COMMUNITY ARCHAEOLOGY

WORKING ANCIENT ABORIGINAL WETLANDS IN EASTERN AUSTRALIA

Edited by
Wendy Beck, Catherine Clarke
and Robert Haworth



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Dedication

The editors would like to dedicate this book to family we lost during the project, for all your years of support and encouragement

Merlin Benjamin Beck 1928-2015

Fabian Haworth 1984-2018

Annette Marshall 1946-2019

Summary

This book has three concurrent aims for investigating wetland heritage as well as increasing opportunities for Australian Aboriginal people to be partner researchers. The research questions are: (1) To undertake a landscape archaeology associated with 'lagoons' (depressional wetlands) of the Tasmanian Midlands region and the New England Tablelands region in eastern Australia (2) To establish whether archaeological research of ancient landscapes can contribute to the theory and practice of community archaeology and (3) To investigate whether successful engagement and educational outcomes can be achieved, using Fraser's ideas (2001) about the 'politics of recognition' as well as Work Integrated Learning.

The book reports several important discoveries which contribute to the archaeology of the Tasmanian Midlands and New England Tablelands. Ours was the first substantial project carried out in these bioregions since 1991. Rockshelters are rare here. Previously no dated sites in New England extend beyond the early Holocene but using OSL and radiocarbon dating at six lagoon sites we obtained dates going back to 8000BP. In both Tasmania and New England a range of new stone artefact scatters were recorded adjacent to lagoons.

Across Tasmania and New England 37 new OSL dates were obtained for lunette formation. These were diverse, ranging from Last Glacial Maximum (LGM) dates in Tasmania to a wider range in New England starting at 70 ka. Records of lunette initiation may indicate drier previous climates which provide sediments for subsequent deflation. However, unexpectedly, our OSL dates (11 sites) were not clustered around the Last Glacial Maximum at 20 k, but ranged from 72 k to 2.2 k in New England and from 48.5 k to 7.2 k in Tasmania. The sediment particle sizes suggest both wind and water deposition. This suggests individual local depositional histories for the lunettes, rather than deposition related to global climate variation.

This book contributes to the important global field of community engagement and education. Unlike most projects where Aboriginal people are involved in commercial archaeology, this project was focused on archaeological research. Elders from the community participated fully in the project. They were equal partners in the research team during field-work and training. This is Fraser's 'politics of recognition'. Work integrated learning was very successful as a site of learning and included partly University locations and partly work on country. The book reports community archaeology which has global implications.

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Lagoons Aboriginal Reference Group 2012-2016 consisted of the (then) CEOs of the four Local Aboriginal Land Councils where the research took place. These were: Armidale LALC (Colin Ahoy (Snr) and Michael Brogan); Guyra LALC (Jeffrey Ho); Anaiwan LALC (Greg Livermore) and Glen Innes LALC (Trevor Potter and Karen Potter). In addition, the following Aboriginal Elders were part of the field teams: Colin Ahoy (Snr), Armidale LALC; Esther Gardiner (BA) Tingha; Isabel Williams, Anaiwan LALC; Dick Blair, Anaiwan LALC; Lee Patterson, Guyra LALC; Eileen Livermore, Glen Innes LALC; Karen Potter, Glen Innes LALC and, Trevor Potter, Glen Innes LALC. These contributors guided the overall project through regular meetings and field-work.

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Aboriginal and Torres Strait Islander people should be aware that this book may contain images, words and names of deceased persons.

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Unless otherwise stated, all figures and tables were completed by the chapter authors.

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Introduction

Wendy Beck and Robert Haworth

This book is about a study of the archaeology and geomorphology of ten lagoons located in two widely separated but analogous regions, namely the New England Tableland in north-eastern New South Wales (NSW) and the Tasmanian Midlands.

The project had its beginnings in the interests of team leader Wendy Beck in water use history and archaeology as a member of the Water Perspectives research group at University of New England, Australia and in discussions with human geographer Judith Burns who has a long history of working with Aboriginal people in New England. At the Australian Archaeological Association Conference in 2010, which had the themes of 'Challenges for archaeology in understanding cultural and natural landscapes: local national and global perspectives', Richard Fullagar and Anne McConnell joined our discussion of comparative landscapes in New England and Tasmania, all of us having been archaeological friends since the early 1980s. This was cemented by follow up discussions with physical geographer Kevin Kiernan in Tasmania in early 2011. A larger team of researchers was put together from this beginning [see Chapter 1 for the full team list]. Around the same time in 2010 a project led by Jamie Shulmeister at the University of Queensland was exploring the palaeoenvironment of lagoons such as Little Llangothlin in New England, and our teams overlapped with Bob Haworth and Kevin Keirnan both being joint team members. Our grant application was successful in 2011 and the field project began in early 2012, with preliminary discussions and field-work to narrow the choice of lagoons. Two fields-schools were held in New England in 2013 and in 2014 a Tasmanian field-school was held. In 2015 time was spent obtaining various field-work permits for the research excavations which took place in 2016 and 2017. The final Australian Research Council report was submitted in 2018, and this book was born.

It describes a community archaeology investigation of researchers working in partnership with the local Aboriginal people and corresponding work experience programs. The project was funded by a large Australian Research Council grant, Working Ancient Wetlands for Social Benefit and Cultural Understanding (DP120102316). This introduction describes the history and rationale of the project, its key outcomes and our general approach. It also gives a general outline of the background to the two study areas in NSW and Tasmania (See Figure I.1, map of Australia showing regions), as an introduction to the book sections which follow.

What is a lagoon?

Before going further, we need to define the meaning of lagoon as this is a central element of this book. 'Lagoon' is a local term used in the highlands of eastern Australia to refer to a series of shallow upland lakes and ponds. These wetlands are found in similar geomorphic locations world-wide on the drier inland side of the plateaus and tablelands of passive continental margins in all of the southern continents and many of the northern ones. In other parts of the world researchers have named these particular landforms as 'depressional wetlands', 'pans' or 'endorheic wetlands' (Goudie *et al.* 2016). They are typically located in saucer-shaped areas of negative relief with closed or semi-closed drainage, on flat or gently undulating landscapes which in New England are often associated with Tertiary basalt flows. Present vegetation ranges from sparse to a diversity of aquatic and semi-aquatic plants (especially sedges and reeds), depending on the type of substrate and range of water fluctuation (Bell *et al.* 2008; De klerk 2016). Even when full, these lagoons are rarely more than 1.5 m deep. Lagoons differ from other



Figure I.1 *Map of Australia showing study regions (K. Newman)*

wetlands of eastern Australia in morphology and location. Most are oval-shaped with distinct rocky margins, though with considerable recent siltation occurring on lagoon edges (Haworth 2006).

However, a distinguishing feature of many lagoons are the landforms known as lunettes. Some of the lagoons have either sand dunes or clay-rich mounds on their eastern (lee) side–called 'lunettes', because of their typical wind-formed crescent shape—probably products of deflation or wave action formed under different local climatic conditions during the glacial cycle (Bell *et al.* 2008). The lunettes provide a sedimentary and archaeological archive, and in some regions may have been a preferred campsite for Aboriginal people.

The lagoons in our study regions ranged from less than one hectare to over 20,000 hectares in size and about two thirds have lunettes, as well as other types of dunes. The New England water bodies are generally smaller than the Tasmanian sample. The accompanying lunettes have been subject to intense study in other world-wide locations, such as Khazakistan, South Africa, South Carolina and the Kansas High Plain (See Chapter 11). Recent studies using remote sensing have investigated large numbers of lunettes, which as in the eastern Australian highlands are often found in association with large flat plains at high altitude (Goudie *et al.* 2016). Of the wetlands we surveyed many had archaeological surface remains—more in Tasmania than in New England. Possibly this variation has to do with the nature of occupation and resource use, as well as wetland resource types. This variability is one of the foci of our investigation.

Goals of the project

This project has a number of concurrent aims including both investigating lagoon heritage and increasing opportunities for Aboriginal people to partner researchers in educational settings. The general goals were:

1. To establish whether archaeological research into ancient landscapes can contribute to the theory and practice of community heritage engagement and help 'close the gap' in Aboriginal higher education by using Fraser's ideas (2001) about the 'politics of recognition' as well as work integrated learning.

2. To undertake a comparative landscape archaeology of lagoons and lunettes in the Tasmanian Midlands region and the New England Tableland region—especially to determine whether the apparent sparsity of Aboriginal occupation in environmentally similar regions of the NSW New England Tablelands and the Tasmanian Midlands during and before the Mid-Holocene is due to the paucity of archaeological field-work or other factors. What was the mode of the occupation in these areas? Was it permanent, transitory or perhaps an alternating pattern of the two affected by climatic and social conditions?

