2006; Wallis 2003). While they vary considerably through time in the Jundaru sediments, they have limited interpretive value owing to their non-specific nature.

Of greater interest are the various globular forms, which derive from trees and shrubs. Without having undertaken systematic studies of all the trees and shrubs in the Pilbara it is hard to state definitively exactly what plants many of the globular forms come from, beyond the general tree/shrub categorisation. Nevertheless, globular echinate forms are known to be a distinctive morphology associated with the Arecaceae family (palms; see Cooney 2010; Piperno 1988, 2006; Wallis 2003), which appear occasionally more commonly in the upper half of the sequence. Acacia leaves sometimes produce a distinctive ornamented form of phytolith (see Hart 1988; Wallis 2003) and, while it is only occasionally seen in the Jundaru sequence, it does appear to be conspicuously absent from U1-L3 to U1-L20. As shown in Figure 12-7, there is a substantial increase in the percentages of phytoliths deriving from trees/shrubs above U1-L20 in the Jundaru sequence (*i.e.*, Zones 2 and 3).

Cyperaceae type phytoliths are distinctive flat forms with echinate and nodular ornamentation, and while produced in abundance in modern plants (*e.g.*, Wallis 2003)seem rarely to survive in sedimentary sequences; they are only seen very rarely in the Jundaru sediments.

Interpretation of these results is discussed in Section 12.7.

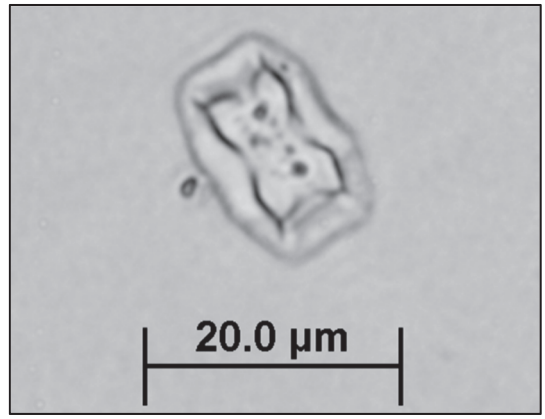


Figure 12-5 Plan View Showing Typical Morphology of an 'Eriachne' Type Phytolith (from *Eriachne helmsii*)

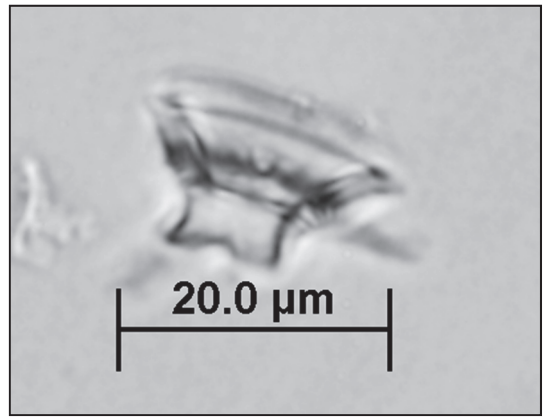


Figure 12-6 Side View Showing Typical Morphology of an 'Eriachne' Type Phytolith (from *Eriachne helmsii*)

Table 12-8 Raw counts of phytolith types observed in Jundaru sediments

Unit-Layer Code	Bilobate	Long shanked bilobate	Rondel	Saddle	Eriachne	Unilobate	Quadralobate	Polylobate	Angular quadrilateral	Prickle	Ovoid prickle base	Conical	Hair cell	Ornamented hair cell	Parallelepipedal	Oblong	Dendritic	Elongate echinate long cell	Elongate psilate long cell	Elongate sinuous long cell	Flat multi-circular	Flat jigsaw	Flat sinuous	Flat rectangular	Flat rectangular with nodular protuberances	Large rondel	Globular psilate	Globular echinate	Globular granulate	Cuneiform bulliform	Acacia	Cyperaceae	Other	Elongate lobate long cell
NW Surface	29	1	71	22	2	29	0	1	8	3	1	0	0	0	5	1	7	59	56	13	0	0	35	27	1	1	20	0	4	1	1	0	2	0
SE Surface	28	0	59	22	6	27	1	0	13	5	2	0	0	0	7	3	3	70	64	9	0	0	34	22	2	2	12	0	3	2	2	0	1	0
E Surface	35	1	82	26	3	15	1	0	12	4	0	0	3	0	3	2	4	42	66	12	0	0	28	23	5	2	18	1	5	1	0	0	6	0
NE Surface	22	0	73	18	7	23	2	0	10	10	1	0	6	0	9	0	11	70	53	14	0	0	28	22	3	0	10	0	2	2	1	0	3	0
U1-L01	31	0	76	8	2	11	0	1	8	5	5	1	1	0	19	5	9	44	79	6	0	3	36	12	5	2	22	2	2	4	0	0	0	1
U1-L02	30	0	104	22	0	12	0	0	5	8	1	0	5	0	5	0	14	42	49	12	0	0	37	12	5	6	13	0	8	0	2	0	4	4
U1-L03	34	0	97	14	1	11	2	0	5	2	3	0	2	0	9	0	9	58	54	8	0	0	32	6	23	2	26	0	1	0	0	0	0	1
U1-L04	53	1	56	16	4	14	1	0	9	11	7	1	1	0	8	1	1	53	62	11	0	0	41	6	6	0	34	0	1	1	0	0	0	1
U1-L05	46	0	51	34	2	27	1	0	7	12	1	0	1	0	6	0	6	51	59	17	0	0	16	19	15	1	18	0	6	0	0	0	3	1
U1-L06*	58	0	39	49	3	38	5	0	7	7	4	0	1	0	12	1	4	44	34	10	0	0	29	22	4	0	18	0	6	5	0	0	0	0
U1-L07	63	0	42	16	4	20	4	1	3	11	0	0	1	0	4	1	4	45	66	18	0	0	36	17	11	0	29	2	2	0	0	0	0	0
U1-L08	51	0	33	31	4	12	6	1	5	9	2	0	0	0	7	1	11	44	58	29	0	0	39	20	15	1	19	0	0	2	0	0	0	0
U1-L09*	45	0	38	33	1	31	0	0	12	10	4	0	4	0	12	1	8	64	55	15	0	0	17	13	2	1	27	1	1	3	0	0	2	0
U1-L10	42	0	50	43	0	27	4	0	16	4	3	0	4	0	8	0	9	56	38	16	0	0	18	18	4	0	25	0	6	2	0	0	7	0
U1-L11	36	0	67	30	4	34	3	0	15	4	0	0	0	0	10	0	17	48	43	18	0	0	21	12	6	1	24	1	2	1	0	0	3	0
U1-L12	30	0	67	25	1	33	3	1	18	13	3	0	5	0	13	1	13	48	22	19	0	0	26	16	10	2	19	0	11	0	0	0	1	0
U1-L13	29	1	61	28	0	27	4	0	9	7	2	1	3	0	8	1	13	52	41	24	0	0	30	21	7	1	19	0	4	1	0	0	6	0
U1-L14*	40	0	71	27	0	34	5	0	10	9	0	0	6	1	10	1	5	34	28	10	0	0	36	26	5	1	28	0	11	2	0	0	0	0
U1-L15	29	1	83	29	1	20	4	2	8	5	2	0	3	0	10	0	21	35	19	36	0	0	45	22	10	0	11	1	1	0	0	0	2	0
U1-L16	34	0	61	23	6	20	2	0	11	11	1	0	3	0	12	0	16	42	29	11	0	0	64	7	21	3	13	0	7	1	0	0	2	0
U1-L17	40	0	62	20	4	27	6	3	6	8	1	0	3	0	5	0	16	46	30	13	2	0	51	19	16	2	10	1	6	2	0	0	1	0
U1-L18	34	0	68	29	4	23	0	4	17	12	3	0	4	0	5	0	2	57	42	10	1	0	43	16	16	1	6	0	0	1	0	0	2	0
U1-L19	31	0	91	29	1	11	2	0	6	6	1	0	0	0	6	1	10	49	61	15	0	0	27	27	10	0	13	0	2	1	0	0	0	0
U1-L20	17	0	107	25	1	9	0	0	8	4	1	0	3	0	4	1	7	57	64	18	0	5	38	21	4	1	3	0	0	1	0	0	1	0
U1-L21	27	0	97	12	0	9	2	0	12	4	1	0	4	0	4	0	9	53	81	12	0	0	29	29	5	2	4	0	0	2	1	0	0	1
U1-L22	18	0	93	19	4	14	0	2	6	6	1	0	1	0	4	0	16	69	64	7	0	0	33	25	8	5	3	0	0	1	0	0	1	0
U1-L23	15	0	174	12	2	4	2	0	8	3	2	0	2	0	8	2	18	43	44	12	0	0	12	25	8	1	1	0	1	0	0	0	1	0
U1-L24	20	0	143	10	0	10	1	0	8	1	0	0	1	0	4	1	22	60	60	6	1	0	9	29	7	2	2	0	1	0	0	0	0	2
U1-L25	15	0	131	13	1	7	1	2	9	10	3	0	3	0	4	0	24	54	61	5	0	3	9	36	0	6	0	0	3	0	0	0	0	0
U1-L26*	11	0	118	24	1	6	0	0	9	4	1	0	0	0	4	0	9	57	95	11	0	0	22	17	1	6	0	2	0	1	1	0	0	0
U1-L27	8	0	116	35	1	7	2	1	11	0	1	0	1	0	5	1	23	46	63	9	1	0	32	30	2	2	2	0	0	1	0	0	0	0
U1-L28*	10	0	114	27	1	8	0	1	9	5	1	0	1	0	8	2	21	61	92	9	0	0	2	21	0	5	1	0	0	0	0	0	1	0
U1-L29	15	2	129	15	1	9	1	3	5	4	0	0	2	0	4	0	6	51	88	18	0	0	10	24	4	1	5	0	0	1	0	2	0	0
U1-L30	23	0	105	23	0	19	0	1	4	3	0	0	0	0	5	0	11	60	77	14	0	0	14	25	5	8	1	0	1	0	0	0	0	1
U1-L31	22	0	139	22	2	5	0	0	3	3	0	0	0	0	4	0	6	51	77	6	0	0	30	22	2	1	2	0	0	2	0	1	0	0
U1-L32	41	0	74	31	0	36	0	0	6	5	1	0	3	0	4	0	10	31	76	6	0	0	23	39	2	1	4	0	4	2	1	0	0	0

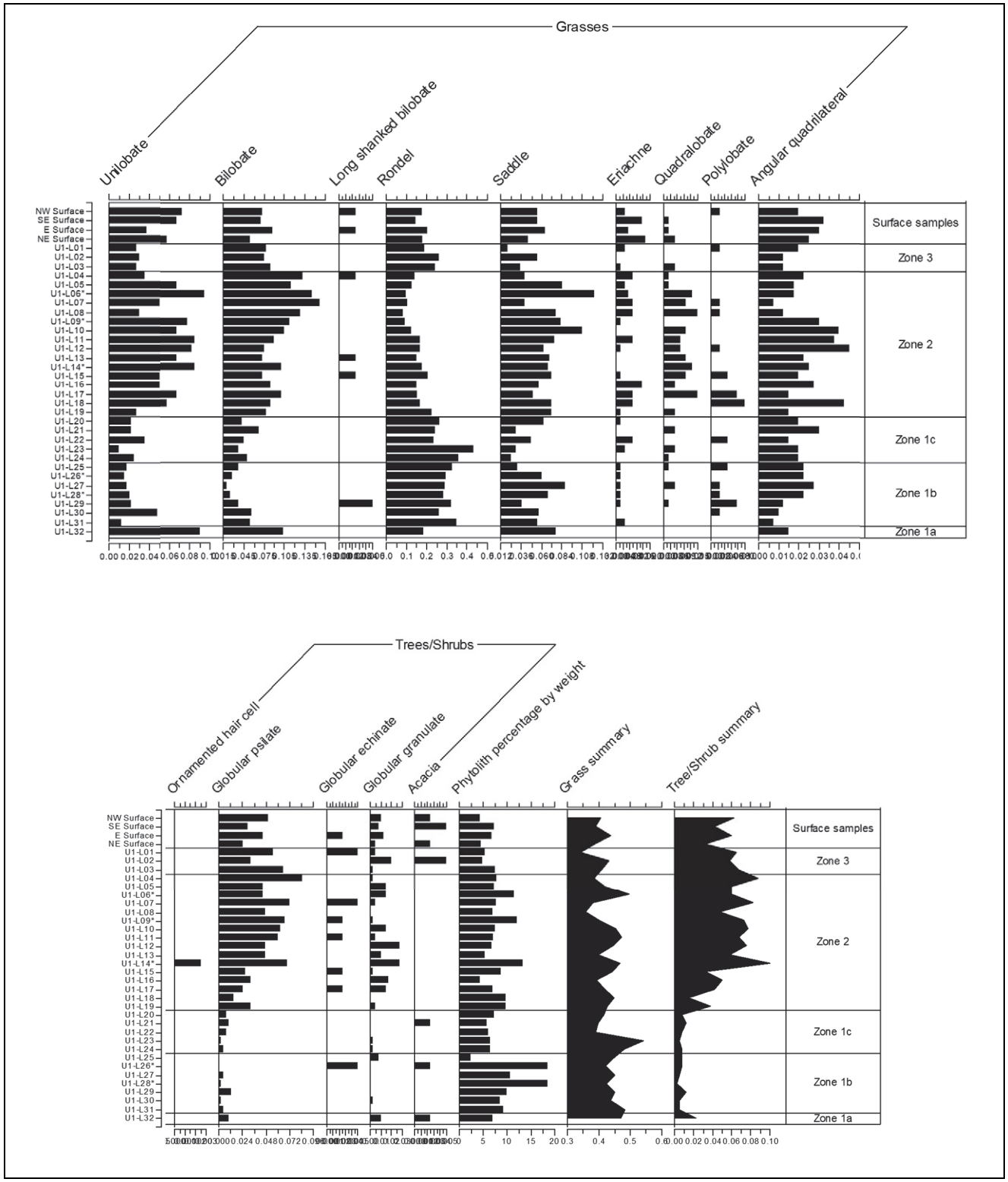


Figure 12-7 Diagram showing percentage values of grass versus tree/shrub phytolith types in Jundaru sediments (based on counts provided in Table 12-8). An A3 versions of this figure can be found online with the supplementary information.

12.6 HD07-3A-PAD13 RESULTS

HD07-3A-PAD13 LOI Values

The LOI values for the HD07-3A-PAD13 samples are presented in Table 12-9. As shown, the values range from a high of 16.4% in a near surface sample (U3-L01), to a low of 3.3% in a sample at depth (U3-L16); the average LOI value is 6.1%.

While there is an initial decline in the percentage of organics a small distance below the surface, from 40 cm to 215cm below datum the organic content appears to be relatively constant with only minor fluctuations (rather than a gradual decline with depth). Beyond the uppermost two spits (average = 13.9%), organics range between 3.3 and 9.1%, at an average of 5.7% with some minor peaks and troughs. Assuming organic content of the sediments is somehow positively related to human presence and use of the site, these results indicate fluctuations in the intensity of site use at different times, though these are more subtle than was the case in the Jundaru and Djadjiling sites. These results are compared against trends in categories of other cultural remains (*e.g.*, stone artefacts, bone, and especially macroscopic organics) and also correlated with the available chronology for the site in the main body of the report in order to provide a more meaningful interpretation of their significance.

HD07-3A-PAD13 Phytolith Abundance

Phytolith abundances in the HD07-3A-PAD13 sediment samples are shown in Table 12-9. Note that the values given in Table 12-9 are more accurate than those presented in Wallis (2010b), as samples were subject to additional processing in the intervening period between the initial Wallis (2010b) report and this one. Phytolith abundances range from a low of 5.6% and 5.7% near the base of the deposit (U3-L36 and U3-L37), to a high of 14% in sample U3-L17 near the middle of the deposit; the average phytolith abundance is 8.7%.

There are some interesting variations in phytolith abundance in HD07-3A-PAD13 through time. At the time of initial sediment deposition, phytolith abundance is extremely high (12.7%, second only to that seen in U3-L17). The following two levels (U3-L37 and U3-L36) show a substantial decline to less than half the initial U3-L38 amount, to approximately 5.6%. Between U3-35 and U3-L28 the phytolith abundance values rise slightly and are relatively constant (average = 7.9%). They then steadily increase (with a few minor falls) to a peak in U3-L17 (14%), before falling to 6.1% in U3-L12 (the average during this period, from U3-L27 to U3-L12, is 8.8%). From U3-L11 values rise again to a peak in U3-L07 (11.9%), after which they fall to a low of 7.0% in U3-L02.

Without knowing further details about the radiocarbon chronology, stratigraphy or patterning of other cultural remains for HD07-3A-PAD13, it is difficult to say more in this chapter about the significance of the general phytolith abundance patterning, though it will be interesting to ascertain whether it correlates with results derived from other categories of archaeological remains; such comparison is discussed in the main body of the report. Like Jundaru, the initially very high levels of phytolith abundance in the lower levels of HD07-3A-PAD13 can be interpreted as indicating either that (1) background levels of phytoliths in the site are high (due to non-human agents such as macropods contributing substantial quantities of organic plant materials to the sediments), and therefore that humanly introduced phytoliths later in the sequence represent a thin veneer over an essentially natural signal, or (2), that human occupation of the site essentially commences concurrently with the accumulation of sediment and that the bulk of phytoliths in the site are related to human activities. Determining which of these is the more appropriate interpretation will depend on an understanding of when the first definitively cultural materials (*i.e.*, stone artefacts) appear in the HD07-3A-PAD13 sequence.

Further discussion of these results is presented in Section 12.7.

Table 12-9 Loss on ignition data and percentage of phytoliths through time (based on raw weight measurements) for sediments from HD07-3A-PAD13

Unit-Layer Code	LOI Value (Percentage by Weight)	Phytolith Abundance (Percentage by Weight)
U3-L01	16.4	7.1
U3-L02	11.4	7.0
U3-L03	8.6	7.4
U3-L04	6.8	10.0
U3-L05	6.8	9.7
U3-L06	9.1	10.7
U3-L07	6.8	11.9
U3-L08	7.7	6.2
U3-L09	5.3	10.1
U3-L10	4.6	7.8
U3-L11	6.7	9.3
U3-L12	6.4	6.1
U3-L13	5.5	6.3
U3-L14	5.9	6.6
U3-L15	4.8	11.3
U3-L16	3.3	9.2
U3-L17	4.3	14.0
U3-L18	4.0	10.9
U3-L19	5.4	7.4
U3-L20	5.1	9.4
U3-L21	5.5	6.7
U3-L22	5.6	10.9
U3-L23	3.9	10.2
U3-L24	6.0	7.4
U3-L25	5.0	8.9
U3-L26	5.4	8.0
U3-L27	4.5	7.6
U3-L28	6.1	8.0
U3-L29	5.7	7.8
U3-L30	4.3	7.5
U3-L31	5.5	7.8
U3-L32	4.9	8.0
U3-L33	6.6	7.1
U3-L34	4.4	8.1
U3-L35	5.5	9.2
U3-L36	4.9	5.6
U3-L37	7.2	5.7
U3-L38	6.0	12.7

HD07-3A-PAD13 Phytolith Morphologies

A total of 33 phytolith types were encountered regularly throughout the HD07-3A-PAD13 sediments. In addition, several other rare types whose plant origins were unknown were also encountered; for the sake of reporting these were graphed collectively under the heading 'Other'. Raw counts of the phytoliths from the HD07-3A-PAD13 sediments are presented in Table 12-10, and diagrams showing these results are presented as Figure 12-8 (note that conical and flat multi-circular types have not been graphed on these figures owing to

their extremely rare occurrences). Zones have been indicated on these diagrams based on the patterning observed and the results of the multivariate statistical analyses (see next Section), though should be considered tentative until other site data are also taken into account.

Many of the phytoliths observed in the HD07-3A-PAD13 sediments are derived from grasses, though they can rarely be identified more specifically than to Family level. Bilobates are typically characteristic of the Panicoid grasses, and these vary significantly through time in the HD07-3A-PAD13 sequence. They are present in relative low concentrations from the base of the deposit until U3-L10, after which they increase substantially, a trend which is persistent thereafter through to the surface of the site. Saddles are characteristic of the Chloridoid grasses and, while present throughout the HD07-3A-PAD13 deposit, they are generally more abundant between U3-L37 and U3-L26. Rondels are found in a variety of grasses, including spinifex grasses and, while present throughout the sequence, they are reduced in U3-L9 to U3-L1 in comparison to the lower levels of the site.

Various forms of elongate long cells and flat forms derive from both grasses and trees and, while they vary considerably through time in the HD07-3A-PAD13 sediments, they have limited interpretive value. Dendritic phytoliths occur around rondels and, unsurprisingly, their abundance between U3-L27 and U3-L10 corresponds with an increase in those levels of rondels.

Of particularly useful interpretive value are the various globular forms, which derive from trees and shrubs. However, beyond noting that they are commonly found in trees, the origins of globular psilate forms cannot be distinguished further at this stage. In the HD07-3A-PAD13 sediments these forms are comparatively abundant in the lowest level of the site (U3-L38) through to approximately U3-L25, after which they become more sporadic, with many levels not containing any of these forms. However, above U3-L8 they make a sustained reappearance at HD07-3A-PAD13. As shown in Figure 12-8, when considered collectively with other morphological types known to derive from trees and/or shrubs (rather than individually) there is a substantial decline in the percentages of phytoliths deriving from trees/shrubs between U3-L30 and U3-L12 in the HD07-3A-PAD13 sequence.

Interpretation of these results is discussed in Section 12.7, below.

12.7 DISCUSSION

Phytolith Abundances in the Pilbara Plants

The weathering of silicate rocks (such as granite) releases silicon which, with the addition of water, then forms monosilicic acid [Si(OH)4] in soils (Hopps *et al.* 1977; Jones and Handreck 1963; Jones and Handreck 1965; Jones and Handreck 1967; McKeague and Cline 1963b; McKeague and Cline 1963a; McKeague and Cline 1963c). In this state the silica is taken up by plants and is then transported around the plant via vascular water conducting tissues (xylem). When supersaturation requirements are exceeded (usually greater than 100 ppm), polymerisation of the silica occurs, resulting in the precipitation and subsequent deposition of amorphous silica (SiO2.nH2O, otherwise referred to as phytoliths) (Kaufman *et al.* 1981; Perry 1989).

Taking into account the various factors known to influence soil silica concentrations (and therefore groundwater; *e.g.*, underlying bedrock, pH levels, precipitation rates, temperature, *etc.*), Hopps *et al.* (1977) suggested that plants in the following geographical regions are likely to be high silica accumulators: semi-arid to arid areas of alkaline soils that experience limited leaching; areas of fresh volcanic activity; areas adjacent to hot springs; areas with fine textured soils that contain low levels of iron and aluminium oxides; and, poorly drained soils.

Hopps *et al.* (1977) also argued that plants that contain low levels of silica will generally be associated with areas of: predominantly weathered soils containing high levels of iron and aluminium oxides; highly leached, coarse textured soils; and, soils developed from limestone.

However, Piperno (Piperno 1985; Piperno 1988; Piperno and Pearsall 1998) has demonstrated that many plants grown in highly weathered, lateritic soils do, in fact, produce abundant quantities of phytoliths. She argued this may be due to the abundant supply of silica provided by accelerated weathering processes in such areas, coupled with the efficiency of nutrient uptake (Piperno 1988: 13). This serves as a warning that, while such generalisations as offered by Hopps *et al.* (1977) may be a useful guide, the only way to confidently ascertain the phytolith productivity of flora in a given region is to carry out locally specific studies of the extant vegetation in that region. Furthermore, since scientists have a poor understanding as to why silica is accumulated at all in plants (with indications that there is a large degree of genetic control with some environmental input), such local studies are critical.

The phytolith production patterns from the modern Pilbara plant specimens observed during the current study are broadly in line with findings from other Australian floristic studies (*e.g.*, Bowdery 1996; Bowdery 1998; Wallis 2000; Wallis 2003), as well as international studies. Many of the plant samples were shown to not accumulate silica in any form, while others were shown to only accumulate non-diagnostic or redundant forms. No particularly unexpected phytolith morphologies were observed in any of the samples examined; this is both promising and disappointing. It is promising since the patterning apparent mirrors that seen in other members of the same families examined from elsewhere, meaning we can have confidence drawing upon the results of other studies to help interpret the Pilbara results. It is disappointing in that, while the identification of distinctive phytoliths from particular plant species, genera or families would greatly improve the level of interpretation that can be offered of the archaeological samples, the absence of such phytoliths means the interpretations offered of the analysed sediments is by necessity general, rather than specific, in nature. Nevertheless, as the interpretation of any group of botanical remains is limited by the inherent characteristics of the particular remains, even general interpretations are valuable. The most robust archaeological interpretations are offered based on multiple lines of complementary evidence (*e.g.*, phytoliths, seeds, wood charcoal, and macrobotanical remains) and even if somewhat general in nature, the phytolith data contribute information not available via any other means that can be correlated in the future with the other categories of remains studied from the sites.

Table 12-10 Raw counts of phytolith types observed in HD07-3A-PAD13 sediments

Unit-Layer Code	Bilobate	Long shanked bilobate	Rondel	Saddle	Eriachne	Unilobate	Quadralobate	Polylobate	Angular quadrilateral	Cuneiform bulliform	Prickle	Ovoid prickle base	Conical	Hair cell	Parallelepipedal	Oblong	Cuboid	Dendritic	Elongate echinate long cell	Elongate psilate long cell	Elongate sinuous long cell	Flat multi-circular	Flat sinuous	Flat rectangular	Flat rectangular with nodular protuberances	Large rondel	Globular psilate	Globular echinate	Globular granulate	Acacia	Cyperaceae	Elongate lobate long cell	Distinctive other	Other
U3-L01	57	1	85	11	2	24	1	0	13	0	8	4	1	0	7	1	0	15	44	72	12	0	2	18	3	3	6	3	4	0	0	2	1	0
U3-L02	60	0	73	29	0	17	1	1	24	3	1	2	0	0	5	0	0	19	50	60	13	0	3	21	2	3	9	0	4	0	0	0	0	0
U3-L03	39	0	70	12	0	8	0	2	23	4	7	2	0	3	13	4	0	14	81	73	7	0	5	20	1	0	9	0	1	0	0	0	2	0
U3-L04	43	0	70	15	0	10	2	0	14	0	7	4	0	1	13	4	0	4	93	92	2	0	0	13	0	0	10	0	0	0	1	0	1	1
U3-L05	51	1	56	36	0	9	1	0	22	2	11	0	0	1	9	5	0	18	76	81	5	0	2	10	0	0	3	0	0	0	0	1	0	0
U3-L06	44	0	53	21	0	10	1	1	17	0	10	0	0	2	4	0	0	7	94	93	16	0	2	12	0	2	3	0	2	0	0	1	3	2
U3-L07	53	0	45	31	0	4	1	0	10	0	13	2	0	3	10	1	0	6	80	91	10	0	2	17	1	6	5	0	2	0	0	3	2	2
U3-L08	34	1	40	18	0	3	0	0	17	1	12	5	0	0	17	1	0	8	86	123	6	0	0	21	1	0	1	1	2	0	0	1	1	0
U3-L09	43	0	32	33	0	11	0	0	13	2	8	2	0	3	17	1	0	2	86	102	8	0	4	21	2	4	0	0	2	0	0	3	1	0
U3-L10	68	0	10	18	0	6	1	2	7	7	9	3	0	4	8	2	2	0	41	89	3	0	4	13	2	1	6	0	0	0	2	2	0	0
U3-L11	12	0	11	11	0	1	1	1	3	4	7	3	0	1	16	3	7	15	59	81	13	0	18	13	2	8	3	0	1	0	1	1	0	1
U3-L12	17	0	13	28	1	6	0	1	15	4	10	6	0	0	12	4	0	12	44	113	13	0	15	17	0	4	1	0	0	0	0	2	1	2
U3-L13	15	0	16	4	0	2	0	0	8	2	4	2	0	0	10	0	5	29	28	88	6	0	9	16	4	2	1	0	0	0	0	0	2	0
U3-L14	15	0	15	13	1	6	0	0	6	0	2	0	0	2	6	3	6	17	59	81	2	0	9	9	2	0	2	0	0	0	0	1	1	1
U3-L15	8	0	17	10	0	1	0	0	8	0	2	0	0	1	4	0	1	26	24	93	6	0	6	30	2	3	1	0	1	1	0	2	0	0
U3-L16	11	0	20	8	0	4	0	0	13	1	2	0	0	1	5	2	0	4	32	88	2	0	4	17	0	2	0	0	0	0	0	1	1	0
U3-L17	9	0	15	29	1	3	3	0	10	2	0	1	0	1	8	1	1	8	37	103	1	1	6	12	1	8	0	0	0	1	0	1	2	0
U3-L18	6	0	15	10	0	2	2	1	6	1	1	1	0	1	8	0	17	16	24	110	4	0	10	18	2	4	2	0	0	0	0	0	1	0
U3-L19	7	0	16	39	0	1	0	0	10	3	1	0	0	0	3	1	12	20	34	82	0	0	6	14	0	4	0	0	0	0	0	1	0	1
U3-L20	6	0	17	16	0	1	1	1	10	0	2	2	0	0	4	0	3	10	22	123	3	0	3	15	0	6	0	0	0	0	0	1	0	0
U3-L21	8	0	17	14	0	0	0	1	4	3	0	0	0	1	7	1	0	16	29	125	2	0	3	10	0	3	2	0	0	0	0	0	1	0
U3-L22	2	0	18	17	0	0	0	0	12	1	1	0	0	2	8	3	5	19	16	111	2	0	0	13	2	3	0	0	0	0	0	0	1	0
U3-L23	6	0	15	19	0	1	0	0	2	2	1	0	0	0	6	1	4	30	21	121	1	0	3	14	2	8	3	1	0	0	0	0	0	0
U3-L24	10	0	13	41	0	1	1	0	10	2	6	0	0	0	3	0	0	30	22	103	2	1	10	10	1	5	1	0	0	0	0	2	0	0
U3-L25	4	0	19	10	1	1	1	0	5	0	2	0	0	1	6	0	4	16	32	102	1	0	1	14	1	2	6	0	0	0	0	0	0	0
U3-L26	13	0	14	26	0	2	1	0	3	1	1	1	0	0	9	0	2	27	43	103	2	0	0	10	1	6	0	0	0	0	0	1	0	1
U3-L27	9	0	15	21	0	9	0	0	6	3	0	0	0	0	7	0	3	16	39	98	1	0	6	21	1	2	2	0	0	1	0	0	1	2
U3-L28	7	0	13	50	0	2	0	1	8	4	1	2	0	2	8	0	3	14	48	92	4	0	7	9	0	4	0	0	1	0	0	2	1	0
U3-L29	11	0	10	86	0	1	0	2	2	5	0	0	0	1	8	0	15	28	25	83	5	0	7	6	0	5	1	0	0	0	0	0	2	0
U3-L30	24	0	10	14	0	4	1	0	1	3	2	2	0	2	3	1	2	8	51	133	6	0	10	17	5	1	7	0	0	1	0	0	0	0
U3-L31	6	0	85	47	0	2	0	1	15	0	1	0	0	0	5	0	6	2	70	119	8	0	10	10	3	6	1	0	0	0	0	3	0	0
U3-L32	10	0	12	58	0	4	0	0	5	0	2	1	0	0	16	0	2	23	39	68	11	0	12	15	2	5	2	0	2	0	0	2	1	0
U3-L33	12	0	14	29	0	3	0	1	8	0	3	0	0	0	13	0	18	10	60	56	8	0	6	17	1	5	2	0	0	0	0	2	1	2
U3-L34	16	0	51	42	0	1	1	0	9	0	5	0	0	2	7	2	2	8	55	142	6	0	21	17	1	4	6	0	1	1	0	0	0	0
U3-L35	14	0	14	16	0	3	1	0	7	3	2	2	0	2	15	2	0	18	50	75	9	0	12	18	1	5	1	0	0	0	0	1	0	0
U3-L36	19	0	92	13	0	3	0	1	7	3	1	1	0	2	0	0	20	9	83	127	2	0	4	8	0	0	1	0	2	0	1	0	1	0

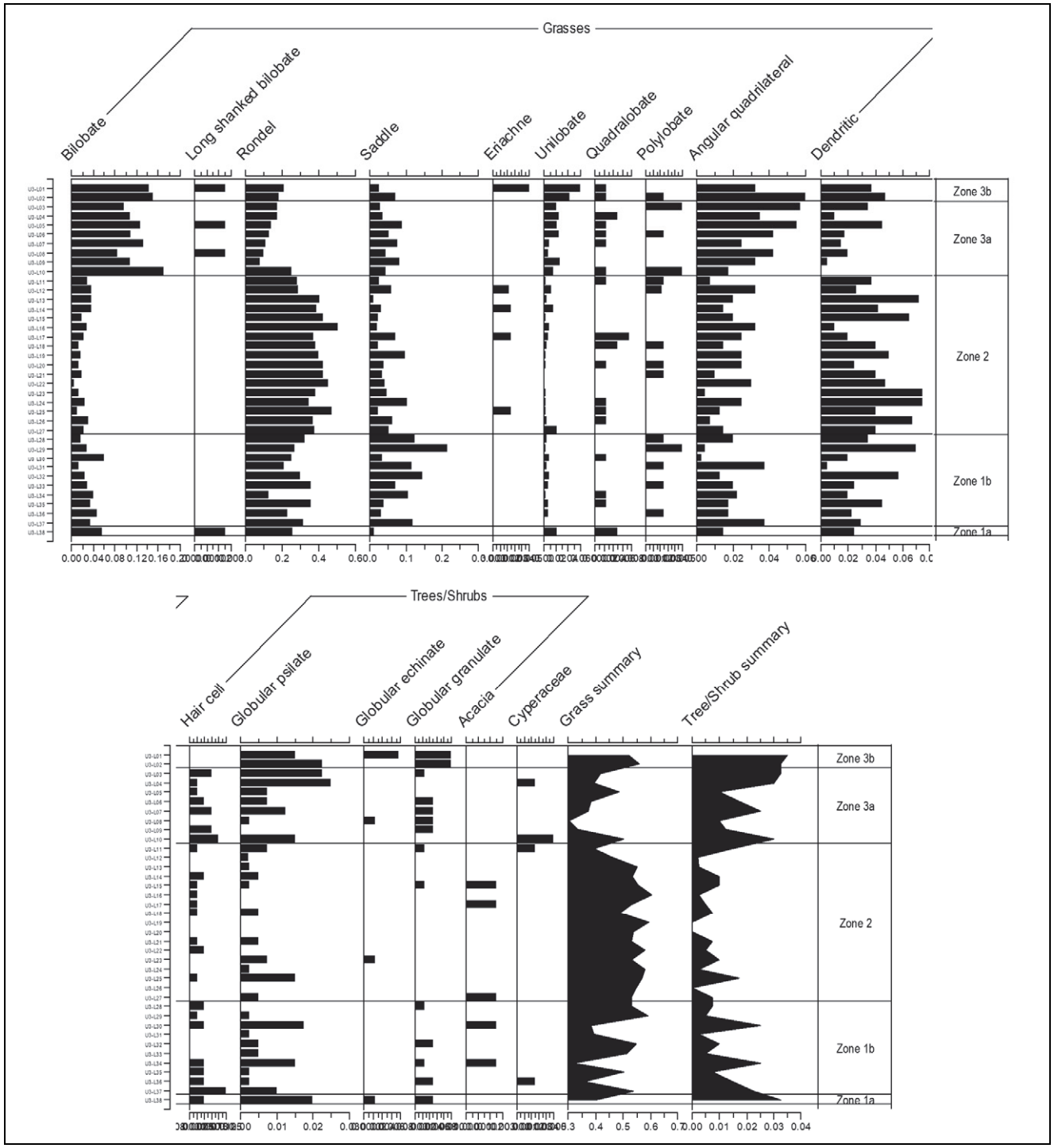


Figure 12-8 Diagram showing percentage values of grass versus tree/shrub phytolith types in HD07-3A-PAD13 sediments (based on counts provided in Table 12-10). An A3 version of this figure can be found online with the supplementary information.

The results available from the modern plant studies do suggest there will be sufficient quantities of phytoliths produced that display enough morphological variability to distinguish between phytoliths produced by broadly different vegetation communities. However, given the absence of silica accumulation in some plant families, phytolith assemblages recovered from sedimentary contexts cannot be expected to be representative of the entire original vegetation community. Similarly, since the quantities of phytoliths vary tremendously between different plants, in many cases it may not be possible to ascertain relative importance of vegetation types across the landscape based on the sedimentary phytolith assemblage. This problem may be compounded by taphonomic factors affecting phytolith types differentially. While additional detailed analysis of a wider array of Pilbara flora would enhance the interpretation archaeological sediment samples, such work was beyond the scope of this project. Despite the comparatively small number of samples examined in this study, the results serve as a useful baseline for any and all future phytolith studies – archaeological, botanical, or sedimentary – in the Pilbara region.

Formation Processes of Phytolith Assemblages

The interpretation of any category of plant remains recovered from archaeological sites is complicated, since the deposition of

materials may have occurred through either cultural or natural agencies (*cf.* Schiffer 1987). Understanding the site formation processes that have operated at Djadjiling, Jundaru, and HD07-3A-PAD13 throughout the sites' histories is therefore critical to developing a robust interpretation of the different categories of remains recovered from their archaeological deposits; such issues are considered briefly below.

Criteria usually based on physical characteristics have been used to help researchers distinguish between naturally deposited macroscopic plant materials and those present as a result of human activities (e.g, Clarke 1989). Generally, plant remains are assumed to have been culturally deposited if they display one, or a combination, of the following aspects: evidence of processing (such as in the form of consistent breakage patterns or selective burning); a species not found in the immediate site vicinity that would therefore have required transportation; or ethnographically recorded use of the plant. By critically assessing archaeobotanical remains in terms of these criteria, it is possible to eliminate some remains as having been introduced as a result of natural agencies. For example, seeds which display rodent chew marks and that are not known ethnographically to have been used by people are unlikely to represent the remains of human activities. Obviously, such arguments are complicated by the possibility of remains having been acted on by multiple agents of transformation. For example, seeds could be discarded in a site by humans and later chewed by rodents, as O'Connor (1999) has suggested might be the case for seeds from sites in the Kimberley. However, while such criteria can aid researchers making an assessment of the origins of macrobotanical remains in archaeological sites, they are not so easily applied to plant microfossils such as phytoliths, primarily due to the small size and general lack of species and/or plant part specificity.

It has been argued generally that the majority of phytoliths present in archaeological sites are derived from the *in situ* decay of macroscopic plant materials (*e.g.*, Pearsall 1989: 341; Piperno 2006; Piperno 1988: 44; Piperno 1985), a view that also includes the often unstated assumption that the majority of the macroscopic remains have been deliberately introduced into the site by people. It also hinges on the assumption that the numbers of phytoliths introduced via other mechanisms are negligible when compared to those present as a consequence of *in situ* decay. However, as is discussed below, there are a number of circumstances that may give cause to reject a priori the *in situ* decay assumption. In addition to humans introducing plants which then decay and contribute any inorganic phytolith component present, other taphonomic agents including wind, water, animals and the weathering of sedimentary rocks may contribute to the phytolith assemblages recovered from archaeological sites.

While pollen is often designed to be aerodynamically proficient so as to facilitate its transportation by wind, phytolith morphologies are not specifically designed for this purpose. Moreover, phytoliths are usually released directly into sediments or the plant litter through the decay of plant material at ground level, rather than into the atmosphere. Phytoliths also weigh more than pollen grains, a factor that serves to further inhibit, to a degree, their transportation by wind. Nonetheless, there are many reports of the recovery of phytoliths from windborne dusts, thus illustrating their capacity for transportation over considerable distances (*e.g.*, Baker 1959; Bowdery 1999). Staff who carried out excavation at Djadjiling, Jundaru, and HD07-3A-PAD13, and therefore who are familiar with the site locations and dynamics, are better positioned to assess the likely contribution of windborne dusts (including phytoliths) to the sediments than the author of this chapter.

Macropods commonly take refuge in rockshelters during the heat of the day, and their faecal pellets are dominated by grass fibres, which are in turn dominated by phytoliths. Wallis (2000) has shown that large quantities of (usually grass) phytoliths were contributed to archaeological rockshelter deposits in the Kimberley, and it is likely this mechanism also operated at Djadjiling, Jundaru, and HD07-3A-PAD13 throughout the sites' histories. A strong indication of whether this is likely the case or not is whether macropod faecal pellets are present on the surface of the site or in the upper levels of the deposit; if they are, their decay will have definitely introduced grass phytoliths to the assemblage.

Given the regional geology, while phytoliths will presumably not have been introduced to Djadjiling, Jundaru, and HD07-3A-PAD13 through the *in situ* decay of phytolith bearing sedimentary rocks, insufficient evidence is available to the author to determine whether phytoliths may have been contributed via waterborne deposition or through the decay of plants growing in the sites themselves; again personnel involved in excavation will be better able to consider this possibility.

For the purposes of this chapter it has been assumed that the bulk of phytoliths at Djadjiling, Jundaru, and HD07-3A-PAD13 were either deposited through the *in situ* decay of plant materials deliberately brought into the rockshelters by people, or via the deposition and *in situ* decay of macropod faecal material. As such, it is considered that the Djadjiling, Jundaru and HD07-3A-PAD13 phytolith assemblages represent a mixture of both culturally and naturally derived vegetation material and should be interpreted as such.

Phytolith Abundances

Phytoliths were shown to be well preserved and abundant in both the Jundaru and HD07-3A-PAD13 sites. Average phytolith abundance at Jundaru was just above 7%, while at HD07-3A-PAD13 it was 8.7%. These values are relatively high for Australian archaeological rockshelter sites (*cf.* Bowdery 1996, 1998; Wallis 2000, unpublished data) and attest to the suitability of these sites for pursuing phytolith analysis. It also suggests that, generally speaking, other archaeological rockshelters in the wider Pilbara region (especially those in the Marra Mamba Iron Formation) are likely to contain well preserved phytolith assemblages. Phytolith abundances at Djadjiling were substantially lower, with an average of just 2.2% by weight; however, this was still easily sufficient to obtain robust counts.

The generally high levels of phytolith preservation at the former notwithstanding, the differences in phytolith abundances through time between the Jundaru and HD07-3A-PAD13 sites, and the Djadjiling rockshelter are worth discussing briefly. At Djadjiling the average phytolith abundance was 2.2% per level, and ranged between a low of 0.1% and a high of 9.2% (Wallis 2012). While the range is approximately the same for levels at Jundaru (2.5% to 10.8%), the comparatively higher average at Jundaru (7%) reveals that more spits at Jundaru contain a greater proportion of phytoliths than did those at the Djadjiling site. At HD07-3A-PAD13 phytolith abundances in the 38 levels range between 5.6% and 14%, resulting in a higher abundance in most spits than at either Jundaru or Djadjiling.

Given the relatively similar geology and age ranges for all three sites, these differences in phytolith abundance are interesting and could be relevant for interpreting the cultural histories of the sites. The main factors of importance in understanding why the sites should contain such different quantities of phytoliths

are (1) site formation processes and (2) taphonomic agents influencing the sediments after deposition. Various scenarios can be hypothesised to explain the overall higher concentrations of phytoliths in the HD07-3A-PAD13 site (or, conversely, the substantially lower abundances at Djadjiling), including that:

- Sedimentary chemical conditions at Rockshelter HD07-3A-PAD13 were sufficiently different such that they enabled greater preservation of phytoliths at this site (or conversely caused poorer preservation of phytoliths in particular at Djadjiling and, to a lesser extent, at Jundaru). However, given the well-preserved physical nature of phytoliths in all three sites–with no signs of chemical pitting or dissolution–this is unlikely to be the case. Examining the pH values at each site would be valuable in this respect, since, generally, as soil pH is increased silica concentration decreases (Jones and Handreck 1967; Wilding *et al.* 1977). Silica solubility rises rapidly above pH 9 (Krauskopf 1956), which helps explain why phytoliths are rarely recovered from soils with a pH above this value (Piperno 1988: 46-47);

- People were using the site more intensively, resulting in increased deposition of plant materials that subsequently decayed and caused there to be increased quantities of phytoliths in the sediments. Assessment of any macrobotanical component of the site might lend support to this notion, as would an understanding of measures of intensity of site use as indicated by, for example, stone artefact deposition rates;

- People were using the site less intensively, resulting in increased use of the site by macropods, which caused increased deposition of faecal material that subsequently decayed and caused there to be increased quantities of phytoliths in the sediments. Assessment of the presence/absence of macropod faecal material preserved in the sedimentary deposits at HD07-3A-PAD13 by the authors of the main report would allow this possibility to be assessed;

- Additional agents of phytolith deposition were operating at HD07-3A-PAD13, causing there to be increased abundances of phytoliths. The author has been advised by ACHM staff (Boone Law, pers. comm. 24 March 2011) that the HD07-3A-PAD13 comprises primarily alluvial sediments, and hence phytoliths could potentially have been introduced into the site via waterborne deposition. However, in such a case I would expect also to see high levels of diatoms in the assemblage (*cf.* Wallis 2000 with regards to abundant diatom presence in different sediment types associated with water in the Kimberley) which is not the case–diatoms are only preserved in small quantities in the HD07-3A-PAD13 site, and I can think of no mechanism which might selectively remove diatoms from the deposit whilst retaining phytoliths; or,

- Some combination of the above, or other as yet unconsidered, factors.

Correlating the phytolith abundance results for each of the other materials recovered (such as charcoal, bone and stone artefacts) will allow for a better assessment to be made as to the relative phytolith contributions of people versus animals (or other mechanisms of deposition), as well as to further clarify the relevance of phytolith abundances in terms of intensity of site occupation. Such comparisons will provide greater interpretive value to the information presented herein and should be considered by the authors of the main report.

Based solely on the phytolith data, the abundance of phytoliths in the lowest level of the HD07-3A-PAD13 site might indicate a strong likelihood that people occupied this site since the onset of sedimentation; this data should be correlated with the results of other cultural material analyses by the authors of the main report. If there are no other signs of people at this level, it would indicate that background levels of phytoliths in the site (introduced through natural formation processes such as wind, water and animals) when people are not present are very high, and that the sequence might represent a largely natural vegetation signal with a thin veneer of humanly derived phytoliths overlying it. If there are signs of people at this level, it would indicate that background levels of phytoliths in HD07-3A-PAD13 are relatively low, and that the sequence represents a largely cultural vegetation signal with a smaller component of naturally derived phytoliths intermixed with it.

In any case, the variability in phytolith abundances throughout each site is indicative that bioturbation and/or sediment mixing was not occurring to any substantive degree—certainly not to the degree that it resulted in a homogenisation of the phytolith assemblages. The authors of the main report should consider this in the context of other sedimentary evidence that reveals information about the site integrity and degree of bioturbation/sediment mixing.

A safe assumption to make is that the sediments at Djadjiling, Jundaru, and HD07-3A-PAD13 all represent a mix of culturally and naturally derived phytoliths, and that they are largely indicative of general vegetation in the site vicinities. Furthermore, given the general absence of highly specific diagnostic phytoliths from key plants known to have been used by Aboriginal people in the Pilbara (*e.g.*, Juluwarlu Aboriginal Corporation nd), the assemblages from all three sites are perhaps best placed to inform us about broad changes to local vegetation patterns in response to changing climates.

Phytolith Zones in the Djadjiling Sediments

The lowest three layers of Djadjiling (Layers 38-40; Zone 1a) contain only small quantities of phytoliths and are understood by the author to not be associated with other archaeological evidence for human occupation. As such they likely represent a 'background' level of phytolith noise during the initial accumulation of sediment in the Djadjiling site. The phytolith assemblage in Zone 1a is dominated by extremely high levels of rondel phytoliths, a type that is representative of the spinifex grasses. There are some 64 species of spinifex in Australia, several of which are common to the Pilbara (Lazarides 1997; Jacobs 2004). While some of these are known to have been utilised by Aboriginal people (Juluwarlu Aboriginal Corporation nd), and young soft spinifex grasses are also known to be consumed by macropods (Wallis 2000). Given the extremely small quantities of phytoliths in this zone and the dominance of spinifex phytoliths, it is likely the phytolith assemblage in this zone is largely the result of the *in situ* decay of macropod faecal pellets rather than the *in situ* decay of macrobotanical plant materials *per se*. Some tree or shrub presence in the landscape is indicated by the presence of globular phytoliths, and the existence of echinate globular forms in particular suggests some species of palm is also locally present. (It is noted that *Livistonia alfredii*, Millstream palm,

occurs in the Pilbara today though it is not possible without detailed botanical studies to determine if the palm phytoliths are from this specific species.)

In Zone 1b (Layers 37-34) there is a general doubling of the quantities of phytoliths present, indicating a significant change in the mechanisms responsible for phytolith deposition at Djadjiling–this could be either an increase in macropod use of the site, or the operation of a new deposition mechanism. Despite the greater quantities of phytoliths, rondels decrease in relative abundance, suggesting a reduction in spinifex, which leads to the assumption that there was probably a decline in the quantity of faecal pellets in the site. There is a much larger and more diverse presence of phytoliths derived from trees and shrubs (including the continued presence of palms, the appearance of phytoliths derived from *Acacia* and the appearance of globular granulate phytoliths of unknown tree origin in reasonable quantities). Coupled with the increased quantities of phytoliths, this increased diversity leads to the suggestion that the first human use of the site might have occurred at this time. However, without knowing exactly when indisputably human cultural materials such as stone artefacts first appear in the sequence, it is difficult to base such an argument solely on an increase in the quantities of phytoliths. Consideration by the authors of the main report of sedimentary, macrobotanical remains, magnetic susceptibility results and lithic distribution in the site would shed further light on this issue, and assist in distinguishing between these phytolith deposition mechanism possibilities.