Previous knowledge about ancient New England

The New England region for this project corresponds with the New England Bioregion which is a stepped plateau of hills and plains with elevations between 600 m and 1500 m on Permian sedimentary rocks, intrusive granites and extensive Tertiary basalts (NSW Department of Planning, Industry and Environment 2021) (See Figure I.2). The bioregion lies mainly in the temperate to cool temperate climate zone of NSW, which is characterised by moderate summer heat and cool winters, with relatively uniform rainfall but with summer maximums (Australian Government, Bureau of Meteorology 2021). Hunter-gatherers of the past have inhabited all of the New England for thousands of years but little is known of Pleistocene occupation as the previously oldest site on the Tableland (near Bendemeer on its southern margin) is only 4300 years old (Bowdler and Coleman 1981; McBryde 1974). Further to the west (180 k from Armidale) outside the New England bioregion, re-dating of the Graman rockshelter GB1 provided a basal date of 7840 BP (8642-8589 cal BP) (Boot 1990: 89). Our work has extended this date to c. 8000 BP at a lagoon site near Uralla 50 km north of Bendemeer. Archaeology and linguistics suggest that the Tableland has been most heavily occupied from about four thousand years ago (Beck 2006; McBryde 1974). At this time coastal peoples from the east and south east migrated to the Tableland and over time formed relationships with western peoples (Beck *et al.* 2015).

Radiocarbon ages from the lunette and basin floor sediments of Little Llangothlin Lagoon at Guyra in northern NSW (Ellerton *et al.* 2017) suggest formation around 19,000 years BP—broadly similar to the formation age of lunettes in other parts of the Murray Darling Basin. However, the one clay lunette we sampled (Barley Fields lunette at Uralla) suggested a formation date before 48,000 years BP. Whatever the ages, the processes involved suggest that unlike most lakes, these lagoon-lunette basins tend to be renewed by deflation (wind erosion) over periods of tens of thousands of years and, as their catchments are small, they are rarely completely infilled during their sedimentation stage. So, while even large and deep lakes have a limited lifespan from sedimentation, the upland lagoons could be some of the oldest wetlands on Earth because of their balancing processes of deflation and accumulation, despite their shallow and often ephemeral nature. Associated sediment sinks such as source bordering dunes could contain long term archaeological and environmental archives. However, the lagoon floor sediments are rarely more than several metres deep, and radiocarbon dating of the peat fraction of these sediments (Gale and Haworth 2005: 129; Woodward *et al.* 2014) indicates that the present cycle of sedimentation commenced ~15 000 years ago as climate became wetter and warmer after the last Glacial Maximum.

A dominant theme in New England archaeology is climate. The whole of the Australian south-eastern highlands between thirty and ten thousand years ago, including the New England Tableland, was a cold, tundra-like environment. On the tableland, the zone would have consisted of cold steppe grassland, with some shrubs and eucalypt woodland in protected locations (Woodward *et al.* 2014). This was a fairly harsh environment with few food resources, quite unlike the present environment, so it is difficult to say exactly what the plant food resources were, although our research indicates that some lagoons had formed before 30,000 years ago so wetland foods would have been probably available some of the time. By ten thousand years ago the tree cover was increasing and temperatures were slightly warmer than present (Ellerton *et al.* 2017; Shulmeister *et al.* 2016). From five thousand years ago the record

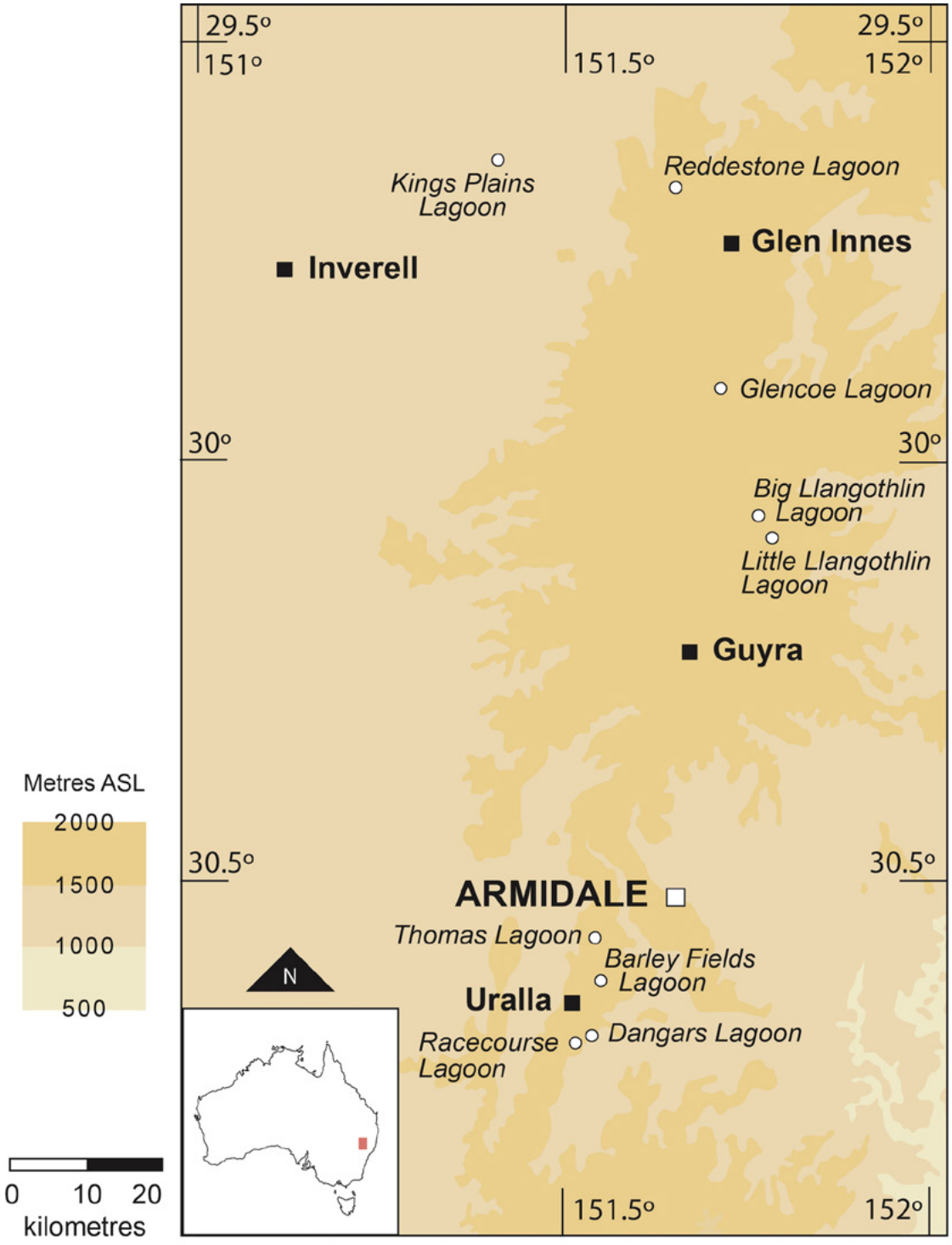


Figure I.2 *Lagoon sites in New England under study. Note: Big Llangothlin Lagoon also known as Lake Llangothlin (K. Newman)*

suggests that the tree cover opened out and grasslands began to develop along with the onset of climatic uncertainty and intensification of El Nino-Southern Oscillation (ENSO) conditions (Beck 2006; Beck *et al.* 2015; Gagan *et al.* 2004).

McBryde (1974) stressed the probable harsh environment of the Tableland which was seen as a major obstacle to year-round occupation, resulting in an archaeological perception of sparsely distributed sites in this zone, compared with other regions. This is still a common understanding, although Godwin (1990) argued differently. He concluded that the Tableland was not abandoned in winter at all, but occupied all year round by small mobile groups. Altogether this evidence seems to prove that the cold climate of the Tableland was not a barrier to year-round settlement. Comparison with Tasmania is useful here. Hunter-gatherers elsewhere successfully lived year-round in very cold climates such as glacial Tasmania and Pleistocene Europe. In Tasmania for example, Parmepar Meethaner rock shelter was inhabited from 34,000 years ago, including times when the Cradle Mountain glaciers were only three kilometres distant (See Chapter 9). Evidence from other parts of the world also suggests that cold climates were not necessarily a barrier to hunter-gatherers (Beck 2006).

Another theme in New England archaeology is that of group movement, that is, scheduled large scale movements by most of the population of an area. Godwin (1997) concluded that group movement was directed both onto and away from the Tableland during winter and summer and not just dictated by environment. Sub-coastal groups moved on and off the Tableland through the gorges. On the Tableland small groups lived all year round and in summer travelled to the west for ceremonies. From linguistic studies, the language spoken by Tableland people was more closely related to the coastal languages than to western slopes languages, yet the recent social groupings do not seem to correspond with this (Beck 2006; Godwin 1997).

Previous knowledge of the ancient Tasmanian midlands

The Tasmanian component was undertaken mostly in the Northern Midlands bioregion of Tasmania. The area includes a number of plains with former wetlands, primarily the Ellinthorpe Plains on the headwaters of the Isis River (a tributary of the Macquarie River which flows to the Tamar River, all part of the main north-flowing drainage system terminating in Bass Strait), now one lake and some seasonal marshes; and the Eastern Marshes at the headwaters of the Little Swanport River, which flows to the east coast of Tasmania, an area of seasonal marshes, some of which have been drained. There are also some intermediate former wetland areas. The most central town is Tunbridge on the Midlands Highway. The area is effectively a plain at c. 200-400 m asl. To the east there are low hills which drop steeply to a narrow coastal escarpment (a similar relationship as for the New England Tablelands and its coastal hinterland). On the western side is the steep escarpment of the east rim of the Central Plateau (which is at c. 900-1,100 m asl). This area is the highest part of the Midlands and is at the divide of drainage to the north, south and east, which possibly explains the presence of former extensive wetlands in the area. The lagoons study sites in Tasmania are shown in Figure I.3.

The Pleistocene environments and Holocene landscape changes for this area are very poorly understood as there has been little specific investigation in this region. Based on Macphail (1979a and b) it is likely that the Midlands was quite a different environment in the Pleistocene with the alpine vegetation/ eucalypt forest boundary at c. 400 m (that is, at the higher levels of the central Midlands region), with conditions ameliorating in the Holocene. The relationship of wetting and drying and the formation and drying of the lagoons and marshes is not established, and there are questions from existing research about the agency of change, in particular whether all Holocene source-bordering dune formation was climatic or whether it was in part due to human agency, especially firing (Kee 1990).

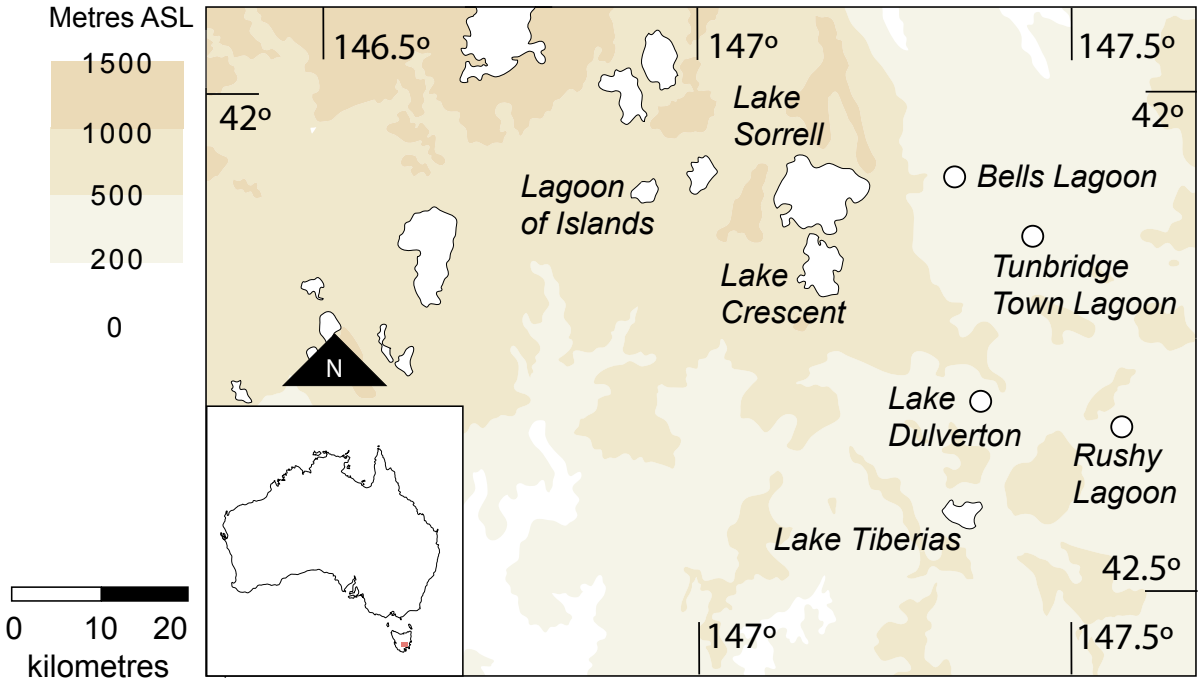


Figure I.3 *Lagoon sites in Tasmania under study (K. Newman)*

The area is at the junction of the historical territories of three tribes—the North Midlands, Big River and Oyster Bay Tasmanian Aboriginal tribes. Although the area is known to have been travelled through and used on a regular basis historically, it is not known to have been the core territory of any of the known bands (Ryan 1996). The area was the central part of a major historical Aboriginal travel route from the Central Plateau to the east coast, probably in part due to the rich resources of the wetland areas of this region. It would seem that the study area was historically largely a crossroads and seasonally the lower lying grassland plains with their watercourses, lakes and marshlands were significant food resource areas.

Few archaeological studies have been undertaken in the central Midlands area. The area is covered by the government regional overview studies undertaken in the 1980s-1990s, specifically Kee's (1990) Midlands region study, and Brown's (1991) East Coast study. The only systematic archaeological survey work undertaken in the area is a block survey in the Ellinthorpe Plains area (Kee 1990) and a recent survey of a proposed water irrigation pipeline by Hydro Tasmania Consulting in 2010. These two surveys confirm the historical use of the area, including intense use of the Ellinthorpe Plains area, the York Plains, and the Salt Pan Plains (the Eastern Marshes have not been surveyed but are expected to have similar evidence of intensive use).

The only other substantive archaeological work to have been undertaken in the area was as part of a study of stone quarries in southeast Tasmania by Painter in 2001, which found a number of quarries in the area immediately south of Ellinthorpe Plains. Strategic forestry surveys by Cosgrove (1990) on the eastern edge of the central Midlands located numerous stone quarries and associated sites to the southeast of the Eastern Marshes. Only three studies: by Lourandos in 1972, Sigleo in 1978, and Kee in 1990, have attempted to investigate the archaeology and human/land relationships over time. Lourandos dated the commencement of Aboriginal occupation as dispersed, nomadic and non-sedentary and independent of the coastal region and Central Plateau region. Kee's results indicate Aboriginal

occupation of the area from the mid-Holocene (c. 4,500 BP) to present, although the basal deposits are considered of probable late Pleistocene/early Holocene age within the lunette. She also interprets the site as being a short-term terrestrial site associated with the marsh/lake system with occasional hunting forays into the hinterland (Kee 1990).

Comparison of the two regions

Most of the human occupation of the New England and Tasmanian regions is thought to be relatively recent, as most of the dated sites in both regions fall within the last five thousand years, despite the fact that the occupation of eastern Australia is much older. The lack of older sites may be due to a lack of archaeological work in suitable preservational environments, and also to the smaller human population in the Pleistocene (before twelve thousand years ago). So, the oldest hunter gatherer Indigenous habitation of these regions remains unknown at the present time, although it is likely that scattered remains of earlier settlement and social networks have yet to be found. A lack of dated sites at present precludes a detailed understanding of changes over time, so speculative models are all we have. There are gaps in the data, especially in terms of dated sites with continuous deposits, and sustained field-work is still required to fill in these gaps. The specific methods used are detailed in later chapters, but the overall approach was one of reconnaissance, setting up Aboriginal steering groups and then targeting specific lagoons with field-schools of generally two weeks duration with various aspects of heritage field-work then carried out.

Historical use of lagoons by Europeans

The use of lagoons exhibits cultural continuity as successive inhabitants used them for different purposes–lagoons were shared by Aboriginal and early European inhabitants, and then there was a sequential use of wetlands for food and water by farmers and stockmen as well as local recreational and sporting activities, and eventually protection for natural conservation values.

In both New England and Tasmania the use of lagoons by Europeans in the nineteenth century and afterwards included their use as water sources, for industrial purposes such as flour mills and gold mining, as well as stock-watering dams, irrigation and recreational uses (See Figures I.4-7). The prevailing attitude was to 'dam or drain them' in order to fundamentally regulate the natural variability of these wetlands (Brock *et al.* 1999; Tyler 1976). As well as intentional water regime changes many unintentional changes occurred as a consequence of land-use in the wetland catchments.

Ecological significance of the eastern Australian lagoons

Both Tasmanian and New England lagoons have been recognized in the last thirty years as important places for conservation of wetland vegetation and fauna. Both Little Llangothlin Lagoon and Interlaken (parts of Lakes Sorrell and Crescent) were declared RAMSAR wetlands in 1996 and 1982. This listing recognises the international ecological significance of these lagoons. Their recognition is based on being high altitude freshwater wetlands in near-natural condition. Both are rare examples as the majority of the wetlands have been degraded or destroyed through hydrological modification, grazing and cropping.

Local, regional, national and international awareness of the ecological value of lagoon wetlands has increased from the 1970s onwards. This is evidenced by recent Federal and NSW legislation which protects the very similar Monaro Plateau lagoons in southern NSW (See Figure I.8). National legislation from the Australian Federal Parliament recognises 'Upland wetlands of the New England Tablelands and



Figure I.4 *Boating on Mother of Ducks Lagoon, New England, 1880s (HRCP1534) New England Archives*



Figure I.5 *Outing on Mother of Ducks Lagoon, New England, 1882 (HRCP1533) New England Archives*



Figure I.6 *An angling party, Great Lake, Weekly Courier, 11th January, 1905, Photo by S. Spurling. Courtesy Tim Jetson.*



Figure I.7 *Oatlands Lagoon (Lake Dulverton) Tasmania. Sketch (1853) - Bishop Nixon (TAHO-PH30-1-360) Tasmanian Archives*



Figure I.8 *Lagoon on Monaro Plateau near Jindabyne, NSW*

the Monaro Plateau' as nationally threatened ecological communities (EPBC 2005) and these have been also listed by the NSW State Parliament in 2002 and 2011.