While the increase in phytolith presence from Layer 37 onwards might represent the first human use of the shelter, the latter might equally be interpreted as occurring from Layer 33 onwards (Zone 2) when there is another doubling in the quantities of phytoliths in the site compared to the underlying layer. However, the results of the multivariate statistical analyses support the major period of change occurring after Layer 37 rather than after Layer 33: the samples from Layers 40 to 38 cluster separately to all other samples (except Layer 20), suggesting their overall phytolith assemblages are statistically different to those from the other layers of the site. This is further support for the proposition that a different phytolith deposition mechanism is operating at the site from this time (*i.e.,* humans).

Zone 2 (Layers 33-30) is characterised by a major increase in the quantities of phytoliths present; phytolith abundance is higher in this zone that in any other layers of the Djadjiling site and might be interpreted as representing the most intensive human use of the site. There is an initial burst of Chloridoid grasses as indicated by saddle type phytoliths, though spinifex grasses and Panicoid grasses (indicated by the presence of bilobates and unilobates) are still present as well. Trees are still present in the landscape (as indicated by the presence of a range of globular psilate phytoliths of unknown tree origin), however there are fewer palms indicated than in Zone 1. Unfortunately the absence of distinctive phytolith morphologies precludes a more detailed analysis of vegetation or human uses of plants in this zone; however, if other macrobotanical remains are preserved they should shed some light on this issue. The authors of the main report should consider if this peak in phytoliths is matched by peaks in other categories of cultural remains at Djadjiling.

Zone 3 (Layers 29-21) is characterised by a substantial decline in the abundance of phytoliths in the site in comparison to the underlying Zone 2, back to levels more characteristic of Zone 1. The quantities of tree/shrub phytoliths generally decline to levels even lower than those seen in Zone 1a when there was apparently no human presence, which can be interpreted as suggesting either a major reduction in these plants in the surrounding landscape, or alternatively a shift in the types of activities people were undertaking in the site. Cross-shaped phytoliths (quadralobates) become more common in this zone, and these phytoliths are often characteristic of Panicoid grasses, which include an extremely wide array of genera; further detailed analysis of Panicoid grasses found in the Pilbara would be required to offer useful insights into the increased levels of these phytoliths in this zone.

Zone 4 comprises Layer 20, with the multivariate statistical analyses indicating the phytolith assemblage from this layer was substantially different to those adjacent to it and, in fact, was most similar to Layers 40-38 (the likely 'natural' background layers of the site). Like samples from Zone 1a, the Zone 4 sample contains a spike in rondel shaped phytoliths derived from spinifex grasses. The minimal quantities of phytoliths present, coupled with the high levels of rondels and very low quantities of phytoliths derived from trees in this zone leads to the interpretation that there is no human use of the site at this time, and that the phytolith assemblage here is the result of natural deposition processes only.

Phytolith abundance in Zone 5 (Layers 19-13) is still limited however displays a greater degree of diversity in comparison to Zone 4. There is a greater presence of trees and Panicoid grasses than in the preceding zone and *Eriachne* grasses become more common.

The major decline in phytolith presence in Zones 3 and 5 is interpreted as suggesting human presence in Djadjiling is minimal and/or highly sporadic in these zones in comparison to the preceding or following periods. In Zone 3 in particular tree presence declines, which might be due to deteriorating climatic conditions association with the LGM period causing a decrease in effective precipitation and corresponding decline in tree cover. The level of confidence in this interpretation would be enhanced by comparing the other data for the site; the authors of the main report should assess this interpretation in light of the other categories of remains and the available radiocarbon chronology.

Layers 12 to 1 are separated into Zones 6a (Layers 12-6) and 6b (Layers 3-1; note that samples were not provided from Layers 4 or 5 for phytolith analysis as these are features that were excavated within arbitrary layers) based on differences in phytolith abundance and types; Zone 6 is argued to represent a major increase in site use by people in comparison to the underlying Zone 5. Zone 6a contains a substantial increase in phytolith abundance in comparison to the previous zone, and includes a consistently increased representation of phytoliths derived from trees and shrubs. This might be interpreted as either an increase in the abundance of such plants in the surrounding landscape. In Zone 6b, representing the uppermost three layers of the site, phytolith abundances decline, as does the presence of tree/shrub phytoliths, suggesting changes to the surrounding environment and or human activities at the site. Interesting, while palm phytoliths (globular echinate forms) are present in most zones (excepting Zone 4), with the exception of Layer 12 (the transition from Zones 5 to 6) they are entirely absent from Zone 6.

In summary for the Djadjiling site, it is reiterated that the phytolith data needs to be integrated with the available radiocarbon chronology for the site by the main report authors, and compared against abundance trends for other categories of recovered remains (such as charcoal, bone, and stone artefacts) to further clarify the situation; such comparisons will provide greater interpretive value to the results summarised herein.

Phytolith Zones in the Jundaru Sequence

Based on the patterning apparent in the individual phytolith morphologies and the results of the multivariate statistical analyses presented in Section 12.5, the Jundaru sequence can be separated into three main zones; the four surface samples have been considered as part of Zone 3 for the purposes of interpretation. Please note that the zones described below are tentative only; consideration of other sedimentary and chronological evidence from the site would lead to greater confidence in these assignations or might require them to be modified slightly; it is anticipated that the authors of the main report will pursue this.

Zones 1a, 1b and 1c are the lowest (and therefore oldest) zones in the site. As they show only minor variations they are perhaps best considered as a single zone. Zone 1a comprises a single excavation layer: U1-L32. This zone contains a low peak in tree phytoliths (including from *Acacia* species), which declines immediately in U1-L31 (where Zone 1b commences). There are very high levels of unilobate and bilobate type phytoliths in Zone 1a, derived from Panicoid grasses, with strong contributions also from Chloridoid and Pooideae grasses. It is not clear how slow the rate of sediment accumulation was during this earliest phase of the sedimentary sequence, and hence this zone might equally be considered a unique zone, rather than a sub-zone of Zone 1.

Zone 1b sees an increase in phytolith abundance in comparison to Zone 1a, and comprises U1-L31 to U1-L25; the final level of Zone 1b, U1-L25, might also be considered a separate zone, given the extremely low quantities and types of phytoliths it contains. Zone 1c sees phytolith abundances increase in comparison to the low of U1-L25. Phytolith types deriving from trees and shrubs are very low in both Zones 1b and 1c, in comparison to Zone 1a. Panicoid grass phytoliths decline in Zone 1b in comparison to Zone 1a, before increasing slightly in Zone 1c. Rondels from Pooideae grasses are at their highest in the Jundaru sequence during Zones 1b and 1c.

In combination, Zone 1 (*i.e.*, U1-L32 to U1-L20) probably equates to the height of the LGM period and its onset, which is now argued to have commenced as early as 30,000 to 35,000 years ago and persisted until approximately 18,000 BP (Hesse *et al.* 2004; Turney *et al.* 2006; Wallis 2001). Effective precipitation in this period appears to have been considerably less than in the upper zones (*i.e.*, Zones 2 and 3), to the point that any tree/shrub presence in the surrounding landscape was essentially reduced to a minimum. This would have had important implications for Indigenous social, subsistence and economic strategies that might be reflected in other categories of cultural remains recovered from the site. Again, comparison of the Jundaru phytolith data with the radiocarbon chronology by the authors of the main report will allow the veracity of this interpretation to be considered.

Zone 2 commences from U1-L19, when phytolith abundances increase again; Zone 2 comprises U1-L19 to U1-L04, representing the bulk of the Jundaru sequence. During Zone 2 there is fourfold increase in the percentage values of trees/shrubs (as indicated by globular forms of phytoliths), indicating a substantial increase in the amount of effective precipitation in the site surrounds. During Zone 2, Panicoid grasses reassert their presence and Pooideae grasses continue decrease in comparison to their levels in Zone 1. Eriachne grasses being to appear more regularly in the sequence (though always in low numbers). Without having been provided with information about the radiocarbon chronology for the site, the phytolith assemblage would seem to indicate that U1-L19 and above are probably correlated with the Holocene period, after approximately 8000 BP when the essentially modern climatic regime and vegetation patterns were established.

Zone 3 (U1-L03 to U1-L01 and the surface samples) is distinguished by a slight decreasing trend in both phytolith abundance and trees/shrubs, in comparison to Zone 2. Panicoid grasses also decrease and Pooideae phytoliths increase in abundance.

Phytolith Zones in the HD07-3A-PAD13 Sequence

Based on the patterning apparent in the individual phytolith morphologies and the results of the multivariate statistical analyses presented in Section 12.6, the HD07-3A-PAD13 sequence can be separated into three main zones. Note that the zones described below are tentative only; consideration of other sedimentary and chronological evidence from the site would lead to greater confidence in these assignations or might require them to be modified slightly; this should be undertaken by the authors of the main report.

Zones 1a and 1b are the lowest (and therefore oldest) zones in the site. As they show only minor variations in their phytolith morphologies they are perhaps best considered as a single zone, though phytolith abundances in Zone 1a is considerably higher than in the Zone 1b levels. Zone 1a comprises a single excavation layer: U3-L38. This zone contains a peak in tree phytoliths which declines immediately in U3-L37 (where Zone 1b commences). There are relatively high levels of unilobate and bilobate type phytoliths in Zone 1a, derived from Panicoid grasses, with strong contributions from spinifex grasses. It is not clear what the rate of sediment accumulation was during this earliest phase of the sedimentary sequence, nor whether any cultural materials are present in U3-L38, and hence this zone might equally be considered a different zone rather than a sub-zone of Zone 1.

Zone 1b sees a substantial decline in phytolith abundance in comparison to Zone 1a, and comprises U3-L37 to U3-L28. Changes in phytolith types during this zone are sporadic, with there being characteristic reversals from tree to grass and back again to tree-dominated levels. Panicoid grass phytoliths decline in Zone 1b in comparison to Zone 1a, while saddles from Chloridoid grasses become abundant during this zone. Rondels from Pooideae grasses appear in Zone 1a, and continue in Zone 1b, albeit with some fluctuations. In general globular psilate phytoliths from trees are found in relatively low quantities through Zone 1b, though there are some peaks (*e.g.*, in U3-L30 and U3-L34).

In combination, and without recourse to information about the radiocarbon dating undertaken at the HD07-3A-PAD13 site, Zone 1 (*i.e.*, U3-L38 to U3-L28) probably equates to the period immediately prior height of the LGM period. This proposition should be assessed by the main report authors. It is known that climatic deterioration had already commenced as early as 30,000 to 35,000 years ago, though the worst of the conditions were experienced from 25,000 BP until approximately 18,000 BP (Hesse *et al.* 2004; Turney *et al.* 2006; Wallis 2001). The continued presence of trees in the landscape around HD07-3A-PAD13 during Zone 1 is an indication of reasonable levels of effective precipitation, though the vegetation appears to have fluctuated between open woodland and open grassland.

Zone 2 represents the bulk of the HD07-3A-PAD13 sequence and comprises U3-L29 to U3-L11. While phytolith abundances

in U3-L27 to U3-L24 are similar to those in Zone 1b, they gradually increase to a peak in the middle of Zone 2 (U3-L17) before gradually declining again in the upper levels of this zone. During Zone 2 there is significant decrease in the percentage values of trees/shrubs (as indicated by globular forms of phytoliths), and corresponding increase in the amounts of phytoliths derived from grasses. Bilobates from Panicoid grasses decrease slightly in value compared to their quantities in Zone 1, while rondels from Pooideae grasses are at their highest levels in the HD07-3A-PAD13 site during Zone 2. Saddles from Chloridoid grasses continue to be present in Zone 2, albeit at reduced levels compared to Zone 1. Ornamented elongated long cells decrease in abundance during Zone 2, while plain (psilate) elongated long cells increase in abundance; this is probably related to changes in the particular species of grasses dominating the landscape, however further investigation into long cell production by modern grasses would be required to provide greater interpretative value to this phenomenon. Effective precipitation in this period appears to have been considerably less than that available in Zone 1 or in the younger Zone 3, to the point that any tree/shrub presence in the surrounding landscape appears to have been reduced to a minimum. This would have had important implications for Indigenous social, subsistence and economic strategies that might be reflected in other categories of cultural remains recovered from the site. It would appear that this Zone corresponds with the height of the LGM period.

Zone 3 comprises U3-L10 through to U3-L01, with the two uppermost levels (U3-L01 and U3-L02) being designated Zone 3b, as opposed to the other samples which are designated Zone 3a. The onset of Zone 3 is indicated by a marked increase in the quantities of bilobate and unilobate phytolith forms, derived from Panicoid grasses. In Zone 3 Rondels from Pooideae grasses decline markedly in comparison to Zone 2, though saddles from Chloridoid grasses continue at essentially the same rates as observed in Zone 2. Hair cells, derived either from a range of trees or more likely shrubs (see Wallis 2003; Wallis 2012) become more common in Zone 3a, though they are absent from Zone 3b. Globular phytolith forms derived from trees become comparatively abundant in Zone 3. Zone 3b is also differentiated from Zone 3a by a substantial decline in general phytolith abundance. During Zone 3, trees become more common in the assemblage (and by inference in the surrounding landscape) at the expense of grasses. Without having been provided with information about the radiocarbon chronology for the site, the phytolith assemblage would seem to indicate that the levels within Zone 3 are probably correlated with climatic amelioration in the closing millennia of the late Pleistocene, or the Holocene period, after approximately 8000 BP when the essentially modern climatic regime and vegetation patterns were established. This proposition should be assessed by the authors of the main report through comparison with the available radiocarbon chronology.

12.8 CONCLUSIONS

The analysis of phytoliths from modern Pilbara plant specimens as reported herein represents the first stage in developing a regional reference collection of phytoliths; this is a vital step in enabling more detailed interpretations of archaeological phytolith assemblages to be made. In this study 55 plant specimens were examined to determine if they were accumulators of silica. While 44 of these samples produced no or only trace quantities of phytoliths, the other samples produced common or abundant quantities of phytoliths. Coupled with known phytolith production patterns from plants in the adjacent central Australian and Kimberley regions, it has been possible to gain a basic understanding of the forms likely to be preserved in sediments of the Pilbara and whether they derive from trees/shrubs or grasses. Ideally, much more intensive research into phytolith production into the many hundreds of plant species present in Pilbara is required to enable more detailed understandings of sedimentary phytolith assemblages to be developed.

The analysis of phytoliths from both the Jundaru and HD07-3A-PAD13 archaeological sediments revealed that phytoliths are very well-preserved in large quantities throughout both sites. While there is minimal evidence to suggest differences in chemical or physical weathering of phytoliths at each site, the fact that there are differences in the quantities of phytoliths present in each site (with more preserved at HD07-3A-PAD13 than at Jundaru) is interesting.

Based on the assumption that the bulk of phytoliths in both sites are the result of the *in situ* decay of macroscopic plant remains deliberately brought in by people, with a more minor though consistent contribution from the *in situ* decay of macropod faecal pellets, the changes in phytolith abundance through time reveals some interesting information about the intensity of site use. Given the general absence of distinctive, diagnostic phytoliths in both sites that could be linked to specific plant species (though there are some exceptions, such as the Eriachne grasses, Acacia and Cyperaceae), the phytolith assemblages at Jundaru and HD07-3A-PAD13 are better positioned to provide information about general vegetation change in the site surrounds, rather than changing human uses of particular plant species through time.

The phytolith assemblage would appear to indicate that at Jundaru people were present from the onset of sediment accumulation, with the intensity of site occupation rising until a sudden drop in U1-L25, when phytolith quantities declines to their lowest levels; phytolith abundances (and presumably intensity of site use) thereafter rise to reach a relatively consistent level after U1-L19 (*i.e.*, during Zone 2) though there is a slight decrease above U1-L04 (Zone 3) and in the four surface samples in comparison to the rest of the sequence. As such it is clear that, for example, in the lowest Zone 1 (U1-L32 to U1-L20) grasses dominate the assemblage, while there is a substantial increase in the degree of tree/shrub cover present around the site in Zones 2 and 3 (*i.e.*, U1-L19 and above). This can be interpreted as representing a substantial increase in effective precipitation in the Pilbara in Zones 2 and 3 in comparison to Zone 1. Correlating this with the available chronological information from the site will allow a better understanding of changing climatic conditions in the Pilbara, which is an important consideration in understanding human behaviour at the landscape scale; this should be attempted in the main body of the report.

The phytolith assemblage at HD07-3A-PAD13 indicates something unusual was happening in the lowest three levels of the site (*i.e.*, U3-L38 to U3-L36) in comparison to the rest of the site. From the base of the site up to U3-28, it appears there was both tree and grass coverage in the vicinity, which would imply reasonably high levels of effective precipitation. It is hypothesised that Zone 1 corresponds with the late Pleistocene period leading up to the LGM. In Zone 2 of the HD07-3A-PAD13 sediments, phytolith forms derived from trees become much less common in the assemblage, and grasses tend to dominate; it is likely this zone equates with the peak of the LGM. In Zone 3 the reestablishment of trees in the vicinity indicates increased levels of effective precipitation in comparison to Zone 2, and probably relates to the Holocene period.

Though far less abundant than at the other two sites, the phytolith analysis of sediments from Djadjiling revealed that phytoliths were well preserved in varying quantities throughout the site, always sufficiently abundant to obtain robust counts. Again, assuming most phytoliths are the result of the *in situ* decay of materials deliberately brought in by people, with some minor component from natural deposition mechanisms, the changes in phytolith abundance through time her too reveals some interesting information about the intensity of site use. The most intensive use of Djadjiling by people appears to have occurred in Zone 2 (Layers 33-30), followed by a substantial decline in use (to the point of abandonment in Zone 4) and an increase in Zone 6 (Layers 12-1).

At Djadjiling it is clear that there are changes in the degree of tree cover present around the site, with fewer trees present in Zones 3-5; as a proxy for environmental change, this can be interpreted as representing a decline in effective precipitation in the Pilbara at this time. Correlating this with the available chronological information from the site by the authors of the main report will allow a better understanding of changing climatic conditions in the Pilbara, which is an important consideration in understanding human behaviour at the landscape scale. Likewise, there are fundamental shifts in the types of grasses present at Djadjiling, and while at least a proportion of these will be derived from macropod faecal pellets, more will be the result of human activity. Further detailed studies of phytolith production in the full range of Pilbara grasses is required to make better sense of the changing patterns of grass phytoliths.

Phytolith analysis of the Djadjiling, Jundaru and HD07-3A-PAD13 sediments has revealed novel information about the vegetation history of the region not available via other means. Integration of this information with other data from the three sites by the authors of the main report will greatly enhance the interpretation of the phytolith results and allow a more nuanced understanding of the sites' histories of human occupation to emerge.

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Chapter 13

Sedimentary, Charcoal and Palynological Analysis of Djadjiling (HD07-1A-04), HD07-3A-PAD13, HD07-3A-03, HS-A1, Jundaru (HN-A9) Rockshelters, Pilbara, Western Australia

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13.1 INTRODUCTION

Despite the cultural and biological significance of the Pilbara region of northwestern Australia, little is known about the long-term environmental changes that occurred in the region over the last 40,000 years. The Pilbara region has a tropical arid climate with low annual rainfall, and lies below the Kimberley region from which key climate phenomena such as the Australian Summer Monsoon, El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) influence precipitation, often resulting in irregular large rainfall events penetrating south into the Pilbara (Bowman *et al.* 2010). This characteristic, coupled with the rugged topography of the region, results in the Pilbara receiving slightly higher rainfall than other regions in the arid zone. The result is a diverse biota consisting of representatives of northern tropical as well as southern taxa and an abundance of endemic species associated with rocky surfaces that have evolved in isolation from the rest of the continent (Burbidge *et al.* 2010; Doughty *et al.* 2011). The region is also proximal to the most likely point of entry for the initial peopling of Australia-Papua (Sahul) around 50,000 years ago, an event which has been suggested to have brought about a fundamental shift in fire regimes, changing the face of Australian ecosystems and climate (O'Connor and Veth 2006; Miller *et al.* 2007; Johnson 2009).

Our present understanding of past ecosystem dynamics in northwestern Australia is limited. Regional-scale, marine-core pollen and charcoal data located off the west and north Australian coast (van der Kaars and De Deckker 2002; Wang *et al.* 1999) depict more extensive savannas during glacial periods and vegetation composition and cover showing strong millennial-scale responses to fluctuations in orbitally-driven solar radiation (precession) through time. These offshore interpretations of late Quaternary wet/dry climatic and vegetation trends prove similar to reconstructions derived from inland Lake Gregory (Hesse *et al.* 2004; Wyrwoll and Miller 2001). Over the last 35,000 years, human occupants of the region would have encountered poorly vegetated environments for at least the first 20,000 years. It is only after approximately 14,000 years ago that monsoon activity increases rapidly and greater moisture and vegetation cover is available (Hesse *et al.* 2004). A Holocene record from a mound spring in the Kimberley region (Black Springs, McGowan *et al.* 2012) shows a dynamic mid-late Holocene vegetation driven by fluctuations in the strength of the Australian Summer Monsoon.

The analysis of microscopic plant and fungal remains from rockshelters in the Pilbara has the potential to provide new insights into vegetation composition, habitation site conditions and plant use through time, concomitant with archaeological evidence for human occupation and site use. The analyses of rockshelter sediments by Wallis (2001; phytoliths) and McConnell and O'Connor (1997; phytoliths plant-macro remains) provide local compositional insight and detail on plant-to-people interactions that broadly support these regional climatic reconstructions. The lack of pollen and spore analysis in Australian rockshelter (for an exception see Rowe 2007) most likely relates to the perception (and often reality) that microscopic remains are often poorly preserved and subject to long-term physical degradation. A preliminary study of the Djadjiling Rockshelter site (Haberle and Roberts 2012) showed that microscopic pollen, spore and charcoal remains can be preserved and identified within rockshelter sediments, potentially providing new insights into past human-vegetation-climate interactions. Despite a low concentration of pollen preserved in the Djadjiling Rockshelter sediments an analysis of the presence-absence of different pollen taxa and microscopic charred plant remains showed that regional burning of savanna plants was continuous over the last 35,000 years. In addition, dung fungi remains (*Sporormiella* and *Podospora*) were found at levels in the rockshelter sediments that corresponded to periods when there was high abundance of large herbivores in the Australian environment (Johnson 2009). Here we report pollen, charcoal and dung fungi analysis from Djadjiling (HD07-1A-04), HD07-3A-PAD13, HD07-3A-03, HS-A1, and Jundaru (HN-A9) Rockshelters (Haberle *et al.* 2013; Haberle and Roberts 2012).

13.2 POLLEN AND MICRO-CHARCOAL ANALYTICAL APPROACHES TO ROCKSHELTER DEPOSITS

The study of pollen and micro-charcoal preserved in sediments is one of the main ways we can reconstruct past vegetation patterns and changes to the landscape through time. The techniques have been in use for nearly a century and have found applications in the study of climate change, archaeology and human impact on the environment through to industrial application in petroleum geology.

Pollen Analysis

Pollen grains are plant parts that play a role in fertilization during plant reproduction and are found in the flowers of angiosperms and gymnosperms. Pollen is dispersed from one plant to another in many ways, but the most common is either wind-dispersed (anemophilous) or insect-dispersed (entomophilous) (Figure 13-1). Pollen grains can also be

dispersed by slope wash and human agency (transported from one place to another by people) (Figure 13-1). Pollen grains are usually spherical or elliptical and vary in size from 10µm (0.01mm) to 100µm (0.1mm) and their shape and surface texture can be used to identify them to a parent plant family, genera or sometimes even species. The tough structure of pollen grains means that they are readily preserved in anaerobic (low oxygen) environments, such as bogs and lakes. Cave sediments may also be suitable for pollen preservation, when moisture conditions are suitable. The pollen grains extracted from sediments samples using a series of chemical and physical treatments that concentrates them (along with other inert organic fractions such as microscopic charcoal). They can then be identified and quantified using light transmitted microscopy (400-1000x magnification). The identification of each pollen type in this study was aided by the use of the Australasian Pollen and Spore Atlas (http://apsa.anu.edu.au).

By looking at the proportion of each pollen type that is preserved in sediments of known age, we can produce an 'index' of the vegetation surrounding the site. A time series of pollen spectra can be constructed by examining samples at intervals down a sediment profile. This provides us with a window into past vegetation changes at a particular point in the landscape.

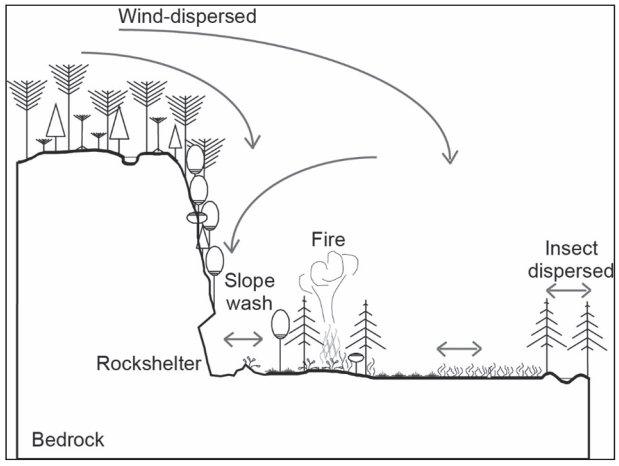

Figure 13-1 Model of pollen dispersal mechanisms from the source plant to the point of deposition. Micro-charcoal is dispersed in a similar fashion, though larger and heavier fragments are less likely to be transported long distances by wind or insect dispersal. Sediments containing pollen are sampled from suitable anaerobic sites in the landscape including rockshelter deposits

Micro-Charcoal Analysis

Fine fragments of charcoal are preserved alongside pollen remains in sediments and can be used to reconstruct fire occurrence through time in the landscape. Micro-charcoal is generally considered to be the fraction between 5µm to approximately 100µm and is quantified on pollen slides. Peaks in charcoal abundance are interpreted to represent fire episodes in the past that may have contributed to changes in vegetation recorded in the pollen record. In some cases increased charcoal occurs when forest pollen proportions are reduced which may indicate that people have been burning the local forest. Larger fragments of charcoal (>125-500µm) can also be rapidly extracted by sieving and bleaching a known volume of sediment. This data provides a record of fires that have occurred in close proximity to the sediment site, generally derived from on sites fires or from slope wash from the local catchment into the site (Whitlock and Larsen 2001).

Treatment of the Samples

Sediment analysis involved Munsell soil colour determination, moisture content (known volume weight before and after drying for 3 hours at 100°C), and carbon content (Loss on ignition, weight after combustion at 550°C for 3 hours). This provides a qualitative measure of sediment moisture and carbon content (Santisteban *et al.* 2004). Micro-charcoal fragments greater than 125µm were quantified for every sample by bleaching and sieved over a stack of 125µm, 250µm and 500µm sieves. The concentrations of fragments per unit volume were then counted under a Ziess stereo microscope at 100x magnification (Whitlock and Larsen 2001). Micro-debitage was also encountered and its presence noted.

Pollen sample preparation follows standard procedures described in Bennett and Willis (2001), which includes HCl, KOK, HF, Acetolysis, Glacial Acetic Acid and Ethonol washes with the addition of a *Lycopodium* spike to determine relative concentrations of palynomorphs. Each slide was scanned under a Ziess binocular transmitted light microscope at 630x magnification for identifiable pollen grains, dung fungi spores (*Sporormiella* and *Podospora*), burnt grass phytoliths (dumbbell-shaped ±opaque phytoliths) and micro-charcoal fragments. These are presented in presence/absence tables. Pollen concentrations (relative to the *Lycopodium* spike) were calculated and micro-charcoal and burnt grass phytolith fragment abundance on the pollen slides estimated on a 5-point scale (0=none to 4=very abundant). Figure 13-2 illustrates the common microscopic pollen and charcoal remains encountered at Djadjiling Rockshelter.

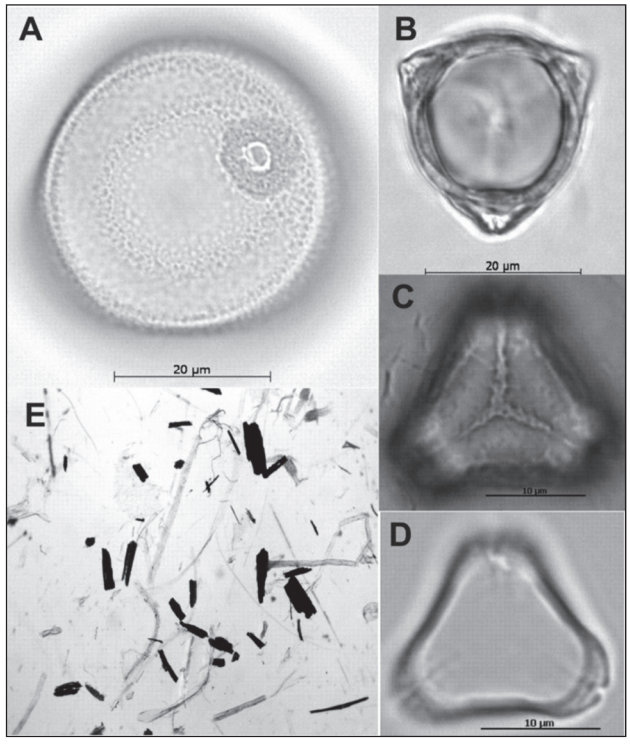

Figure 13-2 Pollen grains (reference slides in the online Australasian pollen and spore atlas) and micro-charcoal from the Kimberley region. A) grass (*Spinifex longifolius,* Poaceae), b) *Dodonaea lanceolata,* Sapindaceae, c) *Eucalyptus dichromophloia,* Myrtaceae, d) *Calytrix exstipulata*, Myrtaceae, and e) microscopic charcoal fragments on pollen slide (10-30µm long).

13.3 RESULTS AND INTERPRETATION

Djadjiling Rockshelter

The Djadjiling Rockshelter (HD07-1A-04) sediment, charcoal, and palynomorph results are presented in Table 13-1 and Figure 13-3 (Haberle and Roberts 2012). The moisture content of the sediments increased towards the base of the profile. Loss on ignition shows two phases of increased carbon content between ui-193 and the surface (Layers 3 to 1, ~24,000 cal BP to present) and ui-210 to ui-202 (Layers 5 and 6, 42,000-28,000 cal BP). Charcoal fragments greater than 125 µm are most abundant in the upper part of the profile above ui-184 (Layer 1, 7000 cal BP to the present). Burnt grass phytoliths and microscopic charcoal less than 63µm are also abundant in Layer 1, Layer 4 and Layer 6. In Layer 1, the high concentration of small and larger fragments of micro-charcoal may be related to very local burning, perhaps onsite. In contrast, the relatively low concentrations of larger fragments compared to smaller fragments of micro-charcoal and burnt grass phytoliths in Layers 4 and 6 suggests that these fragments were likely to be derived from a more regional fire source. The high proportion of macro-charcoal in Layer 1 (after 7000 cal BP) suggests more frequent local fires, either within the rockshelter or within a few metres of the rockshelter.

Table 13-1 Data for samples analysed from Djadjiling rockshelter

Sample Identification					Sediment Characteristics				Charcoal Concentration					Pollen										
Random Sample #	Bag Number	UI #	Unit-Layer Key	Quad	Munsell Colour	Moisture %	Loss on ignition %	Micro-debitage	Sample (cc)	>125µm	>250µm	>355µm	Total	Pollen Concentration (grains/cm³)	*Corymbia* type	*Eucalyptus* (psilate)	*Calytrix* type	*Melalueca*	*Dodonaea*	Poaceae	Burnt Grass Phytolith (0-4 scale)	Dung Fungi	Micro-Charcoal <100 µm (0-4 scale)	
2	4000	ui-179	U4-L01	A	5 YR 3/4	0%	13%		2.5	85	11	29	125	-	-	-	-	-	-	-	-	-	-	
6	4004	ui-180	U4-L02	A	5 YR 4/6	0%	11%		2.5	42	11	6	59	-	-	-	-	-	-	-	-	-	-	
3	4008	ui-181	U4-L03	A	7.5 YR 4/6	1%	12%		2.5	49	13	31	93	8400	■	■	■	■			4	■	4	
4	4017	ui-182	U4-L06	A	5 YR 4/6	2%	11%		2.5	151	32	43	226	700						■	0		2	
7	4021	ui-183	U4-L07	A	5 YR 4/6	1%	11%		2.5	266	53	38	357	3150		■	■				4	■	4	
11	4025	ui-186	U4-L08	A	7.5 YR 4/6	2%	9%		2.5	27	7	15	49											
12	4029	ui-184	U4-L09	A	7.5 YR 4/6	1%	10%		2.5	9	2	5	16	2520		■	■			■	2	■	4	
9	4033	ui-185	U4-L10	A	7.5 YR 4/6	2%	9%		2.5	7	0	1	8	4200		■					3		4	
5	4037	ui-187	U4-L11	A	5 YR 4/6	3%	8%		2.5	4	0	0	4	0							2		3	
23	4041	ui-188	U4-L12	A	5 YR 4/6	3%	8%		2.5	1	0	0	1	0							2		4	
10	4045	ui-189	U4-L13	A	5 YR 4/6	3%	7%		2.5	0	0	0	0	-	-	-	-	-	-	-	-	-	-	
29	4049	ui-190	U4-L14	A	7.5 YR 5/8	3%	9%	*	2.5	1	1	0	2	-	-	-	-	-	-	-	-	-	-	
33	4053	ui-191	U4-L15	A	7.5 YR 5/8	4%	6%		2.5	0	0	0	0	-	-	-	-	-	-	-	-	-	-	
17	4057	ui-192	U4-L16	A	7.5 YR 5/8	2%	6%		2.5	0	0	0	0	-	-	-	-	-	-	-	-	-	-	
24	4061	ui-193	U4-L17	A	7.5 YR 5/8	3%	7%		2.5	3	0	0	3	-	-	-	-	-	-	-	-	-	-	
35	4065	ui-194	U4-L18	A	7.5 YR 5/8	3%	5%	*	2.5	0	1	0	1	-	-	-	-	-	-	-	-	-	-	
20	4069	ui-195	U4-L19	A	7.5 YR 5/8	3%	4%		2.5	3	2	0	5	-	-	-	-	-	-	-	-	-	-	
28	4073	ui-196	U4-L20	A	7.5 YR 5/8	2%	3%		2.5	0	0	0	0	-	-	-	-	-	-	-	-	-	-	
14	4080	ui-197	U4-L21	A	7.5 YR 5/6	4%	5%		2.5	2	0	0	2	-	-	-	-	-	-	-	-	-	-	
34	4084	ui-198	U4-L22	A	7.5 YR 4/6	4%	5%	*	2.5	3	0	0	3	0							3		3	
37	4088	ui-199	U4-L23	A	7.5 YR 4/6	3%	5%		2.5	2	4	0	6	2100		■					3		4	
18	4092	ui-200	U4-L24	A	7.5 YR 4/6	2%	5%		2.5	5	1	0	6	-	-	-	-	-	-	-	-	-	-	
30	4096	ui-201	U4-L25	A	7.5 YR 5/8	2%	6%		2.5	1	0	0	1	-	-	-	-	-	-	-	-	-	-	
25	4100	ui-202	U4-L26	A	5 YR 3/4	9%	6%		2.5	14	0	1	15	-	-	-	-	-	-	-	-	-	-	
15	4104	ui-203	U4-L27	A	7.5 YR 4/6	5%	6%		2.5	2	0	1	3	-	-	-	-	-	-	-	-	-	-	
36	4108	ui-204	U4-L28	A	7.5 YR 3/4	8%	7%	*	2.5	0	0	0	0	1400		■	■				1		0	
26	4112	ui-205	U4-L29	A	2.5 YR 2.5/3	13%	10%	*	2.5	0	0	3	3	2100		■	■				1		0	
8	4116	ui-206	U4-L30	A	5 YR 3/4	9%	10%		2.5	5	0	0	5	525						■	0		1	
21	4120	ui-207	U4-L31	A	7.5 YR 3/4	14%	12%		2.5	1	0	1	2	420		■					2		2	
31	4124	ui-208	U4-L32	A	2.5 YR 2.5/3	13%	9%	*	2.5	2	1	0	3	2800		■			■		2		3	
16	4128	ui-209	U4-L33	A	7.5 YR 3/4	9%	9%		2.5	2	0	0	2	2100			■			■	1	■	4	
38	4132	ui-210	U4-L34	A	5 YR 3/4	5%	9%		2.5	3	2	0	5	0								■	1	
22	4136	ui-211	U4-L35	A	7.5 YR 3/4	6%	7%		2.5	2	0	0	2	-	-	-	-	-	-	-	-	-	-	
19	4140	ui-212	U4-L36	A	7.5 YR 4/6	4%	6%		2.5	2	0	1	3	-	-	-	-	-	-	-	-	-	-	
32	4144	ui-213	U4-L37	A	10 YR4/6	0%	6%		2.5	3	0	0	3	1050						■	1		3	
27	4148	ui-214	U4-L38	A	5 YR 3/4	7%	6%		2.5	1	0	0	1	-	-	-	-	-	-	-	-	-	-	
1	4152	ui-215	U4-L39	A	7.5 YR 4/6	6%	6%		2.5	0	0	0	0	-	-	-	-	-	-	-	-	-	-	
13	4156	ui-216	U4-L40	A	7.5 YR 4/6	7%	7%		2.5	1	0	0	1	525	■	■					2	■	1	

*presence of micro-debitage (see Figure 13-4)
- samples not analyses for pollen
grey squares = presence of pollen type
white squares = absence of pollen type

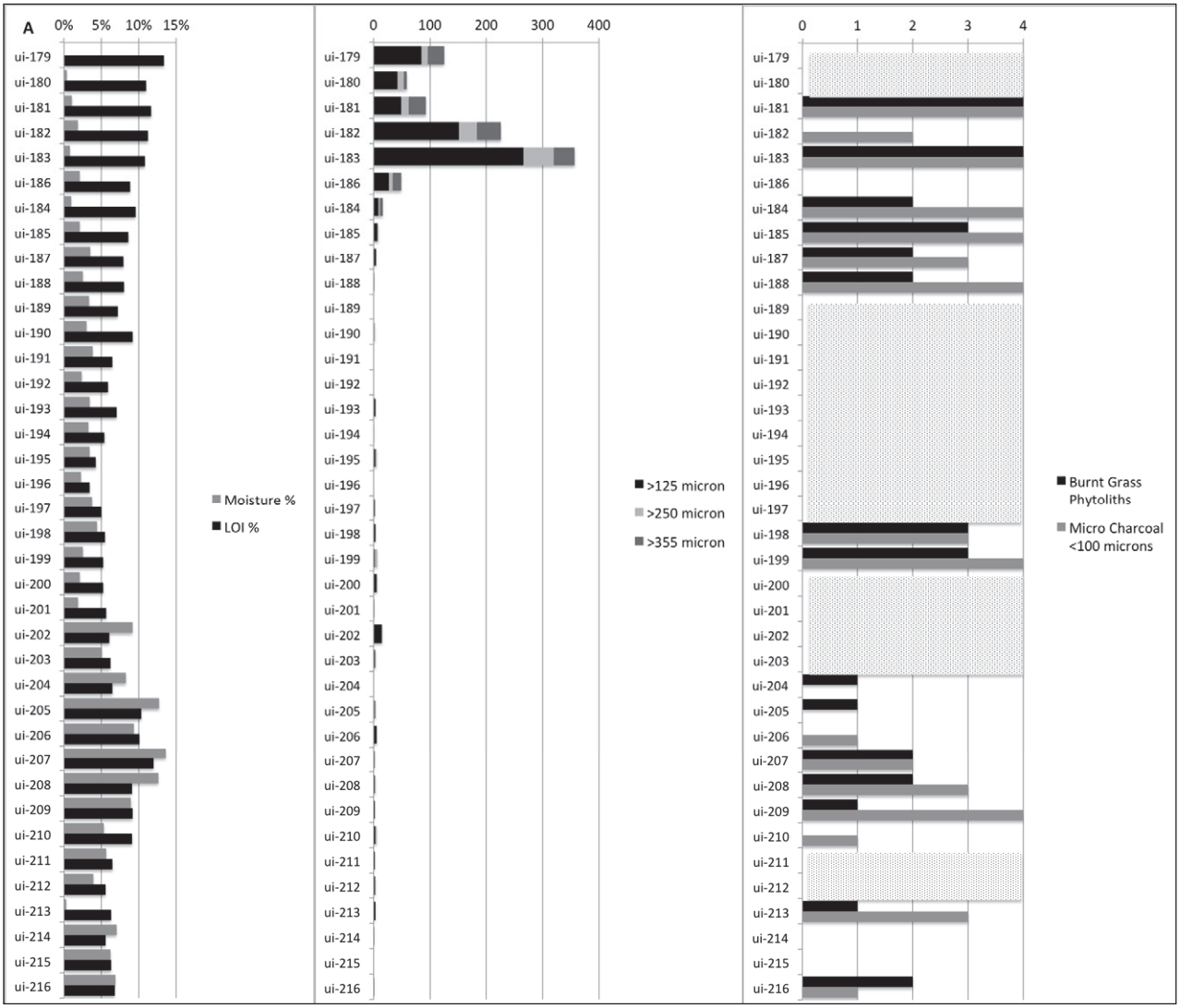

Figure 13-3 Results from Djadjiling rockshelter analysis. (a) sediment moisture and loss on ignition %. (b) charcoal size fractions concentrations (pieces/cm^3). (c) relative abundance of burnt grass phytoliths and micro-charcoal pieces on pollen slides (0=absent, 4=abundant).

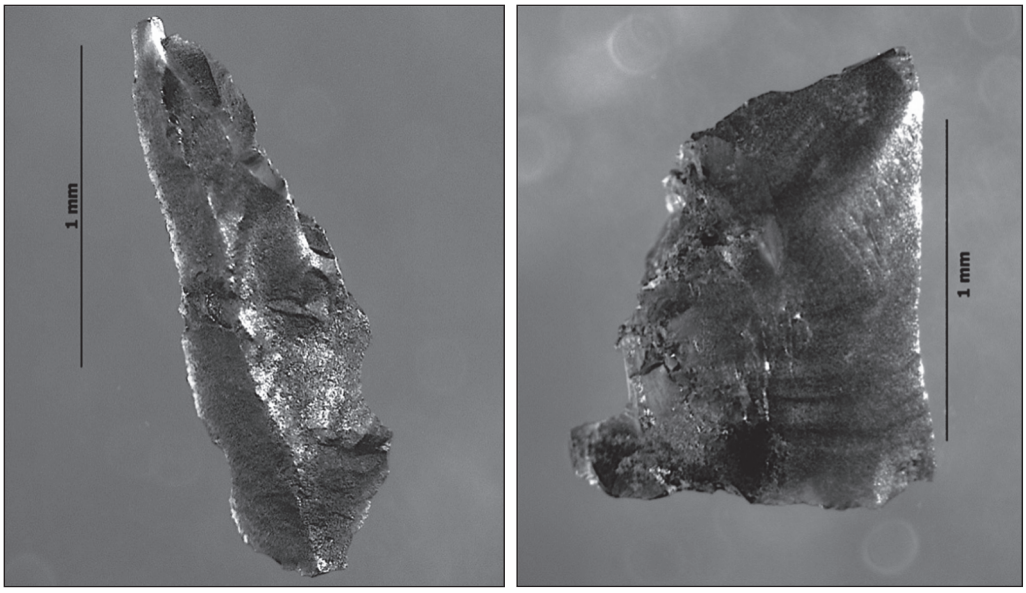

Figure 13-4 Micro-debitage from Djadjiling rockshelter U4-L22 (left) and U4-L28 (right)

Table 13-2 Results for samples analysed from HD07-3A-PAD13 rockshelter

Sample Identification					Munsell	Moisture Content				Loss on Ignition				Macro Charcoal				Comments	Pollen & Spores																						
Random Sample No.	Bag Number	UI #	Unit-Layer Key	Quad	Munsell Colour	Crucible	Wet weight (5cc)	Dry Weight	% Moisture	Crucible	Sample Weight (5cc)	After Ignition	% Loss on Ignition	>125	>250	>355	Total	Comments	pollen concentration (grains/cm^3)	*Corymbia* type	*Eucalyptus* (psilate)	*Calytrix* type	*Dodonaea*	*Acacia*	Euphorbiaceae	Fabaceae	Poaceae	Chenopodiaceae	Amaranthaceae	Asteraceae	Convolvulaceae	Cyperaceae	Minor and unknown pollen types	Pollen Diversity	Dung Fungi (*Podospora* and *Sporormiella*)	Burnt Grass Phytoliths (0-4 scale)	Micro-Charcoal (<63 microns, 0-4 scale)
70	3001	UI-238	U3-L01	C	5YR 3/4	6.21	10.94	10.73	4.44	17.35	21.6	20.72	20.70	528	38	80	646	seeds, insect	653000	72	10	8		2	*		5			*		*	*	9		1	2
76	3003	UI-242	U3-L02	C	5YR 3/3	6.19	11.73	11.51	3.97	18.68	23.82	23.13	13.42	194	29	23	246	seeds, insect	182000	77	7	2		*	*	*	11			*			*	9		3	2
67	3005	UI-246	U3-L03	C	5YR 3/4	6.22	11.70	11.44	4.74	15.08	20.92	20.24	11.64	99	17	11	127																						
89	3007	UI-250	U3-L04	C	5YR 3/4	6.24	11.47	11.30	3.25	18.44	24.09	23.56	9.38	24	4	1	29																						
75	3009	UI-313	U3-L05	C	5YR 3/4	6.21	12.51	12.28	3.65	16.13	21.93	21.41	8.97	8	1	0	9																						
86	3011	UI-317	U3-L06	C	5YR 3/4	6.03	11.21	10.89	6.18	18.68	23.87	23.24	12.14	2	0	0	2		26000	69	27													*	3		1	1
90	3013	UI-358	U3-L07	C	5YR 4/4	6.17	12.07	11.77	5.08	16.26	22.11	21.54	9.74	12	2	1	15		19000	84	5	10														3		4	1
71	3015	UI-370	U3-L08	C	5YR 4/6	6.24	11.99	11.67	5.57	19.85	25.87	25.26	10.13	5	0	0	5																						
98	3017	UI-398	U3-L09	C	5YR 4/3	6.21	12.23	12.00	3.82	19.85	26.28	25.78	7.78	1	0	0	1		0																0		2	0
88	3019	UI-416	U3-L10	C	5YR 4/4	6.20	12.65	12.41	3.72	16.85	22.89	22.47	6.95	7	0	0	7		1800		*														1		3	1
94	3021	UI-434	U3-L11	C	5YR 4/6	6.22	12.04	11.74	5.15	18.08	25.11	24.56	7.82	1	2	0	3		7000	92		3		3			*								4		3	1
74	3023	UI-452	U3-L12	C	5YR 4/6	6.32	12.77	12.46	4.81	16.28	22.37	21.88	8.05	1	0	0	1		0																0		1	1
83	3025	UI-476	U3-L13	C	5YR 4/4	6.18	12.03	11.75	4.79	17.6	24.19	23.78	6.22	2	1	1	4																						
96	3027	UI-480	U3-L14	C	5YR 4/3	6.09	11.44	11.17	5.05	15.06	21.15	20.65	8.21	1	0	0	1		900	*				*											2		1	1
101	3029	UI-509	U3-L15	C	5YR 5/4	6.00	12.19	11.96	3.72	19.06	25.28	24.77	8.20	3	1	0	4																						
82	3031	UI-513	U3-L16	C	5YR 4/3	6.23	13.19	13.02	2.44	17.71	24.43	24.09	5.06	2	0	1	3		0																0		0	1
87	3033	UI-581	U3-L17	C	5YR 4/3	6.18	12.35	12.14	3.40	15.53	21.64	21.24	6.55	2	0	0	2																						
95	3035	UI-585	U3-L18	C	5YR 4/4	6.20	12.49	12.28	3.34	16.72	23.37	22.97	6.02	5	2	0	7																						
72	3037	UI-589	U3-L19	C	5YR 4/4	6.21	12.20	11.92	4.67	18.09	23.42	23	7.88	2	1	0	3		0																0		0	1
97	3039	UI-593	U3-L20	C	5YR 4/4	6.13	12.20	11.94	4.28	17.17	23.37	22.94	6.94	2	0	0	2																						
81	3041	UI-597	U3-L21	C	5YR 4/4	6.01	11.97	11.70	4.53	16.71	22.52	22.11	7.06	2	2	0	4																						
92	3043	UI-601	U3-L22	C	5YR 4/4	6.22	11.83	11.56	4.81	14.64	20.38	19.93	7.84	0	0	0	0																						
93	3045	UI-605	U3-L23	C	5YR 4/4	6.09	12.35	12.16	3.04	15.36	21.93	21.52	6.24	11	2	0	13																						
73	3047	UI-609	U3-L24	C	5YR 4/4	6.14	11.44	11.15	5.47	15.52	21.51	21.01	8.35	0	0	0	0																						
91	3049	UI-613	U3-L25	C	5YR 4/6	6.05	12.04	11.76	4.67	16.11	22.61	22.15	7.08	1	0	0	1																						
66	3051	UI-671	U3-L26	C	5YR 4/4	6.24	11.26	11.01	4.98	17.19	22.57	22.15	7.81	7	0	0	7																						
80	3053	UI-675	U3-L27	C	5YR 4/4	6.11	13.34	13.08	3.60	16.85	23.04	22.62	6.79	3	0	0	3																						
84	3055	UI-679	U3-L28	C	5YR 4/4	6.23	12.95	12.67	4.17	16.52	22.04	21.62	7.61	3	0	0	3																						
65	3057	UI-683	U3-L29	C	5YR 4/4	6.25	12.17	11.87	5.07	19.06	24.55	24.11	8.01	6	1	4	11																						
69	3059	UI-687	U3-L30	C	5YR 4/4	6.19	12.64	12.44	3.10	16.52	23.34	22.9	6.45	2	2	0	4																						
77	3060	UI-773	U3-L31	C	5YR 4/6	6.23	13.08	12.78	4.38	16.48	22.83	22.34	7.72	5	0	1	6																						
100	3061	UI-776	U3-L32	C	5YR 4/4	6.21	13.03	12.78	3.67	17.7	24.84	24.36	6.72	0	1	0	1																						
79	3062	UI-779	U3-L33	C	5YR 4/4	6.30	12.30	11.96	5.67	14.65	20.49	20	8.39	1	0	0	1																						
102	3063	UI-782	U3-L34	C	5YR 4/4	6.19	12.90	12.69	3.13	16.48	22.65	22.29	5.83	1	1	0	2																						
85	3064	UI-785	U3-L35	C	5YR 4/6	6.10	12.25	12.00	4.07	17.35	23.85	23.36	7.54	0	0	0	0																						
68	3071	UI-850	U3-L36	C	5YR 4/6	6.20	12.65	12.41	3.72	15.37	21.92	21.48	6.72	1	1	0	2																						
78	3073	UI-852	U3-L37	C	5YR 4/4	6.19	14.03	13.67	4.59	18.42	25.7	25.12	7.97	7	1	1	9																						
99	3075	UI-871	U3-L38	C	5YR 5/4	6.09	12.39	12.09	4.76	17.59	23.4	22.9	8.61	14	3	1	18																						

Pollen & Spores - presence (%) or * = <1%

Pollen & Spores - not analysed

Pollen & Spores - absent

Burnt Grass Phytolith & Micro-Charcoal Scale: 0=barren; 1=rare; 2=medium; 3=common; 4=abundant

Pollen concentrations and preservation were generally low in most slides and was considered too low for standard percentage pollen analysis to be performed. The initial survey of 19 random pollen samples was completed by scanning each slide in order to calculate the pollen concentration and identify, where possible, the pollen types present in each sample. Table 13-1 lists the pollen types identified and their presence and absence in each slide examined. A selection of pollen taxa identified in these samples are illustrated in Figure 13-2. The pollen taxa identified are from the plant families of Myrtaceae (*Corymbia* sp., *Eucalyptus* sp., *Melalueca* sp., and *Calytrix* sp.), Sapindaceae (*Dodonaea* sp.), and Poaceae. These are generally abundant in the environment due to the source plants pollination strategy relying on wind-dispersal (anemophilous). The taxa are typical of sclerophyll vegetation, which is common throughout the Pilbara region today and was present in the region (unknown extent) in the past.

The dung fungi spores *Podospora* and *Sporormiella* were also identified in these sediments. These spores have been used to identify the presence of herbivorous animals, particularly megafauna in the Americas, Madagascar and in Australia (Gill *et al.* 2009; Burney *et al.* 2003; Rule *et al.* 2012). In the Djadjiling Rockshelter sediments the presence of either or both of these dung fungi indicators is found at Layer 1 (3000 cal BP to the present) and Layer 6 and 7 (older than 32,000 cal BP). The significance of this remains to be tested, though one explanation is that the earlier dung fungi presence relates to megafauna in the region before a minimum of 32,000 cal BP. The absence of dung fungi after this time may be associated with widespread extinction of large herbivores in Australia after the arrival of humans some 40,000 years ago (Johnson 2009; Rule *et al.* 2012). The presence of dung fungi after 3000 cal BP in rockshelter may relate to greater small mammal densities in the rockshelter during the late Holocene or possibly the arrival of dingo into Australia at around this time. These animals may have frequented the rockshelter during the time of most intensive use by humans during the mid-late Holocene.

In summary, the sediment, charcoal and palynomorph analysis of samples from Djadjiling rockshelter provides an insight into the nature of vegetation, burning and human exploitation of the region over the last 35,000 cal BP. Future research should focus on the significance of the identification and presence/absence analysis of dung fungi spores which may prove to be an indicator of faunal (diagnostic of herbivores including megafauna) use of the rockshelter.

HD07-3A-PAD13 Rockshelter

A total of 38 samples from Unit 3 (Layers 1-38) were submitted for analysis (Haberle *et al.* 2013), and the sediment, charcoal, and palynomorph results are presented in Table 13-2 and Figure 13-5. The moisture content of the sediments remains stable across the profile. Loss on ignition shows an increase in organic carbon content above Layer 4 (ui-250) and the surface. Charcoal fragments greater than 125µm are also most abundant in the upper part of the profile above Layer 4 (ui-250) and microscopic charcoal less than 63µm becomes abundant only above Layer 2 (ui-242). Burnt grass phytoliths become abundant much lower in the sequence at Layer 11 (ui-434), which may relate to very local burning of grass. Fires outside the rockshelter (regional fires) appear to have continuously contributed microscopic charcoal and burnt grass phytoliths to the sediments. More frequent local fires, either within the rockshelter or within a few meters of the rockshelter, are only clearly registered above Layer 4 (ui-250).

Pollen concentrations and preservation were found to be high in the sediments above Layer 11 (ui-434) and provided the opportunity to calculate pollen percentages of dominant taxa through each layer. Table 13-2 lists the pollen types identified and their presence and absence in each slide examined. The dominant pollen taxa identified are from the plant families of Myrtaceae (*Corymbia* sp., *Eucalyptus* sp., *Melalueca* sp. and *Calytrix* sp.), Fabaceae (*Acacia* sp.) Asteraceae and Poaceae. The taxa are typical of sclerophyll savanna vegetation, which is common throughout the Pilbara region today and was present in the region (unknown extent) in the past. *Corymbia* sp. pollen dominates the sclerophyll tree component of the pollen assemblage in samples where the concentration is high enough to calculate percentage representation. The concentration of pollen and the diversity of pollen taxa reduces down the sediment sequence.

In summary, the sediment, charcoal and palynomorph analysis of samples from HD07-3A-PAD13 show good preservation of pollen above Layer 11 (ui-434) that suggest the presence of *Corymbia* sp. dominated sclerophyll woodland with a grass understorey in the region and that fire was a constant feature of this environment.

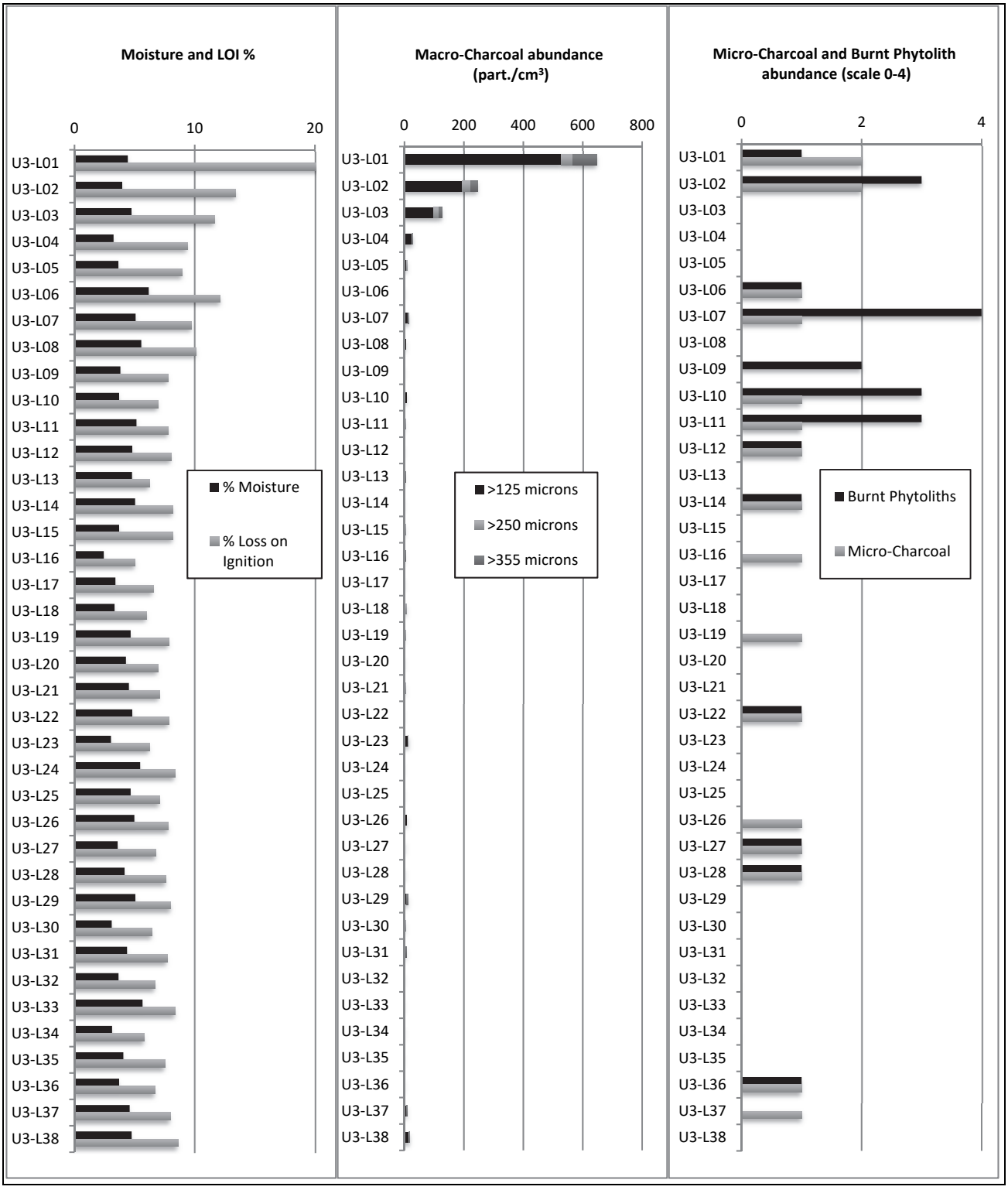

Figure 13-5 HD07-3A-PAD13 rockshelter results. (A) sediment moisture and loss on ignition %. (B) charcoal size fractions concentrations (pieces/cm3). (C) relative abundance of burnt phytoliths and micro-charcoal pieces on pollen slides (0=absent, 4=abundant)

HD07-3A-03 Rockshelter

Eleven sediment samples were submitted from Unit 1 (Layers 1-11) for analysis (Haberle *et al.* 2013). The sediment, charcoal, and palynomorph results are presented in Figure 13-6 and Table 13-3. The moisture content of the sediments remains stable across the profile. Loss on ignition shows a slight increase in organic carbon content above Layer 5 (ui-0205) and the surface. Charcoal fragments greater than 125µm are also most abundant in the upper part of the profile above Layer 5 (ui-0205) and microscopic charcoal less than 63µm becomes abundant only in the top layer. Burnt grass phytoliths become abundant much lower in the sequence at Layer 8 (ui-0223), which may relate to very local burning of grass. Fires outside the rockshelter (regional fires) appear to have continuously contributed microscopic charcoal and burnt grass phytoliths to the sediments. More frequent local fires, either within the rockshelter or within a few meters of the rockshelter, are only clearly registered above Layer 5 (ui-0205).

Pollen concentrations and preservation were also found to be high in the sediments above Layer 5 (ui-0205) and provided the opportunity to calculate pollen percentages of dominant taxa through the upper two samples. Table 13-3 lists the pollen types identified and their presence and absence in each slide examined. The dominant pollen taxa identified are from the plant families of Myrtaceae (*Corymbia* sp., *Eucalyptus* sp., *Melalueca* sp. and *Calytrix* sp.), Fabaceae (*Acacia* sp.) Asteraceae and Poaceae. *Corymbia* sp. pollen dominates the sclerophyll component of the pollen assemblage in sample ui-0069 (Layer 4). In Layer 1 (upper sample ui-0002), the dominance of *Corymbia* sp. is reduced and grasses become more important, perhaps reflecting an increase grassy understorey in the local area. The concentration of pollen and the diversity of pollen taxa reduces down the sediment sequence.

In summary, the sediment, charcoal and palynomorph analysis of samples from HD07-3A-03 show good preservation of pollen above Layer 4 (ui-0069) that suggest the presence of *Corymbia* sp. dominated sclerophyll woodland with a grass understorey becoming more dominant in the upper sample. Fire was a constant feature of this environment but become more prevalent locally above Layer 5 (ui-0205).

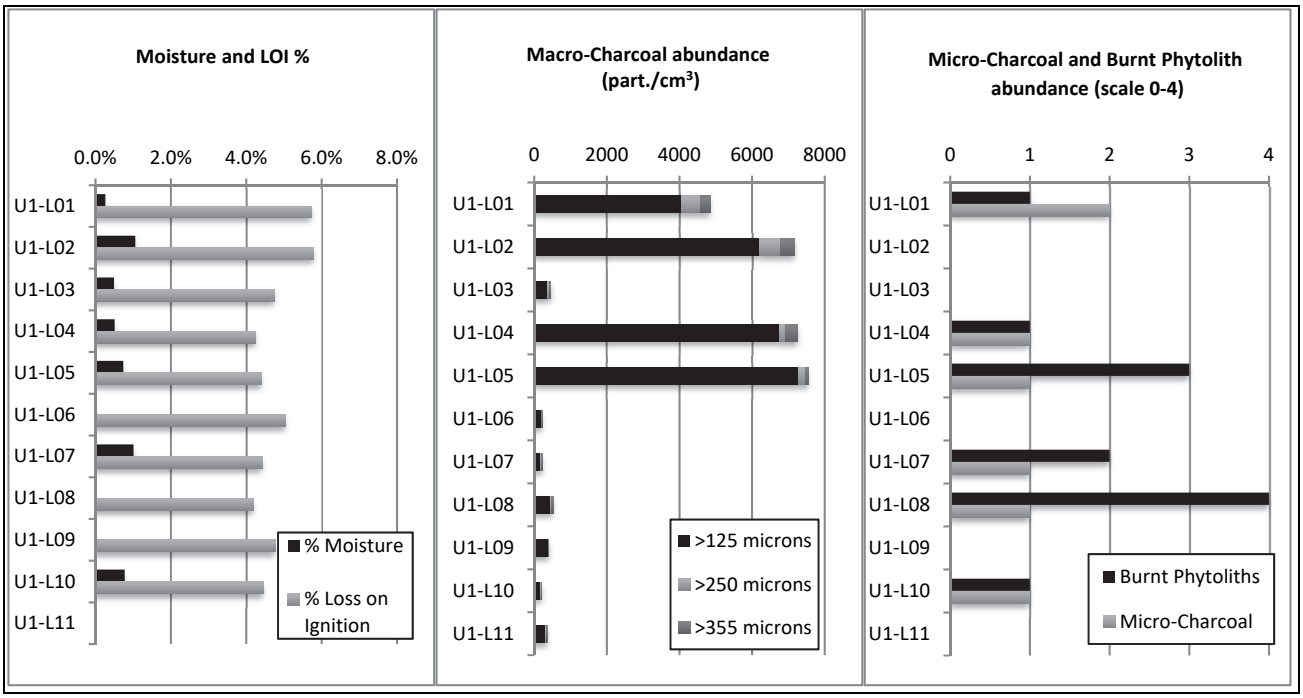

Figure 13-6 HD07-3A-03 rockshelter results. (A) sediment moisture and loss on ignition %. (B) charcoal size fractions concentrations (pieces/cm3). (C) relative abundance of burnt phytoliths and micro-charcoal pieces on pollen slides (0=absent, 4=abundant)

Table 13-3 Results for samples analysed from HD07-3A-03 rockshelter

Sample Identification					Munsell	Moisture Content				Loss on Ignition				Macro Charcoal				Comments	Pollen & Spores																							
Random Sample No.	Bag Number	UI #	Unit-Layer Key	Quad	Munsell Colour	Crucible	Wet weight (5cc)	Dry Weight	% Moisture	Crucible	Sample Weight (5cc)	After Ignition	% Loss on Ignition	>125	>250	>355	Total	Comments	pollen concentration (grains/cm^3)	*Corymbia* type	*Eucalyptus* (psilate)	*Calytrix* type	*Dodonaea*	*Acacia*	Euphorbiaceae	Fabaceae	Poaceae	Chenopodiaceae	Amaranthaceae	Asteraceae	Convolvulaceae	Cyperaceae	Minor and unknown pollen types	Pollen Diversity	Dung Fungi (*Podospora* and *Sporormiella*)	Burnt Grass Phytoliths (0-4 scale)	Micro-Charcoal (<63 microns, 0-4 scale)
15	1000	ui-0002	U1-L01	A	7.5YR 3/3	15.46	19.24	19.23	0.3%	21.41	28.74	28.13	8.3%	4050	532	260	4842		145100	17	35	8	*	*	*	*	21	*	5	*	*	*	*	14		1	2
26	1004	ui-0008	U1-L02	A	7.5YR 3/3	16.67	20.45	20.41	1.1%	16.83	24.32	23.89	5.7%	6210	580	377	7167																							
16	1008	ui-0014	U1-L03	A	7.5YR 3/4	16.64	20.7	20.68	0.5%	17.28	25.92	25.42	5.8%	377	40	44	461																							
18	1012	ui-0069	U1-L04	A	7.5YR 3/4	18.51	22.43	22.41	0.5%	17.2	25.4	25.01	4.8%	6750	158	346	7254		29100	51	38	11													3		1	1
21	1016	ui-0205	U1-L05	A	7.5YR 3/4	15.62	19.69	19.66	0.7%	15.35	22.87	22.55	4.3%	7290	187	67	7544		1100	*	*								*					3		3	1
14	1020	ui-0211	U1-L06	A	7.5YR 4/4	16.77	20.74	20.74	0.0%	22.49	30.21	29.87	4.4%	201	14	11	226																							
23	1024	ui-0217	U1-L07	A	7.5YR 3/3	16.36	20.31	20.27	1.0%	15.08	23.22	22.81	5.0%	184	19	16	219		0																0		2	1
25	1028	ui-0223	U1-L08	A	7.5YR 3/4	17.21	21.19	21.19	0.0%	16.5	24.42	24.07	4.4%	450	36	30	516		800		*								*					2		4	1
24	1033	ui-0386	U1-L09	A	7.5YR 3/4	16.31	20.47	20.47	0.0%	23.61	31.97	31.62	4.2%	380	18	6	404																							
19	1037	ui-0392	U1-L10	A	7.5YR 3/4	16.28	20.13	20.1	0.8%	21.43	29.62	29.23	4.8%	184	22	8	214		0																0		1	1
22	1041	ui-0435	U1-L11	A	7.5YR 3/4	15.62	19.73	19.73	0.0%	18.11	26.17	25.81	4.5%	316	29	10	355																							

Pollen & Spores - presence (%) or * = <1%

Pollen & Spores - not analysed

Pollen & Spores - absent

Burnt Grass Phytolith & Micro-Charcoal Scale: 0=barren; 1=rare; 2=medium; 3=common; 4=abundant

HS-A1 Rockshelter

Fourteen samples were submitted from Unit 1 (Layers 1-14) for analysis, and the sediment, charcoal, and palynomorph results are presented in Table 13-4 and Figure 13-7 (Haberle *et al.* 2013). The moisture content of the sediments and loss on ignition remains relatively stable across the profile. Charcoal fragments greater than 125µm are most abundant in the upper part of the profile above Layer 5 (ui-1025). Microscopic charcoal less than 63µm and burnt phytoliths become abundant slightly lower in the profile above Layer 7 (ui-1035) and then reduce abundance towards the top of the profile. Fires outside the rockshelter (regional fires) appear to have continuously contributed microscopic charcoal and burnt grass phytoliths to the sediments. More frequent local fires, either within the rockshelter or within a few meters of the rockshelter, are only clearly registered above Layer 5 (ui-1025).

Pollen concentrations and preservation were found to be high in most samples and provided the opportunity to calculate pollen percentages of dominant taxa through the sequence. Table 13-4 lists the pollen types identified and their presence and absence in each slide examined. *Eucalyptus* sp. pollen dominates the sclerophyll component of the pollen assemblage in all samples with *Calytrix* sp being important below ui-1019. In Layer 2 (the upper sample ui-1014), the dominance of *Calytrix* sp. is reduced and *Corymbia* sp. and grasses become more important, perhaps reflecting an increase grassy understorey and greater burning in the local area. The concentration of pollen and the diversity of pollen taxa reduces down the sediment sequence.

In summary, the sediment, charcoal and palynomorph analysis of samples from HS-A1 show good preservation of pollen throughout that suggest the presence of *Eucalyptus* sp. and *Calytrix* sp. dominated sclerophyll woodland until Layer 4 (ui-1019), when increased burning (probably locally) changed the dominant sclerophyll taxa to *Corymbia* sp with increased grassy understorey. Fire was a constant feature of this environment but become more prevalent locally above Layer 5 (ui-1025).

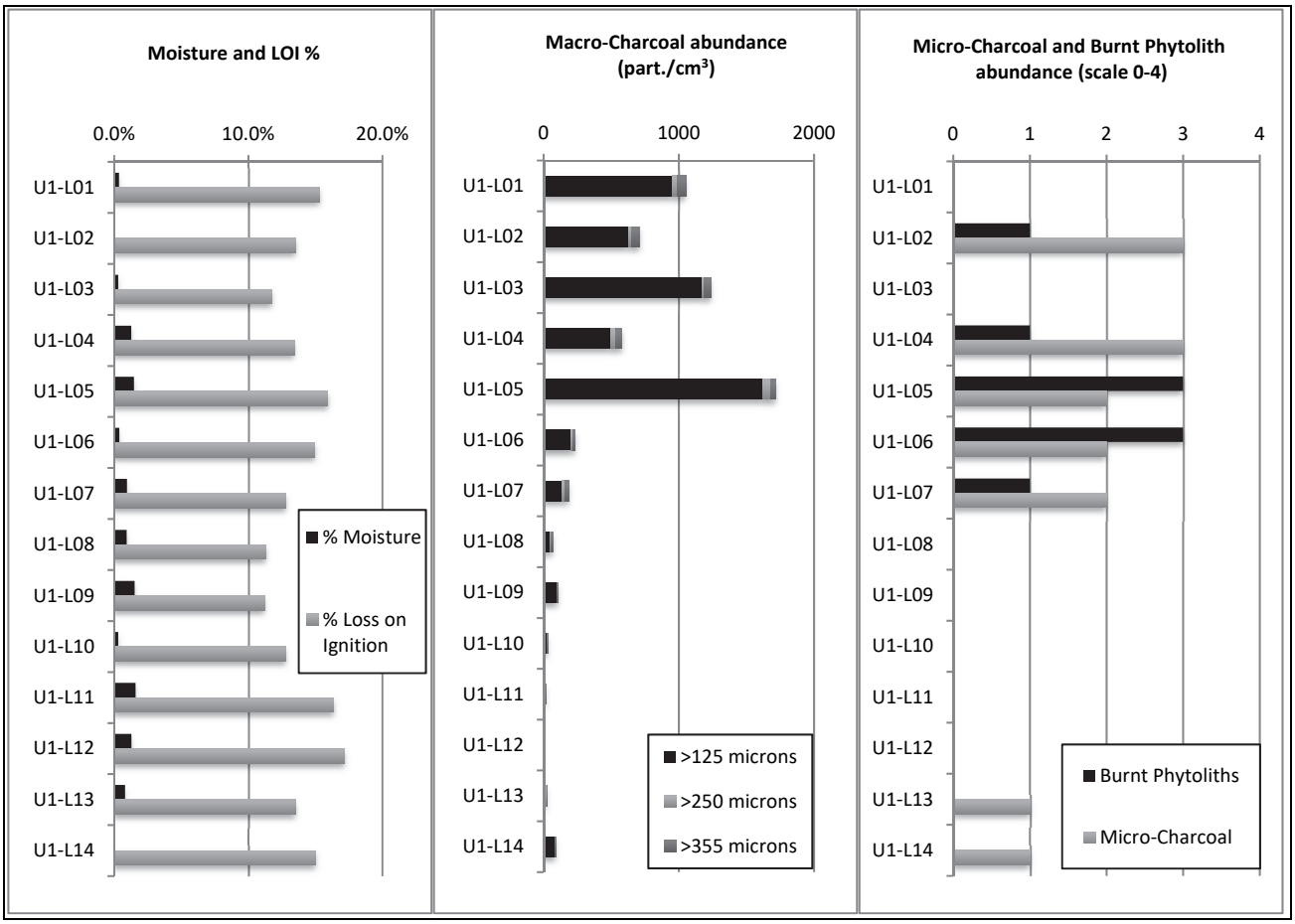

Figure 13-7 HS-A1 rockshelter results. (A) sediment moisture and loss on ignition %. (B) charcoal size fractions concentrations (pieces/cm3). (C) relative abundance of burnt phytoliths and micro-charcoal pieces on pollen slides (0=absent, 4=abundant)

Table 13-4 Results for samples analysed from HS-A1 rockshelter

Sample Identification					Munsell	Moisture Content				Loss on Ignition				Macro Charcoal				Comments	Pollen & Spores																							
Random Sample No.	Bag Number	UI #	Unit-Layer Key	Quad	Munsell Colour	Crucible	Wet weight (5cc)	Dry Weight	% Moisture	Crucible	Sample Weight (5cc)	After Ignition	% Loss on Ignition	>125	>250	>355	Total	Comments	pollen concentration (grains/cm^3)	*Corymbia* type	*Eucalyptus* (psilate)	*Calytrix* type	*Dodonaea*	*Acacia*	Euphorbiaceae	Fabaceae	Poaceae	Chenopodiaceae	Amaranthaceae	Asteraceae	Convolvulaceae	Cyperaceae	Minor and unknown pollen types	Pollen Diversity	Dung Fungi (*Podospora* and *Sporormiella*)	Burnt Grass Phytoliths (0-4 scale)	Micro-Charcoal (<63 microns, 0-4 scale)
7	1000	ui-1012	U1-L01	A	7.5 YR 4/6	6.2	9	8.99	0.4%	18.08	23.63	22.78	15%	955	36	61	1052																							
13	1004	ui-1014	U1-L02	A	7.5 YR 4/6	6.2	9.36	9.36	0.0%	17.7	24.13	23.26	14%	630	18	64	712		564000	23	58	7		*		*	7			*			*	8		1	3
18	1008	ui-1016	U1-L03	A	7.5 YR 3/4	6.13	9.52	9.51	0.3%	18.56	25.53	24.71	12%	1170	16	51	1237																							
2	1012	ui-1019	U1-L04	A	7.5 YR 4/5	6.03	9.17	9.13	1.3%	18.47	25.02	24.14	13%	492	42	44	578		108000	7	55	25	2	*		*	8						*	8		1	3
20	1016	ui-1025	U1-L05	A	7.5 YR 3/4	6.28	9	8.96	1.5%	19.87	25.52	24.62	16%	1620	58	41	1719		147000	1	60	37								*			*	5		3	2
22	1020	ui-1029	U1-L06	A	7.5 YR 3/4	6.25	8.86	8.85	0.4%	17.37	22.98	22.14	15%	204	13	17	234		15500		64	32			*								3		3	2
8	1024	ui-1035	U1-L07	A	7.5 YR 5/6	6.21	9.35	9.32	1.0%	16.49	22.2	21.47	13%	140	18	31	189		2050		*	*					*	*	*		*		6		1	2
3	1028	ui-1041	U1-L08	A	7.5 YR 5/6	6.14	9.36	9.33	0.9%	14.64	20.9	20.19	11%	49	10	12	71																							
1	1032	ui-1071	U1-L09	A	7.5 YR 5/6	6.09	9.37	9.32	1.5%	16.54	23.05	22.32	11%	96	5	6	107																							
14	1036	ui-1080	U1-L10	A	7.5 YR 5/6	6.09	9.39	9.38	0.3%	19.1	25.5	24.68	13%	24	3	4	31																							
21	1040	ui-1089	U1-L11	A	7.5 YR 4/6	6.13	9.28	9.23	1.6%	16.37	22.3	21.33	16%	16	0	2	18																							
9	1044	ui-1095	U1-L12	A	7.5 YR 5/6	6	9.1	9.06	1.3%	16.71	22.77	21.73	17%	2	0	1	3																							
4	1048	ui-1101	U1-L13	A	7.5 YR 5/6	6.17	9.89	9.86	0.8%	18.65	25.83	24.86	14%	19	5	1	25		55100	7	80	11	*	*			*							6		0	1
15	1052	ui-1103	U1-L14	D	7.5 YR 5/6	6.23	9.39	9.39	0.0%	17.61	24.8	23.72	15%	85	3	2	90		2086000	1	76	22	*		*				*				*	7		0	1

Pollen & Spores - presence (%) or * = <1%

Pollen & Spores - not analysed

Pollen & Spores - absent

Burnt Grass Phytolith & Micro-Charcoal Scale: 0=barren; 1=rare; 2=medium; 3=common; 4=abundant

Jundaru Rockshelter

Thirty-six sediment samples were submitted from Jundaru rockshelter (HN-A9), including 32 samples from arbitrary layer contexts (Unit 1, Layers 1-32) and four surface samples (Haberle *et al.* 2013). The sediment, charcoal, and palynomorph results are presented in Table 13-5 and Figure 13-8. The moisture content of the sediments remains stable across the profile. Loss on ignition shows a gradual increase in organic carbon content from the base of the profile to the surface. Charcoal fragments greater than 125µm are most abundant between Layer 20 (ui-3167) and Layer 3 (ui-3065). Microscopic charcoal less than 63µm becomes abundant only between Layer 25 (ui-3204) and Layer 22 (ui-3192) and then again in the top surface layers (ui-1936 and ui-1934). Burnt grass phytoliths are abundant at Layer 31 (ui-3252), Layer 22 (ui-3192) and Layer 8 (ui-3087). Fires outside the rockshelter (regional fires) appear to have continuously contributed macro- and micro-charcoal and burnt grass phytoliths to the sediments. More frequent local fires, either within the rockshelter or within a few meters of the rockshelter, are only clearly registered between Layer 20 (ui-3167) and Layer 3 (ui-3065). Micro-debitage is present between Layer 23 (ui-3196) and Layer 18 (ui-3159).

Pollen concentrations and preservation were found to be high in the sediments above Layer 4 (ui-3071) and provided the opportunity to calculate pollen percentages of dominant taxa through the upper four samples. Table 13-5 lists the pollen types identified and their presence and absence in each slide examined. Corymbia sp. pollen dominates the sclerophyll tree component of the pollen assemblage in samples ui-3071 (Layer 4) and ui-1935 (surface sample) and is present throughout the profile. *Eucalyptus* sp. becomes the dominant woody taxa in the upper surface samples ui-1936 and ui-1934. Grasses and Asteraceae (Daisy's) are present throughout the profile. Dung fungi are present only above ui-3071. The concentration of pollen and the diversity of pollen taxa reduce gradually down the sediment sequence.

In summary, the sediment, charcoal and palynomorph analysis of samples from HN A9 show good preservation of pollen throughout the profile that suggest the presence of *Corymbia* sp. dominated sclerophyll woodland with a grass-daisy understorey. The surface samples show a shift towards a *Eucalyptus* dominated sclerophyll woodland and reduced local burning. Fire was particularly important locally between Layer 20 (ui-3167) and Layer 3 (ui-3065) and was preceded by a zone of micro-debitage deposition between Layer 23 (ui-3196) and Layer 18 (ui-3159). Dung fungi, possibly related the abundance of larger fauna (dingo?), is evident above Layer 4 (ui-3071).

13.4 CONCLUSIONS

The sediment, charcoal and palynomorph study of four rockshelter sequences reveals the potential for good preservation of microscopic plant remains in many samples. There appears to be a gradual (or sometimes rapid) decline in preservation of organics with depth (and age). This is reflected in the loss in concentration and diversity of pollen grains with depth recorded at all sites.

The composition of the rockshelter pollen assemblages is dominated by savanna plant taxa including members of the Myrtaceae family (*Corymbia* sp., *Eucalyptus* sp., and *Calytrix* sp.), Sapindaceae (*Dodonaea* sp.), Asteraceae and Poaceae. These are generally abundant in the environment due to the source plants pollination strategy relies on wind-dispersal (anemophilous). The taxa are typical of sclerophyll vegetation which is common throughout the region today and was clearly present in the region in the past. Changing in sclerophyll tree dominance within savanna environments is reflected in the changes in dominance of different tree taxa through the profiles. *Corymbia* sp. tends to dominate during periods of high fire activity. *Eucalyptus* sp. and *Calytrix* sp. dominate when fire activity is reduced. Herbaceous taxa such as Poaceae and Asteraceae are present in many samples and reflect local grassy understorey conditions.

The dung fungi spores *Podospora* and *Sporomiella* were also identified in some of these sediments and may reflect the abundance of herbivorous animals using the site or at least being proximal to the site. In the Djadjiling Rockshelter sediments the presence of either or both of these dung fungi indicators is found at Layer 1 (3000 cal BP to the present) and Layer 6 and 7 (older than 32,000 cal BP). This may be indicative of the presence of megafauna in the region before 32,000 cal BP. The absence of dung fungi after 32,000 cal BP may be associated with widespread extinction of large herbivores in Australia after the arrival of humans some 40,000 years ago. The presence of dungi fungi after 3000 cal yr BP in rockshelter may relate to higher small mammal densities in the rockshelter during the late Holocene or the arrival of Dingo into Australia at around this time. These animals may have frequented the rockshelter during the time of most intensive use by humans during the mid-late Holocene.

This study has confirmed that a detailed investigation of sediment, charcoal and palynomorphs is possible in the Pilbara environments and that they can provide insight into local vegetation composition and detail on plant-fire-people interactions that broadly support known regional climatic reconstructions.

Table 13-5 Results for samples analysed from Jundaru rockshelter

Sample Identification					Munsell	Moisture Content				Loss on Ignition				Macro Charcoal				Comments	Pollen & Spores																			
Random Sample No.	Bag Number	UI #	Unit-Layer Key	Quad	Munsell Colour	Crucible	Wet weight (5cc)	Dry Weight	% Moisture	Crucible	Sample Weight (5cc)	After Ignition	% Loss on Ignition	>125	>250	>355	Total	Comments	pollen concentration (grains/cm^3)	*Corymbia* type	*Eucalyptus* (psilate)	*Calytrix* type	*Dodonaea*	*Acacia*	Euphorbiaceae	Fabaceae	Poaceae	Chenopodiaceae	Amaranthaceae	Asteraceae	Convolvulaceae	Cyperaceae	Minor and unknown pollen types	Pollen Diversity	Dung Fungi (*Podospora* & *Sporormiella*)	Burnt Grass Phytoliths (0-4 scale)	Micro-Charcoal (<63 microns, 0-4 scale)
45	0	ui-1934	U0-L00	^	7.5YR 3/3	16.34	19.45	19.43	0.6%	16.49	22.53	21.37	19.2%	3960	260	365	4585		212700	19	30	2	12	*			10		*	17			*	9	*	1	4
51	0	ui-1936	U0-L00	^^	7.5YR 3/4	16.65	19.2	19.18	0.8%	19.86	26.63	25.46	17.3%	2250	86	180	2516	insects	208300	3	70	2	5	*		*	2		*	15			*	10		1	3
58	0	ui-1933	U0-L00	+	7.5YR 3/4	15.85	19.61	19.6	0.3%	21.48	30.09	29.33	8.8%	3780	136	82	3998	Insects seeds																				
71	0	ui-1935	U0-L00	++	7.5YR 3/4	16.21	19.22	19.15	2.3%	19.86	25.81	24.74	18.0%	5085	330	138	5553	insects	68600	40	18	13	7				7	*	*	13			*	9		1	1
40	1071	ui-3057	U1-L01	A	7.5YR 3/4	16.76	19.86	19.83	1.0%	18.44	25.17	23.9	18.9%	4050	192	248	4490	insects																				
46	1073	ui-3061	U1-L02	A	7.5YR 3/3	15.6	18.78	18.74	1.3%	16.72	23.04	21.86	18.7%	3150	388	540	4078																					
52	1075	ui-3065	U1-L03	A	7.5YR 3/3	15.64	18.35	18.25	3.7%	16.33	22.02	20.63	24.4%	8910	855	720	10485																					
59	1077	ui-3071	U1-L04	A	7.5YR 4/4	20.09	22.72	22.63	3.4%	20.98	26.48	25.58	16.4%	14440	1890	1364	17694		147000	34	32	4		*	2		12			15				7	*	2	1
64	1079	ui-3075	U1-L05	A	7.5YR 4/6	20.09	23.01	22.91	3.4%	18.11	24.33	23.19	18.3%	12960	884	990	14834																					
53	1081	ui-3079	U1-L06	A	7.5YR 4/4	16.79	19.83	19.76	2.3%	17.36	24.09	23.03	15.8%	6120	367	490	6977		5000	*	*									*				3		2	2
68	1083	ui-3083	U1-L07	A	7.5YR 4/6	16.93	19.87	19.71	5.4%	19.09	24.72	23.85	15.5%	7695	1170	1935	10800																					
41	1085	ui-3087	U1-L08	A	7.5YR 4/4	15.45	18.09	18.02	2.7%	14.66	20.08	19.34	13.7%	15750	1350	2790	19890		3300	*		*					*			*			*	5		3	1
47	1087	ui-3091	U1-L09	A	7.5YR 4/4	15.61	18.72	18.61	3.5%	17.71	23.08	22.33	14.0%	8652	558	788	9998		300	*															1		1	0
60	1089	ui-3095	U1-L10	A	7.5YR 3/4	16.08	18.86	18.77	3.2%	14.65	20.75	19.93	13.4%	11880	1575	112	13567																					
72	1091	ui-3131	U1-L11	A	7.5YR 4/6	18.85	21.48	21.38	3.8%	16.33	22.15	21.31	14.4%	6930	1536	280	8746																					
54	1093	ui-3135	U1-L12	A	7.5YR 4/4	17.43	20.76	20.7	1.8%	22.79	29.11	28.36	11.9%	4140	450	520	5110																					
75	1095	ui-3139	U1-L13	A	7.5YR 4/6	17.24	20.52	20.39	4.0%	21.53	27.26	26.53	12.7%	9870	1980	1295	13145		1800			*									*				2		2	1
65	1097	ui-3143	U1-L14	A	7.5YR 4/6	15.86	18.73	18.61	4.2%	16.5	22.11	21.35	13.5%	10800	1140	840	12780		1500	*	*	*					*								4		1	1
42	1099	ui-3147	U1-L15	A	7.5YR 4/6	16.63	19.69	19.62	2.3%	18.69	24.58	23.81	13.1%	7200	1620	340	9160																					
61	1101	ui-3151	U1-L16	A	7.5YR 3/4	15.85	18.66	18.56	3.6%	18.45	24.05	23.15	16.1%	7920	550	246	8716		1750	*											*				2		2	2
55	1103	ui-3155	U1-L17	A	7.5YR 4/4	16.81	19.77	19.69	2.7%	21.51	26.96	26.19	14.1%	7830	630	536	8996		5500		50						50								2		1	2
48	1105	ui-3159	U1-L18	A	7.5YR 4/4	16.3	19.21	19.18	1.0%	19.07	24.65	23.75	16.1%	7650	720	196	8566	debitage																				
69	1107	ui-3163	U1-L19	A	7.5YR 4/6	16.46	19.51	19.41	3.3%	17.92	23.11	22.31	15.4%	5850	838	375	7063		1500	*	*						*			*			*	5		1	2
73	1109	ui-3167	U1-L20	A	7.5YR 4/6	18.08	21.33	21.25	2.5%	17.37	24.02	23.29	11.0%	8100	572	352	9024	debitage	1200		*														1		1	1
56	1111	ui-3188	U1-L21	A	7.5YR 4/6	16.93	20.13	20.05	2.5%	15.54	22.55	21.86	9.8%	3330	315	130	3775	debitage																				
43	1113	ui-3192	U1-L22	A	7.5YR 4/4	18.48	21.86	21.85	0.3%	16.53	23.7	23.05	9.1%	3060	76	208	3344		0																0		3	4
66	1115	ui-3196	U1-L23	A	7.5YR 4/6	17.59	20.85	20.77	2.5%	16.72	23.41	22.76	9.7%	1125	380	230	1735	debitage																				
62	1117	ui-3200	U1-L24	A	7.5YR 4/4	15.65	18.51	18.4	3.8%	18.68	23.96	23.09	16.5%	2250	560	246	3056																					
49	1119	ui-3204	U1-L25	A	7.5YR 4/4	17.18	20.4	20.34	1.9%	17.62	24.04	23.37	10.4%	2430	234	412	3076		500	*															1		1	3
70	1121	ui-3208	U1-L26	A	7.5YR 5/8	16.78	20.08	20.02	1.8%	18.57	25.03	24.34	10.7%	3555	990	258	4803																					
57	1123	ui-3212	U1-L27	A	7.5YR 4/4	16.46	19.14	19.04	3.7%	19.3	24.8	24.09	12.9%	3375	594	330	4299		2500	*	*						*			*				4		1	2
44	1125	ui-3216	U1-L28	A	7.5YR 4/4	16.27	19.29	19.19	3.3%	18.1	23.9	23.14	13.1%	4230	148	81	4459																					
74	1127	ui-3220	U1-L29	A	7.5YR 4/6	16.39	19.33	19.27	2.0%	22.82	28.87	28.17	11.6%	1230	169	34	1433																					
63	1129	ui-3224	U1-L30	A	7.5YR 4/6	17.44	20.49	20.44	1.6%	16.51	22.56	21.95	10.1%	207	45	20	272		600	*	*						*			*				4		2	1
67	1131	ui-3252	U1-L31	A	7.5YR 4/6	16.83	19.87	19.79	2.6%	17.72	23.66	23.05	10.3%	78	27	4	109		100	*							*							2		3	1
50	1133	ui-3256	U1-L32	A	5YR 5/8	15.87	19.32	19.28	1.2%	18.54	25.5	24.78	10.3%	48	6	3	57																					

Pollen & Spores - presence (%) or * = <1%

Pollen & Spores - not analysed

Pollen & Spores - absent

Burnt Grass Phytolith & Micro-Charcoal Scale: 0=barren; 1=rare; 2=medium; 3=common; 4=abundant

^ NE trench surface; ^^ SE trench surface; + NW trench surface; ++ E trench surface

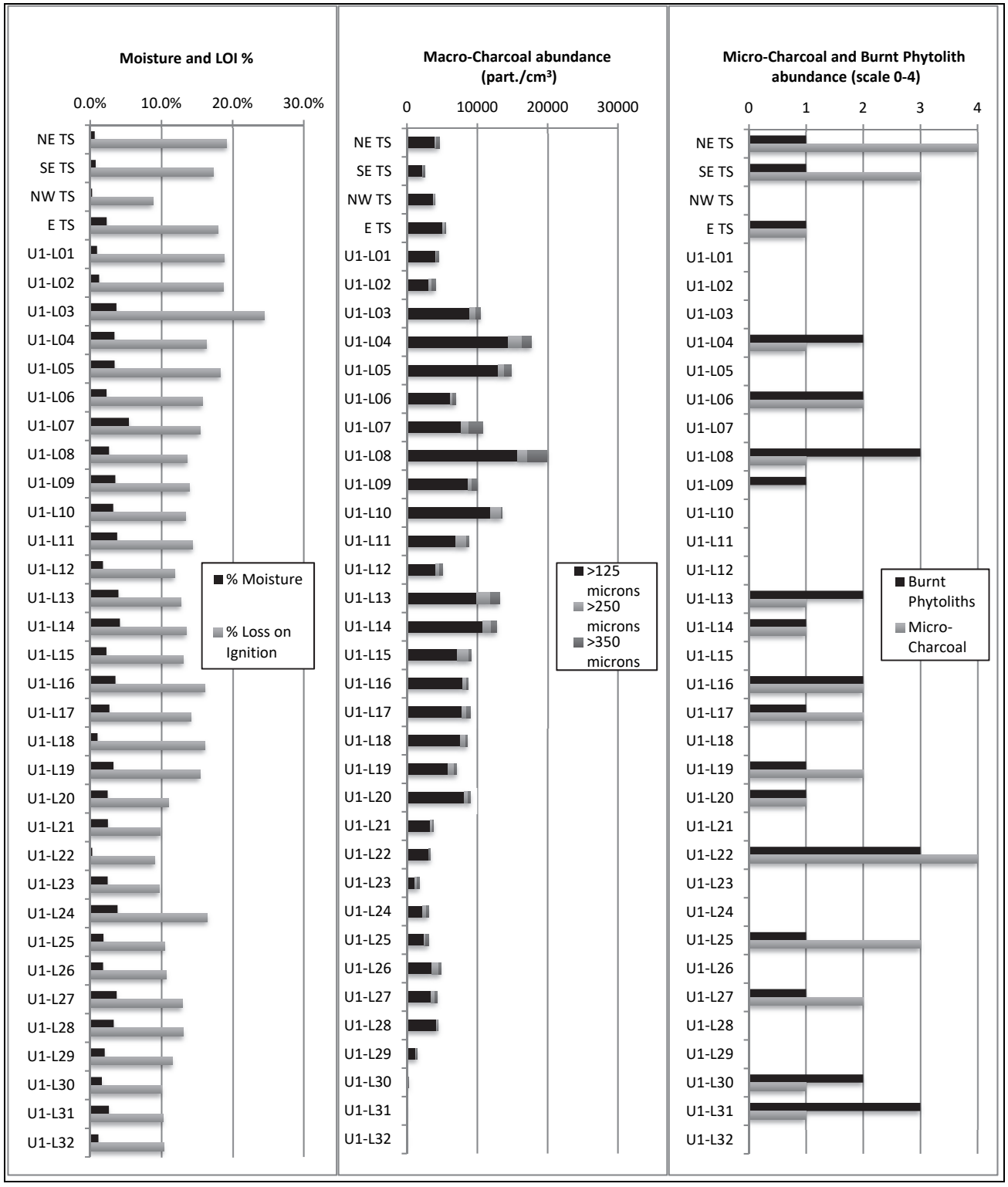

Figure 13-8 Jundaru rockshelter results. (A) sediment moisture and loss on ignition %. (B) charcoal size fractions concentrations (Pieces/cm3). (C) relative abundance of burnt phytoliths and micro-charcoal pieces on pollen slides (0=Absent, 4=Abundant) (NOTE: TS = sample collected from trench surface)

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Chapter 14

Faunal Analysis of Jundaru (HN-A9) and PAD 3 Rockshelters, Pilbara, Western Australia

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14.1 INTRODUCTION

Jundaru (HN-A9) and PAD 3 rockshelters were excavated by ACHM to investigate their archaeological significance. The faunal analyses reported here may provide insight into animal use by indigenous Australians that once occupied the Hope Downs 1 region. Animal remains were investigated to identify the fauna and observe bone breakage, burning, modification and taphonomy. Potential cultural implications based on the faunal analysis are discussed.

14.2 METHODS

Bones were examined under a dissecting microscope at 10–40X magnification and identified using published descriptions and comparative material from the South Australian Museum mammal, bird, and reptile collections. Whole and part skulls, dentaries, teeth (where applicable) and postcranial bones were used to identify taxa. All bones were identified to the lowest taxonomic level possible, though due to a high degree of fragmentation many specimens could not be identified beyond Class.

Three categories were used to describe the reliability of identification of each specimen. Category 1 indicates that the identification is certain; Category 2 indicates that the identification is probably correct (equivalent to the notation *cf.*, an abbreviation of compare), and Category 3 indicates that the identification is uncertain. The preservation of each bone was described as either Good (bone surface is intact), Fair (bone surface is slightly degraded), Poor (bone surface is moderately degraded) or Critical (bone surface is entirely degraded).

The minimum number of individuals (MNI) was determined by counting the most numerous diagnostic element (*e.g.*, left maxillae or right femur, *etc.*) of each species in each sample bag. The MNI for each taxon in each sample bag was then summed to determine an aggregate MNI. This method is thought to minimise estimation biases caused by aggregation (Lyman *et al.* 2003).

Each specimen was observed for evidence of burning, breakage, modification, and cultural use, and then weighed to two decimal places using a pan balance. If the mass of the sample did not register on the balance, a weight of 0.0 g was recorded.

Burning

When bone is burnt it changes in appearance, and sometimes in structure (White and White 1992). Bone burnt at low temperature usually takes on a grey or blackened appearance whereas bone burnt at high temperature becomes calcined, changing in colour and structure. Bone may be blackened by a bush fire, but temperatures required to calcine bone can only occur in camp fires, indicating human activity.

Breakage

When responding to external forces, bone behaves in a predictable way producing particular breakage patterns (Lyman 1994). The most common breakage types include spiral, perpendicular, longitudinal, and crenulated breaks. Spiral breaks occur in green or living bone and when found unhealed indicate that the break occurred at or near the time of the animals death. Perpendicular and longitudinal (to the long axis of a bone) breaks occur in dry or dead bone and indicate that the break occurred after the animals death. Crenulated breaks indicate that a predator or scavenger has masticated the bone. When a bone is broken but the type or cause of the break is unclear the breakage was recorded as indeterminate.