Project Overview

In both Tasmania and New England this project was successful in forming partnerships with the local Aboriginal communities in an educational setting, and in furthering our understanding of the lagoon landscape archaeology of the Tasmanian Midlands and New England Tablelands, by providing new evidence for the degree of antiquity and type of occupation.

New discoveries were made which contribute to our understanding of the archaeology and geomorphology of the Tasmanian Midlands and New England Tableland. New ages for lunette formation and Aboriginal occupation allow a finer-grained understanding of the landscapes and set the scene for future research in these bioregions. Our research was the first substantial project to be carried out in these bioregions since the early 1990s. As Holmes *et al.* (2008) have also suggested, supposedly arid conditions do not routinely lead to lunette formation. Instead, very local conditions of sediment production and availability may be important. This seems to be the case in our project.

This project contributes to addressing the complex interplay of social, economic, educational, and cultural factors that create obstacles to Indigenous communities playing a greater role in the cultural, economic and social life of the regions. This was an opportunity to redefine a contemporary, practical vision of heritage education which can be linked to caring for the land, joining the future of heritage

management to the future social and economic health of the region while simultaneously contributing to strong archaeological research and outcomes. Both regions have active Aboriginal heritage workers, but are disadvantaged in terms of Indigenous higher educational participation.

To date Pleistocene human land use studies in ancient wetland areas have concentrated on presently dry, semi-arid interior parts of Australia (such as Lake Mungo). This project compares people-land relationships in cold, 'harsh' climates with coastal connections. The New England Tableland of New South Wales and the Northern Midlands of Tasmania are ideal for exploring these themes because they have similar cool and sub-humid climates, with open woodland environments and nationally important wetlands (Directory of Important Wetlands of Australia). The ancient wetlands provide very good opportunities for good Pleistocene records of Aboriginal occupation and climate change to be preserved in periglacial settings (Colhoun *et al.* 2010; Haworth 2006). While the Aboriginal history of New England has been the subject of detailed studies in the 1960s (McBryde 1974), little systematic research has been carried out since Godwin in 1990 (Beck 2006; Godwin 1997). Similarly, the Aboriginal history and archaeology of this part of Tasmania has also been outlined in the 1980s (Kee 1990) with little work done since.

Wetlands were chosen for study because water is an essential for human occupation. Wetlands are also cultural landscapes. Indigenous Australians in the past imprinted a range of cultural features on them, such as fish traps, ditches, mounds, myths and stories (Smith and Wobst 2005) and these interactions are likely to be ancient, but linked with climatic changes that affect all water bodies. Wetlands which persist to the present are useful starting points for study because they preserve long-term geomorphological and archaeological evidence over thousands of years, which enables comparative studies of human interactions.

Structure of the book

The book is divided into four parts. The first chapters deal with Indigenous participation during the project, with Chapter 1 (Beck *et al.*) and Chapter 2 (Lagoons Reference Group *et al.*) covering the Indigenous views and engagement and the educational programs developed for the project. The research contributed to the existing field of research into community engagement and education in Aboriginal contexts in NSW. Unlike most projects where Aboriginal people are involved in commercial archaeology, this project focussed on archaeological research not management. Elders from the community participated fully in the project as they were equal partners in the research team during field-work and training. Knowledge holders and scientists were both valued. This is Fraser's 'politics of recognition', which, together with the concept of Work Integrated Learning, allowed for a more sustained, long-term and meaningful engagement. Work integrated learning was very successful as an active site of learning and by including training (partly at University sites, classrooms, college accommodation etc.) and work on country, it provided specific skills and encouragement towards Higher Education. Several students did enrol in higher education, partly as a result of the project. We collected a number of testimonies from the students which demonstrated their enjoyment, learning and satisfaction. Continuing partnerships with the New England Aboriginal Land Councils led to a joint grant application to NSW Land Services for heritage education in 2017. Unfortunately, we were not successful, but the LALCS are keen to re-apply. In late 2018 a further successful application for a large grant was made with the Armidale community.

The second group of chapters is about field-work, dating and chronology. Chapter 3 (Beck *et al.*) describes field sample locations and the overall field methods used for sampling archaeology and geomorphology. Our studies focussed on wetland lagoon sites, as depositional environments which had not been previously studied. Chapter 4 (Hayes *et al.*) describes the dating and chronology, including OSL and radiocarbon from geomorphological and archaeological contexts. Thirty-seven OSL ages in all were

obtained from lunettes in Tasmania and New England in order to ascertain the formation ages of these depositional bodies. The ages are diverse, ranging from LGM dates (~20 ka) in Tasmania to a much wider range in New England, where some lunette formation was dated to as early as 48 ka and one non-lunette dune was dated to before 70 000 ka BP. Previously, no dated sites in New England had extended beyond the late Holocene, and we were able to date occupation, using OSL dating, in six lagoon dunes (lunettes).

The third group of chapters presents the results from the lagoons of the New England Tablelands, including their evolution, and past Aboriginal use. Chapter 5 (Haworth *et al.*) describes the nature and evolution of lagoons and associated aeolian deposits on the New England Tablelands. Lagoon formation is multi-causal, but tectonic and climatic disruption of pre-existing drainage systems are probably the major contributors. Lunettes consist of sediments that are usually derived from the lake-bed and lake edge and may be sand, silt or clay. Records of lunette initiation and development may indicate incidents of climatic disruption which provide sediments for successive cycles of accumulation and deflation. Chapter 6 (Appleton and Beck) describes the surface archaeology of the lagoons and their environs, and a range of new stone artefact scatters recorded adjacent to the lagoons. However, large sites were not found to cluster at lagoon locations. Chapter 7 (Appleton and Beck), describes the excavation archaeology of the lagoons. At Barley Field Lagoon this archaeology extends to the early Holocene, and at other lagoons, including axe grinding groove sites, to the mid to late Holocene. Chapter 8 (Fullagar *et al.*) describes the grinding grooves and residue analysis in locally abundant silcrete, a regionally distinctive archaeological site type.

The fourth group of chapters presents the results from the lagoons of the Tasmanian Midlands and Central Plateau. Chapter 9 (Kiernan *et al.*) outlines the nature and evolution of the Central Plateau and Midlands lagoons and associated aeolian deposits. Variations in the character of lakes along a west-east transect across the Tasmanian Central Plateau and into the Midlands graben reflect a combination of forcing processes over time, including the effects of altitude, climate and tectonics working on the local lithology and landscape. The inferred glacial age of some of the stone tools at Lagoon of Islands contrasts with other sites, where artefacts were recorded only within the uppermost Holocene deposits, that is, dating to the last 5000 years. Chapter 10 (McConnell *et al.*) records the archaeology of the Tasmanian lagoons. The findings of this study indicate that the larger lakes and lagoons, as well as lakes/lagoons on established travel routes, generally have the higher densities of sites and larger sites. The data suggest that the north-east end and west-southwest-south margin of lakes and lagoons were preferentially used historically, but they are not the only parts of a lake or lagoon edge with site evidence.

The conclusion is in Chapter 11 where Beck and Haworth present the results in a global context. Unexpectedly, the lunette and other dune OSL ages (from 11 sites) were not clustered around the Last Glacial Maximum at ~ 20 k, but ranged from 72 k to 2.2 k at Big Llangothlin and from 48.5 k to 7.2 k at Lake Tiberias in Tasmania. The sediment particle sizes suggest both wind and water deposition. This suggests quite individual depositional histories for the lunettes and other dunes, perhaps not so closely related to the major turning points of global climate changes. One hypothesis we suggest from the archaeological results is that in both regions lagoon resources may have been associated with supporting ceremonial activities in the late Holocene with only sparser occupation in earlier phases.

An Appendix section contains primary data for age results, and detailed section diagrams.

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Chapter 1:
Indigenous Participation and Aboriginal Education

Wendy Beck, Catherine Clarke, Judith Burns, Anne McConnell and
Lagoons Aboriginal Reference Group

Introducing the lagoons project

The idea of 'shared authority' (Frisch 1990) in researching and representing cultural heritage has been discussed and debated extensively for more than 30 years. The need for greater equality in establishing and voicing cultural knowledges has been recognised but not always well achieved, especially in post-colonial settings drawing upon a history fraught with injustices in the treatment of Indigenous peoples. What has been recognised is that a key aspect of achieving such equality—as well as a more balanced understanding of cultural heritage—is the exploration of research partnerships where academic researchers work to engage meaningfully with relevant communities to extend and share knowledge. In our project, this aspect includes an educational context.

The development of such community engagement partnerships was a core aspect of the planning and operation of the Lagoons project. In this chapter we discuss the critical factors for achieving and sustaining Aboriginal community engagement with cultural heritage research in the project. 'Community engagement' here meant developing an ongoing and active partnership between the stakeholders, as opposed to short-term, episodic, hierarchical relationships. Part of developing such partnerships is the recognition that, while partners may have concerns for the research that coincide or are compatible, they may also vary in the emphasis placed upon them in the present day. Based on this understanding and following discussions, we wished to explore practical ways of engaging that also supported the social, educational and economic health of the communities concerned in ways identified by the communities themselves as being of value.

In this chapter we ask a number of questions that led to the approaches taken: who were the communities? How could they engage with the lagoons' cultural heritage? What motivates communities to do this? What does it mean to engage? What are the benefits and weaknesses of such engagement?