Modification

Bone modifications are defined here as deliberate physical alterations that have been made to a bone by a human. These modifications include cut marks, hammer marks, or pointing, but may also include modifications caused by bone digestion. These attributes provide potential evidence of human interaction with bones.

Cultural Significance

The likely cause of bone modification or breakage was noted in a field titled ‘cultural significance’. Bone modifications or breaks were categorised as being natural, likely natural, indeterminate, possibly cultural or likely cultural, depending on the likelihood of the modification, or breakage occurring naturally. For example, bones that had been burnt at high enough temperature to become calcined were described as likely cultural, whereas new bone breaks that appear fresh and probably occurred due to rock fall or excavation were categorised as indeterminate and are unlikely to have been caused by humans.

All data was entered into an Access database. Each specimen was then placed in a separate vial with a label that stated the specimen’s database identification number, bag number, unit-layer key, and where possible, the species determination.

14.3 JUNDARU RESULTS

A total of 3533 specimens representing a minimum number of 2611 individuals and at least 22 species were recovered from the Jundaru excavation (Table 14-1). The following paragraphs document the results of the faunal analysis, specifically focussing on the preservation of the assemblage, species

determinations, breakage patterns, and evidence of burning and modification.

In order to examine changes in the faunal assemblage through time, the assemblage has been divided according to the analytical units defined by Cropper (this volume). While the excavation exceeded 185 cm below datum, faunal remains were not recovered below this depth.

Species Determinations

At least 22 species were identified (Table 14-1), including at least 13 species of mammals (1 carnivorous marsupial, 1 bandicoot, 1 bilby, 1 possum, 1 bettong, 2 kangaroos, 1 rock-wallaby, 1 bat, at least 3 native mice, and 1 native rat), four reptile families, at least two birds, including the Emu, two species of frog and a snail. Kangaroo remains occurred in all layers and were more common than any other group of species.

Carnivorous Marsupials

Dasyurus hallucatus (Northern Quoll) once occurred continuously across northern Australia, from the Pilbara region to southeastern Queensland. It still occurs in the Pilbara today, but its range is now quite fragmented. It prefers treed habitat and is most abundant in broken rocky areas (Baynes and McDowell 2010). Specimens identified as indeterminate quoll (*Dasyurus* sp. indet.) probably also represent this species but were too damaged to identify with confidence. This species was found in AU3 through AU6 only and may have accumulated naturally rather than being accumulated by Aboriginals.

Bandicoots

Isoodon auratus (Golden Bandicoot) once occupied the majority of the desert areas of Western Australia, the Northern Territory and South Australia but is now restricted to a few isolated populations in northern Western Australia and the Northern Territory, as well as two islands off the Western Australian coast (McKenzie *et al.* 2008). Though it has been recorded in a number of habitats, it is thought to prefer to forage in open spinifex grasslands. This species was found in AU2 to AU5 and AU8 and was probably hunted and accumulated by Aboriginals.

Macrotis lagotis (Greater Bilby) was represented by a single specimen from AU2. This species once had an enormous range throughout arid and semi-arid Australia, but is now restricted to southeastern Northern Territory and southwestern Queensland (Johnson 2008). It has been associated with open sandy spinifex habitats, but probably once occupied a range of habitats. This species has been identified as Aboriginal prey (Miller *et al.* 1993) but given its low abundance in the assemblage, was probably rare at the time of accumulation.

Possums

Trichosurus vulpecula (Common Brushtail Possum) has one of the widest ranges of any Australian native mammal. It requires hollows for nesting and thus prefers treed areas, but if substitutes (such as caves or rockshelters) are available then they can persist without them. *Trichosurus vulpecula* was prized for its fur and may also have been hunted for food, but as it is represented in the Jundaru assemblage by only two specimens, one of which was blackened and the other unburnt, it was probably rare in the Pilbara at the time of accumulation and may have been incorporated into the assemblage by natural processes rather than being hunted by Aboriginals.

Potorooids

Bettongia lesueur (Burrowing Bettong or Boodie), which had one of the largest ranges of any Australian native mammal, is now extinct on mainland Australia. However, it still persists on four islands off the coast of Western Australia (Burbidge and Short 2008). The species was restricted to Australia's arid and semi-arid zones where it dug extensive burrows wherever soils were deep enough. Bettongs typically eat subterranean fungi (truffles), roots, and invertebrates. *Bettongia lesueur* occurred in the upper four analytical units of the Jundaru assemblage, and was probably hunted by Aboriginals when present in the mammal community.

Kangaroos

Macropus robustus (Common Wallaroo) occurs in a variety of habitats throughout much of Australia but is well adapted to aridity and usually prefers areas with rocky hills and rises where caves and rockshelters provide shelter from extreme and prolonged high temperatures (Morris 2000b). In the cool of evening it grazes on grasses and shrubs on the slopes and plains beneath its shelter. This species occurs in AU2 to AU6. It is well adapted to life in the Pilbara, is known from the original and modern Pilbara faunas and is common in the study area (Baynes and McDowell 2010).

Macropus rufus (Red Kangaroo) occurs throughout central Australia, particularly in open woodland and plains habitats. Red kangaroos spend most days resting under large shade trees and graze at night (Croft and Clancy 2008). Even though well adapted to Australia's arid interior, the species relies on green herbage, the supply of which determines breading rates. These kangaroos occur in the Pilbara region where open plains country occurs (Baynes and McDowell 2010). They were recorded in all but one of the rockshelter's analytical units and were likely hunted by Aboriginals.

Petrogale sp. indet. (Rock-Wallaby) could represent *P. lateralis* or *P. rothschildi*, but probably represents *P. rothschildi* which has been recorded in both the original and modern Pilbara fauna (Baynes and McDowell 2010). *Petrogale rothschildi* occurs in the Hamersley Ranges on granite rock piles and outcrops associated with grassland and shrublands (Morris 2000b; Pearson and Eldridge 2008). Rock-Wallabies occurred in the upper six analytical units in moderate numbers suggesting that they may have been hunted by Aboriginals, but may also have been accumulated naturally.

Rodents

Leggadina lakedownensis, *Pseudomys desertor*, *Zyzomys argurus* and *Rattus* sp. indet. have all previously been recorded in the Pilbara. The occurrence of *L. lakedownensis* (Northern Shot-tailed Mouse) in the Pilbara's original fauna is uncertain but it is known to occur in the modern fauna (Morris 2000a; Baynes and McDowell 2010). *Pseudomys desertor* (Desert Mouse) and *Z. argurus* (Common Rock-rat) occur in both the original and modern Pilbara faunas (Baynes and McDowell 2010). *Rattus* sp. indet. could represent either *R. tunneyi* or *R. villosissimus* but is most likely *R. tunneyi*, which is known from both the original and modern Pilbara faunas (Baynes and McDowell 2010). Rodents may have been incorporated into the Jundaru accumulation by humans or owls, or by an autochthonous process. As rodent remains were well preserved and rare in the accumulation, it is unlikely that they hunted and consumed by humans.

Table 14-1 Fauna identified from Jundaru rockshelter

Common Name	Latin Name	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8	
		MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%
Northern Quoll	*Dasyurus hallucatus*	0	0	0	0	2	0.31	0	0	0	0	1	1.27	0	0	0	0
Indeterminate Quoll	*Dasyurus sp. indet.*	0	0	0	0	0	0	1	0.11	0	0	0	0	0	0	0	0
Carnivorous Marsupial	*Dasyuridae gen. spp. indet.*	0	0	0	0	1	0.16	0	0	0	0	0	0	0	0	0	0
Golden Bandicoot	*Isoodon auratus*	0	0	1	0.25	8	1.26	7	0.8	1	0.23	0	0	0	0	0	0
Likely Golden Bandicoot	*Isoodon sp. indet. cf. I. auratus*	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminate Bandicoot	*Permaelidae gen. spp. indet.*	0	0	1	0.25	9	1.41	1	0.11	0	0	0	0	0	0	1	50
Bilby	*Macrotis lagotis*	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
Common Brushtail Possum	*Trichosurus vulpecula*	0	0	1	0.25	0	0	0	0	1	0.23	0	0	0	0	0	0
Burrowing Bettong	*Bettongia lesueur*	1	0.6	0	0	2	0.31	0	0	0	0	0	0	0	0	0	0
Indeterminate Bettong	*Bettongia sp. indet.*	1	0.6	0	0	1	0.16	1	0.11	0	0	0	0	0	0	0	0
Common Wallaroo	*Macropus robustus*	0	0	6	1.48	9	1.41	8	0.91	10	2.28	2	2.53	0	0	0	0
Red Kangaroo	*Macropus rufus*	1	0.6	3	0.74	3	0.47	6	0.68	4	0.91	4	5.06	0	0	1	50
Indeterminate Macropod	*Macropus sp. indet.*	9	5.39	17	4.19	38	5.97	39	4.45	18	4.11	7	8.86	1	16.7	0	0
Indeterminate Rock-Wallaby	*Petrogale sp. indet.*	1	0.6	4	0.99	6	0.94	8	0.91	5	1.14	4	5.06	0	0	0	0
Indeterminate Kangaroo	*Macropodidae gen. spp. indet.*	30	18	48	11.8	64	10.1	76	8.68	34	7.76	17	21.5	0	0	0	0
Indeterminate Bat	*Chiroptera gen. sp. indet.*	0	0	0	0	1	0.16	0	0	0	0	0	0	0	0	0	0
Northern Shot-tailed Mouse	*Leggadina lakedownensis*	1	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desert Mouse	*Pseudomys desertor*	0	0	0	0	0	0	0	0	0	0	1	1.27	0	0	0	0
Common Rock-rat	*Zyzomys argurus*	2	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminate Native Rat	*Rattus sp. indet.*	0	0	0	0	2	0.31	1	0.11	0	0	0	0	0	0	0	0
Indeterminate native rodent	*Muridae gen. spp. indet.*	3	1.8	2	0.49	6	0.94	3	0.34	3	0.68	0	0	0	0	0	0
Indeterminate Mammals	*Mammalia gen. spp. indet.*	106	63.5	90ε	75.4	445	69.9	705	80.5	360	82.2	43	54.4	5	83.3	0	0
Indeterminate Dragon	*Agamidae gen. spp. indet.*	4	2.4	0	0	1	0.16	0	0	0	0	0	0	0	0	0	0
Indeterminate Snake	*Elapidae gen. spp. indet.*	1	0.6	0	0	0	0	1	0.11	0	0	0	0	0	0	0	0
Indeterminate Skink	*Scinidae gen. spp. indet.*	0	0	2	0.49	1	0.16	1	0.11	0	0	0	0	0	0	0	0
Indeterminate Goanna	*Varanus sp. indet.*	0	0	1	0.25	1	0.16	1	0.11	0	0	0	0	0	0	0	0
Indeterminate Reptiles	*Reptilia gen. spp. indet.*	1	0.6	2	0.49	2	0.31	2	0.23	0	0	0	0	0	0	0	0
Emu	*Dromaius novaehollandiae*	3	1.8	6	1.48	27	4.24	9	1.03	1	0.23	0	0	0	0	0	0
Indeterminate Birds	*Aves gen. spp. indet.*	2	1.2	3	0.74	8	1.26	5	0.57	1	0.23	0	0	0	0	0	0
Indeterminate Burrowing Frog	*Neobatrachus sp. indet.*	1	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminate Amphibian	*Aphibia gen. spp. indet.*	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminate Snail	*Mollusca gen. spp. indet.*	0	0	0	0	0	0	1	0.11	0	0	0	0	0	0	0	0
	Totals	**167**	**100**	**406**	**100**	**637**	**100**	**876**	**100**	**438**	**100**	**79**	**100**	**6**	**100**	**2**	**2**
	Minimum number of taxa	**18**	**-**	**20**	**-**	**23**	**-**	**21**	**-**	**13**	**-**	**10**	**-**	**4**	**-**	**4**	**-**

MNI = Minimum Number of Individuals; Ri% = Relative Abundance

Reptiles

Agamidae (dragons), Elapidae (snakes), Scincidae (skinks) and Varanidae (goannas) are rare in the accumulation. With the exception of the skinks, which are represented by very small species only that probably accumulated autochthonously, the reptiles found in this assemblage are equally likely to represent human prey or animals that lived and died in the rockshelter. However, their low abundance suggests autochthonous accumulation.

Birds

Dromaius novaehollandiae (Emu; represented by eggshell only) and the remains of several small unidentified birds were recovered from the shelter. *D. novaehollandiae* breeds in winter only (Malecki *et al.* 1998). *D. novaehollandiae* shell was present in the five upper analytical units only. The absence of *D. novaehollandiae* bones suggests that humans indirectly preyed on the species, collecting their eggs rather than trying to capture the birds themselves.

Frogs

The specimens of *Neobatrachus* sp. indet. (Indeterminate Burrowing Frog) identified from the Jundaru rockshelter could represent any of the species in the genus. Along with *Cyclorana* spp., *Neobatrachus* spp. are known as "water holding frogs" (Withers 1998). During drought they burrow into the ground and shed several layers of skin to form a leathery bag in which they accumulate water. These frogs are said to be prized by Aboriginals as a water source (Bayly 1999), but the fact that they burrow and that a living frog was encountered during excavation (Law *pers. comm.*) suggests that they could have invaded the rockshelter strata at any time.

Preservation

Bones were generally well preserved, but were highly fragmented (Table 14-2). Consequently, comparatively few bones could be assigned to a species. Bones were typically of a uniform light brown colour, though some had been more heavily mineralised and were dark grey-brown in colour. None of the bones examined displayed evidence of subaerial weathering. The primary taphonomic processes that have impacted the assemblage appear to be treadage and possibly deliberate breakage, which has caused a high degree of bone fragmentation.

Breakage

The types and frequencies of bone breakage are presented in Table 14-3. The frequency of highly fragmented and flaked bone peak in AU3 and have an inverse relationship with indeterminate and longitudinal breaks. In contrast, the frequency of spiral breaks is relatively constant and fluctuates between 14 and 20% of breakage throughout the sequence. Other breakage types occur at low frequency only.

Burning

In all analytical units bone is most commonly unburnt or calcined respectively, though the frequency of calcined bone increases with depth (Table 14-4). Other degrees of burning appear to occur at a relatively low and constant frequency throughout the excavated sequence and may not be related to human activity.

Modification

Unmodified bones are far more common than all other categories of modified bone combined (Table 14-5). However, if we consider modified bone only, indeterminate modifications negatively correlate with depth and peak in AU2. In addition, the frequency of cut marks, acid etching and flaked bones all increase with decreasing depth.

Cultural Significance

Cultural use of bone was evident in all analytical units excavated from the Jundaru rockshelter (Table 14-6). 'Likely cultural' elements decreases slightly with decreasing depth, but were compensated for by 'possibly cultural' elements increasing with decreasing depth. The frequency of 'likely natural' and indeterminate elements were consistently very low in all analytical units.

Discussion

The Jundaru rockshelter contained an enormous amount of faunal remains that provide extensive evidence of cultural activity. Collectively, more than 15% of all bones show evidence of spiral and crenulated breaks, suggesting deliberate breakage by humans. The abundance of highly fragmented bone suggests frequent treadage (possibly by animals as well as human) and site clean up or maintenance, but may also be related to the rocky nature of the depositional environment. In addition, more than half of the bones show evidence of having been burnt, 32.6% of which have been burnt at temperatures that can only be achieved in a hearth. Though it is likely that some species, such as frogs and lizards, were probably accumulated autochthonously, this analysis suggests that the vast majority of bones were accumulated by humans.

The very low frequency of bone in AU7 and AU8, and to a lesser extent AU6, correlates with the lower frequency of stone tools. Similarly, the much higher frequencies of bone in AU1 through AU5 correlate with very much higher tool frequencies. However, species diversity is highest in AU3 even though AU4 has the highest MNI. Kangaroos were most abundant in AU6. Their frequency dropped significantly in AU5 but then gradually increase up to AU1. Their apparent high abundance in AU6 probably stems from its relatively smaller sample size. Bandicoot frequency increased from AU5, peaked in AU3 then decreased to zero in AU1. Similarly, Emu frequency increases from AU5, peaked in AU3 then decrease in AU2 only to increase again in AU1. Rodent and Reptile frequency increased as depth decreased though Rodent numbers peaked in AU3.

Bettongs also peak in AU3 then again in AU1. The combined evidence suggests that as a habitation site, use of the Jundaru rockshelter was most frequent during deposition of AU3 and AU4. However, this may be influenced by sedimentation rate and stone tool frequency suggests that use of the rockshelter peaked in AU2.

The fauna recovered from the Jundaru rockshelter is consistent with other Holocene fossil records from the Pilbara (Baynes and McDowell 2010; How and Cooper 2002; How and Cowan 2006; Morris 2000a; Morris 2000b) and many of the identified species have previously been identified as human prey species (Altman 1987; Berndt and Berndt 1993; Miller *et al.* 1993). A great many of the bones examined provided evidence of burning at high temperature, providing clear evidence for cultural use of the Jundaru rockshelter.

Table 14-2 Bone preservation in the Jundaru rockshelter faunal assemblage

	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8	
Preservation	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%
Good	48	28.74	175	43.10	248	38.93	302	34.47	121	27.63	37	46.84	0	0.00	1	50.00
Fair	84	50.30	151	37.19	276	43.33	416	47.49	200	45.66	22	27.85	5	83.33	1	50.00
Poor	35	20.96	80	19.70	113	17.74	158	18.04	116	26.48	20	25.32	1	16.67	0	0.00
Critical	0	0.00	0	0.00	0	0.00	0	0.00	1	0.23	0	0.00	0	0.00	0	0.00
Total	**167**	**100**	**406**	**100**	**637**	**100**	**876**	**100**	**438**	**100**	**79**	**100**	**6**	**100**	**2**	**100**
MNI = Minimum Number of Individuals; Ri% = Relative Abundance																

Table 14-3 Type and incidence of bone breakage in the Jundaru rockshelter faunal assemblage

	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8	
Breakage	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%
None	7	4.19	7	1.72	10	1.57	15	1.7	5	1.1	0	0	0	0	0	0
Indeterminate	60	35.9	178	43.8	42	6.59	407	46	232	53	36	46	5	83	1	50
Longitudinal	12	7.19	58	14.3	1	0.16	111	13	70	16	2	2.5	0	0	0	0
Transverse	1	0.6	15	3.69	14	2.2	34	3.9	12	2.7	3	3.8	0	0	0	0
Highly fragmented	47	28.1	62	15.3	346	54.3	120	14	54	12	26	33	1	17	1	50
Spiral	33	19.8	76	18.7	128	20.1	167	19	63	14	12	15	0	0	0	0
Flaked	1	0.6	1	0.25	71	11.1	0	0	0	0	0	0	0	0	0	0
Crenulated	6	3.59	9	2.22	25	3.92	22	2.5	2	0.5	0	0	0	0	0	0
Total	**167**	**100**	**406**	**100**	**637**	**100**	**876**	**100**	**438**	**100**	**79**	**100**	**6**	**100**	**2**	**100**
MNI = Minimum Number of Individuals; Ri% = Relative Abundance																

Table 14-4 Type and incidence of burnt bone in the Jundaru rockshelter faunal assemblage

	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8	
Burning	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%
No	92	55.09	175	43.10	308	48.35	352	40.18	163	37.21	39	49.37	0	0.00	1	50.00
Indeterminate	8	4.79	10	2.46	24	3.77	44	5.02	15	3.42	4	5.06	2	33.33	0	0.00
Yes - low temperature	4	2.40	28	6.90	27	4.24	57	6.51	28	6.39	2	2.53	0	0.00	1	50.00
Yes - blackened	27	16.17	73	17.98	56	8.79	144	16.44	71	16.21	2	2.53	2	33.33	0	0.00
Yes - calcined	36	21.56	120	29.56	222	34.85	279	31.85	161	36.76	32	40.51	2	33.33	0	0.00
Total	**167**	**100**	**406**	**100**	**637**	**100**	**876**	**100**	**438**	**100**	**79**	**100**	**6**	**100**	**2**	**100**
MNI = Minimum Number of Individuals; Ri% = Relative Abundance																

Table 14-5 Type and incidence of bone modification in the Jundaru rockshelter faunal assemblage

	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8	
Modification	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%
None	149	88.69	354	87.19	601	94.35	831	94.86	426	97.04	77	97.47	6	100	2	100
Indeterminate	7	4.17	31	7.64	9	1.41	16	1.83	3	0.68	0	0.00	0	0.00	0	0.00
Compression fracture	1	0.60	8	1.97	4	0.63	2	0.23	0	0.00	0	0.00	0	0.00	0	0.00
Conchoidal fracture	0	0.00	0	0.00	1	0.16	1	0.11	1	0.23	0	0.00	0	0.00	0	0.00
Percussion fracture	0	0.00	4	0.99	7	0.94	3	0.34	1	0.23	0	0.00	0	0.00	0	0.00
Bevelled fracture	0	0.00	0	0.00	1	0.16	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Cut marks	6	3.57	5	1.23	7	1.10	6	0.68	5	1.14	1	1.27	0	0.00	0	0.00
Flaked	1	0.60	1	0.25	1	0.16	6	0.68	2	0.46	0	0.00	0	0.00	0	0.00
Acid etched	2	1.19	3	0.74	4	0.63	5	0.57	1	0.23	1	1.27	0	0.00	0	0.00
pointed?	0	0.00	0	0.00	1	0.16	1	0.11	0	0.00	0	0.00	0	0.00	0	0.00
Puncture mark	1	0.60	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Rodent gnawing	1	0.60	0	0.00	0	0.00	1	0.11	0	0.00	0	0.00	0	0.00	0	0.00
Root etched	0	0.00	0	0.00	2	0.31	4	0.46	0	0.00	0	0.00	0	0.00	0	0.00
Total	**168**	**100**	**406**	**100**	**637**	**100**	**876**	**100**	**439**	**100**	**79**	**100**	**6**	**100**	**2**	**100**
MNI = Minimum Number of Individuals; Ri% = Relative Abundance																

Table 14-6 Degree of cultural significance in the Jundaru rockshelter faunal assemblage

	AU1		AU2		AU3		AU4		AU5		AU6		AU7		AU8	
Cultural	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%	MNI	Ri%
Indeterminate	7	4.19	9	1.41	10	1.14	25	5.71	2	2.53	2	2.53	0	0.00	0	0.00
Likely natural	10	5.99	14	2.20	6	0.68	4	0.91	1	1.27	1	1.27	0	0.00	0	0.00
Possibly cultural	44	26.35	156	24.49	194	22.15	75	17.12	6	7.59	6	7.59	0	0.00	1	50.00
Likely cultural	106	63.47	458	71.90	666	76.03	334	76.26	70	88.61	70	88.61	6	100	1	50.00
Total	**167**	**100**	**637**	**100**	**876**	**100**	**438**	**100**	**79**	**100**	**79**	**100**	**6**	**100**	**2**	**100**
MNI = Minimum Number of Individuals; Ri% = Relative Abundance																

PAD 3 RESULTS

A total of 433 specimens representing at least 23 species were recovered from the PAD 3 excavation (Table 14-7). The following paragraphs document the results of the faunal analysis, specifically focussing on the preservation of the assemblage, species determinations, breakage patterns, and evidence of burning and modification.

Species Determinations

At least 23 species were identified in this study (Table 14-7). These included one monotreme, at least 15 species of mammals (3 carnivorous marsupials, 1 bandicoot, 1 bettong, 1 hare-wallaby, 1 rock-wallaby, 1 kangaroo, 2 bats, at least 3 native mice, and 2 native rats), three reptile families, at least one bird family, and a fish.

Preservation

Bones were generally well preserved, but were highly fragmented. Consequently, few bones were identifiable to species. Bones were typically of a uniform light brown colour, though some had been more heavily mineralised and were dark grey-brown. Some bones (usually reptile remains) were almost white, suggesting that they were accumulated by a different process than other associated bones, and they probably represent autochthonous collection. The assemblage was not highly weathered, only one bone showed characteristics of having been weathered due to exposure. The primary taphonomic process that has impacted the assemblage appears to be treadage which has caused a high degree of fragmentation.

Breakage

Breakage types are presented in Table 14-8. The majority (62%) of breaks were of indeterminate origin and most likely occurred as a result of rocks falling or settling in the shelter, treadage, or during the excavation process. Unbroken bones constituted the next most common breakage category, but were closely followed by perpendicular, or dry bone breaks. Crenulated breaks accounted for 5.6% of breakage providing evidence of mammalian predation or scavenging and may relate to human activity. Spiral breaks, which indicate breakage of green bone, accounted for 4.6% of all breaks. This breakage type occurred mainly in murid bones and in two cases fur was found inside a bone shaft, indicating that the specimen was accumulated by a raptor. However, several spiral breaks also occurred in small macropod limb bones and may relate to human activity. Two bones had perpendicular breaks that had been rounded. This may be caused by digestion or abrasion by water born sediment, but has probably been caused by windblown sediment and may indicate an extended period of exposure or a low sedimentation rate. Four bones (0.9%) appeared to have been flaked but of these, only one bone showed a percussion break that is indicative of human activity.

Table 14-7 PAD 3 rockshelter faunal assemblage

Common Name	Latin Name	AU1	AU2	AU3	AU4
Short-beaked Echidna	*Tachyglossus aculeatus*	-	x	-	-
Carnivorous Marsupial	*Dasyuridae gen. spp. indet.*	-	-	-	x
Indeterminate Dunnart	*Sminthopsis sp. indet.*	x	-	-	-
Indeterminate Pseudantechinus	*Pseudantechinus sp. indet.*	x	-	-	-
Indeterminate Bandicoot	*Perameles sp. indet.*	-	-	x	x
Bettong species	*Bettongia sp. indet.*	-	-	x	-
Indeterminate bettong or potoroo	*Potoroidae gen. sp. indet.*	x	-	x	-
Indeterminate Hare-wallaby	*Lagorchestes sp. indet.*	x	-	-	-
Indeterminate Kangaroo	*Macropus sp. indet.*	-	-	x	x
Black footed Rock-wallaby	*Petrogale lateralis*	-	-	x	-
Indeterminate Kangaroo	*Macropodidae spp. indet.*	x	x	x	x
Indeterminate Bat	*Chiroptera gen. spp. indet.*	-	x	-	x
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	x	-	x	-
Short-tailed mice	*Leggadina sp. indet.*	-	x	-	-
Hopping-mice	*Notomys sp. indet*	x	-	-	-
Delicate mouse	*Pseudomys delicatulus*	-	-	x	-
Pale Field-rat	*Rattus tunneyi*	-	-	x	-
Long-haired Rat	*Rattus villosissimus*	-	-	-	x
Indeterminate native rats	*Rattus sp. indet*	-	-	x	-
Indeterminate native rodent	*Muridae spp. indet.*	x	x	x	x
Indeterminate Mammals	*Mammalia gen. spp. indet.*	x	x	x	x
Indeterminate dragon	*Agamidae spp. indet.*	x	x	x	-
Indeterminate snake	*Elapidae spp. indet.*	-	-	x	-
Indeterminate skink	*Scinidae spp. indet.*	x	x	x	-
Indeterminate reptile	*Reptilia gen. spp. indet.*	x	x	x	-
Indeterminate bird	*Aves gen. spp. indet.*	x	x	x	-
Indeterminate Bony fish	*Osteichthyes gen. spp. indet.*	-	-	x	-
	Minimum number of taxa	18	21	46	16
presented as presence / absence as in each bag, each taxon was represented by 1 individual only					

Table 14-8 Type and incidence of bone breakage in the PAD 3 rockshelter faunal assemblage

Breakage category	NISP	Ri%
Indeterminate	268	62.04
Unbroken	59	13.66
Perpendicular	54	12.50
Crenulated	24	5.56
Spiral	20	4.63
Rounded	2	0.46
Crenulated and perpendicular	1	0.23
Flaked	4	0.93
Total	**432**	**100**
NISP = Number of identified specimens, Ri% = Relative abundance		

Burning

Less than 4% of bones examined appeared to have been burnt (Table 14-9). Of these, 1.4% were scored as 'possibly - blackened', an appearance that may have been caused by iron staining, 1.6% were blackened, a condition that may have been caused by bushfire or by the use of a hearth placed stratigraphically above the bones, 0.5% were slightly calcined and 0.5% were calcined, indicating high temperature burning.

Table 14-9 Type and incidence of burned bone in the PAD 3 rockshelter faunal assemblage

Burning category	NISP	Ri%
Unburnt	415	96.06
Possibly blackened	6	1.39
Blackened	7	1.62
Calcined	4	0.93
Total	**432**	**100**
NISP = Number of identified specimens, Ri% = Relative abundance		

Modification

The vast majority of bones appeared to be unmodified by humans. Only 2.5% of the bones examined showed any modification (Table 14-10). Less than 1% of bones were rounded, a condition that isn't necessarily indicative of human activity and less than 1% were flaked. One bone (0.2%) displayed parallel scratch marks which may indicate Human activity but may have been caused by rodent gnawing. One bone (0.2%) may have been chewed and one bone (0.2%) appeared to have cut marks.

Table 14-10 Type and incidence of bone modification in the PAD 3 rockshelter faunal assemblage

Modification category	NISP	Ri%
Unmodified	418	96.76
Rounded	4	0.93
Flaked	4	0.93
Parallel scratches	1	0.23
Chewed?	1	0.23
Cutmarked?	1	0.23
Total	3	0.69
NISP = Number of identified specimens, Ri% = Relative abundance		

Discussion

Data collected from palaeontological analysis of the PAD 3 rockshelter indicates that more than one bone accumulation agent has occupied the site. Accumulating agents have included raptors, mammalian carnivores or scavengers, autochthonous processes and humans.

The overwhelming majority of the PAD 3 faunal assemblage cannot be directly attributed to human activity; however, the assemblage does exhibit some characteristics indicative of past human behaviours. The palaeontological analysis identified a small assemblage of exotic fauna (fish remains), percussion bone breakage, burnt bones, and modified bones that may be attributed to past site use. The overall physical condition of the faunal assemblage suggests that bone preservation was good to moderate but that bone fragmentation was particularly intense. Due to the high fragmentation and moderate preservation of the faunal remains and the limited assemblage size, it is difficult to investigate past subsistence practices. The current dataset implies that the early occupants consumed a variety of local marsupial and reptilian fauna. Fish formed a very small proportion of the diet, and it is likely to have been procured at Weeli Wolli Spring, a permanent water source 20 km northeast of PAD 3.

The fauna recovered from the PAD 3 rockshelter is consistent with other Holocene fossil records from the Pilbara (How & Cooper 2002; How & Cowan 2006; Morris 2000a; Morris 2000b) with the exception of fish remains which can only have been transported to the rockshelter by humans. As numerous specimens were incomplete they could only be identified to genus. However, some species may be inferred based on known distributions. The indeterminate *Sminthopsis* could be either *S. macroura* (Stripe-faced Dunnart) or *S. youngsoni* (Lesser Hairy-footed Dunnart) and the indeterminate *Pseudantechinus* sp. is almost certainly *P. macdonnellensis* (Fat-tailed Pseudantechinus). Specimens determined to be *Bettongia* sp. indet. may represent either *B. lesueur* (Burrowing Bettong) or *B. penicillata* (Brush-tailed Bettong or Woylie). The indeterminate *Lagorchestes* sp. is most likely *L. hirsutus* (Rufous Hair-wallaby) and the indeterminate *Macropus* sp. probably represents *M. robustus* (Euro) which commonly shelter in rocky overhangs, but may also represent *M. rufus* (Red Kangaroo). The indeterminate *Leggadina* sp. probably represents *L. lakedownensis* (Lakeland Downs Mouse) and the indeterminate *Notomys* sp. probably represents *N. alexis* (Spinifex Hopping-mouse), though may be *N. longicaudatus* (Long-tailed Hopping-mouse). The black tar-like substance that was stuck to one specimen appeared to be amberat, a urine-based product that stick-nest rats use in nest building. Its presence suggests that the shelter may have once contained a stick-nest rat nest, which Aboriginals have been seen to set on fire in order to capture the large rodents for food (Copley 1999). This may also be the source of blackened but not calcined bone. While it cannot be determined which of the two species of stick-nest rat was present, nests attributed to *Leporillus conditor* (Greater Stick-nest Rat) were typically found on open plains whereas *Leporillus apicalis* (Lesser Stick-nest Rat) nests were typically found in rockshelters and caves (Medlin pers. comm.).

Many of the mammals and reptiles recovered have been considered human prey species (Altman 1987; Berndt and Berndt 1993; Miller *et al.* 1993). However, palaeontological analysis provides little evidence that PAD 3 rockshelter was a human occupation site. However, some bone breakage patterns may be attributable to deliberate breakage by humans. In a few cases this is highly likely and in one, unmistakable. However, the majority of bone breakage can be attributed to treadage (by animals as well as human) and to the rocky nature of the depositional environment. Few of the bones examined provide evidence of burning at high temperature. However, the few that exist provide evidence for cultural use of the PAD 3 rockshelter. Similarly, modification of some bones also indicates human activity at the site. While PAD 3 rockshelter was probably not used as an occupation site by Aboriginals it sparse but clear evidence of human use may suggest that it was important to humans for some other reason.

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Chapter 15

Usewear and Residues on Stone Tools from PAD 3, Djadjiling, and Jundaru Rockshelters, East Pilbara, Western Australia

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15.1 INTRODUCTION

The stone artefacts (n=238) discussed here are from three sites: 29 artefacts from PAD 3 Rockshelter; 43 artefacts from Aboriginal sites Djadjiling Rockshelter (HD07-1A-04); and 166 artefacts Jundaru Rockshelter (HN-A9). This chapter focuses on a summary of functional traces observed among the technological groups, with no discussion of chronology, which is the subject further study (and limited discussion in other chapters,, this volume).

The artefacts had been ordered into technological groups by ACHM archaeologists, who requested usewear and residue study of the selection (Table 15-1), with the following broad objectives:

- What evidence of use-wear is exhibited in the assemblage?
- Are there any residues preserved on any of the artefact specimens, if so what kind of residue is present?
- Do any of the analytical results provide insight into Aboriginal subsistence?

The ACHM technological grouping of retouched/utilised flakes were refined to discriminate between retouched flakes and utilised flakes on the basis of usewear analysis Table 15-1. Flakes were also further classified on the basis of usewear and size to determine whether the flakes were the result of detachment during use ('use-flakes') or retouch ('retouch flakes', see Hayes *et al.* in press).

This chapter provides an outline of methods, an assessment of usewear and residues on artefacts from each site along with implications for further research in the Pilbara region. The reports submitted to ACHM by Fullagar (2011; 2013a; 2012) provide more detail than presented here; and residue extractions have been held for further study.

15.2 METHODS

All artefacts were examined macroscopically; under low magnification (up to about 30x) using Nikon and Olympus stereo-microscopes with oblique incident light; and under higher magnification (50x, 100x, 200x and 400x) using Olympus BH series metallographic microscopes with vertical incident light, with brightfield and darkfield illumination. Usewear and residues were identified visually on the basis of comparison with experimental data sets following methods outlined previously (see Fullagar 2013b; Fullagar 2012). An objective of these studies has been to examine a large number of artefacts, rather than a small number in more detail, and to assess the potential for more detailed usewear and residues studies. Although residues have been extracted, their analysis has not been completed, as it has for more recent functional studies of Pilbara artefacts, with more detailed identifications utilising biochemical techniques (*e.g.*, Fullagar *et al.* 2013).

Table 15-1 Number of artefacts in usewear/residue study from PAD 3, Djadjiling, and Jundaru rockshelters

Technological Groups	PAD 3 Rockshelter	Djadjiling Rockshelter	Jundaru Rockshelter	Total Analysed
Backed Artefacts	9	0	74	83
Eloueras	0	0	3	3
Tulas	0	0	8	8
Scrapers	1	0	5	6
Retouched Flakes	11	13	15	39
Utilised Flakes	4	24	13	41
Retouch/Use Flakes	0	0	3	3
Burins	0	0	12	12
Burin Spalls	0	0	8	8
Utilised Core	1	2	1	4
Utilised Quartz Crystal	0	0	1	1
Core (unused)	0	1	0	1
Flakes (unused)	1	2	0	3
Heat Shatter (unused)	1	0	0	1
Grinding Stones	1	1	18	20
Polished Pebbles	0	0	5	5
Grand Total	**29**	**43**	**166**	**238**

The artefacts (n=163) from Jundaru Rockshelter were examined with a particular focus on the function of backed artefacts (n=71), and their possible function as projectile barbs or points (*e.g.*, Fullagar 2016; Clarkson 2014). The other 92 artefacts from Jundaru Rockshelter were also examined with a focus on those with more developed usewear.

15.3 RESULTS

PAD 3 Rockshelter

Nine artefacts from PAD 3 had steep backing retouch and were classified as backed artefacts including five asymmetrical and four symmetrical (Table 15-1 and Table 15-2). Usewear including edge-rounding and scarring was common along the chord of each artefact, and less frequently on the tips. The suggested mode of use commonly includes cutting, slicing and piercing; with one instance of scraping wood Cat. 181). Backed artefact (Cat. 575) had a spin-off fracture, an indicator of possible impact from use as a projectile (Fischer *et al.* 1984) (Figure 15-1). Residues on backed artefacts included abundant traces of dark red blobs with possible plant tissue likely to be resin, often concentrated along the backed edge and indicative of hafting. Radiocarbon dates for PAD3 indicate that backed artefacts are younger than 4569-4825 cal BP, with evidence for hafting and a variety of functions including use for spear armatures.

Eleven flakes have margins with retouch (one with bifacial, the other ten with unifacial retouch) that is not as steep as for backed artefacts. Six of these had traces from working wood and other plant tissue. One artefact (Cat. 217) was probably broken from the tip of larger retouched implement with traces that indicate piercing soft tissue, including skin. One artefact (Cat. 276) was classified as a scraper, with retouch on the dorsal distal margin with associated usewear and residues on the ventral distal margin. The smoothing, polish, edge-rounding and alignments indicate wood scraping tool. Five utilised flakes have less developed traces that indicate wood and other plant processing tasks. One core (Cat. 265) has weathered ridges and edges, but two margins have clear traces use, probably woodworking. There is one unused flake (Cat. 170) probably a consequence of heat shatter. One grinding stone (Cat. 287) had abrasive smoothing, a facetted keel, starchy residues and usewear typical of the upper grinding stone type known ethnographically as a ‘muller’.

Residue preservation is generally excellent, particularly for resins and thin translucent films of identified composition (Figure 15-2). The residue have preserved intact alignments of scratches and smears that accord with use, and probably, in some instances, with hafting processes.

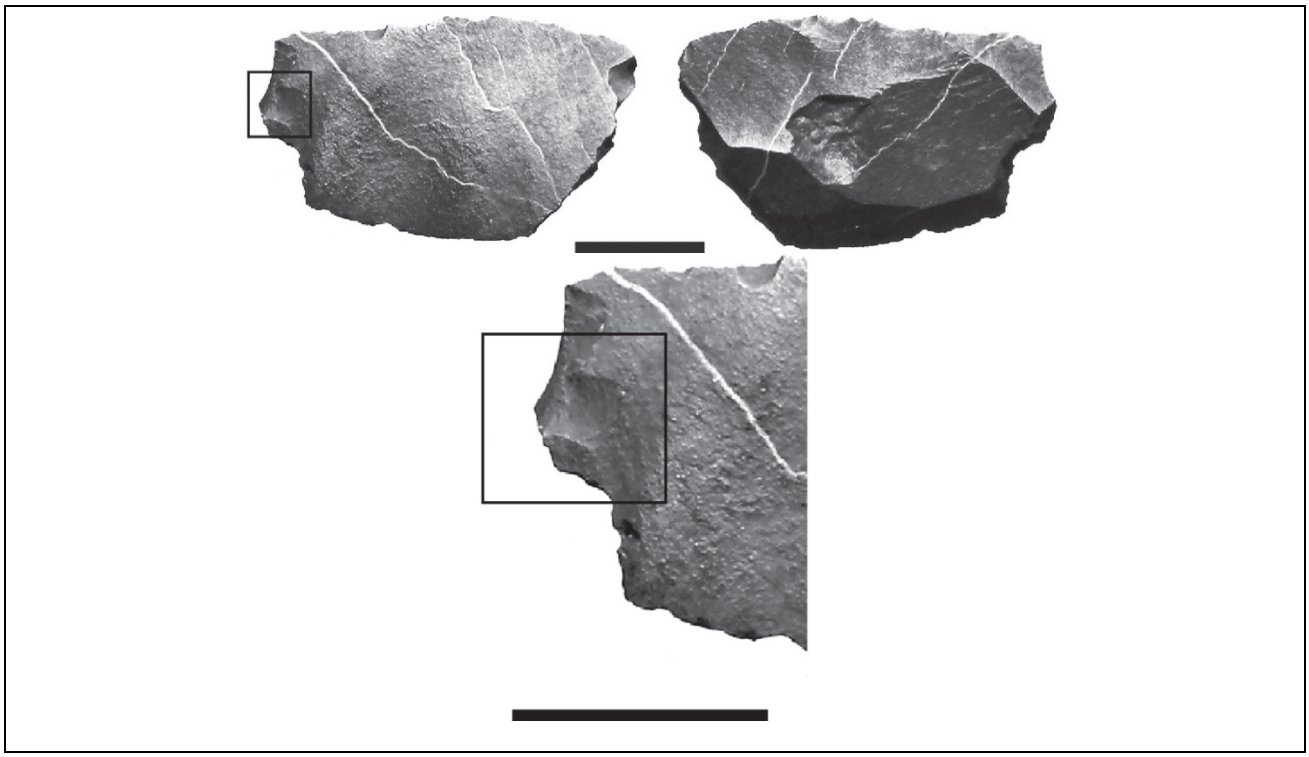

Figure 15-1 PAD 3 rockshelter backed artefact (Cat. 575) above, with a spin-off fracture (below) initiated from a snap break on the ventral distal margin (black square, in upper image). Scale bars are 1cm.

Table 15-2 Summary of usewear and residues on the PAD 3 rockshelter assemblage

CAT	AU	Raw Mat.	Techno. Class	Artefact Type	Used	Mode of Use	Hafting Evidence	Material Worked	Scarring	Use Scarring Loc.	Use Scarring Distribution	Striations Alignment	Edge Rounding	Polish	Retouch (mm)	Retouch Type	Retouch Scar Loc.	Retouch Scar Dist.	Resin	No. Used Edges/ Surfaces
287	0	sandstone	grinding stone	utilised	3	grinding	no	seeds		2 sides		all		1,2,3					no	2
288	0	chert	retouched flake	retouched	3	graving	?	wood	b f s	laterals distal tip.	cont.	perp.	2	1,2,3	5+5	inv.	unif.	cont.	yes	3
92	1	cherty BIF	retouched flake	retouched	3	uncertain	no		b f s	laterals.	cont.		1	1	15	steep	unif.	cont.	no	1
175	1	chert	retouched flake	retouched	3	scraping	no	wood	b s c	distal, laterals	scat.	perp.	1	2	10	inv.	unif.	cont.	yes	3
181	1	siltstone	retouched flake	sym. backed	3	slicing/ scraping	yes	wood	b f s	chord tip	cont.	all	2	1,2,3	50	back.	bif.	cont.	yes	1
195	1	chert	flake	utilised	3	uncertain	no		f s	L lateral.	scat.		1	1,2					yes	1
211	1	chert	flake	utilised	3	uncertain	yes		b	L lateral.	scat.			1,2					yes	1
217	1	chert	retouched flake	retouched	2	piercing	?	*cf.* skin	?	?	scat.		1	1,2	5	inv.	unif.	cont.	yes	1
265	1	BIF	core	utilised	2	scraping	no	*cf.* wood	s	platform	scat.	perp.	2	1,2,3					yes	2
266	1	chert	retouched flake	retouched	3	uncertain	no	*cf.* plant	s	R lateral.	scat.		1	1,2	4	inv.	unif.	cont.	no	1
273	1	BIF	retouched flake	retouched	3	scraping	grip	wood	b f s	lateral.	cont. & scat.	perp.	2	1,2,3	50	inv.	unif.	cont.	yes	1
276	1	chert	retouched flake	scraper	3	scraping	no	wood	b f s	distal.	cont. & scat.		1	1,2	30	inv.	unif.	cont.	no	2
96	2	siltstone	retouched flake	retouched	3	slicing/ scraping	yes		b f c s	R lateral	cont.	45	2	1,2	15	steep	bif.	cont.	no	1
105	2	chert	retouched flake	utilised	3	scraping	no	wood	b f s	laterals	cont.	perp.	1	1	??15	steep	unif.	cont.	yes	2
170	2	chert	flake	unused	0	Not used	no							0					no	0
171	2	chert	retouched flake	asym. backed	3	piercing	yes		f s h	laterals.	scat.		1	1	15	back.	unif.	cont.	yes	3
224	2	chert	retouched flake	asym. backed	3	cutting/graving? piercing	?		b f s c	chord, tip.	patchy		1	1,2	40	back.	bif.	cont.	yes	2
268	2	shale	flake	utilised	3	scraping	no		b f	L lateral.	cont.	perp.	1	1,2					no	1
313	2	chert	retouched flake	sym. backed	3	uncertain	yes		b f s	chord.	cont.		1	1	30	back.	unif.	cont.	yes	1
314	2	siltstone	retouched flake	retouched	3	slicing scraping	no		b f s	Laterals distal	cont.		1	1	20	inv.	unif.	cont.	no	2
543	2	chert	retouched flake	retouched	3	uncertain	no	*cf.* plant		lateral			1	1	5	steep	unif.	cont.	no	1
561	2	chert	retouched flake	sym. backed	3	cutting graving? piercing?	yes	*cf.* skin	b f s	chord, tip	cont.	end-on	1	1,2	50	back.	bif.	cont.	yes	2
572	2	chert?	retouched flake	asym. backed	3	slicing	yes	*cf.* skin	b f	chord,tip.	cont. & scat.		1	1	20	back.	unif.	cont.	yes	1
575	2	chert	retouched flake	sym. backed	3	impact	no		b f	chord tip	patchy		1	1	10	back.	unif.	cont.	yes	1
15	3	chert	retouched flake	retouched	3	scraping	grip?	wood	s	distal	scat.	perp.	1	1,2	20	steep	unif.	cont.	yes	1
257	3	chert	flake	utilised	2	uncertain	no		b f	dorsal.	cont.			1					no	1
312	3	chert	retouched flake	retouched	3	uncertain	yes		b f	L lateral.	scat.	end-on	1	1	10	back.	unif.	cont.	yes	1
460	3	chert	retouched flake	asym. backed	2	uncertain	yes		b	lateral	scat.		1		10	inv.	unif.	cont.	yes	1
524	3	chert	retouched flake	asym. backed	3	piercing	no	*cf.* skin	b s	tip.	scat.	end -on	1	1	5	inv.	unif.	scat.	yes	1

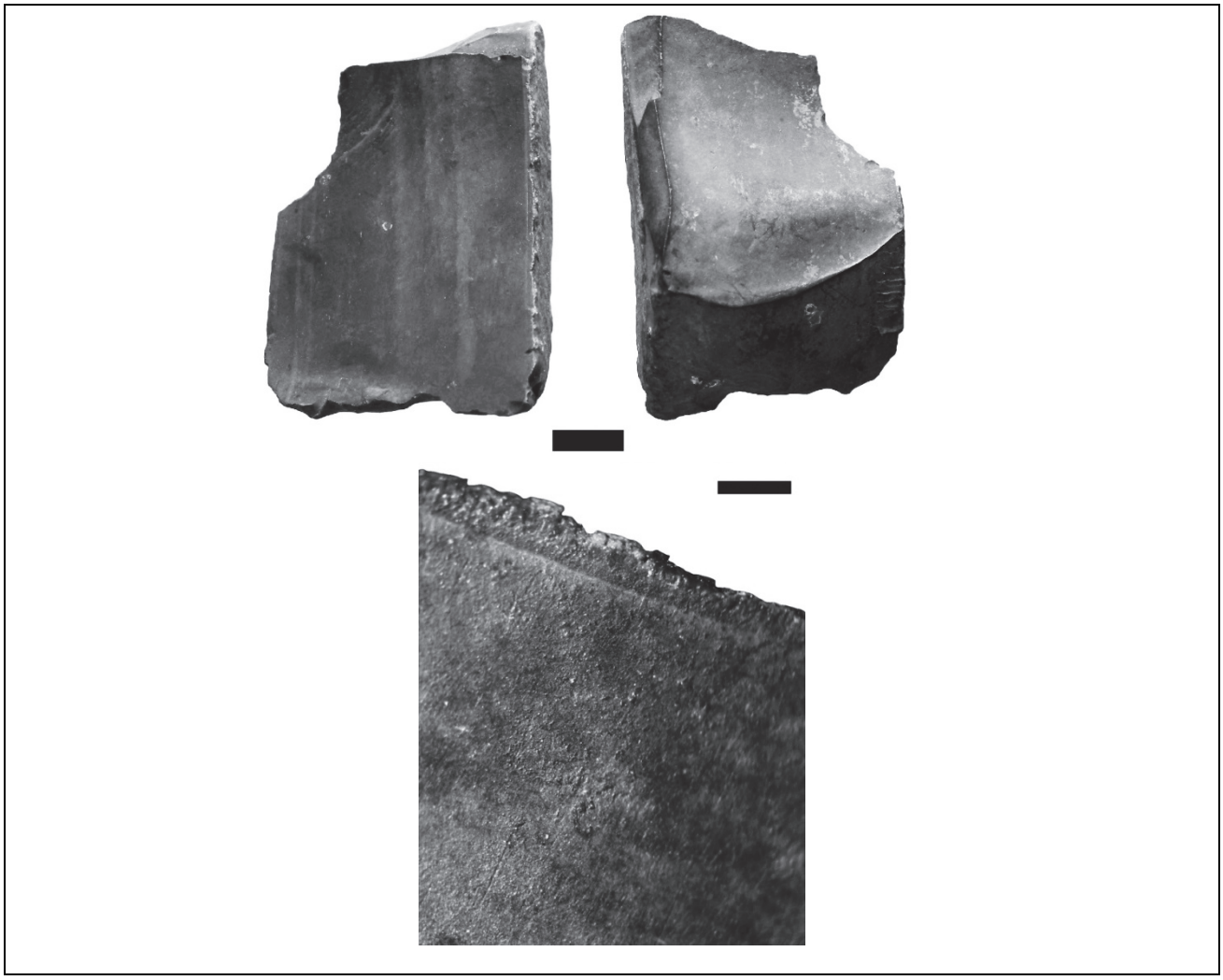

Figure 15-2 PAD 3 rockshelter retouched flake (Cat. 175) above, and traces of use, below. The traces (below) include scratches aligned perpendicular to the used edge and mostly within a woody, red, bubbly resinous film. Scale bars are 1cm.

Djadjiling Rockshelter

Thirteen flakes have retouched margins (all unifacial retouch), and four of these tools are associated with scraping wood and one with plant processing and (Table 15-1 and Table 15-3). There are 25 utilised flakes and at least 13 of these have woodworking traces. The distribution and development of wear on at least one artefact indicate wood graving (Figure 15-3). One skin working awl (Cat. 1459) was documented (Figure 15-4). The one grinding stone examined has diagnostic traces of seed grinding.

One flake (Cat. 474) has dorsal scarring, with alignments of resin and wear on the external platform edge suggesting it was a retouch flake from a utilised tool edge, prior to detachment and then subsequent use along its lateral margins. Other examples of retouch and use-flakes were found among artefacts from Jundaru Rockshelter (see below). The degree of polish development on several artefacts is high (*e.g.* Cat. 1554, see Figure 15-5)

Radiocarbon dates for Djadjiling indicate evidence of hafting and woodworking to be the most common task performed in early levels (AU6), about 41,000 to 38,000 years ago. Overall, residue preservation and usewear development is excellent amongst the assemblage.

Table 15-3 Summary of usewear and residues on the Djadjiling rockshelter assemblage

CAT	AU	Raw Mat.	Techno. Class	Artefact Type	Used	Mode of Use	Hafting Evidence	Material Worked	Scarring	Use Scarring Loc.	Use Scarring Distribution	Striations Alignment	Edge Rounding	Polish	Retouch (mm)	Retouch Type	Retouch Scar Loc.	Retouch Scar Distrib.	Resin	No. Used Edges/ Surfaces
10	1	chert	ret. flake	retouched	3	cutting/ scraping		*cf.*skin/flesh	b,f,s	bifacial	patchy	?parallel	medium	1	40	steep	unifacial	cont.	yes	2
89	3	chert	ret. flake	retouched	3	cutting/ scraping		*cf.* wood	f,s	bifacial	scattered	perp.	slight	2	50	invasive	unifacial	cont.		3
126	4	chert	flake	retouched	3	scraping		uncertain	f,s,b,c	unifacial	scattered		slight	1	60	invasive	unifacial	cont.		3
159	5	shale	ret. flake	retouched	3	uncertain	yes	*cf.* plant	f,s,b	unifacial	scattered	all	slight	2	60	marginal	unifacial	cont.	yes	1
170	5	uncertain	ret. flake	retouched	3	scraping		uncertain	b,f,s	bifacial	scattered		medium	1	50	invasive	unifacial	cont.		1
471	6	chert	ret. flake	retouched	3	scraping		*cf.* wood	b,f,s,c	unifacial	patchy	perp.	slight	3	30	marginal	unifacial	cont.		1
602	6	chert	ret. flake	retouched	3	uncertain	yes	uncertain	f,s	unifacial	continuous		medium	1	90	invasive	unifacial	cont.	yes	2
1326	6	quartz	ret. flake	retouched	3	scraping/ slicing		uncertain	f,s	unifacial	continuous	45	slight	1	20	marginal	unifacial	cont.		1
1401	5	chert	ret. flake	retouched	3	scraping	yes	*cf.* wood	f,s	unifacial	continuous	perp.	medium	3	20	invasive	unifacial	cont.		2
1452	6	chert	ret. flake	retouched	2	cutting/ slicing		uncertain	b,	bifacial	scattered		slight	1	20	invasive	unifacial	cont.		2
1470	2	chert	ret. flake	retouched	2	scraping		*cf.* wood	b,f,s	unifacial	scattered	perp.	medium	2	20	invasive	unifacial	cont.		1
1584	6	chert	ret. flake	retouched	3	scraping	yes	uncertain	b,f,s	bifacial	scattered	perp.	slight	2	10	steep	unifacial	cont.	yes	2
1617	5	shale	dist. flake	retouched	2	scraping		uncertain	b,f,s	bifacial	patchy	perp.	slight	1?	20	steep	unifacial	cont.		1
174	5	chert	dist. flake	utilised	3	scraping		*cf.* wood	b,f,s	bifacial	scattered		slight	2						4
178	5	shale	flake	utilised	2	uncertain		uncertain	b,f,s	bifacial	scattered		slight	1						2
182	5	uncertain	prox. flake	utilised	3	graver		*cf.* wood	b,f,s	unifacial	scattered	perp.	medium	2	?					2
225	6	shale	flake	utilised	3	?scraper		*cf.* wood	b,f,s,	unifacial	patchy	perp.	medium	3	?					
227	6	chert	flake	utilised	3	uncertain	yes	uncertain	b,f,s,	bifacial	patchy		slight	2	?				yes	2
230	6	amethyst	bipolar flake	utilised	3	uncertain		uncertain	b,f,s	bifacial	patchy									1
313	6	chert	flake	utilised	3	slicing		*cf.* wood	b,f,s	bifacial	patchy	45	slight							2
335	6	BIF	flake	utilised	3	scraping		soft wood	b,f,s	bifacial	patchy	perp.	medium	3						1
408	6	shale	flake	utilised	3	uncertain		*cf.* wood	f,s	unifacial	continuous		medium	2						1
474	6	shale	retouch flake	utilised	2	uncertain	yes	*cf.* wood	f,s	bifacial	rare		medium	1					yes	1
498	6	quartz	core	utilised	3	awl/ drilling/ scraping		uncertain	f,s	bifacial	continuous		medium	1						2
604	6	chert	flake	utilised	3	uncertain		uncertain	f,s	bifacial	continuous		medium	1						2
1006	1	chert	flake	utilised	3	scraping/ graving		uncertain	f,s	unifacial	continuous	perp.	slight	2					yes	3
1030	1	shale	flake	utilised	3	graver		uncertain	s	unifacial	rare	perp.	slight	2	?					1
1193	6	quartzite	flake	utilised	1	uncertain		uncertain	f,s	bifacial	scattered		slight	1						3?
1197	6	shale	flake	utilised	3	drilling scraping		*cf.* wood	f,s	bifacial	scattered	transverse	medium-massive	2						3
1231	6	quartz	flake	utilised	3	uncertain		*cf.* wood	b,f,s	bifacial	patchy			1						2
1324	6	chert	flake	utilised	2	uncertain		uncertain	b,f,s	bifacial	patchy			1						
1403	5	chert	flake	utilised	2	cutting/ slicing		plant	f,s	bifacial	continuous	transverse	slight	2					yes	1
1411	6	shale	flake	utilised	3	scraping		*cf.* wood	b,f,s,	bifacial	continuous	perp.	medium	2					yes	4
1459	6	shale	flake	utilised	3	awl	yes	*cf.* skin	b,f,s	bifacial	continuous		medium	2						
1539	4	shale	flake	utilised	3	scraping		*cf.* wood	b,f,s	bifacial	patchy	perp.	medium	3						3
1554	5	chert	flake	utilised	3	scraping		*cf.* wood	b,f,s	bifacial	continuous	perp.	medium	3					yes	3
1577	6	chert	dist. flake	utilised	3	scraping		*cf.* wood	b,f,s	bifacial	patchy	perp.	medium	2					yes	3
1590	6	chert	flake	utilised	3	scraping		*cf.* wood	b,f,s	bifacial	continuous	perp.	slight-medium	3						
30	2	chert	flake	unused	0	not used		not used												0
530	6	quartz	flake	utilised	0	not used		not used												0
1342	6	shale	core	utilised	2	scraping		*cf.* wood	b,s	unifacial	scattered		massive	1						1
1211	6	shale	core	unused	0	not used		not used											yes	0
1618	0	bif	grinding stone	utilised	3	grinding		*cf.* seeds						3						2

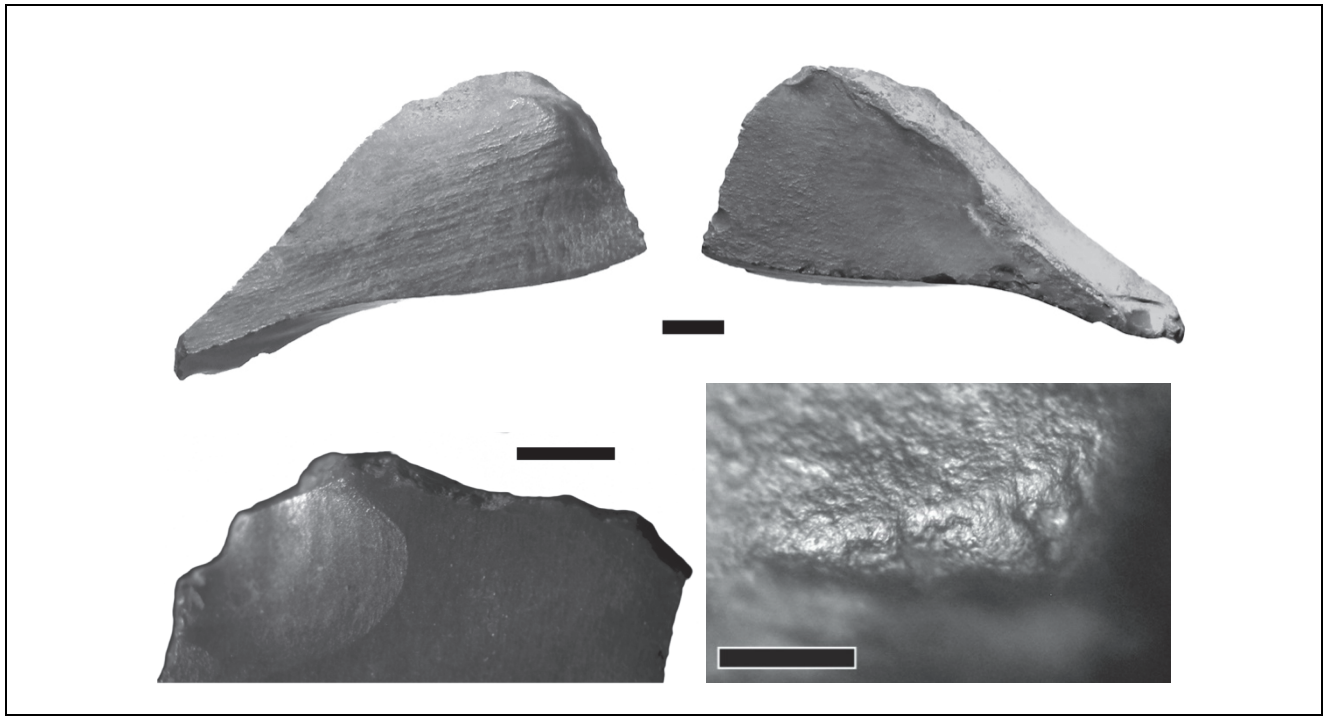

Figure 15-3 Djadjiling rockshelter utilised flake (Cat. 182) above, and traces of use, below along the distal tip (scale bar is 2mm). The traces (below left) include scarring, scratches and resin aligned perpendicular to the used edge (scale bar is 2mm). The traces (below right) include marked edge rounding and polish (scale bar is 0.25mm).

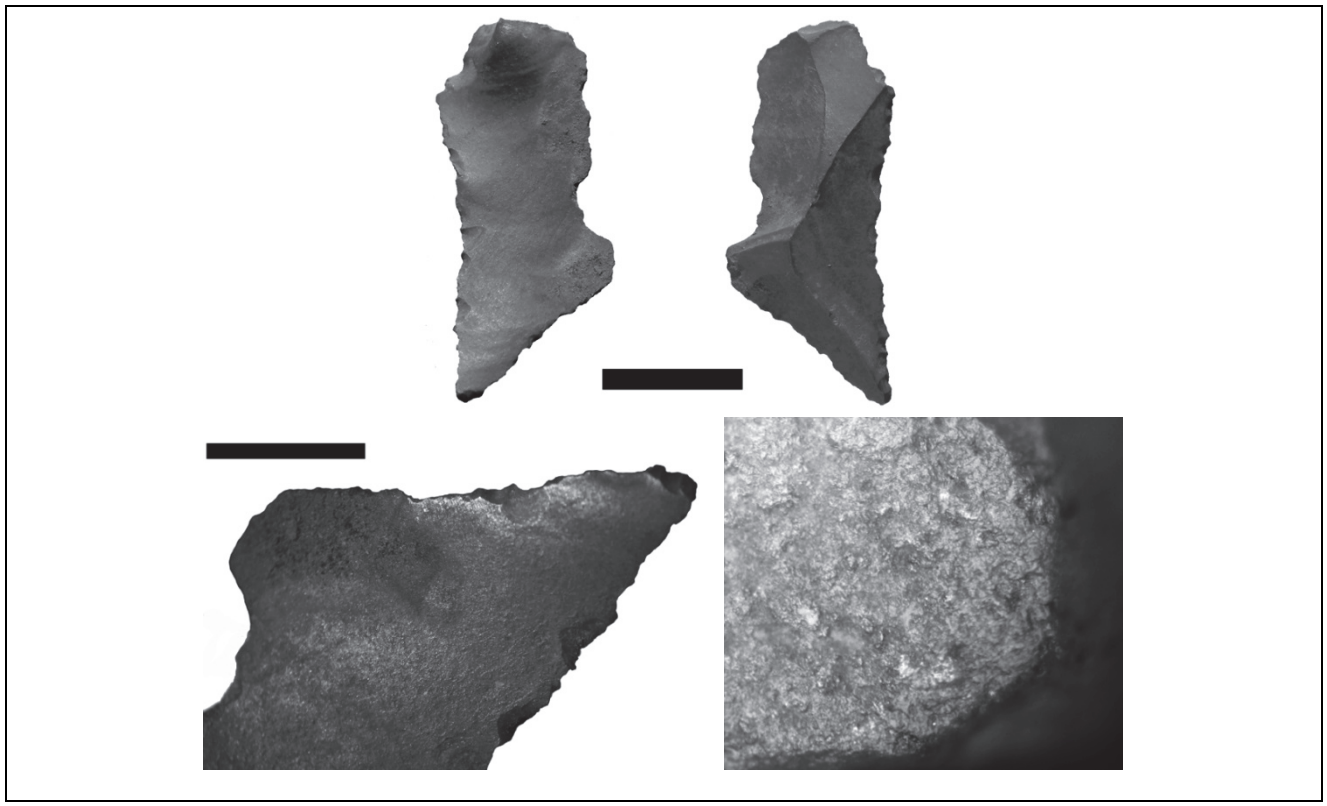

Figure 15-4 Djadjiling rockshelter utilised flake (Cat. 1459) above, and traces of use, below along the distal tip (scale bar is 10mm). The traces (below left) include scarring, and scratches aligned perpendicular to the used edge (scale bar is 5mm). The traces (below right) include marked edge rounding, polish and fine scratches perpendicular to the end (width of field is 0.25mm).

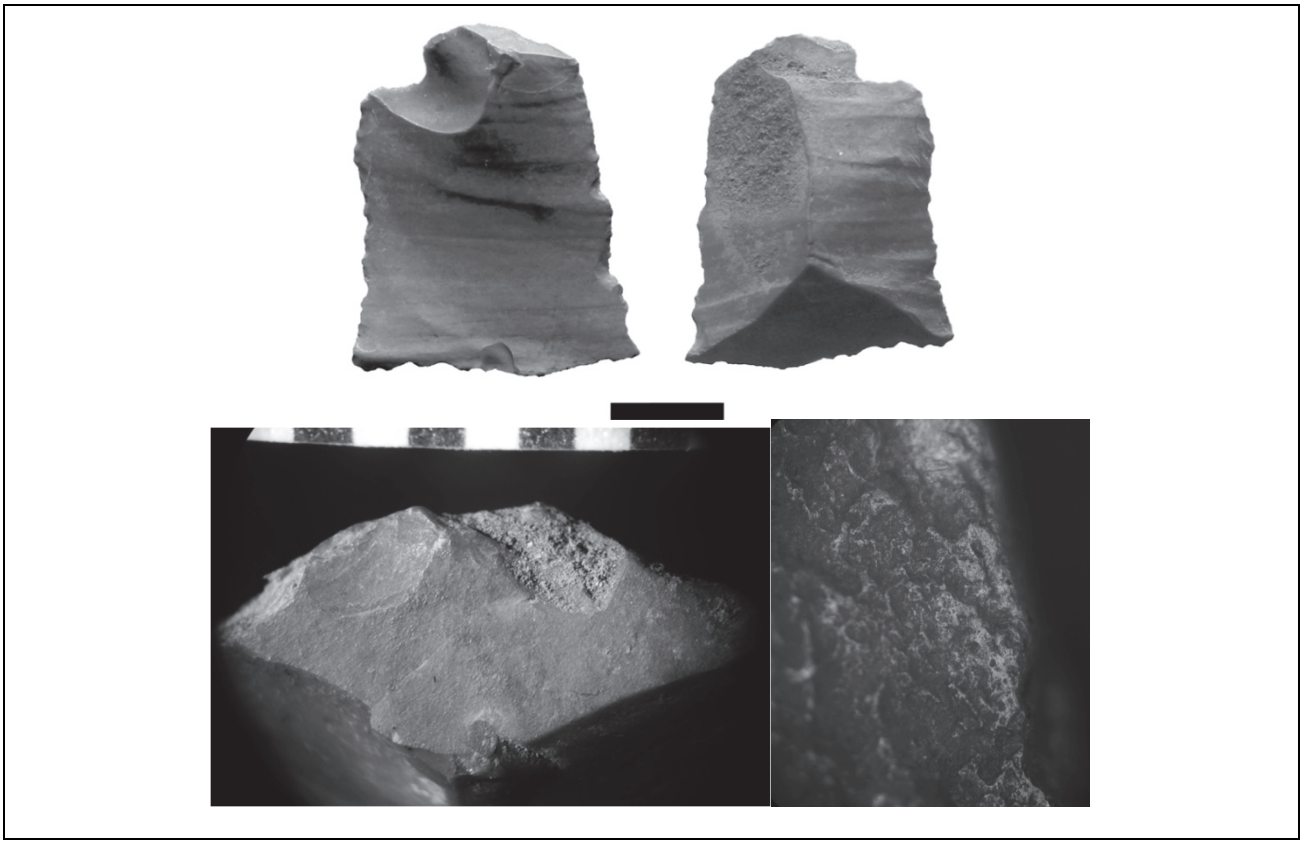

Figure 15-5 Djadjiling rockshelter utilised flake (Cat. 1554) above, and traces of use, below (scale bar is 10mm). The platform (below left) is mostly cortex with include possible haft traces: scarring and edge rounding (scale bar units are 1mm). The traces (below right) on the right lateral edge include marked edge rounding, polish and wear typical of wood working (width of field is 0.25mm).

Jundaru Rockshelter

The technological classes selected for analysis at Jundaru Rockshelter were deliberately broad (Table 15-1 and Table 15-4), and included: backed artefacts, tulas, burins, burin spalls, retouched/utilised flakes, scrapers, retouching/use flakes, quartz crystals, grinding stones (including a selection of small possible ground stone pebbles). Radiocarbon dates for Jundaru Rockshelter indicate evidence for backed artefacts possibly older than 5000 years in AU3. The usewear residue evidence indicates hafting and a variety of functions including use as spear armatures. Artefacts from AU6, 23-16,000 years ago, span the LGM, with evidence for hafting and a variety of tasks.

The backed artefacts (n=74) included 5 asymmetrical, 69 symmetrical forms. Analysis of the breaks, usewear and residues indicates that most backed artefacts were probably hafted, but, as has been found in southeastern Australia, they were used for a variety of tasks (*e.g.* to process soft plant, wood and animal tissues). I suggest that many were multi-purpose tools. For example, 17 (23%) of the 74 backed artefacts with breaks are likely to be from barb or tip impact (Table 15-4), and several of the latter artefacts appear to have usewear along the chords consistent with multiple use. Diagnostic impact fractures are problematic, and further analysis is required (see Fullagar 2014).

All three eloueras, eight tulas and four of the five scrapers have characteristic traces that indicate wood scraping, mostly hafted wood scraping (Table 15-5). Other retouched flakes (n=15) and utilised flakes (n=13) have a range of traces indicating various cutting, scraping and piercing tasks. The most commonly identified task was woodworking. Two retouch-flakes and one use-flake were documented. The use-flake appears to have been detached in the course of woodworking, demonstrating that this was a likely on-site task.

Burins (n=12) and burin spalls (n=8) from Jundaru (Table 15-6) indicate a distinct edge sharpening technique, noted previously by Clarkson in the Victoria River area. The technique involves detaching a spall parallel to the working edge of a wood scraping implement. The technique provides better control of the working edge angle than marginal retouch, which tends to alter the edge angle. The burin spalls could not be refitted to burins but many have the distinct use and residue traces of a wood working edge, truncated by the burin spall detachment.

One utilised quartz core and one possibly utilised quartz crystal were documented (Table 15-7). Eighteen grinding stones were documented and five small polished pebbles with smoothing and residues, suggesting use as hafted ornaments (Table 15-8).

15.4 DISCUSSION

Visible residues (particularly resin and woody fibres) and usewear have generally preserved remarkably well on the artefacts, given the monsoonal tropical climate of the Pilbara. The artefacts analysed span about 41,000 years at Djadjiling, about 23,000 years at Jundaru, and at PAD3, about the last 7,000 years. Residue extracts have not yet been analysed for observation of common residues that may have been incorporated into micro-cracks such as collagen fibres, starch grains, cellulose and phytoliths. Visible blood residues were scarce but present. Further study is recommended to analyse invisible residues to detect protein, carbohydrates, fatty acids and starch. Details of the Jundaru Rockshelter results are presented in the following tables. For further discussion see the relevant chapters in this publication.

Table 15-4 Summary of usewear and residues on Jundaru rockshelter backed artefacts (asymmetrical, symmetrical, eloueras)

CAT	AU	Type	Subtype	Raw Mat.	Use	Tip & Chord	Tip Only	Barb Scars	Tip Impact Likely	Tip & Barb	Probably Not Projectile	Mode of Use	Hafting Traces	Material Used	Scarring	Use Scarring Location	Use Scarring Dist.	Dominant Striations Alignments	Edge Rounding	Polish	Ret. Loc.	Residues Resin	No. used edges surfaces
363	1	symm.	crescent	chert	3		1					cutting impact	resin?	uncertain	b	chord tip	scat.	low angle	1	1	RL	resin	1
364	1	symm.	trapeze-nlb	chert	3	1						cutting	resin?	uncertain	bf	chord	cont.	?	1	1	LL	resin	1
547	2	asymm.	bondi	shale	3	1						cutting awling		uncertain	b	chord	scat.	?	1	1	LL		1
12312	2	symm.	trapeze-nlb	chert	3	1						cutting piercing		soft	bfs	chord	patchy,scat.	low angle	1	1	RL	resin	1
12389	2	symm.	crescent	chert	3		1	1				projectile impact? & graving	?	soft medium *cf.* skin	fbs	chord tip	patchy, scat.	?	3	?	LL	resin?	2
13150	3	symm.	crescent	chert	3	1						cutting scraping	?	*cf.* skin	fbs	chord	cont. & scat.	parallel perp.	3	?	LL	resin	1
13216	3	symm.	trapeze-nlb	chert	3	1						cutting piercing		soft medium *cf.* skin	bf	chord tip	scat.	parallel perp.	1	2	LL	resin ochre	1
14762	1	symm.	crescent	shale	3			1				cutting impact	scars	soft medium *cf.* skin	bfs	chord tips	cont.	?	1	0	RL	?	1
15343	2	asymm.	bondi	chert	3		1					uncertain		uncertain	bfs	chord tips	cont. & scat.	perp?	2	1	LL	?	1
19454	2	asymm.	bondi	chert	3	1						scraping	resin?	wood	bfs	chord tips	cont.	perp.	3	3	LL	resin?	2
20813	2	symm.	trapeze-nlb	shale	3		1					uncertain	resin	uncertain				perp.	?	?	dist.	resin	1
22255	2	asymm.	bondi	chert	3				1			cutting piercing impact	resin?	soft	bfs	chord tip	cont.	low angle	1	1	RL	resin	1
24019	2	asymm.	bondi	chert	3	1						cutting	?	soft	bfs	chord tip	patchy	?	1	?	RL	?	1
14148	1	symm.	triangle	BIF	3						1	drilling	complex break scars	*cf.* wood	bfs	chord tip	cont.	?	2	1	LL RL	resin fibres	1
19313	1		ind.	shale	3						1	uncertain	?	uncertain	fbs	lateral tip	patchy, cont.	?	1	?	LL	?	2
88	1	symm.	trapeze-nlb	chert	3	1						cutting scraping	resin?	uncertain	fbs	chord	cont.	parallel perp.	med	2	RL	resin	1
212	1	symm.	crescent	chert	3	1						cutting scraping		uncertain	fbs	chord	scat.	?	slight		RL	resin	1
213	1	symm.	crescent	chert	3	1						cutting	resin?	uncertain	fb	chord	cont.	?	slight	2	LL		1
809	2	symm.	triangle	chert	3		1					cutting impact	resin?	uncertain	fhbs	chord tip	scat.	?	low	1	LL	resin	1
4101	2	symm.	crescent	chert	3		1					cutting impact	resin?	uncertain	fbs	chord tip	cont.	?	med	1	LL	resin	1
4193	2	symm.	crescent	chert	3				1			projectile impact?	resin?	uncertain	fsb	chord tip	cont.	parallel	low	1	LL	resin	1
4375	3	symm.	triangle	chert	3		1					cutting impact	resin?	uncertain	fbs	chord tip	scat.	parallel	low	1	LL	resin ochre	1
6095	1	symm.	trapeze-nlb	chert	3			1				cutting impact	resin?	uncertain	bfs	chord	scat.	parallel low angle	low	1	RL	resin	1
6099	1	symm.	trapeze-nlb	chert	3		1					cutting impact	resin?	uncertain	bfs	chord tip	cont.	perp.	low	1	LL		1
6457	2	symm.	triangle	chert	3			1				cutting impact	resin?	uncertain	fhbs	chord tip	cont.	parallel	low	1	LL	resin	1
7297	2	symm.	crescent	chert	3				1			scraper impact	resin?	uncertain	bf	chord	scat.	low angle	low	1	LL	resin	1
7616	2	symm.	trapeze-nlb	shale	3	1						cutting	resin?	uncertain	bf	chord	patchy	low angle	slight	1	RL	resin	1
9526	1	symm.	trapeze	shale	3	1						cutting		uncertain	fb	chord	scat.	?	low	1	RL		1
10039	1	symm.	crescent-e	shale	3	1						awling		*cf.* skin	fbs	chord tip	cont.	perp. to tip	med	2	LL		1
10072	1	symm.	trapeze-nlb	chert	3	1						awling	resin?	*cf.* skin	b	chord tip	scat.	perp. to tip	med	2	RL	resin	1
10168	1	symm.	trapeze-nlb	chert	3	1						awling?		uncertain	b	chord	scat.	?	med	1	RL		1
10214	1	symm.	crescent-e	chert	3	1						cutting		uncertain	fbs	chord tip	patchy	?	med	1	RL		
10287	1	symm.	crescent-e	chert	3						1	gravin drilling	resin?	uncertain	bf	chord tip	cont.	perp. to tip	low	1	RL	resin	1
10524	2	symm.	crescent	chert	3	1						cutting		uncertain	fbs	all	cont.	parallel	med	1	RL		1
10662	2	symm.	crescent	chert	3	1						awling?		*cf.* skin	b	chord tip	scat.	parallel	med	2	RL		1
10774	2	symm.	triangle	chert	3	1						scraping		plant	fb	chord	scat.	perp.	slight	1	RL		1
11076	3	symm.	triangle	chert	3			1				cutting impact		uncertain	bf	chord	cont.	parallel & perp. to tip	slight	1	LL		1
11596	1	symm.	crescent	chert	3	1						cutting slicing	resin?	soft	bfs	chord	cont.	low angle	slight	1	RL	resin	1
11911	3	symm.	triangle	chert	3	1						cutting piercing	?	plant?	b	chord tip	cont.	parallel	slight	1	LL	resin	1
13052	3	symm.	crescent	shale	3	1						cutting scraping		uncertain	fbs	chord tip	cont.	parallel perp.	2	2	RL	resin	1

CAT	AU	Type	Subtype	Raw Mat.	Use	Tip & Chord	Tip Only	Barb Scars	Tip Impact Likely	Tip & Barb	Probably Not Projectile	Mode of Use	Hafting Traces	Material Used	Scarring	Use Scarring Location	Use Scarring Dist.	Dominant Striations Alignments	Edge Rounding	Polish	Ret. Loc.	Residues Resin	No. used edges surfaces
13053	3	symm.	trapeze-nlb	chert	3	1						cutting scraping	?	*cf*. plant	bf	chord tip	patchy, cont.	parallel perp.	1	2	RL	resin	1
13054	3	symm.	crescent	chert	3	1						cutting piercing	?	uncertain	bf	chord tip	patchy, cont.	parallel	1	1	RL	resin	1
14169	1	symm.	crescent	shale	3	1						uncertain		uncertain	bf	chord	scat.	?	1	1	LL	oxide stain	1
14392	1	symm.	crescent-e	shale	3	1						cutting piercing	?	uncertain	bfs	chord tip	cont.	?	2	1	LL	resin	1
15102	2	symm.	trapeze	chert	3	1						scraping	?	uncertain		chord tip	?	?	1	2	RL		1
15344	2	symm.	triangle	chert	3	1						cutting	?	uncertain	b	chord	patchy, cont.	?	1	1	LL	resin	1
15463	2	symm.	crescent-e	shale	3	1						awling? projectile	?	*cf*. skin	fs?	tips	patchy	perp. to tip	1	1	LL	?	2
15670	2	symm.	trapeze	chert	3		1					cutting slicing	resin?	soft	bf	chord tip	scat.	parallel low angle	1	?	LL	resin	1
16608	2	symm.	trapeze-nlb	shale	3	1						scraping	resin align-ments usewear	soft	f	chord tip	cont.	perp.	2	2	RL	resin	1
16877	2	symm.	crescent	chert	3				1			cutting impact	resin?	soft	b	chord tip	scat.	parallel	1	?	RL	resin	1
16922	2	symm.	trapeze-nlb	chert	3		1					cutting impact	resin?	soft	b	chord tip	patchy, cont.	parallel perp.	1	1	LL	resin	1
17370	3	symm.	trapeze-nlb	chert	3	1						uncertain	resin?	soft	b	chord tip	rare	?	1	?	LL	resin	1
21418	1	symm.	trapeze-nlb	chert	3		1					cutting scraping	resin?	uncertain	bfs	chord tip	cont.	parallel perp.	1	?	RL	resin	1
21631	1	symm.	triangle	chert	3				1			uncertain	?	uncertain	bf	chord tip	cont.	?	?	?	LL	?	1
21638	1	symm.	trapeze-nlb	shale	3	1						awling cutting	?	soft	bf	chord tip	cont.	perp. to tip	?	?	LL	?	1
21751	1	symm.	trapeze-nlb	chert	3	1						projectile impact?	resin?	bone? uncertain	bfs	chord tips	cont. & scat.	?	?	?	RL	resin	1
22269	2	symm.	trapeze	chert	3		1					cutting piercing impact	?	uncertain	bf	chord tip	patchy	?	?	?	RL	resin	1
22418	2	symm.	trapeze-nlb	chert	3		1					scraping	?	wood	bf	chord	cont.	perp.	1	2	RL	resin	1
22421	2	symm.	trapeze-nlb	shale	3		1					cutting scraping impact?	?	soft	fbs	chord tip	patchy, scat.	parallel perp.	2	1	RL	?	1
22507	2	symm.	triangle	shale	3		1					cutting	?	soft	fbs	chord	cont.	?	2	?	LL	?	1
22510	2	symm.	trapeze-nlb	shale	3	1						cutting	?	soft	fbs	chord	patchy, scat.	?	1	?	RL	?	1
22512	2	symm.	crescent	chert	3					1		projectile impact?	?	uncertain	bf	chord	scat.	?	1	?	RL	?	1
22517	2	symm.	crescent	chert	3	1						cutting	?	soft	bfs	chord	patchy	?	?	?	LL	resin	1
23545	1	symm.	trapeze-nlb	chert	3			1				cutting scraping impact	scars	uncertain	bfs	chord	cont.	perp?	?	?	LL	resin	1
23546	1	symm.	trapeze-nlb	chert	3	1						cutting	?	soft	bfs	laterals	cont.	parallel	?	?	RL	resin	2
23849	2	symm.	crescent	Agate	3				1			projectile impact?	resin align-ments usewear	soft	bf?	chord tip	scat.	?	?	?	RL	resin	1
24356	2	symm.	trapeze	shale	3	1						uncertain	resin?	uncertain	bfs	chord tip	cont.	?	?	?	LL	resin?	1
24666	2	symm.	trapeze	chert	3		1					cutting scraping impact?	resin?	uncertain	bf	chord tip	rare	?	1	?	LL	resin?	1
26143	0	symm.	trapeze-nlb	chert	3			1				projectile scraping	?	uncertain	bfs	chord tip	cont.	?	2	?	LL	bone?	1
26167	0	symm.	trapeze	chert	3	1						cut pierce	?	soft	b	chord tip	patchy	parallel	1	?	LL	resin?	1
14164	1	symm.	crescent	chert	3		1				1	scraping graving	resin	wood	fs	chord	scat.	parallel perp.	3	2	LL	resin fibres	2
6680	2	elouera	elouera	shale	3						1	elouera scraper		skin wood		chord tip		low angle perp.	high	2	RL		1
12306	2	elouera	elouera	BIF	3						1	scraper	resin?	wood	fs	chord tip	cont.	perp.	2	1	RL	resin	1
12308	2	elouera	elouera	shale	3						1	scraper		wood	fbs	laterals tip	scat.	perp.	2	3	LL RL Tip	resin ochre	1
Counts						**38**	**17**	**7**	**6**	**1**	**7**												
As % 74 (total backed artefact count):						**51.4**	**23.0**	**9.5**	**8.1**	**1.4**	**9.5**												

Table 15-5 Summary of usewear and residues on Jundaru rockshelter tulas, scrapers, retouched flakes, and utilised flakes

CAT.	AU	Raw Mat.	Tecno. Class	Rype	Use	Mode of Use	Hafting Traces	Material Worked	Edge Scarring	Use scarring location	Use Scarring Distribution	Striations Alignment	Edge Rounding	Polish	Retouch type	Retouch Location	Resin	No. Used Edges/Surfaces
101	1	chert	retouched flake	tula	3	scraping	resin?	wood	s	distal	scat	perp.	3	3	marg.	distal	yes	2
9789	1	chert	retouched flake	tula	3	scraping	resin?	wood	f,s,h	distal	scat	perp.	2	2	marg.	distal	yes	2
10140	1	chert	retouched flake	tula	3	scraping		wood	s	distal	scat	perp.	2	2	invasive	distal/ laterals	yes	3
10356	1	chert	retouched flake	tula	3	scraping	resin?	wood	s	distal	scat	perp.	2	2	invasive	distal/ laterals	yes	2
14368	1	chert	retouched flake	tula	3	scraping	resin?	wood	s	distal	scat	perp.	2	2	invasive	distal	yes	1
14937	2	chert	retouched flake	tula	3	scraping	resin?	wood	s	distal	patchy	perp.	2	2	invasive	distal	yes	2
18973	1	shale	retouched flake	tula	3	scraping	resin?	wood				perp.	2	2	invasive	distal	yes	1
8039	3	chert	retouched flake	scraper	3	scraping	hand-held	wood	f,b,s	laterals	cont.	perp.	3	2	marg.	laterals	yes	4
10286	1	shale	retouched flake	scraper	3	scraping		wood	f,s	right lateral	patchy	perp.	2	2	marg.	right lateral	?	1
10530	2	chert	retouched flake	scraper	3	scraping slicing	?	wood	f,b,s?	distal	cont.	parallel perp.	2	2	marg.	prox, distal	?	1
12876	2	chert	retouched flake	scraper	3	scraping		wood	f,b,s	prox, laterals	patchy	perp.	2	2	marg.	prox	yes	2
21732	1	shale	retouched flake	tula	3	scraping	resin?	wood	f,s	distal	patchy	perp.	2	2	invasive	distal	yes	1
23854	2	shale	retouched flake	scraper		scraping	yes, resin?	uncertain	f,b,s	distal, laterals	patchy	parallel perp.	2	2	steep	left lateral	yes	3
545	2	shale	retouched flake	retouched	3		resin?	uncertain	b,f,s	laterals	patchy, bifacial	uncertain	3	1	invasive	laterals	yes	3
808	2	chert	retouched flake	retouched	3		resin?	blood?	b,f,s,c	distal, laterals	scat.	perp.	1	1	marg.	tip	yes	2
2997	8	chert	retouched flake	retouched	3	cutting sawing		wood	f,b,s	distal, laterals	cont.	parallel perp.	1	2	marg.	left lateral	yes	3
6100	1	chert	retouched flake	retouched	3	cutting sawing scraping		wood	f,s	distal, laterals	cont.	parallel perp.	1		invasive	left lateral	yes	3
6917	2	shale	retouched flake	retouched	3	scraping	?	skin	b,s,f	distal, laterals	cont.	perp.	3	2	marg.	distal laterals	rare	3
11736	2	BIF	retouched flake	retouched	3	scraping	?	uncertain	f,s	laterals	patchy	perp.	1	1	marg.	left lateral		2
12006	2	chert	retouched flake	retouched	3	cutting scraping		soft tissue	b,f	distal, laterals	patchy		1		marg.	left lateral		3
13830	5	chert	retouched flake	retouched	3	scraping		wood	b,f,s	prox, distal, laterals	scat.	perp.	2	2	marg.	laterals	fibres	4
14044	7	SHG	retouched flake	retouched	3	scraping		wood	f,b,s?	right lateral	scat.	perp.	2	2	marg.	right lateral		1
18884	7	chert	retouched flake	retouched	3	scraping		uncertain	f,b,s?	laterals	scat.	perp.	1	1	marg.	laterals		
19358	2	chert	retouched flake	retouched	3	uncertain	resin?	uncertain	?	laterals	rare		1	1	invasive	bifacial laterals	yes	2
25194	4	chert	retouched flake	retouched	3	scraping	?	wood	b,f	distal, laterals	cont.	perp.	2	2	invasive	laterals	yes	3
25700	7	chert	retouched flake	retouched	3	awling		uncertain	f,b,c,h	distal, laterals	patchy	perp.	2	1	marg.	distal	yes	1
25756	8	SHG	retouched flake	retouched	3	scraping sawing		wood	f,b,s	laterals	cont.	parallel perp.	2	2	marg.	laterals	?	2
26092	8	BIF	retouched flake	retouched	3	scraping		wood	f,s	laterals	rare	perp.	3	2	invasive	laterals	?	2
589	2	chert	utilised flake	utilised	3	uncertain	resin?	uncertain	f,b,s	laterals	patchy cont.		2				yes	2
6470	2	shale	utilised flake	utilised	3	scraping		soft tissue	f,b,s	laterals	cont.	perp.	2	2			?ochre	2
7766	2	shale	utilised flake	utilised	3	cutting		skin	f	laterals	scat		2		marg.			2
10102	1	shale	utilised flake	utilised	3	cutting		soft tissue	b,f	laterals	patchy	parallel	1					2
11423	6	chert	utilised flake	utilised	3	cutting scraping		uncertain	f,b	distal, laterals	patchy		1	1				2
15030	2	shale	utilised flake	utilised	3	cutting scraping		uncertain	b,f	distal, laterals	scat		1	1				3
15142	2	shale	utilised flake	utilised	3	awling		skin	f,b,s	distal, laterals	patchy cont.		2	2				3
15672	2	chert	utilised flake	utilised	3	cutting	resin?	uncertain	f,b,s	laterals	scat	parallel	1	1			yes	2
17206	2	SHG	utilised flake	utilised	3	scraping	resin?	uncertain	b,f	laterals	patchy	perp.	1	1			yes	2
19280	1	chert	utilised flake	utilised	1	uncertain		uncertain	b	laterals	scat		1	1				2
19295	1	chert	utilised flake	utilised	1	uncertain		uncertain	f,b,s	laterals	scat		1	1				2
19618	2	shale	utilised flake	utilised	3	scraping		uncertain	f,b,s	laterals	scat	perp.	1	1				2
20141	2	chert	utilised flake	utilised	3	uncertain		uncertain	b	tip	patchy		2	1	?backing	?tip		1
1092	2	chert	use-flake	flake	1	scraping?		?wood	s	ext plat edge	cont	perp.	2	2			yes	1
1101	2	chert	retouch-flake	flake	1	uncertain	resin?	uncertain		?		?					yes	?
12005	2	SHG	retouch-flake	flake	1	uncertain		uncertain									yes	?

Table 15-6 Summary of usewear and residues on Jundaru rockshelter burins and burin spalls

CAT.	AU	Raw Material	Tecno. Class	Type	Use	Mode of Use	Hafting Traces	Material Worked	Edge Scarring	Use Scarring Location	Use Scarring Distribution	Striations Alignment	Edge Rounding	Polish	Retouch Type	Retouch Location	Resin	No. Used Edges/Surfaces
823	2	chert	retouched flake	burin	3	graving		?wood or bone	c,s	burin bit, lateral	cont.	perp.	2	3	Burin		yes	2
3608	2	chert	retouched flake	burin	3	scraping	resin	wood	f,b,s	left lateral	cont.	perp.	2	2	Burin		yes	2
6455	2	shale	retouched flake	burin	3	scraping		wood	s,b	lateral	scat.	perp.	2	2	Burin		yes	1
6920	2	chert	retouched flake	burin	3	uncertain		uncertain	present	prox.	scat.		1	1	Burin		yes	2
9784	1	chert	retouched flake	burin	3	scraping		wood	s	left lateral	scat.	perp.	2	2	Burin		yes	2
10387	2	chert	retouched flake	burin	3	scraping		wood	s	right lateral	scat.	perp.	2	2	Burin		yes	2
10616	2	chert	retouched flake	burin	3	scraping		wood	s,f	laterals	patchy	perp.	2	2	Burin			
10621	2	shale	retouched flake	burin	3	scraping		wood	s	laterals	scat.		2	1	Burin		yes	
12302	2	chert	retouched flake	burin	3	scraping		wood				perp.	2	2	invasive marg. Burin	laterals	yes	2
12304	2	SHG	retouched flake	burin	3	scraping		wood	s	distal laterals	scat.	perp.	2	2	invasive marg. Burin	distal	yes	2
21881	1	shale	retouched flake	burin	3	uncertain		uncertain	s	distal laterals	scat.		2	2	invasive marg. Burin	distal	yes	
22267	2	shale	retouched flake	burin	3	uncertain		uncertain	b,f,s	laterals	scat.		1	1	Burin		yes	2
472	1	chert	flake	burin spall	3	scraping		wood				perp.	2	3			yes	1
950	2	chert	flake	burin spall	3	uncertain		?blood										
10405	2	chert	flake	burin spall	3	scraping		wood	s	dorsal ridge	scat.	perp.	2	2			yes	1
11913	2	chert	flake	burin spall	3	scraping		wood	f,b,s	dorsal ridge	cont.	perp.	2	2			yes	1
12574	2	chert	flake	burin spall	3	scraping		wood	s	dorsal ridge	scat.	perp.	2	2			yes	1
14730	1	shale	flake	burin spall	3	scraping		wood	s	dorsal ridge	scat.	perp.	2	2				2
20857	2	chert	flake	burin spall	3	scraping sawing		wood	s,f	dorsal ridge	patchy	parallel perp.	2	2			yes	1
22505	2	shale	flake	burin spall	3	scraping		wood	f,s	all	patchy	parallel perp.	2	2			yes	3

Table 15-7 Summary of usewear and residues on Jundaru rockshelter quartz core and quartz crystal

CAT.	AU	Raw Material	Technological Class	Type	Use	Mode of Use	Material Worked	Edge Rounding	Polish	No. Used Edges/ Surfaces
26132	8	quartz crystal	utilised core	crystal quartz core	2	uncertain	uncertain	2	1	1
9284	6	quartz crystal	utilised crystal	crystal quartz manuport	2	uncertain	stone?	3	3	2

Table 15-8 Jundaru rockshelter grinding stones and small pebbles (possible ornaments)

CAT	AU	Raw Mat.	Complete or Fragment	Use	Mode of Use	Traces	Material Worked	Residue	Ochre	Min. No. Used Surfaces
210	1	BIF	fragment	3	grinding	striations smoothing polish	uncertain	mineral	red	1
211	1	BIF	fragment	3	grinding	striations smoothing polish	plant	residues	no	2
537	1	BIF	fragment	3	grinding	striations smoothing	plant	?	no	1
538	1	BIF	fragment	3	grinding	striations smoothing polish	plant	?	no	1
1240	2	BIF	fragment	3	grinding	striations smoothing polish	plant	charred plant	no	1
1398	3	BIF	fragment	3	grinding	striations smoothing polish	starchy plant	starch, charred plant	red	1
1476	3	BIF	fragment	3	grinding	striations smoothing polish	plant	?	no	1
1477	3	BIF	fragment	3	grinding	striations smoothing polish	plant	?	no	1
1516	3	BIF	fragment	3	grinding	striations smoothing polish	plant	?	red	1
4073	2	BIF	near complete	3	grinding	striations smoothing polish	plant	?	no	2
4557	3	BIF	fragment	3	grinding	striations smoothing polish	uncertain	?	red	1
7760	2	BIF	complete	3	grinding	striations smoothing polish	uncertain	?	red	1
8060	3	BIF	fragment	3	grinding	striations smoothing polish	ochre	?	red	1
10071	1	BIF	fragment	3	grinding	striations smoothing polish	plant	?	no	1
10382	2	BIF	complete	3	grinding	striations smoothing polish	plant	?	red	2
21460	1	BIF	fragment	3	grinding	striations smoothing polish	plant	?	no	1
22575	2	BIF	fragment	3	grinding	striations smoothing polish	plant	?	no	2
25052	4	BIF	fragment	3	grinding	striations smoothing polish	uncertain	?	?	1
22576	2	Shale	pebble	uncertain	uncertain	striations smoothing	uncertain	resin	?	?
22791	3	BIF	pebble	uncertain	uncertain	striations smoothing polish	uncertain	resin	red	?
24408	2	Shale	pebble	uncertain	uncertain	striations smoothing polish	uncertain	?	red	?
24888	3	BIF	pebble	uncertain	uncertain	striations smoothing	uncertain	?	red	?
26040	8	BIF	pebble	uncertain	uncertain	striations smoothing	uncertain	?	red	?

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Chapter 16

Report on Optically Stimulated Luminescence (OSL) Dating of a Further Four Samples from HD07-3A-PAD13 Rockshelter, Pilbara, Western Australia

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16.1 INTRODUCTION

Four samples of cave-fill sediment from HD07-3A-PAD13 rockshelter, east Pilbara, Western Australia, were collected in 2009 by Dr Dawn Cropper and Mr W. Boone Law of ACHM, and analysed at the Environmental Luminescence Laboratory (now Prescott Luminescence Laboratory), University of Adelaide. In the light of the ages obtained from these initial samples, and the emerging potential significance of the rockshelter, a further four samples were collected in 2010 by Ms Frances Williams, from the above laboratory, and Dr Martin Williams. The two sets of samples were designated as DC and HD respectively and are listed in Table 16.1, together with the sample depths and other information which will be discussed later in this chapter. The laboratory record numbers and the sample numbers, as shown in Table 16.1, should be quoted in any publication of this data.

16.2 SAMPLE COLLECTION

The original samples (DC) submitted for optical dating were collected during the initial test excavations of HD07-3A-PAD13 rockshelter. Each DC sample was individually collected using 30mm diameter PVC conduit at 10cm tube lengths (2mm wall thickness). Starting with the lowest sample in the north wall of Unit 1, the conduit tube was gently hammered into the section profile. Whilst *in situ*, a bulk sediment sample was carefully removed within a 5cm radius of the conduit tube. Approximately 1 litre of bulk sediment was collected into a green plastic gasbag. The conduit sample was subsequently removed and the tube ends were sealed with foam padding and duct tape. The labelled samples were immediately placed into a light-proof box. Bulk sediment and conduit samples collected at depths of 0.93m, 1.19m, 1.48m and 1.49m below datum. The field archaeologists delivered the samples to the laboratory.