First, we look briefly at the history of Indigenous community archaeology in Australia, the development of different attitudes to heritage research, and then the general significance of our research, together with the kinds of previous work and methods of engagement, especially in workplace learning, that we drew on in our project. Next, we outline our project stages as we moved towards community engagement. Finally we outline the educational aims and program and provide real examples of the workplace literacies that the community members developed in the project.

We argue that among a range of factors, recognition, representation and redistribution are critical. Community engagement is neither a singular event nor a finite outcome – rather, it is creating the space and dialogue for ongoing learning and engagement over time.

Indigenous community engagement in research in Australia

Direct Indigenous community engagement in research is a relatively recent phenomenon. Historically, Aboriginal Australians, as with Indigenous peoples in other colonised contexts, have been the subject of research which has effectively advanced the colonialist project by producing grand narratives which serve to totalise and dehumanise, to erase Indigenous epistemologies, and to silence Aboriginal voices:

> From the vantage point of the colonized, a position from which I write and choose to privilege, the term 'research' is inextricably linked to European imperialism and colonialism. The word itself, 'research', is probably one of the dirtiest words in the indigenous world's vocabulary. When mentioned in many indigenous contexts, it stirs up silence, it conjures up bad memories, it raises a smile that is knowing and distrustful (Smith 2012:1).

Given the historical and often, sadly, the contemporary experience, it would have been understandable had Aboriginal people chosen to repudiate research altogether. However, the collective response has largely been towards wresting control of the research agenda from the colonialist institutions and re-focussing it towards the knowledge-seeking and policy objectives of Aboriginal communities. A seminal point in the move towards Indigenous community engagement in research in Australia occurred in 1974, when the motivations for research in Aboriginal studies were unpicked in the Eaglehawk and Crow letter. This document attacked then Australian Institute of Aboriginal Studies for its lack of accountability to Aboriginal communities and lambasted its intentions for a forthcoming international anthropology conference for its irrelevance to Aboriginal people's needs. The authors, instead, sought repatriation of research results to Aboriginal communities, training of Aboriginal people as researchers, and participation by community in the Institute's affairs (Gray 2007:226).

The history of cultural heritage research suggests that the first extensive use of community 'values' in a heritage context was in Australia, seen in the formulation of the Burra Charter in 1979 (Diaz-Andreu 2017:3). This Charter for the conservation and restoration of monuments and sites was developed as an Australian version of the European Venice Charter (Australian ICOMOS 1979:1). The assessment of significance incorporated the serious consideration of community voices for the first time.

Similarly with academic circles, 'community' archaeology appeared around this time and there was a shift in the meaning of Public Archaeology to reflect 'archaeology for the public' an open, participatory archaeology (Marshall 2002; Diaz-Andreu 2017). The term 'engagement' has replaced 'participation' in recent publications but

> Engagement is rarely seen as a long-term, multi-layered moral and relational commitment to redressing social inequalities... Originally envisioned as a more emancipatory approach to increase community power and increase community ownership (Arnstein 1969) participation, now read as engagement, is often criticized as simply co-opting people into predetermined research and activity (Carter 2010: 201).

However, Indigenous community engagement is part of a long tradition of working in archaeology in Australia and cultural heritage management approaches have a long history here, being first developed in the 1960s and 1970s (Greer 2010: 47). There is much diversity in how Aboriginal people, with different life experiences and histories, will view their heritage and its management. In the Lagoons project this can be seen in the different views held by groups from northern NSW and Tasmania. For instance, over the past 40 years the Tasmanian Aboriginal people, long marked as an iconic case of 'extinction', have revitalised many elements of their 'lost' culture (Berk 2017) and have recently (2013) gained

management control over land at Gowan Brae, a first for local people in Tasmania. Many years of prior heritage work experience shape both the Aboriginal and non-Aboriginal researchers' views here.

In Australia, there can be contrasting views about 'heritage' held by Aboriginal and non-Aboriginal people. For example, particular contestation arises around indigenous heritage landscapes, where landscape features, such as wetlands and lagoons, which might be classified as 'natural' by European observers are also part of a network of symbolic relationships and landscape-scale narratives which relate back to the Dreaming of the Aboriginal ancestors (David and Wilson 2002, Waterton *et al.* 2006). Alternatively, there can be similar views of heritage. For example, in the management of Wattle Ridge Indigenous Protected Areas in northern NSW, material culture such as art sites and grinding grooves are valued, actively recorded and managed (Hunt 2010: 13). So community heritage values and attitudes cannot be generalised.

Based on discussions and in accord with community deliberations at the time where 'education and training are viewed by the Land Councils as the principal long-term contributors to community social and economic wellbeing' (NSW Aboriginal Land Council Northern Region, 2010, p.98), the Lagoons research was integrated with an archaeological education program for young Indigenous people. The program, discussed in more detail below, was designed to value both Indigenous and non-Indigenous knowledges and support community engagement.

History of Aboriginal views towards engagement with archaeology

The reasons why Aboriginal communities might wish to engage with heritage academics have been voiced clearly as well as become more diverse over a number of decades.

An important early paper presented by Ros Langford for the Tasmanian Aboriginal Community (Langford 1982) narrowed the focus to white archaeologists:

> ....you have built your fortunes upon the lands and bodies of our people and now, having said sorry, want a share in picking out the bones of what you regard as a dead past. We say that it is our past, our culture, our heritage, and forms part of our present life. As such it is ours to control and it is ours to share on our terms (Langford 1982: 2)

Thirty years later, in a more recent paper presented in 2012 at the World Archaeological Congress in Jordan, Warlpa Thompson, an Indigenous member of our research team and Graham Knuckey, a non-Indigenous member, made the following similar statement about archaeology's control of knowledge:

> How do we counterbalance the lack of credibility placed on Aboriginal oral history as well as foster more respectful and collaborative discussions around Australian Aboriginal archaeology? Reaching a balance in a place like Australia where Aboriginal people make up 1% to 2% of the total population of their traditional country requires Western society to relinquish a bit of its control. Knowledge has been said to be power but perhaps more significantly, claiming the validity of certain forms of knowledge is a claim to the right to have political power over others – the right to oppress.
>
> There are many types of knowledge of landscape: traditional; memory; intuitive; primary written sources; analysis and synthesis by commentators; material items as evidence; experimental; biophysical; and others. Also, each culture may have a different perspective and give different emphasis to these different forms of knowledge.
>
> If we are to truly understand the landscape and see its richness through human eyes of many

> cultures, we must recognise the validity of all forms of knowledge. (Thompson and Knuckey 2013).

The common thread over the years is the issue of control of heritage and what counts as knowledge. Community engagement is not just about participation, it is also about creating the prospect for the local communities to assume power in both research and management contexts (Zimmerman 2005, Chirikure *et al.* 2010). It is about making space for the scope of the authorised discourse to expand to make way for 'the insurrection of subjugated knowledges' (Foucault 2003 (1997): 7). In this project current ideas about community engagement theories were evaluated through archaeological fieldwork research and a work integrated learning (Cooper *et al.* 2010) education program for young Indigenous people.

'Work-integrated learning' is defined as

> an intentional aspect of a ...curriculum whereby the learning is *situated* within the act of learning, whether that work occurs within a recognisable workplace or a community. The term integration is significant because the principal purpose is the nexus of work and learning; each informs and critiques the other (Cooper *et al.* 2010: 1).

We aimed to adopt a multi-layered, inter-disciplinary approach involving contributions from higher education, archaeology, palaeoenvironmental studies and social history. When knowledge-holders and scientists are both valued as full partners in the research, more successful Indigenous heritage education can be designed. As an example of this groups of young people from eastern Australia successfully participated in work integrated learning during our archaeological fieldwork.

Reviewing the theory: what does community engagement mean?

We reasoned that more successful engagement and educational outcomes, as well as more meaningful understanding of cultural heritage, could be achieved through Aboriginal and archaeological research partnerships, drawing upon Fraser's (2001) ideas about the 'politics of recognition' and the concept of work integrated learning.

Fraser points to two camps of political philosophy:

> On one side stand the proponents of 'redistribution'. Drawing on long traditions of egalitarian, labour and socialist organizing, political actors aligned with this orientation seek a more just allocation of resources and goods. On the other side stand the proponents of 'recognition'. Drawing on newer visions of a 'difference-friendly' society, they seek a world where assimilation to majority or dominant cultural norms is no longer the price of equal respect (Fraser 2001: 21).

Fraser goes on to expound on her view that a reconciliation of these opposing camps is possible through a model which treats status as central. For example:

> If and when such patterns constitute actors as peers, capable of participating on a par with one another in social life, then we can speak of reciprocal recognition and status equality. When, in contrast, institutionalized patterns of cultural value constitute some actors as inferior, excluded, wholly other or simply invisible, hence as less than full partners in social interaction, then we should speak of misrecognition and status subordination. (Fraser 2001: 24).

So the notion of 'status' is the key to improved community engagement in heritage practice (Waterton & Smith 2010). 'What requires recognition is not group-specific identity but rather the status of group members as full partners in social interaction' (Fraser 2001: 24). We put these ideas into practice by drawing upon the principles of work integrated learning: incorporating Indigenous and non-Indigenous students into the archaeological workplace through partnership agreements; by valuing different kinds of knowledges; and by contributing to Aboriginal community knowledge sharing (e.g. wetland stories, personal reflections, literary responses).

Indigenous archaeological research and Fraser's ideas could therefore prove to contribute more nuanced understandings of 'heritage' and 'landscape' theory and practice in eastern Australia than those held at the time. New theory and practices were needed. We considered that the archaeology of ancient wetlands in eastern Australia was a particularly useful arena for this work because it has both physical and cultural features of importance for such knowledge exploration.

The study area

The study area was one where the concept of 'landscapes' could challenge the boundaries between types of knowledges, but where a 'misrecognition' of heritage values could also lead to what we sought to avoid: a lack of meaningful community engagement (Waterton and Smith 2010).

Our academic archaeological part of the project undertook a comparative wetland archaeology of the Tasmanian Midlands region and the New England Tablelands region, thus enabling a comparison of landscape change and people/land relationships in a changing environment (see Fig I.1). Wetlands were chosen for study because water is essential for human occupation from all time periods, especially in this driest of continents. Wetlands are also cultural landscapes. Indigenous Australians in the past imprinted a range of cultural features on them, such as fish traps, ditches, mounds, campsites, ceremonies, myths and stories (Smith and Wobst 2005) and these interactions are ancient, but linked with climatic changes that affect all water bodies.

The New England region of New South Wales and the Northern Midlands of Tasmania are ideal for exploring these themes because they have similar cool and dry climates, with open woodland environments and nationally important wetlands (*Directory of Important Wetlands in Australia*). These ancient wetlands provide opportunities for good Holocene and Pleistocene records of Aboriginal occupation and climate change to be preserved in periglacial settings (Colhoun *et al.* 2010, Haworth 2006). While the Aboriginal history of New England had been the subject of detailed studies in the 1960s (McBryde 1974), little systematic research had been carried out since Godwin in 1990 (Beck 2006, Godwin 1997). Similarly, the Aboriginal history and archaeology of the Northern Midlands of Tasmania was also outlined in the 1980s (Kee 1990) with little work done since. Both regions had active Aboriginal heritage workers, but were disadvantaged in terms of Indigenous higher educational participation.

Who are the project communities? Partnership steps

In late 2011, the Australian Research Council awarded a large grant for our project *Indigenous Heritage: Working Ancient Wetlands for Social Benefit and Cultural Understanding Project (DP 120102316)* which included academics from University of New England (Wendy Beck—archaeologist, Judith Burns—human geographer, Robert Haworth—physical geographer, Catherine Clarke—higher education/archaeology), University of Wollongong (Richard Fullagar—archaeologist), University of Tasmania (Kevin Keirnan-—physical geographer), together with consultant archaeologists Anne McConnell and John Appleton. Local Indigenous woman from the New England community, Esther Gardiner (Kamilaroi/Dhungatti woman), was employed for part of the time as a research associate and to collect oral histories. We had

obtained provisional support from the Northern Region Forum (the peak representative grouping of the sixteen Local Aboriginal Land Councils from the NSW Aboriginal Land Council Northern Region) and from a meeting with the Tasmanian Aboriginal Centre CEO.

After the success of the application was announced in November 2011 a Reference Group for the New England area, comprising four Local Aboriginal Land Councils (LALCs: see below for further details): Anaiwan, Glen Innes, Guyra, and Armidale was set up with a formal Partnership Agreement. This agreement was signed in mid-2012 and specified the roles of the Reference Group, remuneration, interview protocols, Aboriginal student participation, intellectual property and use of information, reporting, information storage, selection of fieldwork areas, and elder participation. Contracts were then drawn up for each LALC, which specified their roles and remuneration scales.

In Tasmania a similar Agreement was drawn up with the Tasmanian Aboriginal Centre (TAC: see below for further details), where services provided, remuneration, oral history interviewing, student participation, project data and information generation and sharing and intellectual property were negotiated and agreed upon. These agreements had differences that reflected the different nature of the communities and the representative structures.

In addition to these agreements, other formal documents required by the Project included UNE (approval HE12-157) and UTAS (approval H0012890) ethics clearance for the oral history interviews and Aboriginal Heritage Impact Permits (AHIP no. C0002673)) for the excavations. The AHIP process requires broad consultations outside the LALC framework, including advertising for Aboriginal stakeholders in local newspapers. At the request of the TAC no excavations were carried out in Tasmania.

Many community members worked with us during the project as well as the students and elders who collaborated during the field-work. These are listed below in Table 1.1.

Excavations during 2015/2016 were carried out with small teams of local Aboriginal students who had attended field-schools together with volunteer university students (see Table 1.1).

TABLE 1.1 LIST OF PARTICIPANTS AND FIELD-SCHOOLS ATTENDED

Aboriginal community teams

The Aboriginal Reference Group for the lagoons project consisted of the CEOs of the four Local Aboriginal Land Councils where the research took place. These were: Armidale LALC (Colin Ahoy snr and Michael Brogan); Guyra LALC (Jeffrey Ho); Anaiwan LALC (Greg Livermore) and Glen Innes. LALC (Trevor Potter and Karen Potter).

Aboriginal elders attending field-work: Colin Ahoy (Snr): Armidale LALC, Esther Gardiner (BA) Tingha, Isabel Williams: Anaiwan LALC, Dick Blair (Anaiwan LALC), Lee Patterson (Guyra LALC), Eileen Livermore (Glen Innes LALC), Karen Potter (Glen Innes LALC), Trevor Potter (Glen Innes LALC).

Tasmanian Aboriginal Centre: Heather Sculthorpe, Andry Sculthorpe, Teangi Brown.

Aboriginal Students:

April 28-May 10 2013: Armidale NSW Field-School:

Colin Ahoy (Jnr), Armidale; Thomas Froome, Armidale; Corey Livermore, Tingha; Lex Livermore, Tingha; Jessica Mongta, Guyra; Justin Patterson, Guyra; Jaydyn Potter, Glenn Innes; Ron Byrne, Glenn Innes. Additional Aboriginal participant was Steven Ahoy (Armidale).

November 11-22 2013: Glen Innes NSW Field-School:

NSW: Dylan Pearce, Armidale; Larissa Ahoy, Armidale; Jessica Mongta, Guyra; Justin Patterson, Guyra; Corey Livermore, Tingha;, Lex Livermore, Tingha; Timothy Levy, Glen Innes; Dylan Pearce, Armidale; Jaydyn Potter, Glenn Innes. Tasmanian team members: Andry Sculthorpe, Tasmanian Aboriginal Centre (TAC); Teangi Brown, TAC.

March 3-16 2014: Tasmanian Field-School:

Tasmania: Teangi Brown, Aaron Everett, Jessie Digney, Nala Mansell, Nathan Maynard, Sara Maynard, Adam Thompson, Andry Sculthorpe, Heather Sculthorpe, Cody Summers.

NSW: Colin Ahoy snr, Larissa Ahoy, Eileen Livermore, Lex Livermore, Jessica Mongta, Lee Patterson, Jaydyn Potter, Warlpa Thompson, Isabel Williams.

UNE Students/Alumni: Rod Cliff, Matt Elsley, Karen Holznagl, Ray Fife, Paul Howard, Anna Ingham, Jacob Lambert, Roger Mehr, Cate Mitchell, Kirsten Nash, Crystal Phillips, Tim Reid, Matthew Smith, Warlpa Thompson, Hugh Watt

UNE Staff: Robyn Bartel, Kim Newman, Michael Reid, Malcolm Ridges, Emma Watt.

Education, social and economic health in northern NSW and Tasmania

A significant motivation for community engagement related to the current social contexts of the communities. Education was perceived by all parties as key to the means of addressing disparities between Indigenous and non-Indigenous Australians. In 2004, a joint Government and community agency report pointed to a clear link between education outcomes, employment and learning, socioeconomic status and health (The Report of the Review of Aboriginal Education 2004: 13). In 2010, current social and economic health in northern NSW was still assessed to be poor. For example, in the NSWALC Northern Region, Indigenous Northern Region Forum representatives

> ... cite racist stereotyping, mismatch between training inputs and employment outcomes, entanglement with the criminal justice system, and a high incidence of substance misuse coupled with lack of alcohol and other drug services, as critical constraints on Aboriginal people's ability to engage with the economy. (NSWALC Northern Region Local Aboriginal Land Councils, 2010: np)

There is still a gap between non-Aboriginal and Aboriginal school students in Tasmania. LIke NSW, the results from NAPLAN (National Assessment Program - Literacy and Numeracy) show that in Tasmania Aboriginal students are more likely to be at or below minimum literacy and numeracy standards than their non-Aboriginal counterparts.

> Despite an increasing awareness and the development of strategic policies to address Aboriginal educational inequality, it is evident that little has changed between 2008 and 2016 [*in Tasmania*]. It is strongly argued that Aboriginal students' underachievement is more likely tied to schooling and policy environments that do not adequately meet their needs, rather than the students themselves. As such, policies and interventions that create long term, embedded improvement of Aboriginal students' schooling experiences and the engagement of their families and communities are a prerequisite for improving Aboriginal student outcomes (Stone, Walter and Peacock 2017: 90).