The aims of collecting the second sample set (HD) were, firstly, to obtain material from greater depths, and secondly, to make in situ measurements of the environmental dose rate using a portable gamma ray spectrometer. Both sample collection and gamma ray spectrometer measurements turned out to be more difficult than expected, due to the large number of rock fragments contained within the cave-fill sediment, particularly toward the bottom of the archaeological excavation. These consist of the ironstone of which the walls, roof and floor of the shelter are formed. Large blocks impeded penetration of both the gamma ray spectrometer tube and OSL sample collection tubes. To overcome this difficulty the collection and measurements were done as follows. Having covered the entrance to the rockshelter with a black plastic sheet in order to block out any daylight, and using red light emitting diode (LED) head torches for illumination, a hole large enough to accommodate the spectrometer tubing was excavated horizontally into the north wall of the archaeological trench using a trowel, a spoon and by hand. Smaller rock fragments which would prevent penetration of the spectrometer tube were removed carefully by hand; larger ones had to be dug around. When the hole had extended far enough (at least 40cm), material for dating was collected as carefully as possible by hand and placed in a light-proof tin which in turn was wrapped in black plastic. The gamma ray spectrometer was then inserted into the same hole, within a protective tube of rigid plastic, and the in situ dose rate measured.

Bulk samples of the material surrounding each hole were also collected in order to carry out additional laboratory dosimetry measurements. The locations of the sampling holes are shown in Figure 16-1.

16.3 DETERMINATION OF ENVIRONMENTAL DOSE RATES

Radioactive Nuclides and Gamma Ray Contribution

For the DC sample series, concentrations of uranium (U) and thorium (Th) were determined using thick-source alpha counting (TSAC), and potassium (K) using X-ray fluorescence spectroscopy (XRS). The gamma-ray contribution was determined indirectly from the results of these measurements.

For the HD series, the concentrations of U Th and K, and their gamma ray contribution, were measured *in situ* using a portable gamma ray spectrometer, model GR-256 with a model GPS-21 detector, manufactured by Exploranium G.S. Ltd. Measurements were carried out for a minimum of 900 seconds for each sample, with the gamma ray spectrometer inserted at least 40cm into the material as described above.

Two additional *in situ* dosimetry measurements were made. The first was in the creek bank about 30m from the entrance to the rockshelter, in order to compare the dose rate of this material with that within the rockshelter. The second was an attempt to measure the dose rate of the country rock, the same ironstone of which the rock fragments within the cave sediment were composed, by inserting the spectrometer into a cleft in a nearby ridge of the country rock.

U Th and K contents were also obtained, for both sets of samples, by ICPMS (Inductively Coupled Plasma Mass Spectrometry, for U and Th) and ICPAES (Inductively Coupled Plasma Atomic Emission Spectroscopy for K) at Genalysis Laboratories, Adelaide, using the bulk samples that had been collected.

The nuclide concentrations and gamma ray measurements are shown in Table 16-1. There are clearly some discrepancies between measurements made by the different methods, which will be discussed below.

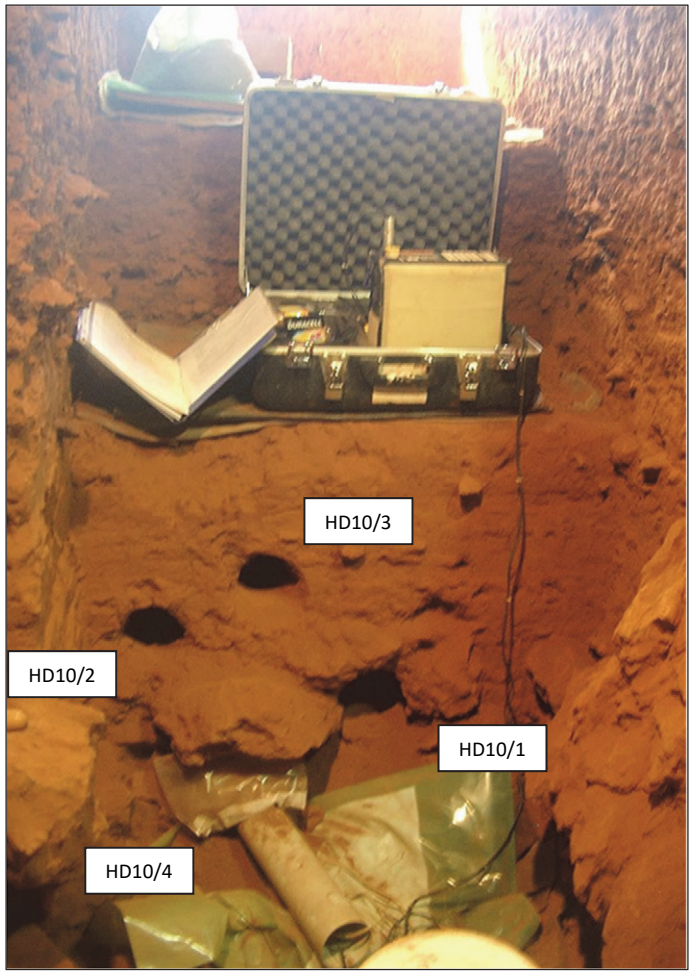

Figure 16-1 Locations of the HD samples

Table 16-1 Nuclide concentrations and environmental dose rates for HD07-3A-PAD13 rockshelter

Sample Designation	Lab No	*Analysis Method	U (ppm)	err	Th (ppm)	err	K (%)	err	Gamma (Gy/ka)	err	H2O% dry wt± 10%	Depth below Datum (m ±4.5cm)	Depth below Surface (m ±4.5cm)	Cosmic (Gy/ka ± 10%)	Dose Rate (Gy/ka)	err
2010 Series																
HD10/3	Ad10011	GAMMA	1.28	0.11	6.14	0.19	0.71	0.02	0.646	0.014	2.5	1.57	1.31	0.109	1.57	0.03
		ICP	*1.12*	*0.03*	*5.64*	*0.31*	*0.72*	*0.07*							*1.46*	*0.07*
HD10/2	Ad10012	GAMMA	1.46	0.12	5.61	0.20	0.67	0.02	0.609	0.013	1.5	1.68	1.42	0.108	1.52	0.03
		ICP	*0.97*	*0.02*	*4.78*	*0.26*	*0.59*	*0.06*							*1.25*	*0.06*
HD10/1	Ad10013	GAMMA	0.92	0.11	3.29	0.20	0.33	0.02	0.343	0.008	4.5	1.77	1.51	0.107	0.87	0.02
		ICP	*0.94*	*0.02*	*4.47*	*0.24*	*0.58*	*0.05*							*1.13*	*0.06*
HD10/4	Ad10014	GAMMA	0.65	0.07	1.72	0.11	0.18	0.01	0.199	0.005	1.0	1.94	1.70	0.105	0.56	0.02
		ICP	*0.66*	*0.02*	*2.03*	*0.11*	*0.24*	*0.02*							*0.65*	*0.03*
Creek bank		GAMMA	0.93	0.11	5.52	0.19	0.48	0.02	0.498	0.011					1.11	0.03
Bedrock		GAMMA	0.48	0.66	1.03	0.11	0.14	0.01	0.149	0.004					0.34	0.09
2009/2010 Series																
DC131	Ad09004	*TSAC/XRS*	*1.96*	*0.21*	*5.05*	*0.68*	*0.96*	*0.05*							*1.87*	*0.09*
		ICP	0.99	0.05	4.93	0.25	0.70	0.04			1.9	0.93	0.69	0.115	1.37	0.04
DC132	Ad09005	*TSAC/XRS*	*1.31*	*0.23*	*6.16*	*0.75*	*1.06*	*0.05*							*1.87*	*0.09*
		ICP	1.20	0.05	6.72	0.15	1.01	0.05			2.3	1.19	0.95	0.113	1.84	0.06
DC133	Ad09006	*TSAC/XRS*	*1.61*	*0.25*	*4.71*	*0.82*	*1.04*	*0.05*							*1.78*	*0.10*
		ICP	0.91	0.04	5.28	0.12	0.79	0.04			3.8	1.48	1.24	0.110	1.42	0.04
DC134	Ad09007	*TSAC/XRS*	*2.00*	*0.25*	*3.47*	*0.82*	*1.04*	*0.05*							*1.79*	*0.10*
		ICP	1.02	0.05	5.31	0.27	0.79	0.04			3.8	1.49	1.25	0.110	1.46	0.05

*GAMMA refers to gamma ray spectroscopy; TSAC to thick source alpha counting for U and Th, XRS to X-ray spectrometry for K, ICP to ICPMS for U and Th and ICPAES for K. (abbreviation explanations in text). Note: the gamma ray contribution was not determined directly for the DC samples.

Water Content

For all the samples, the water content of the material, as collected, was measured by weighing a portion of the bulk sample, drying overnight at 125°C, and re-weighing. Water contents are shown in Table 16-1 as percent of dry weight. Possible variations in the water content during the depositional history of the sample may affect this value. It should be noted that in increase of 1% in water content Results in an increase of 0.5% to 1% in the measured age.

Cosmic Ray Contribution

The contribution of cosmic radiation to the dose rate depends upon both density and thickness of the overlying material. In this case the rockshelter has a roof of thickness 1.6 m, formed of iron hard-pan whose density was measured as 5 gm/cc and which would have a strong attenuating effect on cosmic radiation. The total cosmic contribution, taking into account the attenuating effect of both the roof and the sediment, was obtained by using the relationship between cosmic dose rate, density, thickness of overburden, latitude and altitude determined by Prescott and Hutton (1994), and is shown in Table 16-1.

16.4 PREPARATION OF SAMPLES FOR OPTICAL DATING

All the samples were prepared for optical dating using standard procedures in order to isolate pure quartz grains. The procedure may be summarised as follows. A 10% solution of hydrochloric acid was used to digest carbonates, followed by treatment with sodium hydroxide solution to break up clay aggregates and remove any small amounts of organic material. Grains in the ranges 90 to 250µm were selected by sieving, and etched for 40 minutes in 40% hydrofluoric acid to remove feldspar and other non-quartz material, and to remove the outer 9µm of the quartz grains. This eliminates the effect of alpha particle contribution to the irradiation of the grains. The hydrofluoric acid had a strong reaction with the material, indicating the presence of a large quantity of non-quartz constituents. The retrieved material was washed in warm hydrochloric acid to remove fluorides, dried and floated in 2.67g per cubic centimetre of lithium polytungstate to remove heavy minerals (a large quantity of which was obtained) and in 2.64g per cubic centimetre of lithium polytungstate to separate out any feldspar. A significant amount of dark material (probably biotite) still remained after these treatments, and this was successfully removed by use of a Franz magnetic separator. The samples were finally re-sieved at 90 to 125µm and 125 to 180µm.

For all the samples, a quantity of material weighing approximately 250gm at the commencement of the preparation process finally yielded between 0.5gm and 1gm of pure quartz greater than 90µm . About two thirds of this was in the 90 to 125µm fraction, and a third was in the 125 to 180µm fraction. No grains greater than 180µm were obtained.

16.5 LUMINESCENCE MEASUREMENTS

Equipment Used

Luminescence measurements were carried out using the RisØ TL/OSL reader (model TL/OSL-DA-20) in the School of Chemistry and Physics, University of Adelaide. Radiation was applied using a $^{90}Sr/^{90}Y$ β source, luminescence was stimulated using either blue light-emitting diodes of wavelength 470nm or a green laser of wavelength 532nm, as explained in the following section, and detected using an EMI 9235QB photomultiplier and 7mm thick Hoya U340 filter.

Measurement Protocol

In the following sections the term 'equivalent dose' (D_e) refers to the applied laboratory radiation dose which produces the same amount of luminescence as the natural sample. It is therefore numerically equal to the total radiation dose which the material has received since burial (the burial dose).

The initial analysis of the DC samples had indicated that the material had exceptionally high intrinsic luminescence. From this point of view it would be ideal for single grain analysis, but unfortunately grains large enough (200µm) for conventional single-grain measurements were not available. Instead it was decided to carry out a measurement protocol using 90 to 125µm grains on a single-grain disc designed to hold an array of 100 grains of 200µm diameter. Using the smaller grains means that three to six grains occupied each single-grain position, effectively acting as extremely small aliquots. These will be referred to henceforth as 'grain clusters'. This method allowed a large number of measurements (100) to be made relatively quickly, as well as enabling D_e differences to be detected. This measurement protocol was used in running all samples of the HD series, and in re-running the samples of the DC series. In addition, a conventional protocol using very small aliquots was carried out on samples HD10/2 and HD10/4. Aliquots 1mm in diameter were prepared using grains in the 125 to 180µm range (thus 40-60 grains per aliquot). 24 aliquots were run for each of these two samples.

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All runs, for both sets of samples, used the single aliquot regeneration (SAR) protocol of Murray and Wintle (2000). Six regeneration dose points were used in the grain cluster runs and five in the small aliquot runs. All included a zero dose point to test for recuperation, and two repeats of the first dose: one to test for recycling and the second, preceded by a shine using infra-red light, to test for the absence of feldspars.

The D_e of each aliquot and grain cluster was determined using the 'Analyst' programme, version 3.24, written by G.A.T. Duller, Aberystwyth University, UK. Over 90% of the aliquots and grain clusters produced acceptable dose response curves (i.e., showing less than 10% recuperation and 90% or higher

recycling ratios in response to both re-applications of the first dose), and hence acceptable D_es.

16.6 ANALYSIS OF THE RESULTS

Interpretation of the Environmental Dose Rates

It is clear from Table 16-1 that there are some significant discrepancies in the dose rates obtained by the different methods. This is largely, or even entirely, due to the inhomogeneous nature of the cave fill, which is particularly pronounced near the contact with bedrock where large blocks of ironstone, which provide very little dose, constitute a large proportion of the deposit. The measured dose of the bedrock (see Section 16.3), which forms the roof, floor and walls of the shelter, was 0.34 Gy/ka, only a third of that of the creek bank sediment and only about a fifth that of the fine-grained cave fill (see Table 16-1). Sample HD10/1 which was taken very close to a large, un-moveable block of ironstone, and HD10/4 which was taken between this block and the floor of the excavation (see Figure 16-1) would be especially susceptible to this inhomogeneity.

In the case of the DC series there are significant discrepancies between the dose rates obtained by alpha counting and by XRS, and those obtained by ICPMS/ICPAES. These are thought to be due to the smaller and hence less representative sample of bulk material used in these analyses, and the possibility that large, hard to grind rock fragments were not included in the grinding process. This is not altogether a satisfactory explanation of the discrepancy, but is partly justified on the basis that the ICPMS/ICPAES dose rate is lower in each case, which could certainly be due a larger proportion of ironstone being included in those analyses. For consistency, and in the absence of in situ measurements which would have been more satisfactory, the ICPMS/ICPAES dose rates were used in the age calculations for these samples.

Considering the inhomogeneity of the material, discrepancies between the measured dose rates are not unexpected. Since it was difficult to ensure that representative proportions of rock fragments and cave sediment were included in the laboratory analysis, it was considered preferable to use the *in situ* gamma spectrometer measurements in the age calculation. Clearly, this could only be done in the case of the HD samples.

Dose rates were determined using the AGE99 programme of R. Grün (see Grün 2009).

Interpretation of the Optical Dating Measurements

Interpretation of the optical dating measurements was challenging, since all the samples showed a considerable spread of D_es, justifying the concerns expressed above. The challenge was to select, for each sample, the group of D_es most representative of material that had been fully bleached before, and remained undisturbed since, deposition.

In selecting these D_es two guidelines were used. Firstly, in a scattered distribution, grains showing smaller D_es are those most likely to have been fully bleached at deposition (on the basis that they carry no remnant dose left over from a previous burial). Secondly, grains having very low D_es which are clearly inconsistent with the main distribution may have been incorporated from an overlying layer by processes such as bioturbation or trampling, or may have anomalous luminescence properties. Although these considerations will to some extent be blurred when the D_es of a number of grains, such as in a grain cluster or even moreso in a small aliquot, are averaged, the general principles were considered as being valid.

For each sample the measured D_es were plotted as radial plots, in which the curved y axis shows D_e values and the x axis the precision of each D_e measurement (Figure 16-2). The D_e value of an individual point is found by drawing a radius through the point from the origin and finding where it intersects the y axis. Points falling between the two parallel 'standardised estimate' lines are within a 95% confidence limit of the 'correct' value. For comparison, radial plots are also shown for the DC series samples.

The D_es to be used in the age calculation were selected as follows: (i) low value outliers were excluded (ii) the weighted average of the remaining values was calculated, starting with the lowest, until the standard deviation x 2 of the group just included the lowest value (excluding low value outliers). This procedure is best illustrated by observing the radial plots. The points used in calculating the D_e to be used fall within, or very close to within, the shaded area between the two parallel lines on the radial plots.

Interpretation of the data for HD10/4 was particularly difficult. This sample shows a large group of higher value D_es, but also a number of smaller ones which are regarded as too numerous and of too high precision to be outliers. This is particularly apparent on the radial plot (Figure 16-2). This sample thus appears to contain two populations of grains – an older (higher D_e) population and a small but significant younger (lower D_e) one. The D_es of both populations are shown on Figure 16-2, the higher value in italics.

Figure 16-2 also shows the results of the very small aliquot measurements for HD10/2 and HD10/4, and the small aliquot measurements for the DC series. It is reassuring that these measurements fall within the same scatter as the grain clusters. However, their D_e values are generally somewhat higher, particularly in the case of HD10/4. This is to be expected as they are averaging a larger number of grains which would include a greater proportion of incompletely bleached ones. For this reason, as well as the larger number of measurements obtained, the grain cluster data were used for the age calculations.

Ages were calculated by dividing the D_es by the corresponding environmental dose rates. In the case of HD10/4 the age based on the younger set of D_es is taken as the most probable age on the basis, as explained above, that they are most likely to represent grains that have completely bleached prior to burial. With somewhat more certainty they can be considered to give the youngest possible age for the deposition of this horizon.

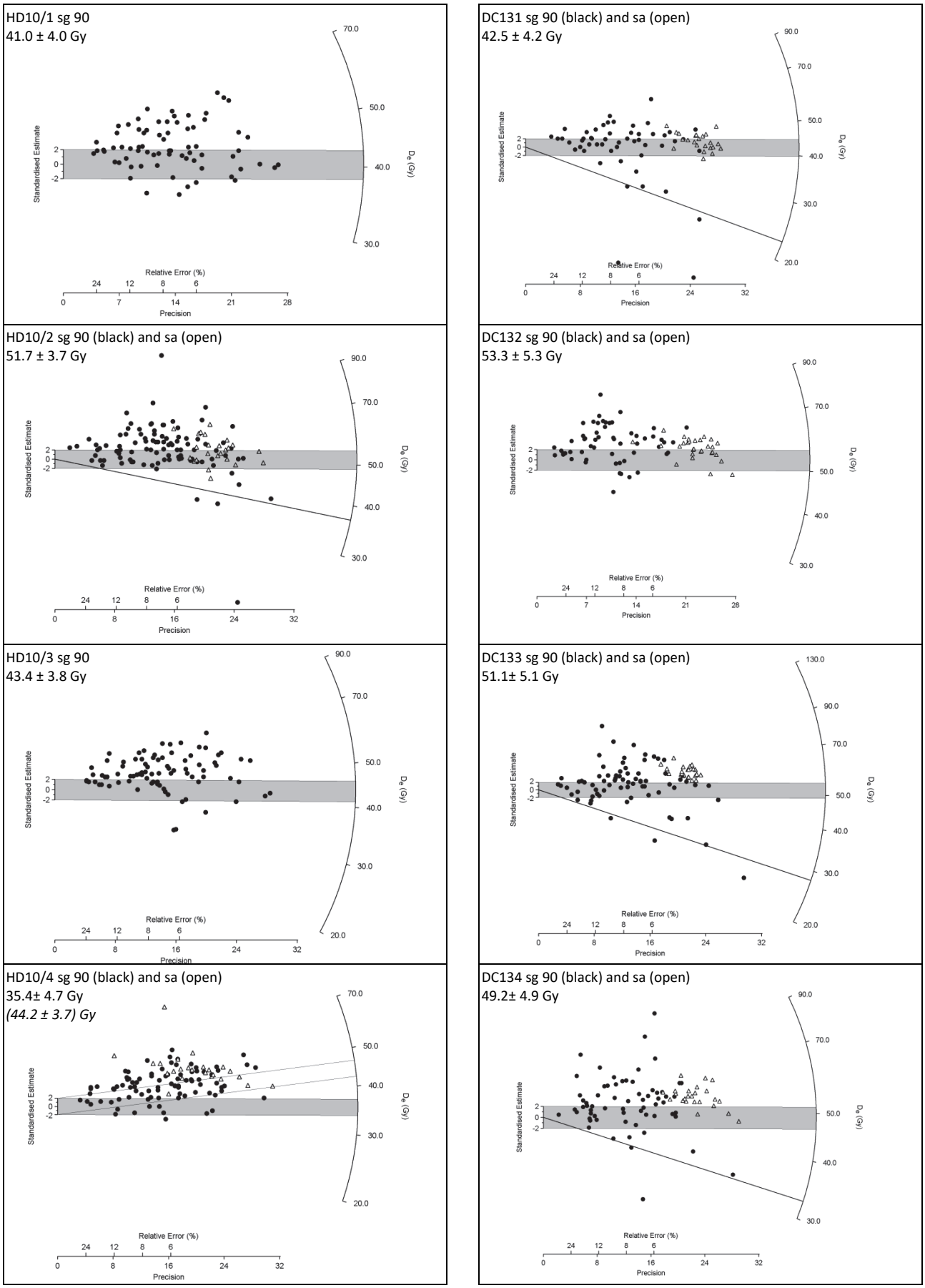

Figure 16-2 Radial plots for HD and DC samples showing D_e values selected for age determination. Note: sg 90 refers to clusters of 3-6 grains, in the 90-125µm size fraction, as described in the text, and sa refers to 1mm diameter small aliquots, consisting of 40-60 grains (for the HD series) or 100-200 grains (for the DC series) in the 90-125µm size fraction

Table 16-2 Equivalent doses and ages for HD07-3A-PAD13 rockshelter

Sample Designation	Lab No	Depth Below Datum (m)	Dose Rate (Gy/Ka)	Err	D_e (Gy)	Err	Age	Err
HD10/3	Ad10011	1.57	1.57	0.03	43.4	3.8	27.6	2.5
HD10/2	Ad10012	1.68	1.52	0.03	51.7	3.73	33.9	2.5
HD10/1	Ad10013	1.77	0.87	0.02	41.0	4	47.1	4.8
HD10/4	Ad10014	1.94	0.56	0.02	35.4 **44.2*	4.7 *3.7*	63.1 **78.9*	8.4 *7.0*
DC131	Ad09004	0.93	1.37	0.04	42.5	4.3	31.0	3.1
DC132	Ad09005	1.19	1.84	0.06	53.3	5.3	29.0	2.9
DC133	Ad09006	1.48	1.42	0.04	51.1	5.1	36.0	3.6
DC134	Ad09007	1.49	1.46	0.05	49.2	4.9	33.7	3.4
*refers to an older group of grains in this sample as explained in the text								

16.7 SUMMARY

The calculated ages for the HD series, and recalculated ages for the DC series are summarised below, and are also given in Table 16-2. It should be noted that the ages for the DC series are not based on *in situ* dose measurements.

HD10/3: (Ad10011) 27.6 ± 2.5 ka
HD10/2: (Ad10012) 33.9 ± 2.5 ka
HD10/1: (Ad10013) 47.1 ± 4.8 ka
HD10/4: (Ad10014) 63.1 ± 8.4 ka*

DC131: (Ad09004) 31.0 ± 3.1 ka
DC132: (Ad09005) 29.0 ± 2.9 ka
DC133: (Ad09006) 36.0 ± 3.6 ka
DC134: (Ad09007) 33.7 ± 3.4 ka

***A substantial number of older grains (78.9 ± 7.0 ka) was also present in this sample**

Note that some of the samples, most obviously DC131, DC133, DC134 and HD10/2 contain a small but significant number of low D_e grains as indicated by the single lines on Figure 16-2. The reason for their presence is not certain; they could represent younger grains carried from overlying layers as a result of bioturbation or trampling (see M. Williams, this volume); some of them at least could represent grains which have inconsistent luminescence properties.

There are a number of uncertainties which are not fully reflected in the error terms quoted above:

(i) Dose rate discrepancies due largely to inhomogeneity of the material in the lower part of the excavation. These are indicated in Table 16-1

(ii) Uncertainty due to the broad range of D_es obtained and the selection process for those to be used in the age calculation.

(iii) Possible mixing of grains due to the sampling procedure. OSL samples would normally be collected by inserting a narrow tube into the sediment, as was done in the case of the DC samples. As explained above, the HD samples were collected by hand on account of the amount of rocky material present. Although this was undertaken as carefully as possible, it almost certainly resulted in inclusion of some material falling from above, and in a more extensive sampling volume than would normally be the case. This would have contributed to the broad range of D_es.

Although these uncertainties should be borne in mind, confidence may be placed in the overall result when the ages are examined as a group, emphasising the importance of collecting a series of samples from a particular locality. In Figure 16-3 the ages of both series of samples are plotted as a function of depth below datum and, within the error limits, show a consistent pattern of increasing age with depth. This is discussed further in the HD07-3A-PAD13 geomorphological report by M. Williams (this volume).

It is never possible to know for certain, in any OSL age determination, that grains have been fully bleached prior to deposition. In a case like the one under discussion, where there is a large scatter of D_es, it is possible that no grains at all have been fully bleached, and that any age determined will therefore be too old. In this case this is considered unlikely since, if the material had not undergone considerable exposure to sunlight, a large proportion of the grains, would be expected to show evidence of a very high residual dose and to be over saturated. This was not observed.

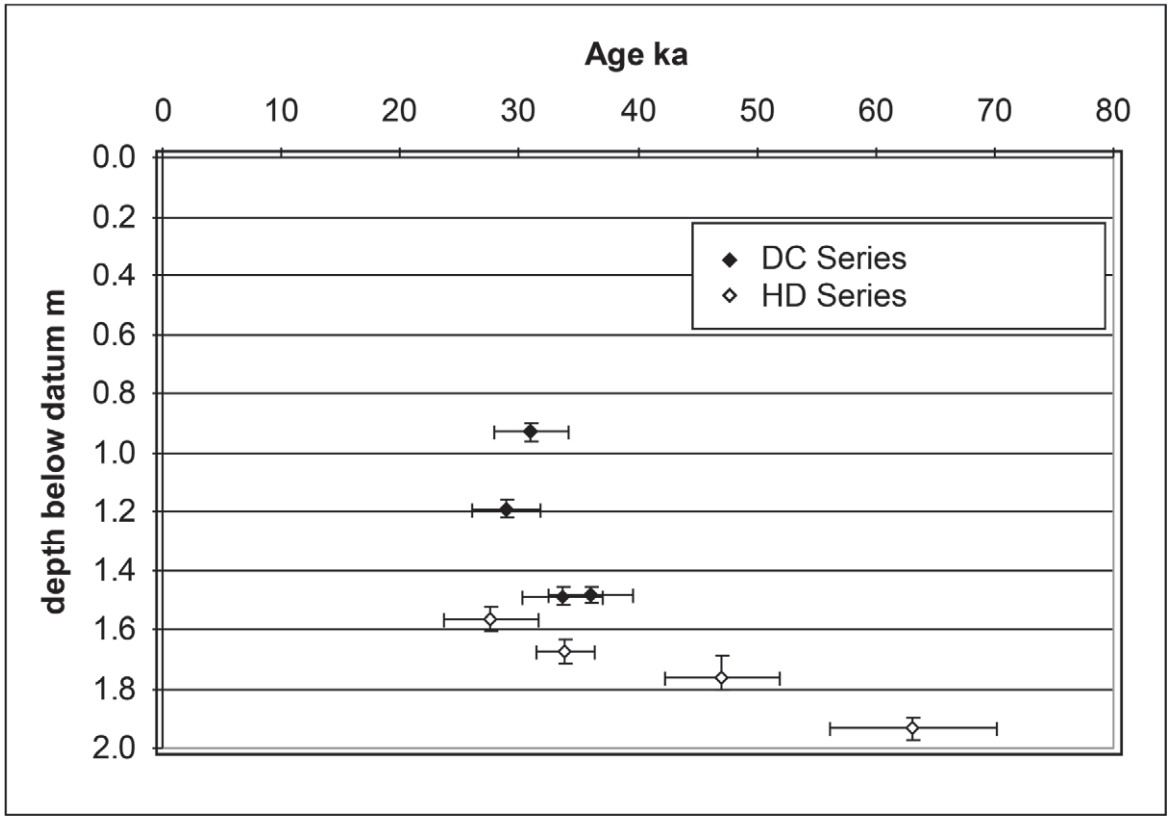

Figure 16-3 Age vs depth variation for HD07-3A-PAD13

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Chapter 17

Report on the Geomorphology and Quaternary Geology of HD07-3A-PAD13 Rockshelter, Pilbara, Western Australia

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17.1 INTRODUCTION

This report complements the *Report on Optically Stimulated Luminescence (OSL) Dating of a Further Four Samples from HD07-3A-PAD13 Rockshelter* by Frances Williams (this volume). The aims of this report are to describe the geomorphology and Quaternary geology of the rockshelter site and its immediate environs, and to provide a brief account of the probable depositional history of the sediments within the rockshelter.

After an initial inspection of the site in the afternoon of Sunday 5 September, 2010, the next two days were spent working at the site in order to collect samples for optical dating, measure the environmental dose rate at six specific locations, examine the geomorphology and Quaternary geology of the area around the site, and conduct a brief reconnaissance of other rockshelters within the vicinity accompanied by the Traditional Owners. During this time we received site visits from Martin Candy, Senior Mine Geologist, who subsequently provided the writer with a useful summary of the regolith evolution of the Hamersley Province prepared by Mark Paine, and from the Mine Heritage Officer and the Mine Environmental Impact Officer, with whom we discussed our work.

17.2 GEOMORPHIC AND CLIMATIC HISTORY OF THE REGION

The Hamersley geological province has been continuously exposed to weathering and erosion for the past hundred million years at least. During this time there have been four major episodes of deep weathering accompanied by iron mobilisation and precipitation, each associated with a relatively prolonged interval of tectonic stability, denudation and the formation of a regionally extensive erosion surface. These episodes of weathering were of continental extent and have been dated to Early Eocene, late Middle Eocene, Middle Miocene and Early Pliocene, all of which were times of warmer and wetter climate. The progressive northward movement of Australia during the past 45 million years at a mean rate of five centimetres per year has conveyed the Pilbara region from high southern latitudes during the Eocene into its present tropical latitudinal zone characterised by dry subsiding air and enhanced aridity (Williams 2009). The geodetic coordinates of the shelter are 22°59′04.1′′S, 119°04′39.7′′E, placing it climatically in the semi-arid summer rainfall zone of northwest Australia.

Australia became progressively drier from the mid-Miocene on, evident in the disappearance of the rainforests from what is now the arid zone (Martin 2006; Byrne *et al.* 2008). The onset of extreme aridity in central Australia dates to ~3 Ma, and was associated with the build-up of major ice caps over North America and Europe at that time (Fujioka *et al.* 2005). The earliest desert dunes identified so far in central Australia date from a million years ago (Fujioka *et al.* 2009), since when there have been about ten glacial-interglacial cycles, each roughly one hundred thousand years in duration. Each cycle consisted of a progressive 'saw-toothed' build-up to extreme glacial conditions, followed by rapid warming and a short interglacial interval of about ten to twenty thousand years in duration (Williams *et al.* 1998).

Glacial intervals in Australia were cold, dry and windy, with sea levels up to 135m lower than today and an increase in continental land area by about 20 to 25% (Williams 2000; Williams 2001). The LGM (21,000±2000 years ago, or 21±2 ka) was a time of reduced plant cover, active dunes in all the sandy deserts, (including the Little Sandy Desert situated some 100-200km east of Newman township), enhanced dust plumes across NW Australia, temperatures 8 to 12°C cooler than today, and precipitation reduced to about a third of the present rainfall in this region. The last interglacial peaked at 125,000 years ago, and although there have been brief intervals of higher rainfall since then, evident in high levels of Lake Eyre at about 95 to 80 ka, 65 to 62 ka and 45 to 40 ka (Magee *et al.* 1995; Magee and Miller 1998; Magee 1998; Magee *et al.* 2004) these wet events may not have extended as far as the Pilbara. In fact, there is almost no late Quaternary climatic information available for the Pilbara region and its environs. The only pollen data available for the semi-arid northwest of Australia comes from marine core Fr10/95-GC17 taken about 60km west of the Cape Range Peninsula, and located at 22° 2.74′S, 113° 30.11′E (van der Kaars and De Deckker 2002). The interval spanning from 33 to 20.4 ka reflects the onset of full glacial conditions and was the driest interval of the last 100,000 years, with virtually no summer rain (van der Kaars and De Deckker 2002; Williams *et al.* 2009). High lake levels in Lake Gregory and enhanced flow in the Fitzroy River indicate a return of the summer monsoon in NW Australia by about 14 ka (Wyrwoll and Miller 2001). We may conclude from these somewhat fragmentary data that for most of the occupational history of the rockshelter, (as determined from the OSL ages), the surrounding region was more arid than today.

17.3 GEOMORPHIC CONTEXT OF THE SITE

The rockshelter is located in a narrow valley bounded on either side by steep hills of massive banded ironstones that have been partially weathered to ferruginous laterite prior to the current phase of vertical incision that probably began in the late Pliocene, following the early Pliocene phase of weathering and iron precipitation. Immediately adjacent to the mouth of the shelter is an ephemeral second-order stream channel, the bed of which is about 2m lower than the surface entrance to the shelter, and is presently armoured with fine ironstone gravel. On the opposite side of the channel (*i.e.*, on the left bank) is an alluvial bench up to 20m wide, the surface of which is covered with a very compact and very stable ironstone lag gravel, forming a

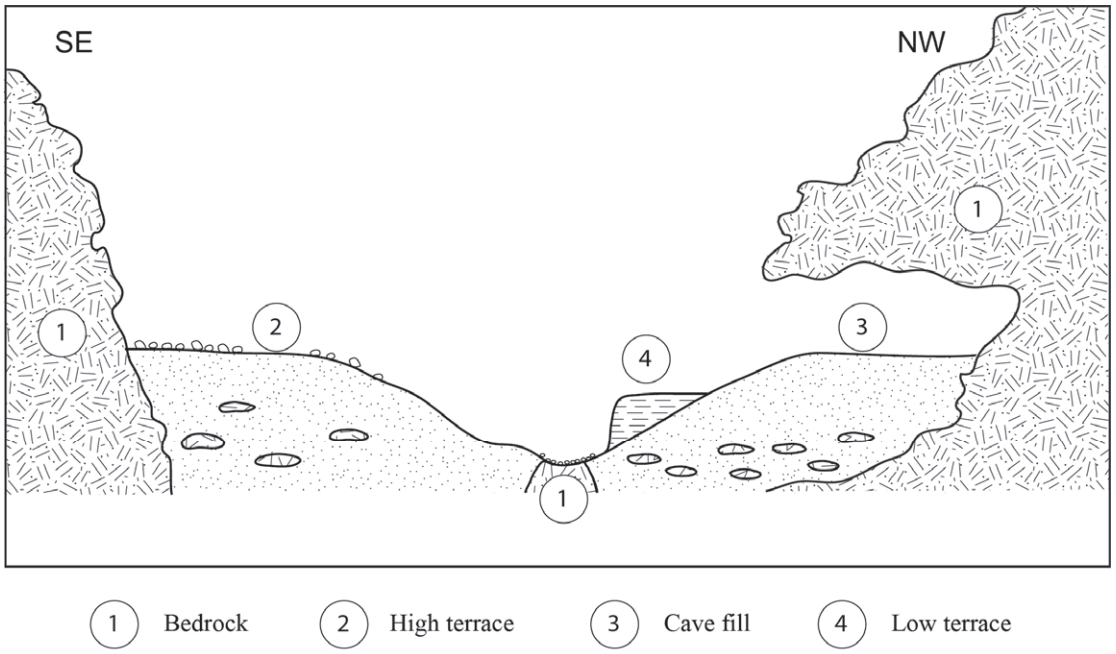

Figure 17-1 Schematic cross section from the rockshelter across the ephemeral stream channel showing the high and low alluvial terraces and the accordance between the surface elevation of the high terrace and that of the rockshelter fill

well-developed desert pavement[1]. The surface elevation of this bench is accordant with that of the uppermost surface of the sediment fill within the rockshelter (**Figure 17-1**). The bench (or terrace) represents the former flood plain of the ephemeral stream, and has been stable for at least several centuries, since trees of that age are presently growing upon it. The age estimate for the trees was based on discussion with the Traditional Owners. We do not know how long it took the stone pavement to form, but it may have been centuries rather than decades. Banked up against the terrace on the right bank is a low alluvial bench about 40cm high composed of very fine sand and covered with low shrubs two to three years in age. For the purposes of this report we will term the 40cm sandy bench the low terrace and the stable 2m alluvial bench the high terrace. The high terrace forms a discontinuous surface on either side of the channel and abuts directly against the ironstone bedrock.

A key question raised by the archaeologists was whether the rockshelter deposits are wind-blown, fluvial or fluvio-eolian. The closest source of dune sand is the Little Sandy Desert some 150 to 200km to the east, so it is unlikely that dune sand was a direct source. However, during times when the prevailing easterly winds were stronger and gustier than today, particularly during colder drier intervals in the past 100 ka, when the dune fields and alluvial outwash areas east of the shelter were far more sparsely vegetated, considerable volumes of wind-blown dust were blown from the arid centre in a NW direction out to sea. Wind-blown dust is as a rule very well sorted, with the grains rounded to sub-rounded, and a high proportion of quartz particles. More locally derived dust can be bimodal in terms of particle size but generally better sorted than fine alluvial sediments. The rockshelter would have been in the pathway of this very wide dust plume. Dust scavenged from the atmosphere during sporadic rains would be deposited downwind of source, and so available for re-working by local streams. The particle size of dust is usually in the silt to clay fraction, that is, generally finer than about 15 to 20µm, but within the longitudinal axis of the dust plume particles as coarse as very fine sandy silt (20-60µm) can be transported for several hundreds of kilometres downwind before deposition from suspension. Fine sand is more likely to have been transported by saltation near the base of the dust plume (Pye 1987: Chapter 6). It is therefore quite possible that the ephemeral streams were carrying a mixed load of both locally derived ironstone sand and gravel and very fine sand of fluvio-eolian origin that had undergone multiple cycles of reworking. (The 'brightness' of the quartz samples dated by OSL is also indicative of multiple phases of transport and 'bleaching'). Some support for this hypothesis was provided on the first afternoon during a short visit to a nearby rockshelter, in the uppermost outlet of which were remains of a debris flow. This deposit consisted of poorly sorted ironstone clasts in a finer-grained matrix of silty fine sand. However, it is unlikely that the bulk of the rockshelter-fill came from the dune fields to the east for one simple reason: there is very little quartz in the rockshelter deposit.

The low terrace mentioned earlier consisted of very fine sand and was predominantly made up of ironstone particles with minimal amounts of quartz. This material is very similar to the fine fraction in the rockshelter fill. The ephemeral stream channel once flowed at a higher level, as witnessed by the high terrace. Before it incised down to its present base level, controlled by local outcrops of ironstone now exposed in the channel floor, the stream would have regularly deposited fine sediment in the rockshelter during seasonal floods[2]. As it cut down, only extreme flood events would have kept up the supply of sediment to the rockshelter. As it reached present level, the stream would cease to supply sediment to the rockshelter,

[1] Desert pavements or stone pavements are 'armoured surfaces composed of angular or rounded fragments, usually one or two stones thick, set on or in matrices of finer material comprising varying mixtures of sand, silt or clay' (Cooke *et al.* 1993: 68). They can form in several different ways or by a combination of processes. Winnowing of finer particles from the surface by wind or running water can lead to the formation of a protective layer of surface stones sometimes called a lag gravel. A more common process is upward displacement of stones as a result of expansion and contraction of the soil, usually caused by wetting and drying, a process that gradually moves the larger particles to the surface.

[2] A possible analogue from the lower Blue Mountains of eastern Australia is provided by the Shaws Creek KII sandstone rock shelter excavated by Kohen, Stockton and the writer(Kohen *et al.* 1984; Kohen *et al.* 1981). Periodic flooding from the adjacent Nepean-Hawkesbury River deposited fine alluvial silts and clays across the floor of the shelter. These deposits were preserved from trampling and erosion by sporadic rock falls from the roof, some up to a metre across and 10 to 30cm thick.

leaving the rockshelter fill free to be reworked by ants and, perhaps, by termites[3].

17.4 ROCKSHELTER DEPOSITIONAL PROCESSES

Sediment within rockshelters falls into two broad categories: allochthonous and autochthonous, or external and internal sources. The fill within this shelter had roughly equal proportions from both sources, but the proportion of rock fragments increased considerably towards the base. About half of the fill by volume consisted of poorly sorted platy ironstone rock fragments derived by spalling from the roof and walls of the rockshelter. Occupying the interstices between the rock fragments was a remarkably homogeneous silt loam comprising ~10 to 15% clay, ~70% silt and ~15% very fine sand. The individual grains of very fine sand ranged from sub-rounded to sub-angular, and were mixed with abundant dark minerals and ironstone of similar particle size. The lithology, mineralogy and grain size is consistent with deposition under low-energy stream flow as a type of slack-water deposit. Any original stratification had long since been obliterated through the homogenising activities of ants[4] in a process termed bioturbation, the evidence for which was especially noticeable in the upper 50cm of the deposit.

Trampling by human feet inside a rockshelter can cause a more subtle form of disturbance, with small objects tending to move upwards and large objects downwards (Stockton 1973). The writer witnessed the experiment performed by Stockton in a small sandstone rockshelter in the lower Blue Mountains of eastern Australia, and noted that the sedimentary fill within the shelter was a very fine loamy sand, very comparable in its grain size (but not in its lithology – it was primarily composed of fine quartz grains). Butzer (1982: 108-109) in citing this work observed that wetting of clayey soils can facilitate the trampling process, but it is not clear what percentage of clay is needed to enhance this process.

17.5 SEDIMENT SOURCES AND VARIABLE ENVIRONMENTAL DOSE RATES

The accompanying report on the OSL dating (F. Williams, this volume) points out that the dose rates measured by scintillometer within the rockshelter sediment fill decreased quite sharply when in close proximity to the bedrock. In order to explore this in more detail we performed a small field experiment outside the shelter. We first excavated a hole into the surface of the low terrace using a 10cm diameter Jarrett soil auger, and measured the dose rate at 30cm depth. The rationale for this was that the low terrace consisted of very fine sand comparable in size to the finer fraction in the rockshelter fill, which we concluded was primarily alluvial in origin. The result showed a high dose rate (0.498 Gy/ka), but lower than that of the rockshelter fill silt, the details of which are in the OSL dating report. We next inserted the scintillometer into a narrow crevice in the ironstone bedrock just across from the low terrace on the left bank of the creek bed, and obtained a dose rate that was likewise extremely low (0.149 Gy/ka), as in the shelter close to bedrock. Three lessons emerge from this. First, one cannot assume that the dose rate within a rockshelter deposit will be constant throughout. Second, it is always useful to obtain dose rate measurements in a range of geomorphic settings outside the shelter as well as within. Full details of the range of variation are given in the OSL dating report. Third and most fundamental, any collection of samples for OSL dating should, wherever possible, be accompanied by *in situ* dose measurements at each sampling spot.

17.6 GEOMORPHIC INTERPRETATION OF THE OPTICAL DATING AGES

Figure 16-3 of the OSL dating report shows the distribution of ages with respect to depth. It should be noted that the two series of ages: DC (blue) and HD (red) are not entirely comparable as both dose rates and luminescence were measured using different methods as explained in the OSL report. However, even taking this into account, it is evident that the upper two ages are very similar, while the six lower ones show a linear increase with depth.

The upper two samples show a rapid rate of rockshelter fill accretion in the depth interval ~120 to ~95cm below datum (cmbd). Several explanations are possible. First, the surface of the rockshelter fill was very irregular, which is possible but unlikely. Second, rapid accumulation occurred during this time interval, either from roof fall and/or from flood events. Third, rockshelter-fill disturbance was most acute at this time. If so, we might expect a higher concentration of stone artefacts at this time. We saw in Section 17-3 above that in northwest Australia the driest interval of the past hundred thousand years was from 33 ka to ~20 ka, at which time there was almost no summer rainfall (van der Kaars and De Deckker 2002). Assuming that the marine core dates are correct, and there is no reason to suspect otherwise, it is unusual to find such high rates of sedimentation during such an arid time unless the aridity was punctuated by occasional extreme events, as occurred during the LGM in the arid Flinders Ranges of South Australia (Haberlah *et al.* 2010a; Haberlah *et al.* 2010b).

The samples located between a depth of ~170 and ~195cmbd show a very slow rate of sediment accretion from 63 ka to 34 ka. It would be unusual to expect a negligible rate of rockshelter fill accretion for this long interval of time, roughly thirty thousand years, unless this was an exceptionally arid interval with little or no flooding into the rockshelter and only rare occupation of the rockshelter. It is possible that the 33 to 20 ka arid interval discussed above may have begun sooner in the Pilbara region than further to the north, but this remains speculative.

The lowest sample dated lies at a depth of ~194cm has two possible ages (63.1±8.4 ka or 78.9±7.0 ka). The reasons for selecting the younger date as a more likely approximation to the true age than the older are set out in the OSL dating report and need not be repeated here. However, it does seem likely that we are dealing with two different populations of quartz grains, one older and imperfectly bleached, the other younger and more fully bleached.

The inference we may draw from the OSL ages obtained is that accumulation of sediment within the rockshelter was at first very slow, and remained slow until ~ 34 ka, when a pulse of rapid sedimentation is evident from ~34 ka to 31 ka, which was also a time of widespread regional aridity. It seems highly likely that sporadic extreme rainfall events occurred during this otherwise arid interval, leading to flash floods and deposition of slack water sediments within the rockshelter, accompanied by roof fall of coarser debris.

[3] Under a mean annual rainfall of ~1200 mm in the seasonally wet tropics of northern Australia, termites are capable of bringing 0.48 m^3 of soil per hectare to the surface each year (Williams 1978; Williams 1968). Termites are only likely to have had a significant role in sediment disturbance at this site during extreme wet intervals and only if there was vegetation growing inside the shelter, for which there is no evidence.

[4] Rates of soil movement by ants in Australia are highly variable, and range from as little as 0.003 t/ha/yr to as much as 68 t/ha/yr (Paton *et al.* 1995: Table 3.3).

17.7 SUMMARY AND CONCLUSIONS

- The sedimentary fill within the rockshelter is in part derived from spalling processes within the rockshelter and in part from episodic flooding from the local ephemeral stream channel. The finer fraction within the rockshelter textures out as a silt loam, and consists of roughly equal proportions of clay and very fine sand (~10% each), with most (~70%) of the sediment in the silt size range.
- There is evidence of disturbance within the fill resulting from ant activity and, to an unknown degree, human trampling. In both cases coarser particles, including stone artefacts, will tend to sink downwards and finer fragments will preferentially concentrate upwards.
- The prevailing regional climate during the time humans visited the rockshelter was considerably more arid than nowadays, but was probably punctuated by occasional rare downpours giving rise to sporadic flash floods. It seems likely that the rockshelter was only used intermittently as an overnight staging post during travel from one source of permanent or at least seasonally reliable water to another. This provisional conclusion must await verification or refutation from the archaeological data.
- The rockshelter was occupied at least occasionally from about 47 to 40 ka onwards, until at least 34 to 27 ka.
- Occupation of the rockshelter coincided at least in part with the 33 to 20 ka interval of most arid climate for the past 100,000 years. Humans were therefore able successfully to withstand extreme aridity, and no doubt developed a variety of ingenious adaptive strategies to cope with these environmental and climatic extremes.

17.8 RECOMMENDATIONS FOR FUTURE EVALUATION OF ROCKSHELTERS IN THIS REGION

Arising from our experience of working in this and other late Pleistocene prehistoric rockshelter sites in Australia, India and Africa, we offer the following recommendations.

Coupling of OSL sample collection with dosimetry measurements

Given that it is unwise to assume that the dose rate within a rockshelter deposit will be uniform, we recommend that collection of samples for OSL dating should, wherever possible, be accompanied by *in situ* dose measurements at each sampling spot.

Additional dosimetry measurements of targeted sites outside the rockshelter

Since the sediments within a shelter are made up in part of materials derived from outside the rockshelter, we recommend that it is advisable to obtain dose rate measurements in a range of geomorphic settings outside the shelter as well as within.

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Chapter 18

Summary and Discussion of Rockshelter Investigations at Hope Downs 1

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Six exceptional rockshelters in the east Hamersley Range of Western Australia were excavated as part of a larger mitigative salvage project at the Hope Downs 1 mine. With the ever-increasing development of iron ore mines in the Pilbara, there is little doubt that more rockshelters like Jundaru (HN-A9), Djadjiling (HD07-1A-04), HS-A1, HD07-3A-PAD13, PAD 3, and HD07-3A-03 will be encountered in the near future. These rockshelters improve our overall understanding and depiction of the east Pilbara archaeological record, and for the sake of respecting and preserving the long record of Aboriginal occupation at these places, it is important that significant findings of the Hope Downs 1 rockshelter investigations be made available to other Traditional Owners, researchers, consultants, and land managers.

While the excavations at Hope Downs 1 program were conducted in order to fulfil the legal obligations for the development of the mine, we endeavoured to learn as much from these sites as possible. Primary research areas investigated include: (1) the antiquity and intensity of Aboriginal occupation in the project area; (2) identifying changes in past environmental conditions and how they relate to settlement patterns; (3) patterns of stone artefact manufacture; and (4) the temporal occurrence of prominent artefact types.