In Tasmania, contemporary Aboriginal perspectives serve to resist the notions of genocide and extinction that have prevailed during, and subsequent to, the nineteenth century European colonial invasion. There have been some important political events since the project began in 2012. In particular, in 2016 the Premier Will Hodgman and the Liberal Government introduced a Constitution Amendment (Constitutional Recognition of Aboriginal People 2016) into Parliament, and received unanimous support for this legislation which recognises, for the first time in the State's history, the Aboriginal people as Tasmania's First People, and the traditional and original owners of Tasmanian lands and waters. However, there remains disparity in education, health and employment between Aboriginal and non-Aboriginal Tasmanians.

Working on country

The general social and economic benefits of communities working on their land, including heritage work (through Indigenous Protected Areas (IPAs) or other public lands such as Travelling Stock Routes) were widely acknowledged in NSW and Tasmania. For example,

> In the...Australian context...one way of regaining power has been through the agitation for recognition of traditional custodial rights and their return to host communities...These traditional custodial rights were destroyed at colonisation, a process which has since excluded host communities from not only using their past, but determining its meaning,

TABLE 1.2 LEVEL OF ENGAGEMENT (IAP2) EXPLAINED

Level of engagement (IAP2)	Example from Tasmania	Example from New England
Inform—Provide balanced and objective information	Written description of project	Northern Regional Forum presentation,
Consult—Obtain feedback on project, acknowledge Aboriginal concerns	Meeting with TAC CEO	Northern Regional Forum presentation, met with LALC CEOs
Involve—Work with Aboriginal community to ensure that their concerns are reflected	Finalised Memorandum of Understanding	Finalised Memorandum of Understanding
Collaborate—Communities provided direct advice in formulating the project activities	Initial field meeting Report review and co-writing	Regular Reference Group meetings of CEOs and Project Team. Chaired by CEOs.
Empower—Communities decide how to use heritage education for now and future	Participate in field schools Exchanges between TAS and NSW Aboriginal communities	Participate in field schools. Artefacts returned to communities. Exchanges between TAS and NSW Aboriginal communities

use and future. Furthermore, community participation and engagement also involve using heritage as an economic resource and ploughing back into the community the results of the research in various media (Chirikure *et al.* 2010).

In both NSW and Tasmania we tried to work on Aboriginal lands as much as possible, utilising Travelling Stock Routes for excavation sites and two Indigenous Protected areas (Wattle Ridge and Borabee and the Willows). During the project, in May 2013 the Tasmanian Aboriginal community gained possession of the 6750-hectare property known as Gowan Brae in the Central Highlands — the largest area of land ever returned on the mainland of Tasmania, and a place we also visited during the project in 2014.

Conceptualising engagement

One way of conceptualising the overall process of engagement is the IAP2 model (International Association for Public Participation, Head 2007, De Leiuen and Arthure 2016). This model of participation outlines the types of participation processes in five forms, from weakest to strongest: informing, consulting, involving, collaborating and empowering. Using this model, a number of steps were taken in order to engage with the communities. These are outlined in Table 1.2 below.

These steps took place over a number of years from 2012 to the present and are ongoing.

Critical factors needed for engagement

The table above describes the practical steps taken in our projects, however there are underlying factors which must also be present for successful engagement.

We argue that a range of factors such as representation, recognition and finally redistribution of whatever is deemed to be valuable can achieve a narrowing of the gap in status between Indigenous and non-Indigenous people both in matters of cultural heritage and in the wider social and economic senses.

In this endeavour, a discourse of learning and a commitment to 'praxis' (practice as opposed to theory) (Freire 2006 [1968]), were seen by everyone as key informing attitudes for both building knowledge 'across the gaps' and for sustaining social and economic health.

Our project drew upon strategies informed by the politics of recognition from which Fraser (2001, 2005, 2007), Honneth (1997) and Taylor (1994) among others have developed social justice ideas based on Bourdieu (1972, 2013). Particularly relevant here are strategies based on the concepts of recognition, representation and redistribution mentioned just above.

Representation: New South Wales

In contrast to that reported by Walker *et al.* (2007: 438) where the Zoque leaders 'speak in the language of the unquestionable 'we'', there is a great diversity of Indigenous voices in NSW, where different processes also have different types of community representation:

Local Aboriginal Land Councils (LALCs)

LALCs are autonomous bodies governed by boards elected every two years by local Aboriginal community members. The network of 120 Councils is divided into nine regions. Each region comprises 10-21 individual Councils. LALCs are established under statute; the NSW Aboriginal Land Rights Act 1983 sets out the object and functions of LALCs. Key among these functions, and of primary relevance to this project, are: land acquisition; land use and management; and protection and dissemination of knowledge of Aboriginal cultural heritage in the LALC area. LALCs are not traditional owner organisations; their objects require them to work for all the wider local Aboriginal community in their areas. They assist with housing, legal issues, employment and other day-to-day matters. LALCs are often primary points of contact for cultural heritage research consultations and representation. LALC membership is open to all Aboriginal adults living, owning property or having an association with land within the LALC boundary; they thus have the potential to be (and often are) the organisations with the broadest representative base in any community.

Registered Aboriginal Parties

The NSW Dept of Environment and Heritage administers cultural heritage legislation – including a system of Aboriginal Heritage Impact Permits (AHIP) aimed at protecting Aboriginal objects and places.

Key representatives in this process are Aboriginal people, Aboriginal organisations or their representatives who have registered an interest in being consulted (LALCs may be one of these parties). In our project the LALCs and the Registered Aboriginal Parties mostly overlapped.

This project had four main forms of representation:

- A Reference Group of four LALCs (Anaiwan, Armidale, Glen Innes and Guyra Councils)
- Indigenous researcher (colleague and co-author, Esther Gardiner)
- Involvement of elders and other community members as knowledge holders and youth mentors
- Young Indigenous people as students.

TABLE 1.3 SAMPLE WORDING OF AGREED INTELLECTUAL PROPERTY AND USE OF INFORMATION IN THE LAGOONS AND HERITAGE RESEARCH PARTNERSHIP 2012.

General Interview Material: Information gathered in interviews will be used to inform the direction of the research and interpretation of its outcomes. To report on the project, information gathered may be presented at conferences, in print or on the internet if agreed with participants beforehand. Any recordings of interview, including any images, will not be used for purposes outside the project except with the express written permission of the participant (or in the case of a participant who has died, the family) and the relevant participating Aboriginal organisation/s.
Generated Data The types of information or data that might be generated or collected in the course of the research may include: • Field notes from archaeology & geomorphology surveys, field photos • Excavation notes, forms & photos • Coring notes and photos • Cores • Archaeological finds (these will not be collected) • Geophysical data from subsurface prospecting • Analysis of artefacts, measurements, photos • Analysis of sediments • Video footage of field-work activities • Interview data: Recordings, notes, photographs, consent forms. • Printed and/or electronic newsletters • Possible video copies • Student e-portfolios, consent forms, evaluation forms. Copies of academic papers and historical sources, including photographs. Reports and other data from previous research on lagoons or in the Project area. Documents required under legislative or statutory instruments (eg, site recording forms & correspondence logs). Information gathered by the project will be used to inform the direction of the research and the interpretation of the geomorphic history an Aboriginal history and heritage and contemporary views of lagoons in southeastern Australia.
Reporting: Regular exchange of information between members of the Reference Group and the research team will occur on an on-going basis Progress reports summarising the information collected and any interim results will be prepared by the Research Team and submitted to the Australian Research Council and to the Reference Group for consultation each year. Regular exchange of information between members of the Reference Group and the Research Team will occur on an on-going basis but particularly at scheduled Reference Group meetings. Regular reports will be made to LALC members' meetings.
Information storage & sharing During the terms of the project (2012-2014), information will be kept for working purposes in secure files at the University of New England. After the project, copies of text documents, copies of interview recordings, photographs and artefacts under "Care and Control" permits will be transferred to the participating Aboriginal organisations that will provide for its secure storage and access in accordance with consents. Confidentiality of relevant information will be respected.
Publication and communication of outcomes: During the course of the project, members of the research team may write or present at conferences papers or presentations in other formats that describe and/or discuss information arising from the research. The research team undertakes to: submit any material in draft form to the relevant participating Aboriginal organisation/s for consultation for a period of one month before it is made public, acknowledge the contribution of the relevant participating Aboriginal organisation/s and other participants in any publication. This will usually take the form of co-authorship between the Aboriginal knowledge holders and the researchers.

Representation: Tasmania

In Tasmania the core representative body in 2012 was the Tasmanian Aboriginal Centre (http://tacinc.com.au/about-us/). Arising from negotiations:

- A Memorandum of Understanding was finalised
- Initial joint field meetings were undertaken
- Student members participated in field schools on a waged basis.

Recognition

Cultural ownership was acknowledged through consultation and collaboration with the Reference Groups as had been formalised in the Research Partnership agreement (NSW) and the Memorandum of Understanding (TAS). The legal University contract between the Reference Group and UNE was written so that the standard 'Background IP' section was replaced by a negotiated agreement in which the particulars of the Intellectual Property and Use of Information was agreed to (Table 1.3). Registered Aboriginal Parties in NSW were also identified and recognised as research proceeded through AHIP processes.