18.1 THE ANTIQUITY AND INTENSITY OF ABORIGINAL OCCUPATION

One of the primary goals of the Hope Downs 1 Mitigative Salvage Program was to recover evidence regarding the antiquity and intensity of Aboriginal occupation in the east Hamersley Range. The data from the six rockshelters detailed in this monograph provides greater resolution of past Aboriginal occupation patterns. This data, combined with evidence from the other rockshelters investigated at Hope Downs 1, also makes it possible to evaluate existing demographic models. The results provide unequivocal evidence of early Aboriginal occupation within the inland Pilbara, extending to at least 45,000 years ago. The excavations at Hope Downs 1 also reveal important changes in the intensity of occupation over time. The occupational sequences in these sites suggest a minor decline in site use over peak LGM conditions and an increased occupational intensity during the middle and late Holocene.

Timing of the Initial Occupation

Prior to the 2007 excavations at Hope Downs 1, archaeological research suggested that the inland Pilbara was first occupied between 28,000 and 31,000 cal BP based on the data from Newman Rockshelter (30,897±372 cal BP, SUA-1510; Brown 1987) and Mesa J24 Rockshelter (28,317±415 cal BP, Wk-2514; Hughes *et al.* 2011). Our first indication of a much earlier date for the occupation of this region came from Djadjiling, which pushed back the initial occupation date by at least 10,000 years, with evidence of occupation from approximately 41,000 years ago (Law *et al.* 2010; Law and Cropper 2012; Law *et al.* 2008). Further confirmation of this early occupation was gained from the excavations at Jundaru (HN-A9), HD07-3A-PAD13, HS-A1, and Hope 1-41 rockshelters (Cropper 2013b).

The earliest Pleistocene occupations at Hope Downs 1 were identified at HS-A1, HD07-3A-PAD13, and Djadjiling, with Jundaru and Hope 1-41 (see Cropper 2013b) having been occupied slightly later. A series of radiocarbon dates and OSL dates from these sites firmly establish that Aboriginal people occupied the region prior to 41,000 years ago (Table 18-1), or as the OSL dates suggest, 47,000 years ago (Table 18-2). Together, we are comfortable interpreting these various radiometric results and artefact associations to conclude that early Aboriginal people were active in the east Hamersley Plateau by 45,000 years ago.

Excavations have demonstrated that HS-A1 was occupied by at least 40,248±936 to 40,670±939 cal BP. The timing of the initial occupation of HS-A1 correlates well with Djadjiling, which has an initial occupation dating to approximately 40,911±580 cal BP. The age estimates for HD07-3A-PAD13 suggest this particular site may have been occupied slightly earlier. Unlike the other Pleistocene sites, the chronology of the early archaeological sequence at HD07-3A-PAD13 was established using OSL dating. The lowermost sample yielded a result of 63.1±8.4 ka (AdBL10014), and this sample is interpreted to be anomalous due to its early age. A date of 47.1±4.8 ka (AdBL10013) was determined for a sediment sample collected between 172.5 and 181.5cmbd (midpoint of 177cmbd), and this age provides a better estimate for the initial occupation of the site. Artefacts were recovered from below this OSL sample up to a maximum depth of 220cmbd; however, it is likely there was rapid fluvial deposition during this period due to the wetter climatic conditions.

Jundaru may not have been occupied as early as Djadjiling, HS-A1, or HD07-3A-PAD13, but it is a significant site due to its large Pleistocene artefact assemblage. Jundaru has considerably higher Pleistocene artefact densities than any of the other Pleistocene sites investigated at Hope Downs 1 or currently reported elsewhere in the greater inland Pilbara. Based on the radiocarbon dates from the Jundaru excavations, the initial occupation at Jundaru was found to date to at least 35,978±653 cal BP. A small number of artefacts were identified below the dated charcoal sample, suggesting that the site may have been visited even earlier.

Table 18-1 Radiocarbon dates for excavated rockshelters at Hope Downs 1 (adapted from Cropper and Law 2012a; Law and Cropper 2011; Cropper 2013a)

Site	Lab Code	Material	Context	Depth (cmbd)	Approximate Depth (cmbs)	$\delta^{13}C$	^{14}C Age (years BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
HD07-3A-03	Wk-26733	Charcoal	U1-L01-QA	23.5	2	-23.3±0.2	165±30	289 to -3	177±86
HD07-3A-03	Wk-26734	Charcoal	U2-L05-QC	46.5	18	-22.9±0.2	601±30	665 to 542	603±32
HD07-3A-03	Wk-32635	Charcoal	U1-L08-QA	61.5	40	-25.2±0.2	3023±25	3337 to 3159	3241±52
HD07-3A-03	Wk-26735	Charcoal	U1-L11-QA	76.5	55	-24.7±0.2	4994±30	5887 to 5645	5716±64
HD07-3A-PAD13	Wk-26727	Charcoal	U1-L01-QC	28	3.5	-23.7±0.2	840±30	893 to 686	747±39
HD07-3A-PAD13	Wk-26728	Charcoal	U1-L03-QC	38	13.5	-24.0±0.2	235±30	422 to -4	280±101
HD07-3A-PAD13	Wk-26729	Charcoal	U1-L05-QC	47	22.5	-23.9±0.2	1559±30	1526 to 1385	1462±41
HN-A7	Wk-26721	Wood	U3-L01-QC	32.5	1.5	-24.0±0.2	Abandoned	-	-
HN-A7	Wk-26722	Charcoal	U1-L03-QA	49.5	17	-24.1±0.2	6758±54	7688 to 7512	7615±42
HN-A7	Wk-26723	Charcoal	U2-L10-QD	82	47	-25.2±0.2	6041±35	6985 to 6791	6890±45
Jundaru	Wk-26720	Charcoal	F1	31	8	-23.5±0.2	162±30	287 to -3	176±86
Jundaru	Wk-26719	Charcoal	F10	56	33	-25.0±0.2	3594±30	3978 to 3834	3899±45
Jundaru	Wk-32636	Charcoal	F15	72	39	-24.6±0.2	6859±30	7782 to 7617	7686±34
Jundaru	Wk-26718	Charcoal	F19	88	67	-25.0±0.2	9502±38	11,071 to 10,608	10,774±135
Jundaru	Wk-26717	Charcoal	F23	101	77	-24.2±0.2	16,686±67	20,153 to 19,553	19,820±172
Jundaru	Wk-26716	Charcoal	U10-L19-QA	123	90	-24.5±0.2	15,430±58	18,822 to 18,539	18,659±74
Jundaru	Wk-32637	Charcoal	U01-L22-QA	139	107.5	-24.5±0.2	22,267±114	27,589 to 26,219	26,793±369
Jundaru	Wk-26715	Charcoal	U11-L26-QA	154	126	-21.5±0.2	28,738±404	34,517 to 32,059	33,255±651
Jundaru	Wk-26714	Charcoal	U01-L29-QC	173	139	-23.8±0.2	31,539±576	37,362 to 34,865	35,978±653
Jundaru (MHA)^	Wk-3209	-	Spit 2	-	6.3-9.9	-	290±50	492 to -1	375±85
Jundaru (MHA)^	Wk-3381	-	Spit 6	-	27.0-30.4	-	2820±80	3161 to 2764	2943±107
Jundaru (MHA)^	Wk-5748	-	Spit 11	-	55.0-60.0	-	6570±60	7578 to 7333	7477±52
Jundaru (MHA)^	Wk-3382	-	Spit 16	-	72.5-79.6	-	15,230±230	18,877 to 17,928	18,410±264
Jundaru (MHA)^	Wk-3210	-	Spit 19	-	97.3-102.1	-	20,360±320	25,075 to 23,505	24,314±404
Hope 1-16	Wk-32641	Charcoal	F1	25.5	8.5	-21.5±0.2	170±25	288 to -4	182±87
Hope 1-16	Wk-32642	Charcoal	U1-L4-QC	32	15	-22.9±0.2	158±25	285 to -3	179±85
Hope 1-39	Wk-32643	Charcoal	U1-L1.1-QD	30	9	-24.3±0.2	809±25	768 to 680	715±22
Hope 1-41	Wk-26731	Charcoal	U1-L02-QC	22	6	-24.0±0.2	582±30	651 to 533	603±34
Hope 1-41	Wk-26730	Charcoal	U1-L07-QA	47	31	-23.8±0.2	630±30	664 to 552	599±35
Hope 1-41	Wk-26910	Charcoal	U1-L12-QC	74.5	58.5	-23.1±0.2	24,420±134	29,555 to 28,641	29,275±242
Hope 1-41	Wk-26732	Charcoal	U1-L13-QC	78	62	-	Abandoned	-	-
Hope 1-46	Wk-32644	Charcoal	U1-L02-QA	32	8.5	-23.5±0.2	156±25	285 to -2	177±85
HS-A1	Wk-26740	Charcoal	F2	26	9	-23.4±0.2	2958±30	3240 to 3004	3113±58
HS-A1	Wk-32638	Charcoal	F6	34.5	11.5	-25.0±0.2	2901±25	3156 to 2956	3036±50
HS-A1	Wk-26741	Charcoal	F5	54	37	-22.3±0.2	23,378±153	28,561 to 27,841	28,200±188
HS-A1	Wk-26743	Charcoal	U3-L12-QB	88	52	-24.2±0.2	35,175±914	42,085 to 38,533	40,248±936
HS-A1	Wk-26742	Charcoal	U2-L10-QD	64	47	-23.4±0.2	35,617±958	42,328 to 38,784	40,670±939
HS-A2	Wk-26738	Charcoal	U1-L05-QD	54	24	-24.3±0.2	2678±30	2845 to 2749	2779±29
HS-A2	Wk-26739	Charcoal	U1-L08-QD	66-68	36-38	-24.9±0.2	5779±30	6656 to 6497	6583±45
HS-A2 (MHA) ^	Wk-5549	-	U2-Spit 1	-	-	-	500±50	644 to 475	530±45
HS-A2 (MHA) ^	Wk-5550	-	U2-Spit 10	-	-	-	6260±60	7309 to 7004	7187±84
PAD 1	Wk-32639	Charcoal	U1-L4-QB	56.5	11.5	-25.0±0.2	474±29	541 to 496	517±13
PAD 1	Wk-32640	Charcoal	U1-L14-QA	107	62	-21.8±0.2	593±25	651 to 540	605±31
Djadjiling*	Wk-22784	Charcoal	F2	27	14.5	-23.4±0.2	2766±32	2946 to 2784	2858±45
Djadjiling	Wk-23306	Charcoal	U6-QB-L06	43	29	-24.6±0.2	6130±38	7160 to 6912	7024±73
Djadjiling	Wk-23307	Charcoal	U6-QB-L09	58	40	-24.4±0.2	12,621±63	15,222 to 14,256	14,907±214
Djadjiling	Wk-22785	Charcoal	U1-QA-L19	83	70.5	-23.6±0.2	17,975±72	21,705 to 21,172	21,436±126
Djadjiling	Wk-23308	Charcoal	F4	83-85	75	-22.1±0.2	19,943±84	24,208 to 23,450	23,813±184
Djadjiling	Wk-23309	Charcoal	F5	88-96	80	-23.6±0.2	19,949±84	24,216 to 23,457	23,820±185
Djadjiling	Wk-23310	Charcoal	U6-QA-L16	94	77.5	-22.0±0.2	19,757±83	23,921 to 23,301	23,624±161
Djadjiling	Wk-23311	Charcoal	U5-QB-L22	117	104	-21.6±0.2	25,519±154	30,786 to 29,693	30,377±235
Djadjiling*	Wk-22786	Charcoal	U1-QD-L26	128.5	112.5	-22.1±0.2	24,522±129	29,696 to 28,615	29,380±212
Djadjiling	Wk-22787	Charcoal	U1-QA-L30	148	137	-22.0±0.2	35,159±537	41,365 to 38,955	40,267±642
Djadjiling	Wk-23312	Charcoal	F10	157	142.5	-23.3±0.2	35,396±518	41,576 to 39,189	40,546±615
Djadjiling	Wk-23313	Charcoal	U5-QB-L30	159	145	-22.8±0.2	35,753±546	41,901 to 39,548	40,911±580
Djadjiling^{R}	Wk-23314	Charcoal	U5-QB-L33	170.5	158.5	-23.2±0.2	28,461±223	33,451 to 31,932	32,815±402
Djadjiling^{R}	Wk-23315	Charcoal	U4-QA-L39	193	180.5	-23.0±0.2	33,584±410	39,442 to 37,017	38,317±604
HD07-1A-07	Wk-26725	Charcoal	U1-L03	38	16.5	-24.3±02	977±30	954 to 795	866±46
HD07-1A-07	Wk-26726	Charcoal	U1-L09	66	44.5	-23.8±02	6221±31	7249 to 7013	7117±70
HD07-1A-07	Wk-26724	Charcoal	U1-L11	80	58	-22.5±02	8887±41	10,185 to 9793	10,027±95

Site	Lab Code	Material	Context	Depth (cmbd)	Approximate Depth (cmbs)	$\delta^{13}C$	^{14}C Age (years BP)	Calibrated Age (cal BP) IntCal09 2σ	Median Calibrated Age (cal BP)
PAD 3	Wk-21659	Charcoal	F2	10	5	-24.1±0.2	2417±30	2696 to 2349	2439±98
PAD 3	Wk-26736	Charcoal	Beneath F8 & F9	17	12	-23.9±0.2	3688±30	4145 to 3926	4032±50
PAD 3	Wk-21658	Charcoal	F1	21	16	-22.8±0.2	4143±34	4825 to 4569	4686±78
PAD 3	Wk-26737	Charcoal	F5	27.5	22.5	-24.5±0.2	5621±34	6469 to 6313	6399±43
PAD 3	Wk-21660	Charcoal	F11	34	29	-25.6±0.2	6899±41	7833 to 7663	7730±46
PAD 4	Wk-21377	Charcoal	U1-L6-QD	30	26	-24.3±0.2	3352±32	3687 to 3480	3593±50

* Denotes conventional radiocarbon date; all other dates are AMS
^ Source: (Edwards *et al.* 2001); Note: the depths of the samples for HS-A2 have not been reported.
R Denotes dates that are rejected based on anomalous results

Table 18-2 HD07-3A-PAD13 OSL Results

Lab Code	Sample No*	Depth (cmbd)^	Dose Rate (Gy/Ka)	Err	D_e (Gy)	Err	Age (ka)
AdBL09004	c-006 (DC131)	93 (91.5-94.5)	1.37	0.04	42.5	4.3	31.0±3.1
AdBL09005	c-007 (DC132)	119 (117.5-120.5)	1.84	0.06	53.3	5.3	29.0±2.9
AdBL09006	c-008 (DC133)	148.5 (147-150)	1.42	0.04	51.1	5.1	36.0±3.6
AdBL09007	c-009 (DC134)	149 (147.5-150.5)	1.46	0.05	49.2	4.9	33.7±3.4
AdBL10011	c-035 (HD10/3)	157 (152.5-161.5)	1.57	0.03	43.4	3.8	27.6±2.5
AdBL10012	c-034 (HD10/2)	168 (163.5-172.5)	1.52	0.03	51.7	3.73	33.9±2.5
AdBL10013	c-033 (HD10/1)	177 (172.5-181.5)	0.87	0.02	41.0	4	47.1±4.8
AdBL10014R	c-036 (HD10/4)	194 (189.5-198.5)	0.56	0.02	35.4	4.7	63.1±8.4

* For the sample numbers, the number in the brackets was used by the Luminescence Laboratory, while the number at the beginning is the ACHM code.
^ For the sample depth, the midpoint and range is given to reflect the diameter of the sample collection area.
R Denotes dates that are rejected based on anomalous results

Test excavations at Hope 1-41 provide further confirmation of an early Aboriginal presence in the region. A radiocarbon date of 29,275±242 cal BP was determined for the lowermost charcoal sample at the site (Cropper 2013b). An additional six flakes were identified below the charcoal sample, suggesting the site may have been utilised prior to 29,000 years ago.

Contemporary work elsewhere in the Hamersley Range has revealed at several sites with initial occupations consistent with those at Hope Downs 1. Juukan-1 is situated in the central-west Hamersley Range, and it has yielded evidence of an early occupation (37,504±373 cal BP; Beta 249759; Slack *et al.* 2009). There is also evidence of Aboriginal occupation dating to approximately 41,000 years ago in the nearby Chichester Range (YMAC 2012; Archae-aus 2013); although, there are currently few available details for this site. A little further north, on the Abydos Plains, Morse *et al.* (2012:170) have revealed occupational ages of 45,704–42,682 cal BP at Yurlu Kankala rockshelter, and more recently, Marsh et al. (2018) have demonstrated early occupation in the Yarrie area of the northeast Pilbara approximately 42,000 to 45,000 years ago. Thus, it is clear that with additional iron ore exploration in the Hamersley Range and surrounding areas, it is highly likely that additional archaeological sites will be found that have pre-40,000 year early occupational evidence.

The data from Hope Downs 1 suggests that the occupation of the inland Pilbara occurred concurrently with, or perhaps slightly earlier than, other areas of the arid zone. Nearby in the Little Sandy Desert, a Pleistocene occupation at Serpent's Glen rockshelter occurs slightly before 28,300±186 cal BP (23,550±140 BP; ANSTO-0ZB582; O'Connor *et al.* 1998). More recent evidence from the margin of the Great Sandy Desert suggests that the occupation of the shoreline of Lake Gregory may have occurred as early as 45,000 to 50,000 years ago (Veth *et al.* 2009). Radiocarbon dates from Puritjarra and Kulpi Mara rockshelters suggest that the central Australian ranges were occupied between 35,730±481 cal BP (31,140±470 BP; ANU10013; Smith *et al.* 1997) and 34,178±343 cal BP (29,510±230 BP; Beta-98034; Thorley 1998; Thorley *et al.* 2011).

During the early pre-LGM period, most sites have limited archaeological remains. The low density and intermittent distribution of artefacts recovered from the Hope Downs 1 Pleistocene sites suggests that the rockshelter use was ephemeral for much of this period. It is likely that there were long periods of time between site visitations. Even though Jundaru has higher artefact densities in its pre-LGM analytical unit than other Pleistocene sites at Hope Downs 1, only 1029 artefacts were deposited over a period of approximately 6000 years. Artefact numbers increased slightly upwards through this analytical unit, but it remains clear that Jundaru and the other early sites were not intensively occupied during the pre-LGM. It is possible that open habitation sites were favoured over rockshelters, but no such early open sites have been reported for the inland Pilbara to date. Rockshelters may have provided temporary shelter during periods of extreme weather or perhaps they were used as temporary rest places as people moved through the region.

The LGM and Transition to the Holocene

The onset of the cool and arid LGM climatic conditions that began 33,000 to 30,000 years ago and persisted until 18,000 years ago would have presented considerable subsistence challenges to resident Aboriginal populations, particularly between 23,000 and 19,000 years ago when arid conditions were most extreme (Williams *et al.* 2009; Fitzsimmons *et al.* 2013; Mix *et al.* 2001: 636). In comparison to deep-time palaeoclimatic periods, the LGM is perceived to be drier, colder, windier, and more climatically harsh than any other palaeoclimatic period of the past 50,000 years. Understandably, the relationship between LGM environmental changes and

Aboriginal settlement patterns is a prominent research topic that is of great interest to Australian archaeology (Veth 1989; Veth 1993; O'Connor *et al.* 1993; Williams *et al.* 2013; Hiscock and Wallis 2005; Smith 2013). One of the difficulties in evaluating LGM settlement behaviours has been a lack of archaeological data from this early period. In this regard, the Hope Downs 1 investigations have much to offer researchers.

The prospect that Hamersley Range, with its relatively reliable food and water resources, served as a refugium for Pleistocene Aboriginal populations is a common theme in early settlement models of the northwest arid zone. Many researchers have supported the notion that the area likely functioned as refuge for the resident populations at this time (see Veth 1995; Hiscock and Wallis 2005; Smith 2013). Indeed, it seems reasonable that this mountainous region would have been richer in resources than surrounding sandy and stony deserts. If this is the case, as some models suggest, then there should be widespread evidence of rockshelter use during the LGM. Otherwise, there would be an absence of discarded archaeological materials during the LGM, inferring possible regional abandonment. The attractiveness of this simple evaluation method is obvious, but we do not believe that the archaeological record can be viewed in such black and white terminology. The story of the LGM Aboriginal occupation of Hope Downs 1 is much more complex.

The Hope Downs 1 archaeological evidence points to intermittent episodes of ephemeral rockshelter use throughout the last glacial period. This may be interpreted by some researchers to mean people regularly occupied the area throughout the LGM; however, we note that all of the Hope Downs analyses indicate that the frequency of occupation, as indicated by artefact densities, is considerably diminished in LGM site layers, suggesting that some rockshelters were disused for long periods of time. Artefact discard is generally low throughout the LGM, particularly during the LGM proper, approximately 23,000 to 19,000 years ago. Similarly, pollen, phytolith, and magnetic susceptibility studies suggest diminished human activity in LGM site layers. To some researchers, this may be interpreted as site abandonment, but it does not necessarily indicate widespread regional abandonment. It is possible the LGM climatic period was concomitant with a change in Aboriginal mobility and subsistence-settlement patterns, resulting in lower frequency rockshelter use. It could also mean that localised areas within the ranges were more favourable than others, or there was a shift to greater open site use during this time; a prospect that remains uninvestigated regionally.

If the Hamersley Range was indeed refuge during the LGM, then two prominent patterns may be expected. The first pattern is that an increased number of rockshelter sites should show initial occupations dating to the LGM period due to an increased reliance on local resources and foraging activities in the ranges. The second pattern would be that earlier rockshelter sites, already established as habitation locales, would show increased utilisation during the LGM phase. Thus, at rockshelters like Jundaru, Djadjiling, HS-A1, and HD07-3A-PAD13 one might expect discarded artefact numbers to increase throughout the LGM as foraging activities intensified in the 'refuge' areas. Several sites in the inland Pilbara are reported to have been initially occupied leading up to peak LGM conditions (*ca.* 25,000-23,000 years ago), including Milly's Cave, Newman Orebody XXIX, Yirra Rockshelter, and Juukan-2 (see Table 2-3 for dates). Prior to ACHM's investigations, Jundaru also seemed to fit into this category; however, further work at this site has demonstrated it was occupied prior to the onset of glacial conditions. At Newman Orebody XXIX, the excavations did not reach bedrock; hence, there is a possibility (and good likelihood) that this site also was occupied prior to the onset of the LGM. The fact that there are several sites with initial occupations during the LGM may be considered by some as evidence in support of a population influx; however, there is limited data from many of these sites, which have only been subject to test excavations or have small cultural assemblages dating to this period (see Chapter 2 for more detailed discussions of these sites). In the future, broader regional investigations of Pleistocene rockshelter use will undoubtedly contribute to determining if there is an increase in initial site occupation during the LGM.

Artefact densities through time are considered to be a robust indicator of rockshelter occupation intensity. Newman Orebody XXIX, Yirra Rockshelter, and Juukan-2 show low artefact densities through the LGM (Comtesse 2003; Dias *et al.* 2007; Slack *et al.* 2009), suggesting the sites were utilised briefly and intermittently. Milly's Cave is one site that shows an increase in artefact abundance during the LGM (Marwick 2002b), but the artefact assemblage contains a high proportion of angular pieces (for further discussion see Chapter 2 and Marwick 2002a). However, in order to evaluate settlement patterns during the LGM, more data is needed.

The archaeological record at Jundaru, Djadjiling, HS-A1, HD07-3A-PAD13, and Hope 1-41 demonstrates that the rockshelters at Hope Downs 1 were periodically occupied both prior to and during the LGM. The occupation of these sites in the pre-LGM and LGM transition suggests a continued pattern of site use, rather than new land-use practices. These sites continued to be utilised during the LGM, but there are lower artefact densities at each site. The paucity of artefact numbers over this period likely indicates a decline in the frequency of site use, most likely coincident with longer intervals between occupation events (perhaps seasons, years or even decades). At Djadjiling, the decline in the frequency of LGM anthropogenic activity is supported by Herries' (this volume) magnetic susceptibility study and Wallis' (this volume) phytolith research. Similarly, the phytolith and magnetic susceptibility at HD07-3A-PAD13 suggest low frequency of occupation during the LGM (Herries 2013; Wallis, this volume).

Jundaru is the only site in this study that has substantial artefact numbers throughout the entire sequence. Artefact densities are modest during the initial pre-LGM site occupation of Jundaru (AU8; *ca.* 36,000-30,000 cal BP), showing that there was repeated occupation of the site throughout this period. Only 1029 artefacts deposited over an estimated span of 6000 years, and these artefacts were recovered from a 40cm-thick deposit. The number of artefacts and their distribution through the deposit suggests the site was utilised on many occasions, but likely only for a brief periods of time.

At Jundaru there is a slight decline in artefact densities during the initial onset of the LGM (AU7; dating between 30,000 and 23,000 years ago), continuing through peak LGM conditions. Artefact numbers slowly begin to increase at Jundaru midway through AU6, and this may coincide with the end of the LGM. There is also is a concomitant appearance of combustion features at this time. The increased artefact densities could reflect more frequent site visitation, greater duration of site occupation, or perhaps a combination of both scenarios.

The evidence from Hope Downs 1 tentatively supports the model that there was a consolidation of a resident population within their existing territory (Hiscock and Wallis 2005), rather than an influx of new populations into a refuge. Having said that, these sites represent a tiny proportion of the rockshelters

that were likely occupied in the Hamersley Range during the LGM. It is possible that the slight decline in occupational intensity (as represented by decreased artefact densities) represents a localised pattern. Moreover, resident Aboriginal population size cannot be quantified for this early time, so it cannot be unambiguously determined if LGM populations significantly decreased due to increased aridity and limited water. There are certainly areas elsewhere in the Hamersley Range that have greater access to water (both permanent and ephemeral sources) and food resources. Only detailed work elsewhere will clarify if the data from Hope Downs 1 is representative of the broader region.

Following peak LGM conditions, there are observed increases in artefact densities at Jundaru, HD07-3A-PAD13, and Djadjiling. The distribution of artefacts at Jundaru shows a sharp rise in artefact numbers beginning midway through AU5 (*ca.* 16,000-12,000 cal BP) with a low peak in artefact density at the beginning of AU4 (*ca.* 12,000 cal BP). This trend continues through the Holocene. At HD07-3A-PAD13, there is a peak in artefact densities in AU3. The exact timing of this phase of occupation is not know, but it is believed to represent the terminal Pleistocene and early Holocene occupation. Following this peak, artefact densities decline, rising again only around 1500 cal BP.

The Holocene

There are few sites at Hope Downs 1 with early Holocene occupations, apart from those with sequences spanning from the Pleistocene to the late Holocene. The latter tend to show increased artefact densities from the Pleistocene through the early Holocene, with the exception of Djadjiling that has only limited use throughout the Holocene. PAD 3, HN-A7, and HS-A2 are the only sites with initial occupational phases in the early Holocene. In each instance, there are few artefacts in the earliest layers. At HN-A7, artefact numbers are low throughout the entire sequence. HS-A2 also has low artefact densities, but shows an increase in artefact numbers in the late Holocene layers. PAD 3 shows an increase in site use from the mid-Holocene with increased artefact numbers and cultural features.

Sites with continuous occupations from the Pleistocene through the Holocene generally show a trend towards increased artefact densities, particularly in the middle and late Holocene. At Jundaru, artefact numbers rise steadily through the early Holocene and into the late Holocene, but there is a sharp increase in artefact density beginning around 4,000 years ago. Artefact numbers are extremely high throughout the two uppermost analytical units, with a combined total of 15,313 artefacts recovered in AU2 and AU1. The intensification of site use during the mid-Holocene is not restricted to Jundaru, but has also been observed at HS-A1, HD07-3A-PAD13, HD07-1A-07, PAD 3, and PAD 4. HD07-3A-03 shows considerable artefact density during the mid-Holocene, and it has a particularly high abundance of artefacts in the late Holocene layers. HD07-3A-03 shows a peak in site use beginning around 600 years ago, and it is the only site to have artefact densities that rival Jundaru. Djadjiling is one of the only sites at Hope Downs 1 that shows a drop in artefact densities during the Holocene, and it has been argued that this is due to a roof collapse event.

Amongst the Hope Downs 1 rockshelters, there are a number of sites with late Holocene initial occupations dating within the last millennium. Hope 1-39 and PAD 1 have occupations dating to approximately 715±22 cal BP and 605±31 cal BP respectively. Situated immediately across from PAD 1 is Hope 1-41 rockshelter, which has an occupation sequence dating back to 29,275±242 cal BP, but the primary phase of site use was from approximately 600 years ago. Four artefacts were recovered from nearby Hope 1-40, and it is likely that this site was also initially utilised around 700 to 600 years ago. There are also a number of sites with recent occupations that have been dated to the last several hundred years, including Hope 1-16 and Hope 1-46. A similar recent age can also be inferred for Hope 1-17 (based on similarities with Hope 1-16), as well as for rockshelters with surface artefacts only (*e.g.*, HD07-3A-PAD05). These sites demonstrate the continued occupation of the inland Pilbara into recent times. Importantly, these sites help to document the technologies that continued to be utilised into the recent past, including the production of backed artefacts, tulas, burrens, and burins. These sites suggest that a greater number of rockshelters were utilised over the last millennium. This may indicate an increased population within the area, or perhaps greater residential mobility. It is, however, important to point out that many of these sites have shallow deposits and it is possible that older deposits (and artefacts) may have been scoured away. This possibility is discussed in more detail in Section 18.5 (also see Table 18-4 for deposit depths of the Hope Downs 1 rockshelters).

18.2 ENVIRONMENTAL VARIATION DURING THE ABORIGINAL SETTLEMENT AT HOPE DOWNS 1

Recent syntheses of Australian palaeoenvironmental change demonstrate that throughout the 45,000 years of occupation at Hope Downs 1 there have been significant climatic variations and numerous palaeoenvironmental phases. There are often subtle variations in the periodization between researchers, which is largely due to the variation in local responses to environmental change. There is general agreement that the period from approximately 40,000 to 30,000 years ago represents the transition from the warmer and more humid late MIS 3 to cooler conditions. During this period, climatic conditions across the Australian arid zone were likely warmer, wetter, and more seasonally predictable than present, and there is evidence suggesting that summer monsoons penetrated the continental interior at regular intervals (Magee *et al.* 2004: 1151; Johnson *et al.* 1999; Fitzsimmons *et al.* 2013). After approximately 33,000 to 30,000 years ago, the region experienced decreased, unpredictable rainfall patterns and decreased terrestrial temperature until approximately 18,000 years ago (Williams *et al.* 2009; Fitzsimmons *et al.* 2013). Aridity and cool temperatures peaked at the end of this period during the LGM between roughly 23,000 and 19,000 years ago (Mix *et al.* 2001: 636; Williams *et al.* 2009: 2400; Fitzsimmons *et al.* 2012).

Early deglaciation began around 18,000 years ago, but in the arid zone there is continued evidence of aeolian activity until roughly 15,000 years ago (Williams *et al.* 2009; Fitzsimmons *et al.* 2013). Climatic conditions became more favourable by 14,000 years ago after the re-initiation of the northern summer monsoon cycle across northern Australia (Wyrwoll and Miller 2001: 127). Climatic fluctuations also occurred throughout the Holocene, and there have been a number of studies suggesting that the arid zone experienced a period of decreased rainfall and climatic variability that began around 5000 years ago (*e.g.*, Hesse *et al.* 2004; Quigley *et al.* 2010; McCarthy and Head 2001; Fitzsimmons *et al.* 2013). Nott (2011) has shown that the annual monsoonal cycle ceased along the mid-northwest coast of Western Australia between 5400 and 3700 cal BP, resulting in a 1700-year period of increased aridity. This has also been demonstrated in the Gregory Lakes region by a period of dune

building (Fitzsimmons *et al.* 2012). Increased aridity if further suggested from pollen cores collected from Kimberley region of northwest WA, where McGowan *et al.* (2012) demonstrate a period of ENSO-induced drought starting around 5750 years ago and continuing through to approximately 3200 to 2800 years ago.

These large-scale continental changes provide a guide for investigating how environmental variation may have affected archaeological patterns, but it is the local responses and their timing that provide the best context for understanding the archaeological sequence. The specialist studies conducted on the materials from sites at Hope Downs 1 help to reconstruct the environmental changes that affected the local area.

Archaeomagnetic Analysis

Archaeomagnetic analysis of sediment samples from Jundaru, HD07-3A-PAD13, and Djadjiling provide insight into environmental changes at Hope Downs 1. Each of these sites suggest that the region experienced cool conditions during the late MIS 3 and LGM (Herries, this volume; 2012). At Djadjiling, the data suggests that cool conditions were experienced between 145 and 60cmbd, followed by a warm climate phase (Herries, this volume). When this data is correlated with the radiocarbon sequence, it suggests that the initiation of cooler conditions began as early as 40,000 years ago during the late MIS 3. Low magnetic susceptibility values at Jundaru below 170cmbd are indicative of a cooler and drier climate, which persists until around 100cmbd. According to the ACHM radiocarbon series, sediment below 170cmbd was deposited around 35,000 and this may suggest that glacial conditions were experienced from this period. HD07-3A-PAD13 also shows the same pattern with the sediment between 235 through 80cmbd deposited under cold glacial conditions, and with a distinct cold climate phase between 100 and 80cmbd (Zones 1-5; Herries, this volume). The OSL dates indicate cool conditions began from at least 47.1±4.8 ka and continued beyond 31.0±3.1 ka.

The timing of the transition to warmer conditions is difficult to pinpoint at Jundaru and HD07-3A-PAD13 due to low chronological resolution for these periods, and further radiocarbon dating may help to clarify this. At Djadjiling, the transition from cool to warm climatic conditions occurred around 60cmbd, and a radiocarbon date from 58cmbd indicates this occurred prior to 14,907±214 cal BP. The highest magnetic susceptibility values at Jundaru occur between 100 and 30cmbd, and Herries (this volume) suggests that this pattern may represent the transition to warmer and wetter conditions. The age-depth trend suggests that the change to warmer and wetter conditions occurred around 17,000 years ago during the early deglaciation. The sediment in Zone 6 (75cmbd to the surface) at HD07-3A-PAD13 was deposited under warm conditions (Herries 2013). The lack of dates between 93 and 47cmbd at this site makes it difficult to determine the timing of the transition to warmer conditions. If consistent deposition is assumed between the uppermost OSL date and the lowermost radiocarbon date, it would suggest that 75cmbd correlates to roughly 19,000 years ago. It is likely that this estimated age is slightly too early, and should perhaps be pushed later into the early deglaciation as this climatic change occurred several millennia later at both Jundaru and Djadjiling.

Climatic variations during the Holocene are only indicated at Jundaru. Herries (2013) found that there were elevated magnetic susceptibility values between 95 and 60cmbd, and suggests that this could be due to climatic fluctuations or anthropogenic alteration. This phase corresponds with the transition to the Holocene through to the early Holocene. Over this period the artefact densities steadily increase to 80cmbd and then drop slightly for the remainder. There are a number of combustion features dating to this period, including two pit hearths (Features 20 and 17).

Phytolith Analysis

Phytolith analysis was conducted for sediment samples from Jundaru, HD07-3A-PAD13, and Djadjiling. Wallis (this volume) notes that while phytoliths are present in the rockshelter sediments, there is an absence of distinctive or diagnostic phytoliths in the assemblage; therefore, the assemblage is better positioned to provide information on generalised vegetation change over time rather than human use of specific plant species through time. These observed vegetation changes can provide useful information regarding local responses to climate change.

In the earliest phase of occupation at HD07-3A-PAD13, there is a peak in tree phytoliths (Zone 1a, Layer 38), and there is a shift from Panicoid to Chloridoid grasses from Zone 1a to Zone 1b (Layers 37-28 or 210-165cmbd; Wallis, this volume). Zone 1 roughly corresponds to the end of MIS 3 and the onset of glacial conditions. In Zone 2 (Layer 27-11, 160-80cmbd) there was a continued decline in the proportion of trees and shrubs, while grasses increased (Wallis, this volume). This vegetation change is likely due to increasing aridity through to the LGM. There is a subsequent increase in trees and a reduction in grasses in Zone 3 (Layers 10-1, 75cmbd to surface), and Wallis (this volume) observes that the phytolith assemblage in this zone reflects the modern vegetation patterns. Wallis (this volume) suggests this phase corresponds to the beginning of the Holocene with the return to warmer climatic conditions, and this interpretation corresponds precisely with the archaeomagnetic sequence.

Like at HD07-3A-PAD13, the phytolith assemblage at Jundaru shows an early minor peak in tree phytoliths (Zone 1a, 195cmbd), along with a higher frequency of phytoliths from Panicoid grasses as well as Chloridoid and Pooideae grasses (Wallis, this volume). There is a subsequent increase in phytoliths from Pooideae grasses and concomitant decline in tree/shrub phytoliths in Zones 1b and 1c (190-130cmbd; Wallis, this volume). Wallis (this volume) suggests that Zone 1 occurs at the beginning of the glacial period through to the onset of peak LGM conditions, and this corresponds well with the age-depth trend line for the ACHM date series. The phytolith record shows good agreement with the archaeomagnetic data; although, the archaeomagnetic data suggests that cool and arid conditions persisted slightly longer. Tree/shrub phytoliths and Panicoid grasses return at the beginning of Zone 2 (Layers 19-4, 125-50cmbd), Wallis (this volume) suggests that this vegetation transition likely corresponds with the early Holocene. The radiocarbon data suggests that Zone 2 began in the early deglacial period following the LGM and continued through to the mid-Holocene. Additionally, there are declines in tree/shrub phytoliths at 70 and 60cmbd (Layers 8 and 6; Wallis, this volume), which may reflect local responses to a decline in aridity which has been demonstrated between 5400 and 3700 cal BP along the northwest coast of Western Australia (Nott 2011). Climatic variation during this period is also suggested by the archaeomagnetic data. In the uppermost zone (Zone 3, 45cmbd to the surface), there is a slight decline in the abundance of phytoliths as well as tree/shrub phytoliths (Wallis, this volume).

The phytolith assemblage from Djadjiling indicates a decline in tree cover around the site between Layers 29 and 19 (145-95cmbd), which is considered indicative as a decline in regional rainfall (Wallis, this volume). Based on the radiocarbon dates and site stratigraphy, these layers roughly correspond to AU5 and AU4, which are estimated to span from 38,000 to 24,000 cal BP. This data generally correlates with the phytolith sequences at both Jundaru and HD07-3A-PAD13, as well as with the archaeomagnetic data. The correlation with archaeomagnetic data is significant, especially since the analysts were presented blind sample numbers and were unaware of the sample provenance until after their analysis was completed. Within Layers 19 to 13 (AU3 through to mid-AU2), the phytolith assemblage included an increase in the numbers of trees and Panicoid grasses, which corresponds to the LGM and early deglacial period.

18.3 ABORIGINAL SUBSISTENCE AND DAILY LIFE

Reconstruction of subsistence strategies are integral to understanding how Aboriginal people lived in the past. The rockshelter excavations at Hope Downs 1 provide the opportunity to not only document past subsistence strategies, but to also determine if there were changes over time. Many of the specialist studies provide evidence regarding Aboriginal subsistence and daily life, including faunal analysis, macrobotanical analysis, usewear analysis, and artefact analysis. Additionally, the culturally modified trees documented in the project area demonstrate the procurement of honey and bark/wood.

Faunal Remains

Faunal remains are typically scarce at most rockshelters. Only at Jundaru was a large faunal assemblage recovered, with a much more modest assemblage was recovered from PAD 3. In the Jundaru assemblage, 3533 specimens were identified that represent at least 2611 individuals and 22 species (McDowell, this volume). Kangaroo was most frequently represented in the analytical units. Numerous other mammals also were identified, including quoll, bandicoot, bilby, possum, bettong, rock-wallaby, bat, mice, and rat (McDowell, this volume). The remains of reptiles, birds, frogs, and a snail were also included in the assemblage (McDowell, this volume).

Faunal remains were covered throughout the sequence, but abundance decreased with increasing depth. Three specimens were recovered from AU8 and 12 specimens were recovered in AU7. Beginning in AU6, there is a considerable increase in the abundance of faunal remains; however, the frequency of faunal remains is not proportional with the distribution of artefacts. The density of faunal remains peaked in AU4, while the diversity of species is greatest in AU3 (McDowell, this volume). By far AU2 and AU1 have the greatest number of artefacts, yet these periods of site use show a decline in the number of bones. It is possible that in the later stages of occupation, food items were not consumed as regularly as in AU3 and AU4. Two large hearths were identified in AU4, which have been interpreted as possible roasting or cooking pits. The high number of faunal remains associated with these features supports this interpretation. A number of combustion features were identified in AU3, including four ash lenses and a hearth.

McDowell (this volume) found that bone preservation was good, but they were highly fragmented making identification of the specimens difficult. Most bones are believed to have been broken through treadage and deliberate breakage, including a high frequency of spiral and crenulated breaks (McDowell, this volume). Over half of the bones were burned, and the proportion of calcined bones increases with increasing depth (McDowell, this volume). Bones that do not show signs of thermal alteration may also have been derived from cooked food. For example, if an animal was roasted with the skin on (a practice that continues today), it is unlikely that it will result in a high amount of burned bone (Gould 1996: 78).

Through the sequence there are subtle changes in the frequency of animals represented. Macropods are the most commonly represented family in the assemblage, occurring in each analytical unit. The samples in AU8 and AU7 are limited and include macropod and one Peramelid bone. In AU6, rodents (*Pseudomys*) and quoll are represented by single specimens. The diversity of the assemblage increases in AU5, with emu, Murids, bandicoots, and possums occurring along with numerous macropod bones. The frequency of bandicoot increases from AU5 and peaked in AU3, while no specimens were identified in AU1. Both rodents and reptiles are more frequent in the upper three analytical units, both peaking in AU3. Emu frequency also increases from AU5, peaking in AU3, followed by a trough and a low rise again in AU1.

Emu eggshell fragments were identified in 49 contexts from AU6 onwards. Eggshell fragments provide a rare opportunity to explore seasonality within rockshelter occupations, assuming that the eggs were consumed rather than the shells having been used for secondary purposes. While most shell fragments were recovered from arbitrary excavation contexts, shell fragments were recovered from the matrix of Features 12, 13, and 20, and this provides compelling evidence suggesting that the eggs were a food item. Emus lay eggs on a seasonal basis in autumn and winter, generally beginning in early April and extending through to early September, with a peak in June (Western Australia Department of Environment and Conservation 2009; Malecki and Martin 2002: 167). The presence of these faunal remains in the assemblage provides evidence that Aboriginal people occupied the shelter during the cooler months, but this data does not discount the likely possibility that the site was also visited during the summer and spring. The greatest abundance of emu eggshell fragments was in AU3 (7686±34 to 3899±45 cal BP). Further investigation of the emu eggshell fragments may provide more information regarding the minimum number of eggs in the assemblage and seasonality.

While the remains of some species in the assemblage are likely the result of natural accumulation (*e.g.*, frogs and lizards), McDowell (this volume) argues that the majority of faunal assemblage is associated with the past human occupation. This evidence indicates that Aboriginal people hunted a broad range of animals as part of their subsistence strategies. This conclusion is further supported by the analysis of faunal remains from PAD 3, where a fish vertebrae recovered (McDowell, this volume). Weeli Wolli Spring is the closest permanent water source (roughly 20km northeast of the site) and is the likely source of the fish.

Macrobotanical Remains

Macrobotanical analysis of assemblages from sites Jundaru and HS-A1 builds upon the information gained through the Djadjiling and PAD 3 analyses (Fairbairn 2011; Fairbairn 2012; Fairbairn 2013). The analyses focused on samples recovered from hearth features, as they can be directly linked with the Aboriginal occupation at the site. Apart from wood charcoal,

small assemblages of other plant macrofossils were analysed that provide some insight into Aboriginal subsistence.

A small number of other plant macrofossils were identified in the Jundaru and HS-A1 assemblages. The greatest abundance of specimens was from Feature 6 at HS-A1 (3036±50 cal BP). Fairbairn identified nutlets from the gum family, a *Proteaceae* seed fragment, unidentified seeds, and indeterminate thorns and twigs. The *Proteaceae* family is not represented amongst the wood charcoals from any of the sites studied at Hope Downs 1 (this volume). The *Proteaceae* family includes *Grevillea* and *Hakea* species, and it is possible that this specimen could have been a food item (*e.g.*, nectar; Brown 1987).

At Djadjiling, a small assemblage of plant macrofossils was identified. The assemblage includes a Nitre Bush fruit that was recovered from Feature 6 (Fairbairn 2012). Nitre Bush fruits are edible and are a documented bush food (Fairbairn 2012). A range of plant macrofossils were recovered from the first several arbitrary excavation layers. Fairbairn (2012) cautions that most of the specimens were likely recently introduced into the deposit, noting the presence of goat faeces amongst the samples and the fresh condition of the materials (including living tissue in some seeds).

PAD 3 rockshelter had the largest sample of plant macrofossils, including seeds, fruits, and bark. All of the plant macrofossils, including those recovered from hearths, were uncharred (Fairbairn 2011). It is possible that some may be intrusive (particularly those in the upper deposit), as Fairbairn identified fragments of goat faeces in the assemblage. Identified specimens in the assemblage include *Eucalyptus* fruits, fragments of paperbark, and an *Acacia* pod and seed (possibly *A. aneura*). A small cache of spinifex seeds was identified, and while they are known to have been utilised by Aboriginal people, it is more likely that they were cached by rodents considering the number of rodent bones in the assemblage.

Evidence from Grindstones

Grindstones are a common artefact in both rockshelter and open artefact assemblages, and it is generally assumed that most specimens were utilised for seed grinding or processing other food items. The earliest artefacts with ground or polished surfaces were recovered from HD07-3A-PAD13, with one artefact (ground BIF river cobble) identified in the first occupational phase (*ca.* 47.1±4.8 to 33.9±2.5 ka). The function of this artefact is not certain, but it bears similarity to polished pebbles at Jundaru. The earliest examples of a lower grindstones are also from HD07-3A-PAD13, where several specimens recovered from AU5 (*ca.* 33.9±2.5 and 31.0±3.1 ka). The early grindstones at HD07-3A-PAD13 are all amorphous, and generally were produced from river cobbles. Given their early age of these grindstones, usewear analysis of these artefacts would provide greater certainty of their function. HD07-3A-PAD13 is situated in a fluvial environment, and the site formation processes (i.e., low-energy floodplain deposits) negate the possibility that these rounded rocks were introduced into the rockshelter naturally. At Jundaru, lower grindstones only appear in the assemblage from AU4 onwards and the context of the two lowermost specimens suggests that they are slightly earlier than 7686±34 cal BP. These artefacts include the earliest example of a grindstone produced on a tabular BIF slab amongst the studied sites.

Grindstones were submitted for usewear analysis from Jundaru, Djadjiling, and PAD 3. Of the 16 lower grindstones submitted for usewear analysis from Jundaru, Fullagar (2013) that most were utilised for working plants. Starchy plants were worked on one specimen from AU4, and one of the grindstones from AU3 was likely used to process ochre (Fullagar 2013). The material work on three of the lower grindstones was uncertain. The grindstones analysed from Djadjiling and PAD 3 showed usewear consistent with seed grinding (Fullagar 2012). The grindstones from HD07-3A-PAD13 have not been subject to usewear or residue analysis. Further study of the grindstones from this site would be useful to determine the material worked on these early specimens.

Evidence from Combustion Features

Combustion features are the only excavated features identified at rockshelters in Hope Downs 1 that provide evidence regarding subsistence behaviour and daily life. Fire can be used in many different ways, such as providing heat and light and cooking; however, fire was also instrumental for manufacturing tools and materials. The manner in which combustion features presented during excavation was variable, but generally speaking, the well-preserved combustion features contained ash and charcoal matrix resting atop reddened sediment. Heat fractured roof spall fragments are not uncommon to observe beneath the hearth features. Hearths, charcoal lenses, and ash lenses have been identified at numerous sites at Hope Downs 1. Stratified combustion features have been identified at Jundaru, HS-A1, Djadjiling, and PAD 3.

Some hearths identified at Jundaru were ash-rich and had very little charcoal. These features may have been left to smoulder for long periods of time, as hearths with similar ash-rich matrix, consisting predominantly of ash and containing little charcoal, were observed amongst the Alyawarra in central Australia (O'Connell 1987: 80). It is also possible that the lack of charcoal may be due to the fuel selection. If small twigs and branches were utilised, it is less likely that charcoal would be produced. Brown (1987: 41) noted similar ash-rich hearths at Coffee Table Rockshelter (Site P4623) and Bastion Rockshelter (Site P5315), and suggested that they may have been sleeping fires.
Most hearth features were fairly thin and have a limited horizontal extent; however, several large and deep hearths have been identified, including Features 17 and 20 at Jundaru, Feature 6 at HS-A1, and Feature 2 at Djadjiling. These large features are interpreted to be cooking or roasting pits, and the earliest example identified at Hope Downs 1 is Feature 20 at Jundaru. This feature has not been directly dated, but it is believed to be approximately 11,000 years old. Similar features have been identified elsewhere in the Pilbara. At Bastion Rockshelter, two hearths (Features 12 and 14) were identified as cooking pits (Brown and Mulvaney 1983: 55-56). A similar feature was identified at Whispering Trees Rockshelter (Brown and Mulvaney 1983: 71). Possible cooking pits were also identified at Newman Rockshelter and Newman Orebody XXIX (Troilett 1982: 33; Brown 1987: 24, 41).

Amongst the various types of hearths, there are no clear patterns of fuel selection. The lack of woody charcoals in the ash-rich hearths compounds this problem. The analysis of wood charcoals from Jundaru shows consistency throughout the sequence, with Myrtaceae types being dominant and one type of *Eucalyptus* comprises the majority of the sample (Fairbairn 2013). The features from HS-A1 show a greater variety of species amongst the wood charcoals, including *Ficus platypoda* in Feature 5 (Fairbairn 2013), which is one of the oldest dated features at Hope Downs 1 (28,200±188 cal BP). Fairbairn (2013) also notes that the wood charcoals identified as *Ficus platypoda* match an indeterminate type identified Feature 12 at PAD 3 assemblage. This species is not a part of the current

vegetation within the project area as it requires wetter conditions (Fairbairn 2013). Fairbairn (2013) suggests that the wood may have been a burned artefact (*e.g.*, walking stick, tool, or other item) that was brought to the sites from river valleys. While only wood charcoals were identified, *Ficus platypoda* is well know for its edible fruit. As has been discussed earlier, a fish bone and paperbark were identified at PAD 3, and this data provides further evidence that the occupants of the rockshelters at Hope Downs 1 utilised riverine resources, such as can be found at Weeli Wolli Spring.

Manufacture of Artefacts from Organic Materials

Stone artefacts are the most common artefact identified at the archaeological sites at Hope Downs 1, including knapped and ground artefacts. No artefacts produced from organic materials were identified during the rockshelter excavations. The usewear analysis of flaked stone artefacts hints at the importance of these other materials.

Usewear and residue analysis of artefacts from Jundaru show that a high proportion of the artefacts were utilised to work wood, including non-formalised retouched and utilised artefacts, burins, tulas, scrapers, and backed artefacts (Fullagar 2013). Artefacts with usewear consistent with working wood occur within the earliest analytical unit, and wood is the predominant material worked throughout the sequence. This is also true of the artefacts from Djadjiling (Fullagar 2012). As only a small sample of artefacts was submitted for analysis, it is difficult to determine if there were changes in the materials worked over the sequence. Many of the formalised implements that appear in the late Holocene show evidence of having been utilised for woodworking, and this may indicate a greater emphasis on the production or even decoration of wooden artefacts.

At Jundaru, flaked stone artefacts used on soft tissue and skin were second in abundance, and this includes many of the backed artefacts. The associated mode of use is generally piercing or cutting. A similar pattern was also identified in the PAD 3 assemblage (Fullagar 2011).

Evidence from the usewear analysis of artefacts from Djadjiling suggests that resin was used as an adhesive or haft for artefacts from the initial occupation 41,000 years ago. Spinifex resin has been identified in several hearth features, including specimens from HS-A1 Feature 6, HS-A1 Feature 2 (3113±58 cal BP), and Feature 7 at Jundaru (late Holocene; Fairbairn, this volume). The resin may have been introduced to the hearths for numerous reasons, such as resin production, softening of resin for application, or maintenance of artefacts that incorporate resin as an adhesive or haft.

18.4 LITHIC TECHNOLOGY

Flaked stone artefacts constitute the bulk of the archaeological materials recovered from the sites investigated during the MIB40 program, and each assemblage was subject to a thorough technological analysis using the same methodology. Many sites lack assemblage sizes to make statistically informed evaluations, but collectively, the sites do reveal many interesting technological trends. Additionally, the artefact analyses revealed that assemblages recovered using different methodologies, such as those from excavated sites and open artefact scatters, may not be directly comparable.

Reduction Strategies and Raw Material Procurement

Raw material procurement strategies are the first stage of artefact production, and the assemblages provide the opportunity to consider raw material use over time, as well as examine differences amongst sites in different geomorphological settings. At Jundaru there were shifts in raw material types procured over time. BIF was most heavily utilised in AU7, AU6, AU4, and AU3, while chert was used in moderate proportions early in the sequence (AU8-AU7 or *ca.* 36,000-23,000 years ago), before its use declined from AU6 through to AU4. Beginning in AU4 (*ca.* 12,000 years ago), the proportion of chert rose, but BIF remained the predominant raw material type. By approximately 4,000 years ago, chert became overwhelmingly dominant and while there was a coincident decline in BIF artefacts. This pattern is repeated at numerous other sites, including HD07-3A-PAD13, HS-A1, HD07-3A-03, PAD 4, and HD07-1A-07 (Cropper 2013a; Cropper and Law 2012a; Law and Cropper 2011a). At PAD 3, the predominance of chert begins slightly earlier (AU3, *ca.* 4686±78-6399±43 cal BP). Analysis of the Djadjiling assemblage revealed a different use of raw materials, with chert having been a heavily utilised throughout the entire occupation. The sites with assemblages dating to the last millennium show that chert continued to be the preferred material type in to recent times (*e.g.*, Hope 1-16, Hope 1-39, and PAD 1). There are very few sites with Holocene occupations where chert was not heavily utilised, and HS-A2 is one such example. HS-A2 shows an unusually high use of goethitised shale and it is the only rockshelter to show such a dominance of this material type.

Chert appears to have been an important resource throughout the entire occupation history of the project area, and there is a wide range of chert varieties represented in each assemblage. Dark grey chert and greyish brown chert are amongst the most common varieties represented in the assemblages; hence, it seems reasonable to suggest that these are also the most widely available chert types in the local region. The proportion of red chert is much more prevalent at open artefact scatters, and this may be due to the fact that these assemblages are much more susceptible to heating than excavated assemblages. It is difficult to determine the occurrence of naturally red chert and chert that has become reddened due to heating.

The data demonstrates that knappers often preferentially selected chert and fine-grained brown shale over other raw material types for the production of both formalised retouched artefacts and non-formalised retouched and utilised artefacts. The vast majority of formalised retouched artefacts were produced from chert flakes, and there are only few instances where other finer grained materials were used. This pattern is repeated amongst most sites at Hope Downs 1.

Through time, no definitive technological changes can be identified in flake manufacture. Regardless of their age, most flakes were produced through the expedient reduction of unidirectional or rotated cores. There is no evidence to suggest that cores were prepared prior to knapping, or that the knappers systematically modified platforms or overhangs prior to flake detachment. Most cores retain some cortex, suggesting that they were not highly reduced. While chert cores are typically smaller than coarser-grained cores, they too retain cortex, suggesting that smaller pieces of chert were more common than large chert cobbles throughout the region. Blades occur rarely in the assemblage, and there is no indication that knappers deliberately focused on their manufacture. The uniformity in the reduction methods over time shows a degree of cultural conservatism, where people did not experiment outside of the traditionally

accepted methods of flake manufacture. Moreover, it demonstrates that these expedient reduction methods were highly successful, negating the need for alternative reduction strategies that have been costly in terms of time, energy, or resource procurement.

The data from the Pleistocene sites shows that since the earliest occupation of the region, retouching has been an important technological strategy. At Jundaru, the phases with the highest frequency of retouched and utilised artefacts occurs during the initial use of the site (AU8 and AU7) and in the last phases (AU2 and AU1), with a considerable drop in their frequency in the intervening analytical units. HD07-3A-PAD13 shows the same pattern as Jundaru, while HS-A1 shows similar frequencies of retouched and utilised artefacts throughout the sequence. Djadjiling has considerably higher frequencies of retouched artefacts over the course of the occupation, but there are troughs throughout the sequence (AU6, AU4-AU3, and AU1).

Simple, non-formalised retouched artefacts occur from the Pleistocene throughout the Holocene; however, in the middle and late Holocene, artefact manufacture was altered to incorporate new technologies that produced formalised stone tools with extensive use-lives. Odell (2001: 64) states that 'once a satisfactory level of tool efficiency has been achieved by a particular group of hunter-gatherers, the successful strategy tends to continue until essential parameters of the system change, rendering the strategy less adaptive.' In order to explore the possible reasons why these new artefacts were introduced, it is necessary to determine when they initially appeared and how long they continued to be manufactured.

Antiquity of Formalised Retouched Artefacts

One of the aims of this research is to investigate the temporal occurrence of prominent formalised retouched artefact types, such as backed artefacts, tulas, burins, and burrens, in an attempt to understand both when these new technologies were first adopted, as well as to consider the impetus for this technological shift. It has been argued that increased aridity in the mid-Holocene was an integral factor in the appearance of backed artefacts and tulas (Hiscock 1994; Veth *et al.* 2011). This pattern needs to be explored further at a local level as the timing of the appearance of these artefacts varies across Australia (see Slack *et al.* 2004).

Backed artefact technology was previously documented from Newman Rockshelter at 4108±147 cal BP (3740±100 BP) (Brown 1987: 27). Thus far, PAD 3 provides the earliest evidence of backed artefacts at Hope Downs 1, with four backed artefacts recovered from Feature 1, which was dated to 4686±78 cal BP. One additional backed artefact was also found in the sediment below Feature 1 at PAD 3; hence, it is possible that backed artefacts were manufactured even earlier. The appearance of backed artefacts at Hope Downs 1 occurs during a period of aridity, and this supports the theory that this new technology was a response to climatic change.

The data from Jundaru and HS-A2 also supports this early appearance of backed artefacts, suggesting that they became an integral part of the tool-kit in the mid-Holocene. The lowermost backed artefacts from Jundaru were recovered from between 60 to 65cmbd and include an asymmetrical Bondi point and a symmetrical trapeze. The context of these artefacts places them below Feature 10, which was dated to 3899±45 cal BP. The age-depth trend line suggests that these artefacts have a similar antiquity to the oldest backed artefacts from PAD 3 or even slightly older, possibly pre-dating 5000 cal BP. The deepest backed artefact at HS-A2 was identified in AU3 (U1-L07) and two radiocarbon dates bracket this analytical unit, indicating that it spans from 6583±45 to 2779±29 cal BP. The backed artefact was recovered *in situ* at a depth of 63cmbd, and the trend line between the two radiocarbon dates suggests that this artefact could have been deposited at the site as early as approximately 5500 cal BP. As the lowest backed artefacts from both Jundaru and HS-A2 have been recovered from contexts that were not directly dated, the early estimated age of these artefact should be considered with caution.

There is significant evidence that demonstrates backed artefacts continued to be utilised within the last two centuries. The backed artefacts identified on the surface of Jundaru provide evidence that these tools continued to be manufactured until the recent past, as a radiocarbon date from Feature 1 (U4-L1.1; 8cmbs) yielded a date of 176±86 cal BP. The continued use of backed artefacts is also confirmed by excavations at Hope 1-16, where a symmetrical backed artefact was recovered in Layer 3. Radiocarbon dates from above and below the artefact both date to approximately 180 years ago. At HD07-3A-03, seven symmetrical backed artefacts and ten backed artefact fragments were recovered from AU1 (12 from Layer 1 and 5 from Layer 2), and a date of 177±86 cal BP was determined for a charcoal sample in Layer 1. Hope 1-39 had one symmetrical backed artefact on the surface of the shelter.

Evidence from sites investigated at Hope Downs 1 indicates that while the earliest occurrence of backed artefacts is in the mid-Holocene, tulas, burrens, and eloueras appear considerably later, by no earlier than 1000 years ago. This finding does not support the theory that mid-Holocene climatic changes were a factor in the adoption of tulas (see Veth *et al.* 2011). Eight tulas were recovered during the excavation of HD07-3A-03 and were restricted to AU1 and AU2, which represent the occupation of the site over the last 600 years. The three lowermost specimens were recovered from between 40 to 35cmbd, and a charcoal sample from 46.5cmbd was dated to 603±32 cal BP. Two burrens were also recovered from HD07-3A-03, including specimens in AU1 and AU3. The deepest burren was recovered *in situ* at a depth of 48cmbd, placing it slightly below the charcoal sample dated to 603±32 cal BP (46.5cmbd). Hence, in the context of the HD07-3A-03 excavations, the data suggests that burrens first occurred in the archaeological record only slightly earlier than 600 years ago.

Nine tulas and two burrens were identified during the excavation of Jundaru. Seven tulas were recovered from AU1 and two specimens from AU2. In AU2, Artefact 14,937 was recovered *in situ* at a depth of 42cmbd (U4-L04) and Artefact 20,138 was recovered from between 40 and 45cmbd (U5-L04). The burrens were recovered from AU1 and AU2, with the lowermost specimen recovered from between 40 and 45cmbd. The initial appearance of tulas and burrens is much later than backed artefacts. Based on the age-depth relationship of the ACHM radiocarbon series, it is estimated that they only occurred in the archaeological record within the last millennium.

The recent late Holocene use of burrens and tulas at Hope Downs 1 is also demonstrated at Hope 1-41, Hope 1-46, HS-A2, and HD07-1A-07. A burren from Hope 1-41 (Layer 1) is likely less than 600 years old as charcoal from Layer 2 was dated to 603±34 cal BP. A tula slug was recovered from HD07-1A-07 (U1-L02; 30-35cmbd) and was deposited shortly after 866±46 cal BP (38cmbd). Hope 1-46 provides good evidence for the continued use of burrens into the recent past, with two specimens recovered from the first arbitrary

excavation layer (Layer 2 was dated to 177±85 cal BP). A tula slug was recovered from HS-A2 (U1-L02; Artefact 233), and its context tentatively correlates with those from Jundaru and HD07-3A-03. A charcoal sample from the McDonald, Hales and Associates excavation indicates that Spit 1 dates to 530±45 cal BP (Edwards *et al.* 2001: 149), but the depth range of this sample has not been reported. Tulas were also identified in the first arbitrary excavation layers at HN-A7 and HS-A1, as well as on the surface of two rockshelters, including at HD07-1A-02, Hope 1-24.

Previous research has often suggested that tulas occur in the arid zone much earlier than what has been found at Hope Downs 1. Researchers continue to report that tulas appear in the inland Pilbara from 3700 BP based on evidence from Newman Rockshelter (see Veth *et al.* 2011: 10; Marwick 2009: 16). When the original excavation report for Newman Rockshelter is consulted, it indicates that two adzes (unspecified types) were recovered, including a specimen from Pit B Spit 2 (Accession No. C 0898-03) and one from Pit B Spit 16 (Accession No. C 0930) (Troilett 1982: 56). It is unlikely that the specimen in Spit 16 is a tula because of its antiquity and it is not discussed as such by either Brown or Comtesse, who carried out subsequent analyses of the assemblage (see Brown 1987; Comtesse 2003). Brown (1987: 29) notes that 'the five backed pieces and single adze slug all occur in the uppermost levels of the excavation…. This data indicates that the use of backed pieces and the adze occurred between about 3700 years BP and the time of European contact, less than 100 years ago'. A more recent re-analysis of the artefact assemblage from Newman rockshelter (in which tulas were not mentioned) included a new series of radiocarbon dates that provides greater chronological resolution for the site (see Comtesse 2003). A radiocarbon date for charcoal recovered from Spit 2 indicates the tula at Newman Rockshelter is much more recent that previously reported, dating to approximately 1388±37 BP or 1305±26 cal BP (Comtesse 2003: 48).

Archaeological investigations throughout the inland Pilbara also generally indicate a recent age for tulas, further corroborating the sequence from Hope Downs 1. In the mining lease adjacent to Hope Downs 1 (BHP Mining Area C), there are recent age determinations for adzes. Comtesse and Harris (2009: 151-152) report radiocarbon dates of seven adzes (each from different sites) that range in age from 462±59 BP (506±68 cal BP; Wk-19783; Site MACE FS1) to 195±35 BP (179±93 cal BP; Wk-19768; Site MAC04-01). Similarly, Harris (2000: 18) reports a date of 310±50 BP (Wk-8364; 385±69 cal BP) for a tula recovered from Spit 2 at Site RR3-O in West Angelas. A burren was also recovered from Spit 3 at Site RR3-O, indicating it was deposited sometime prior to 310 years ago (Harris 2000: 25). At Site P4623 (Packsaddle Ridge), a tula was found in deposits reported to be less than 690 years old (Brown 1987: 48). One of the earliest reported specimens was recovered in Spit 4 at Mesa J23 (Hughes and Quartermaine 1992: 86). Spit 4 was initially reported to date to 650±190 BP (Hughes and Quartermaine 1992), which is consistent with the age of tulas from Hope Downs 1; however, a recent paper indicates that Spit 4 dates to 2230±160 BP or 2240±212 cal BP (Hughes *et al.* 2011: 59). Hughes (2012, pers. com., 13 Jan.) indicated that the spit data was 'internally inconsistent' and that the tula indeed relates to the 2230±160 BP date. While discrepancies such as this are understandable, it does bring doubt into the antiquity of this tula.

Eloueras were not a common component of the excavated assemblages from Hope Downs 1. Three eloueras were recovered *in situ* from AU3 at Jundaru (41.5-46cmbd). There are no radiocarbon dates for these artefacts, but they are believed to have a similar temporal distribution as the burrens and tulas recovered from Jundaru. One elouera was also collected from the surface of HD07-1A-03 (Cropper 2012c), suggesting that these artefacts continued to be utilised into the recent past.

Twenty-four burins were recovered from the excavated assemblage at Jundaru, and they predominantly occur in AU1 and AU2, but there is also one specimen identified in AU6. Apart from the outlier in AU6, the deepest burins were recovered between 45 and 50cmbd, and they continue up throughout the sequence. The provenance of burins at Jundaru indicates that their chronological distribution generally parallels that of tulas, burrens, and eloueras; although, they may occur slightly earlier. Three burins were identified at HD07-3A-03, including specimens from the surface, AU1, and AU2. Radiocarbon dates from the site suggest that they are less than 600 years old. While most burins are found in late Holocene contexts, a transverse burin was identified at HS-A1 (U2-L12), and the identification of this artefact in AU5 demonstrates that burin technology was utilised as early as 40,248±936 to 40,670±939 cal BP. The data suggests that burination has occurred since the initial occupation of the inland Pilbara, but it was not until the recent past that burins became a common component of the artefact assemblage.

Artefact Function

Backed artefacts, burrens, and tulas, which appear to have been used in conjunction with hafts or resin grips, may have been a technological response to subsistence risk during periods of less favourable climatic conditions. Many researchers have suggested that risk minimising strategies were employed in the production of tools associated with food procurement (Bamforth and Bleed 1997; Bousman 2005; Bousman 1993; Hiscock 1994; Myers 1989; Torrence 1989; Winterhalder *et al.* 1999). Maintainable design and reliable design are two systems that can be used to describe the production of tools associated with high-risk activities (Bleed 1986; Hiscock 2006). In reliable systems, tools are carefully made so that they are stronger than necessary, and they often have redundant components that act as a backup (Bleed 1986: 739-740). Reliable tools are designed so that it is unlikely that they will break, and they are often utilised for activities that are planned or scheduled and have severe consequences if failure occurs (Torrence 1989: 62-63). Maintainable systems have a modular design, and if a component is broken during use, it can be repaired with a kit containing replaceable parts (Bleed 1986: 739-740).

The backed artefacts, burrens, tulas, and eloueras in the Hope Downs 1 assemblages were normally, but not always, produced from high quality raw materials, thereby increasing their reliability and maintainability within the system. Based on the ethnographic evidence of tula use, as well as observations of the stages of tula reduction and usewear, it is clear that these artefacts were reliable tools that were hafted and resharpened over a period of time. When the tula was no longer efficient, it was removed from the haft and replaced with a functional specimen. Because tula hafts are seldom (if ever) recovered during excavations, we tend to focus on the tulas themselves, but these are the disposable working edges of the tool. Much more time and energy would have been required to fashion the wooden hafts than the tulas (Keeley 1982). The Djadjiling data has shown that hafting occurred much earlier than the first appearance of tulas, and many of the Pleistocene hafted artefacts were utilised for woodworking (Fullagar 2012). Perhaps this suggests that the establishment of a formalised design for tulas enabled easier replacement within the haft?

Backed artefacts appear in a variety of different forms, and research suggests that they were used as multi-functional composite tools (Fullagar 2011; Robertson *et al.* 2009). Low's (2010, 2015) research on Bondi points in eastern NSW found a high degree of standardisation among the specimens, suggesting that they could have been used as replacement parts within a maintainable system. In the Hope Downs 1 assemblages, there are at least 129 complete backed artefacts, as well as numerous broken specimens (identifiable to subtype) and backed artefact fragments. The quantitative attributes for the complete backed artefacts are presented in Table 18-3, which indicates that Bondi points and elongated crescents are generally longer and narrower than any of the other backed artefact types. Crescents, trapezes (including those with no lateral backing), and triangles all have similar average dimensions. Apart from irregular specimens, the elongated crescents show the greatest variation in their lengths.

Table 18-3 Average dimensions of all complete backed artefacts at Hope Downs 1

Artefact Type		Average (mm)	Min (mm)	Max (mm)	SD
Bondi Point (n=11)	Length	29.16	17.86	37.18	4.85
	Width	8.85	5.29	13.20	2.32
	Thickness	4.33	2.54	7.03	1.47
Crescent (n=40)	Length	22.74	13.30	36.62	5.63
	Width	16.18	6.47	25.01	4.63
	Thickness	4.58	1.64	8.59	1.48
Crescent – E (n=8)	Length	25.52	13.12	38.80	9.15
	Width	6.30	2.19	10.75	3.29
	Thickness	3.34	2.17	5.59	1.25
Irregular - Asymmetrical (n=3)	Length	17.04	7.50	30.93	12.30
	Width	10.98	8.90	12.94	2.02
	Thickness	3.83	2.05	6.35	2.24
Oval (n=1)	Length	17.58	17.58	17.58	-
	Width	11.20	11.20	11.20	-
	Thickness	4.05	4.05	4.05	-
Trapeze (n=13)	Length	23.02	17.27	28.40	3.79
	Width	15.04	8.30	21.60	3.44
	Thickness	4.41	2.59	9.42	1.90
Trapeze – NLB (n=33)	Length	23.13	10.67	41.56	6.33
	Width	14.85	8.05	23.49	3.40
	Thickness	3.43	1.78	7.13	1.32
Triangle (n=20)	Length	22.83	12.00	34.48	5.50
	Width	15.04	10.90	19.15	2.62
	Thickness	3.90	1.95	6.79	1.51

When the data is plotted by length and width, as is pictured in Figure 18-1, Bondi points and elongated crescents cluster together to form a quite distinct group from other backed artefact types. The fact that these two backed artefact forms fall within the same spectrum, implies that they may have served a similar function.

There are a small number of other backed artefacts that overlap, in particular the symmetrical specimens of the classic 'geometric microlith' type with this group. Crescents, trapezes, and triangles show a great deal of overlap; although, the crescents have a broad range of widths and triangles have a narrower range of widths. Having said that, the average width data shows that crescents, trapezes (including those with no lateral backing), and triangles have similar widths and there is less overall variation than amongst backed artefact length. This may indicate that the width of these backed artefacts was more important than their length. This is well-illustrated by the similar average widths of trapezes with and without lateral backing at Jundaru.

In short, the data from Hope Downs 1 does generally suggest that backed artefacts were produced in fairly standardised shapes, supporting Low's theory that backed artefacts, such as Bondi points, were manufactured as readily replaceable components within a maintainable system.

Seventy-one backed artefacts from Jundaru were examined for usewear and residues, including 65 symmetrical backed artefacts, five Bondi points, and one fragmentary backed artefact. The majority of these backed artefacts exhibit evidence of having been hafted (n=42; 59%), and an additional six artefacts have residue that may be resin (Fullagar 2013a). This data provides compelling evidence indicating that many backed artefacts were used as composite tools.

Usewear patterns indicate that an average of 40.85% of the sample show usewear traces that are focused on the tips (based on Fullagar, this volume). When the data is compared by backed artefact subtype, triangles have the highest incidence of this type of usewear, followed by crescents. Usewear focused on the tip is slightly less common amongst Bondi points, trapezes with no lateral backing, and trapezes. Most of these artefacts have only minor tip damage, and clear evidence suggesting that they were likely used as barbs or projectile tips is less common.

Crescents and triangles have a greater incidence of usewear, suggesting they functioned as barbs or projectile tips, while the elongated crescents showed no such usewear. Bondi points and trapezes with no lateral backing show a low frequency of usewear characteristic of barbs and projectile tips. One of the backed artefacts submitted from PAD 3 (Artefact 575; irregular asymmetrical backed artefact) exhibited spin off fractures indicative of projectile damage, while other backed artefacts had usewear indicative of several modes of use (Fullagar 2011).

While this research indicates that some backed artefacts may have been utilised as projectile tips, it also demonstrates that there was diversity in the mode of backed artefact use. Fullagar (this volume) identified various modes of use amongst the backed artefacts, including awling, cutting, piercing, graving/drilling, scraping, slicing, and projectile impact. Many of the backed artefacts were utilised on a range of materials (*e.g.*, soft tissue, wood, and plant tissue), but the material worked was uncertain in most cases (Fullagar, this volume). The data from Jundaru supports the theory that backed artefacts were 'multi-functional, multi-purpose and frequently part of composite tools used in both subsistence and craft activities' as suggested by Robertson *et al.* (2009: 298). It is also possible that some artefacts were recycled once they were de-hafted.

The tulas and eloueras from Jundaru analysed by Fullagar (2013a) show usewear traces consistent with woodworking. One of the eloueras appeared to have been a hand-held implement, while the other two specimens were hafted. Fullagar (2013a) noted that the usewear on the tulas appeared more grainy than on experimental specimens, which may signal that they were utilised for a broader range of tasks than adzing or scraping wood. The scrapers submitted for analysis also showed signs of having been utilised to work wood (Fullagar 2013a). Burins are a common component of late Holocene assemblages, although they occasionally appear earlier in the archaeological record at Hope Downs 1. Fullagar (2013a) analysed 12 burins from Jundaru, and he concluded that burination was utilised to sharpen or rejuvenate the burin bit, which generally showed usewear consistent with woodworking. One specimen is believed to have been used as a graver (Fullagar, this volume).

A significant outcome of the usewear analysis of artefacts from Djadjiling is that there is evidence of hafting in the earliest

phase of occupation (Fullagar 2012). None of the artefacts in the early sequence at Jundaru that were submitted for usewear analysis exhibit usewear traces or residue that are consistent with hafting (Fullagar 2013a); although, only a small sample from this sequence was submitted for analysis. Hafting is a technological innovation that increases the amount of force that can be applied with the tool, and it enables greater efficiency or precision with which a stone artefact can be used (Rots 2003: 805). Two different modes of use are apparent on the specimens with evidence of hafting; most specimens appear to have been used for scraping (wood and uncertain materials) and there is one artefact that has usewear typical of awls used for working skin (Fullagar 2013a). Hafting appears to have been a technology that was present during the colonisation of Australia (Stern 2009; McConnell 1997), but the extent to which hafting was utilised is a research subject that has largely gone investigated. The evidence from Djadjiling suggests that hafting was a common strategy, particularly for tools associated with woodworking.

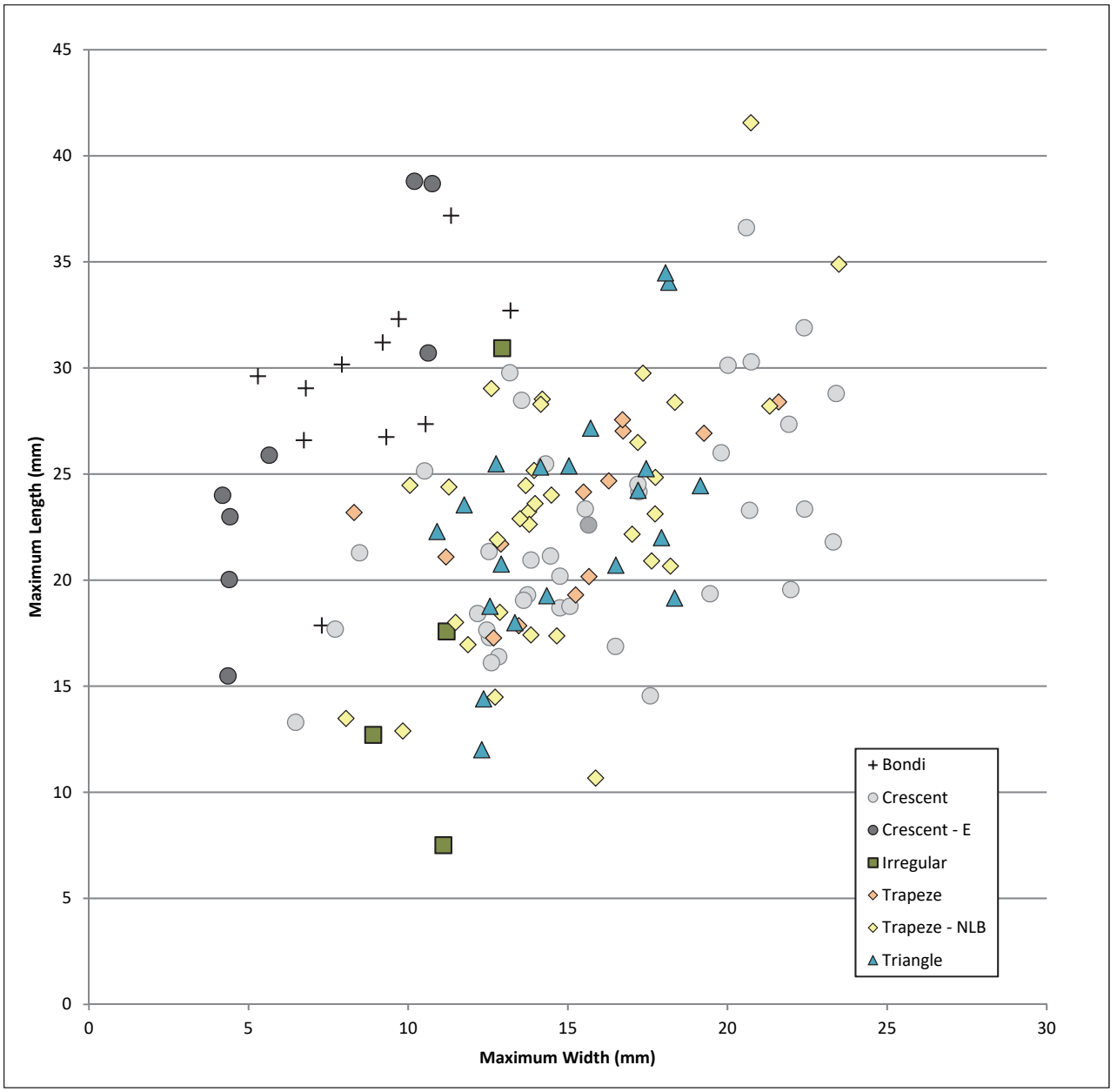

Figure 18-1 Scatter plot of length and width for all complete backed artefacts at Hope Downs 1

18.5 SITE FORMATION PROCESSES

The accumulation and preservation of deposits within the rockshelters of the Pilbara is only marginally understood. Individual rockshelter sediments vary considerably based on the local bedrock, individual geomorphological circumstances, and erosional patterns. The following sections aim to address issues of sedimentation and preservation in Hope Downs rockshelters.

Sedimentation within Rockshelters

Rockshelter deposits may comprise three sediment types: geogenic, biogenic, and anthropogenic (Farrand 2001: 539). Geogenic sediment is deposited through natural erosional processes. In the rockshelters investigated at Hope Downs 1, the sediment is primarily geogenic, consisting of shaly fragments of exfoliated roof spall intermixed with fine sediments derived from windblown dust particles as well as the chemical weathering of the exfoliated rock fragments and bedrock. The proportion of rock fraction varies amongst the sites and generally increases with depth. The excavation at HD07-3A-PAD13 also demonstrated that there is the potential for low-lying rockshelters to have fluvial deposits. While fluvial deposition appears to be a rare mode of sediment deposition in rockshelters, HD07-3A-PAD13 demonstrates that the archaeological potential of low-lying rockshelters should not be overlooked. Thus, careful attention to sediment type needs to be carefully considered when assessing sediment depth potential.

Precipitated minerals are also present in many rockshelter deposits as the result of rainwater percolating through the bedrock and sediment. Highly cemented sediment was encountered at HS-A1 rockshelter and Jundaru, and it was also encountered at other sites but to a lower degree. The analysis of the samples shows that even within the small project area, the composition can vary. Halite was the principal mineral in the cemented sediment at HS-A1, while gypsum was prevalent at Jundaru (Gilkes and Yusihami 2013). Halite and gypsum are chemically precipitated salts, which are deposited when saturated water moves through the sediment (Warren 2006: 2, 38). At both sites, the cemented sediment was found in greatest abundance near bedrock, demonstrating that salt-enriched water was flowing through the bedrock and into the sediment. Excavators also observed that it was possible that some mineral-rich water may drip onto the sediment from the rockshelter roof, thereby causing patchy cementation.

Other minerals have been identified at numerous rockshelters, including fibrous calcite and kaolinite. Fibrous calcite was first encountered while excavating HD07-1A-02, brittle, white and translucent needle-like filaments were found throughout the sediment. Like the precipitated salts, the calcite generally occurs near bedrock and is likely precipitated as water percolates from the bedrock after heavy rains. Kaolinite is found at many of the Hope Downs 1 rockshelters, but was very prominent at Hope 1-39 and HD07-1A-02. Kaolinite is a product of chemical weathering and has a white powdery talc-like appearance with a greasy texture. Kaolinite often adheres to rocks, but it is often dispersed throughout the sediment, possibly due to human or macropod disturbance. When kaolinite is disturbed, it gives the surrounding sediment an ashy appearance. Care should be taken when excavating kaolinite-rich deposits to ensure that natural deposits are not mistaken for cultural features.

Biogenic sediments are derived from the plants and animals that have occupied the rockshelter (Farrand 2001: 539), and all of the rockshelter deposits have included this type of sediment. The animals and insects that inhabit the rockshelters contribute to the deposit through their droppings, which can introduce new material (*e.g.*, phytoliths, seeds, *etc.*) as well as affect the preservation of the deposit (as in HD07-1A-02). Bones may also be introduced into the site through faecal material, owl pellets, scavenged remains, or through natural death assemblages. The plants that grow near to and within the shelter also add organic material to the deposit through leaf litter and their roots.

Macropod activity is common in most rockshelters, as evidenced by abundant macropod faeces. Wallis (this volume) noted that macropod faeces can add a significant quantity of grass phytoliths to the deposit. Additionally, depressions on the shelter surface were often noted, particularly near the rockshelter walls, and these are interpreted to be sleeping nests. These areas show that it is possible for a macropod to shift significant amounts of sediment. Bat guano and leaf litter are also common biogenic components of rockshelter deposits. Stick nest rat materials and evidence of rodent burrowing are also not unusual. Mud wasp brood chambers and pupal cases were commonly encountered during excavation. A high density of mud wasp brood chambers were identified at HD07-3A-PAD13, and the abundance of brood chambers at this site is likely related to the presence of fine silty loam at the site. Because mud wasps construct their brood chambers on the rockshelter ceilings and they eventually fall to the ground, they are not a source of disturbance to the deposit. Burrowing water-holding frogs were identified during excavation of Jundaru and PAD 4 (Cropper 2011b: 204), and they may have a considerable impact on the preservation of the deposit. Other burrowing insects are likely to have affected the deposits in many rockshelters, with termites being the most common. Locusts were also identified at HS-A1. It is important that biogenic sediment is recognised as well as the potential for bioturbation.

The primary anthropogenic sediment identified in rockshelters is ash and charcoal remaining from combustion features; although, other organic material was also introduced into sites through human activity (*e.g.*, faunal remains). PAD 3, Jundaru, and HS-A1 had the best preservation of combustion features and organic remains. The oldest feature identified is at Djadjiling (40,546±615 cal BP), but early features were also encountered at HS-A1 (28,200±188 cal BP) and Jundaru (19,820±172 cal BP).

Combustion features identified at the rockshelters include hearths, ash lenses, and charcoal lenses. Hearths are defined as combustion features that retain evidence of *in situ* burning, and they generally demonstrate a layered appearance (light ashy layer, followed by dark grey charcoal-rich layer over heat-affected sediment). Some hearths are ash-rich and do not exhibit the dark grey layer, but have a light grey matrix over reddened sediment. This variation may be due to the type of hearth and the fuel selection. The hearths vary considerably in size and shape, and a small number of pit-like features have been identified. These features may have been utilised as roasting pits. Ash and charcoal lenses do not exhibit evidence of *in situ* burning and are either ash-rich or charcoal-rich. The lack of reddened sediment beneath these features suggests that they are not hearths, as even minimal burning typically produces this effect (see Mallol *et al.* 2007). Ash and charcoal lenses may be discrete secondary deposits that were created through cleaning and maintenance of contemporary hearths. The maintenance of hearths is a good indication that the site was occupied for a considerable period of time, rather than only briefly. If the site was abandoned soon after the hearth was constructed, there would have been no requirement to maintain the hearths.

Preservation of organic materials in archaeological deposits is complex, and it can be affected by numerous factors such as

matrix composition, pH, diurnal temperature changes, and groundwater flow. PAD 3 had exceptional preservation of organic materials, including paperbark

Few sites investigated at Hope Downs 1 had well-preserved organic material that rivals the assemblage from PAD 3. A large faunal assemblage was recovered from Jundaru, and a smaller assemblage was recovered from HS-A1. Organic remains apart from charcoal were relatively rare. At HS-A1, faunal remains were recovered from 33 separate contexts and material was concentrated in the excavation units that were less affected by cemented sediment. While the faunal material from the site was not analysed, emu eggshell fragments were identified in Units 2 (Layers 4-5) and Unit 4 (Layer 9, 52.5cmbd). An assemblage of 3533 faunal specimens, representing at least 2611 individuals and 22 species, was recovered from Jundaru (McDowell,, this volume). The material was well-preserved, but highly fragmented making identification of many specimens difficult. Most of the faunal remains were identified as having been deposited as the result of the past human occupation. It is possible that the precipitated salts at Jundaru and HS-A1 may have improved the preservation of organic materials to a degree, but the highly cemented sediment at HS-A1 likely limited the recovery of both faunal and macrobotanical material. Additionally, it is likely that these sites naturally had a greater abundance of faunal and macrobotanical remains due to greater past activity at these sites.

The rockshelters investigated at Hope Downs 1 have also demonstrated that there can be variation in the type of bedrock that is encountered at the base of the excavation. At most sites, the bedrock exposed across the base of the trench is very degraded and weathered, and several centimetres (if not tens of centimetres) of this degraded bedrock can be removed before solid bedrock is encountered (*e.g.*, HS-A2). Often halite and similar gypsum mineralisation has contributed to the fragmentation of the bedrock. More rarely, the bedrock can be extremely hard and have a polished appearance, such as at PAD 3. The bedrock exposed across the trench at both Jundaru and Djadjiling was also relatively well-preserved (apart from a few weathered areas), but it did not have the polished appearance of the bedrock at PAD 3. These experiences demonstrate the importance of understanding the site formation processes within the study area and recognising considerable differences may exist from site to site.

The Accumulation and Preservation of Rockshelter Deposits

The accumulation and preservation of rockshelter deposits is a complex issue that has not been well-documented in the Pilbara. There are numerous erosional processes that can effect the preservation of sediment in rockshelters, including wind erosion and water erosion. Rainfall can affect rockshelter deposits through both splash erosion and sheet erosion through overland flow. Because there is so little sediment and large exposures of bedrock in the ranges where the rockshelters are located, there is low infiltration and high rates of overland flow. High-energy flood waters moving down ephemeral channels can also erode the deposits in low-lying rockshelters.

Rockshelters that have protected entrances (*e.g.*, roof collapse or through the natural geomorphology) are likely to be less affected by erosional processes. In most cases, the rockshelters at Hope Downs 1 that have deep accumulations of sediment are typically high on the hillslope above ephemeral gullies and most have large accumulations of roof collapse at the entrance that protect the deposit. The high position on the hillslope may protect many of the rockshelters from high-energy floodwaters during heavy rainstorms. The roof collapse may protect the deposit against wind erosion, as well as acting as a natural sediment trap for aeolian sediment. The roof collapse could also stabilise the deposit and prevent downslope movement.

The aspect of the rockshelters may be an important factor in the preservation and accumulation of deposits. Currently, easterly prevailing winds are predominant in the region (Bureau of Meteorology 2009); hence, the winds originate in the east and blow towards the west. However, it is possible that there may have been some variation in the direction of prevailing winds over time, as changes in the wind regimes, likely due to shifts in the circulation systems, have been identified elsewhere in Australia (see Fitzsimmons *et al.* 2013). Because there is significant regional variation (Fitzsimmons *et al.* 2013), it is not possible to quantify how such changes affected the local area. Wind not only deposits fine-grained materials within rockshelters, but it also erodes deposits through deflation. Many of the sites with deep deposits have east aspects (Table 18-4), and if easterly prevailing winds were also experienced in the past, the orientation of these shelters may have protected the deposits from the erosional forces of the wind. Jundaru has a southwest aspect, while Hope 1-41 and HS-A2 have west aspects. Each of these shelters has large accumulations of roof collapse, which likely helped to preserve the deposit against wind erosion as well as erosion from driving rain. The sediment accumulation at HS-A1 is lower than at other Pleistocene sites, and this may be due to the broad and unprotected entrance. The rockshelter has an east aspect and this may have reduced wind erosion.

There are few low-lying rockshelters that have deep deposits, but HD07-3A-PAD13 and HD07-1A-07 are two exceptions. HD07-3A-PAD13 is low lying and does not have a significant accumulation of roof collapse along the entrance; however, the site formation processes are considerably different from the other sites with deep deposits. The sediment within the rockshelter is a continuation of a low alluvial terrace that was deposited through low-energy floodwaters (M. Williams, this volume). This site demonstrates that low-lying sites, particularly those near to alluvial terraces, should be carefully evaluated for their potential of having sub-surface cultural remains. HD07-3A-03 and HS-A2 occur within the vicinity of HD07-3A-PAD13 and also have reasonably deep deposits. HD07-1A-07 is also relatively low-lying and does not have an expanse of roof collapse at the entrance. This rockshelter has a narrow entrance with an east aspect, which may have helped protect the deposit (Cropper and Law 2012b). Additionally, there is a flat and heavily vegetated area in front of the shelter that may have helped to protect the deposit from erosional processes (Cropper and Law 2012b).

There are numerous rockshelters investigated at Hope Downs 1 that have very shallow deposits, and sites with dated assemblages (*e.g.*, Hope 1-16, Hope 1-39, Hope 1-46, and PAD 1) suggest that sediment has accumulated in these shelters within the last millennium. It is likely that these rockshelters had earlier deposits that were routinely scoured away. Many of the sites with shallow deposits are either low-lying, have minimal overhangs, or are oriented in such a way that they would have been susceptible to overland flow. If this hypothesis is correct, then there is a bias in the archaeological record towards recent sites.

It is difficult to quantify the complexity in sedimentation observed in the Hope Downs 1 rockshelter excavations. As noted above, there is significant variability in sediment depths, and depositional processes. Now that we have excavated a number of Pleistocene rockshelters, we can offer some sedimentation generalisations that may be useful to future excavators. By no means are these observations absolute, they are merely generalisations gained from excavating several deposits exceeding two metres in depth.

Our excavation generalisations may be summarised as the following. The upper 10-20cm of deposit is normally greyish-brown and rich with kangaroo faeces. This is not surprising, but it does give archaeologists pause to consider what disturbances the deposit has succumbed to over millennia. Eventually, the faeces rich sediment will disappear. If lucky, the excavator may encounter formal implements such as tulas and backed artefacts to provide an indication of Holocene sediment age. Sometimes artefact numbers will decrease significantly when early Holocene deposits are reached, but by no means is this always true.

It is not uncommon to encounter a striking red to reddish brown sediment when excavating deep Pleistocene age deposits. The red colour is likely due to the lack of fine organics preserved in the sediment and mineral leaching over time. After excavating a few layers into the bright red sediments, it is not unusual to encounter large boulder-sized rockfall. Rockfall is more common in cold and dry conditions, which may indicate peak LGM conditions. If it is possible to chisel through or excavate beneath the rock fall, pre-LGM deposits may be reached. Artefact numbers often increase in the pre-LGM layers.

The above description is merely based on field experience and observations. We offer it to help others that may find themselves on a major salvage project in the Pilbara one day.

Potential Archaeological Deposits

After investigating a variety of different rockshelters, it has become apparent that in the Hope Downs 1 lease, most rockshelters with accumulated sediment contain buried cultural remains (Table 18-4). Rockshelters should not be judged according to the presence or absence of artefacts on the shelter surface. Archaeologists should be extremely cautious when evaluating the archaeological potential of rockshelters. Shelters with accumulated sediment should be recorded and investigated regardless of their size. This point is well-illustrated by HD07-3A-PAD13, which was initially disregarded as a potential archaeological site as it was low-lying, had a low ceiling height, and there were no observed surface artefacts. Fortunately, the site was later recorded as a rockshelter with a PAD and subsequent excavation revealed an archaeological sequence spanning over 45,000 years.

Table 18-4 Summary of rockshelters excavated by ACHM at Hope Downs 1

Project Stage	Site Name	Location	Assemblage Size	Max Deposit Depth (cm)	Entrance Aspect	Large Roof Collapse at Entrance	Approximate Age Range
MIB25	HOPE 1-24	HN	9 (surface only)	0	E	No	No dates; likely recent
	HOPE 1-43	HN	14	49	E	No	No dates; likely mid-Holocene to recent
	PAD 2B	HN	7	58	SW	No	No dates; likely mid-Holocene to recent
	PAD 3	HN	585	50	W	Yes	Early to late Holocene
	PAD 4	HN	850 (1 surface)	66	E	No	Mid-Holocene to recent
	PAD 5	HN	21	58	E	Yes	No dates; likely mid-Holocene to recent
	PAD 6	HN	9	45	E	No	No dates; likely mid-Holocene to recent
MIB50	HD07-1A-02	HS	126 (9 surface)	25	W	No	No dates; likely recent
	HD07-1A-03	HS	16 (8 surface)	8	W	No	No dates; likely recent
	HD07-1A-04 (Djadjiling)	HS	1316 (1 surface)	210	E	Yes	Pleistocene to recent
	HD07-1A-07	HS	365 (1 surface)	71+	E	No	Early Holocene to recent; possibly Pleistocene
	HD07-1A-22	HS	2 surface	27.5	E	No	No dates; likely recent
	PAD 7	HS	0	35.5	E	No	NA - not an archaeological site
MIB40	HD07-3A-03	HS	5180 (57 surface)	60	W	No	Mid-Holocene to recent
	HD07-3A-13	HS	0	68	NW	No	No buried material just MMS
	HD07-3A-17	HS	9	50	SW	No	No dates; likely mid-Holocene to recent
	HD07-3A-PAD05	HS	1 surface	21.5	NE	No	No dates; likely recent
	HD07-3A-PAD07	HS	22 (1 surface)	41.5	SW	No	No dates; likely mid-Holocene to recent
	HD07-3A-PAD13	HS	1718 (4 surface)	214.5	E	No	Pleistocene to recent
	HN-A7	HN	180	76	E	Yes	Early Holocene to recent
	HN-A9 (Jundaru)	HN	26,181 (5 surface)	171	SW	Yes	Pleistocene to recent
	HOPE 1-16	HN	93 (1 surface)	24.5	NW	No	Recent
	HOPE 1-17	HN	36 (5 surface)	32.5	N	No	No dates; likely recent
	HOPE 1-22	HN	15 (1 surface)	11	W	No	No dates; likely recent
	HOPE 1-39	HN	121 (25 surface)	27	E	No	Late Holocene to recent
	HOPE 1-40	HN	4 (2 surface)	50	W	No	No dates; likely Late Holocene to recent
	HOPE 1-41	HN	324 (16 surface)	116	W	No	Pleistocene to recent
	HOPE 1-46	HN	159	18.5	E	No	Recent
	HS-A1	HS	1430 (1 surface)	82	E	No	Pleistocene to recent
	HS-A2	HS	630	82	W	Yes	Early Holocene to recent
	PAD 1	HS	212 (4 surface)	74	SE	No	Late Holocene to recent

Over the course of the Hope Downs 1 investigations, nine sites with potential archaeological deposits were excavated. Artefacts were identified at each site, with the exception of PAD 7. Just one surface grindstone was recovered at HD07-3A-PAD5. Three sites with potential archaeological deposits are demonstrated to have archaeological remains, including HD07-3A-PAD13, PAD 3, and PAD 4. PAD 3 had numerous well-preserved hearths and has provided one of the earliest dates for backed artefacts in the inland Pilbara, and a large artefact assemblage was recovered from PAD 4 (albeit from disturbed contexts). HD07-3A-PAD13 had a deposit nearly two metres deep and an occupation sequence spanning over 45,000 years. At the remaining rockshelters with potential archaeological deposits, only small artefact assemblages were recovered. The proportion of rockshelters with potential archaeological deposits that had no buried cultural material is low (22.22%) and this is comparable to the proportion of rockshelters that had surface artefacts or man-made structures but no buried artefacts (13.63%).

The excavation of numerous rockshelters at Hope Downs 1 has illustrated that rockshelters are dynamic environments and their present physical characteristics may be very different from how they were in the past. Rockshelters such as Jundaru, HD07-3A-PAD13, and Djadjiling also demonstrate that the appearance of the shelter changes through time. These changes may include reduction of the rockshelter size through roof collapse, or variation in the spaciousness of the shelter due to the accumulation of sediment over time. At Djadjiling and HD07-3A-PAD13 (as well as some areas of Jundaru), the average ceiling heights are currently very low, but when these shelters were first occupied, the floor level was approximately two metres lower

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