In both study regions, a number of steps were identified as key to the project aims of recognising and valuing cultural knowledges and knowledge partnerships. In consultation with the Reference Group, we worked with Elders to support students and collect oral histories. We designed educational programs for and with young people that recognised Aboriginal and European knowledges and aimed to establish transferable as well as cultural heritage knowledge/skills. Our research partnerships worked to recognise and articulate the value of cultural knowledge, its uses and access. In our field programs, reflection/iterative dialogue was built into the education program/field experience, with evaluative feedback used as a formative strategy (cf Martin and Rutagarama 2012).

Redistribution

Knowledge of cultural landscapes was valued, built, recorded and shared as illustrated here and in the following pages. For example, from Cody Somers (Tasmania):

> Richard Fullagar gave a scientific way of knapping (stone), but Warlpa showed a more Indigenous way of understanding stone knapping. More purpose to it. Now I know to look for bulbs, grinding, use wear etc. so know when you go to the beach what is what. Landscape versus cultural heritage.

In practical terms, there was participation reimbursement for LALC and TAC communities and students were waged (in accord with Work Integrated Learning principles). Experience was gained by students to enhance their potential for further education and employment in line with partners' priorities.

The experience of engagement: education

Throughout the Lagoons project we have come to a closer understanding of how communities can work together for a range of tangible and intangible present and future benefits. Community engagement is neither a singular event nor a finite outcome—rather it is a process of creating the space and dialogues for ongoing learning and engagement over time. This ongoing nature of the relationship is expressed by Dick Blair (elder, NSW):

> Thus far the course has been very interesting for me because I intend to learn as much as

> I possibly can about the cultural aspects of my ancestors so I can pass the knowledge on to my grandchildren (and great grandchildren).

The same is true of the non-Indigenous members of the team—knowledge to learn and pass on.

Aim for education programs

The aim of the education program was to contribute to the current paucity of effective and culturally relevant educational opportunities for a group of community-selected regional Aboriginal students in NSW and Tasmania.

Teaching and learning methods - formal and informal

The basis of work integrated learning is learning at 'the intersection and engagement of theoretical and practice learning' (Cooper *et al.* 2010: xiii). There are various models for work integrated learning but all are ideally designed to assist learners not only to achieve 'specific vocational skills' but also to understand the 'interconnections between theoretical, practical and general life experience knowledge' (Cooper *et al.* 2010: 4). It thus seeks to go beyond a basic 'learn on the job' experience to a more supportive (and reciprocal) one in which the learners' social and cultural realities are understood and respected and, in turn, inform the knowledge of all involved.

Through this approach, we aimed to prepare students for specifically cultural heritage work environments in ways that were culturally relevant, but also to provide them with some generic professional skills as well. We aimed to give students skills in six workplace learning areas: organisational, legal and ethical, profession-specific, career advice, social and cultural. The kinds of learning which took place were: getting to know more about workplaces (such as exploring the University colleges and campuses, exploring museums, exploring the landscape of field-sites; preparing for work experience (e.g. personal safety clothing for field-work and other safety practice information); negotiating workplace and other cultures (e.g. barriers to communication, differences between NSW and Tasmanian heritage work); and how learning happens in workplace contexts (dialogue and exchange of new information and techniques with what students already know and bring to the context). The workplace literacies covered in the Field-Schools are summarised in Table 1.4.

The field-schools, a key element of the educational program, also included a residential component in both locations so that learning could continue in both formal and informal settings. The program also sought to work in partnership. and draw upon the knowledge and experience of community elders as learning guides and contributors. The students were nominated from each of the four Local Aboriginal Land Councils in New England and from the Tasmanian Aboriginal Centre in Tasmania. An elder from each Land Council accompanied students and participated fully in the programs.

Table 1.4 Workplace Literacies (Cooper et al 2010: Appendix 1) covered in the three Field-Schools

Workplace Literacy Skills, Knowledge, Attributes	Fieldschool Formal Activities
Organisational-Understanding workplace organisational values and priorities	Study skills session – Writing reports 1 (Paragraphs, topic sentences)
	UNE Antiquities Museum
	Identifying management issues
	Study skills session – Writing reports (structure, referencing)
	Developing management strategies
	Project update
	– Day tour – landscape & Aboriginal heritage of Central Highlands – Central Plateau Morning tour - landscape & Aboriginal heritage of Central Plateau lakes area (visit to Lake Ada, Lake Augusta & Great Lake (& quarry if relocatable) - Drive down to the Midlands (visit Lake Sorell/Crescent Lake and Ross en route)
	Welcome & Orientation/background –Tasmanian geology, landscape & landscape history; Aboriginal history & heritage; the project in Tasmania - PM: travel to the Central Plateau (CP); introduction to the Lagoon of Islands & CP environment en route
	Cleveland & Smith Lagoon research: geomorphic mapping (& possible sampling), and archaeological survey (assumes access) possible opportunity for oral history interviews
	– site visits to Lake Dulverton, Tunbridge Town Lagoon, Bells Lagoon and Annandale white chert quarry
	pulling it all together (finalising field documentation, oral histories & debrief
Legal and ethical-Understanding legislation for Heritage protection	– Assessing significance (inc. NSW Heritage legislation - Overview
	Principles of Cultural Heritage Management (Burra Charter Basics)
Profession-specific-Understanding specific practical competencies needed for cultural heritage practice	Map reading skills
	Field tour of Guyra Country
	Field work day-Llangothlin Lake, Little Llangothlin
	Geology and land forms in NE and TAS (inc. visit to basalt quarry @ UNE
	Barleyfields Field Work Day
	Lagoon of Islands research: geomorphic mapping (possible sampling), and archaeological survey
	SE lagoons orientation and research: geomorphology test pits at Rushy Lagoon to test for sand (using archaeological methods); drive to Eastern Marshes; possible archaeological survey in nearby State forest; oral history recording.
	- Lake Tiberias research: geomorphic mapping (& possible sampling), and archaeological survey (assumes access)
	– Orientation Hobart & Aboriginal Heritage visits to Mt Wellington, Museum, Bedlam Walls rockshelter & quarry & middens, Oyster Cove AL & silcrete quarry

Career possibilities- Identifying other possible workplaces	Visit to Aboriginal Cultural Centre and Keeping Place
	Visit to University of New England Library
Social- Practice communication skills and connect with wider community	Evaluation focus group
	University College Dinner/BBQ at The Willows/Graduation Ceremony at UNE
	Independent sight seeing (opportunity to vest Salamanca Markets, Hobart, Tasmania)
Cultural- Learn to value different types of knowledge and share with others.	Recording oral history & Working with oral history recordings, Transcription, Digital formats
	Setting up consultations about heritage with appropriate stakeholders
	Lithics/knapping (presentation/lecture) / Workshop

Educational Outcomes

Field school programs

The field-schools were held three times during the project, and consisted of 10-day blocks of time, with the sessions split between fieldwork days and classroom days. The first two field-schools were held in NSW in two different parts of the New England region and the final school was held in Tasmania. For the Tasmanian school the students from NSW travelled to Tasmania to participate and two Tasmanian students travelled to NSW for the NSW schools.

As summarised in Table 1.4, the subjects covered included a range of technical skills ranging from map reading to principles of cultural heritage management, and generic skills such as writing reports and selecting appropriate field clothing. In addition, various site visits and field-work were carried out, ranging from geomorphological sampling to practice archaeological excavations and stone knapping.

Conferences

Over the project timeframe, opportunities arose to participate in various conferences, which both included contributions voiced by Indigenous project team members and provided work and professional experience in sharing and networking knowledge in these forums. Students thus had a useful space in which to compare notes with other Aboriginal heritage workers.

One educational tool which students participated in was the construction of posters for conference presentations. This honed their communication and academic skills and was done by a team of Aboriginal and non-Aboriginal students and academics. The writing was done by the students (See Figure 1.1).

Early in the project, for example, at the Australian Archaeological Association Conference in Wollongong, NSW, December 9-13, 2012, two students involved in the project, Warlpa Thompson and Jacob Lambert, presented their poster, *'Tale of Two Wetlands: Aboriginal Travel Routes in Cool Climate Drainage Divides'*

At the same AAA meeting, Esther Gardiner from the project team co-presented the paper presentation, 'Towards Twin Tales', which included her poetry.

One of the largest conferences attended was the international World Archaeological Congress held at the Dead Sea in Jordan from 13-18 January, 2013. At a session, 'The Politics of Recognition: Concepts and Strategies', convened by project team members Catherine Clarke, Wendy Beck and Esther Gardiner,

we presented a paper, 'Community Engagement: Sustaining the Transitions', which addressed and generated discussion about what might be the critical factors in sustaining community engagement in ways that join heritage with social health. We argued that 'Closing the Gap' between Indigenous and non-Indigenous status requires improved strategies for challenging boundaries between types of knowledge as well as opening avenues for young Indigenous people in education and employment.

Other contributions to the session were made by students and other team members associated with the project, which included paper presentations and discussions. As well, there was further participation in other conference sessions, such as the organized student debates. Here are two examples:

1. Extract from World Archaeology Conference (WAC-7, 2013) paper by W. Thompson and G. Knuckey

> *Stories and material items*
>
> There is a relationship between storylines and artefact distribution because as people are travelling along storylines they would bring trade items, including material that is preserved in the archaeological record such as ochre and stone. The story of the Bronzewing Pigeon is well-known throughout western Queensland, northern South Australia and far western New South Wales.

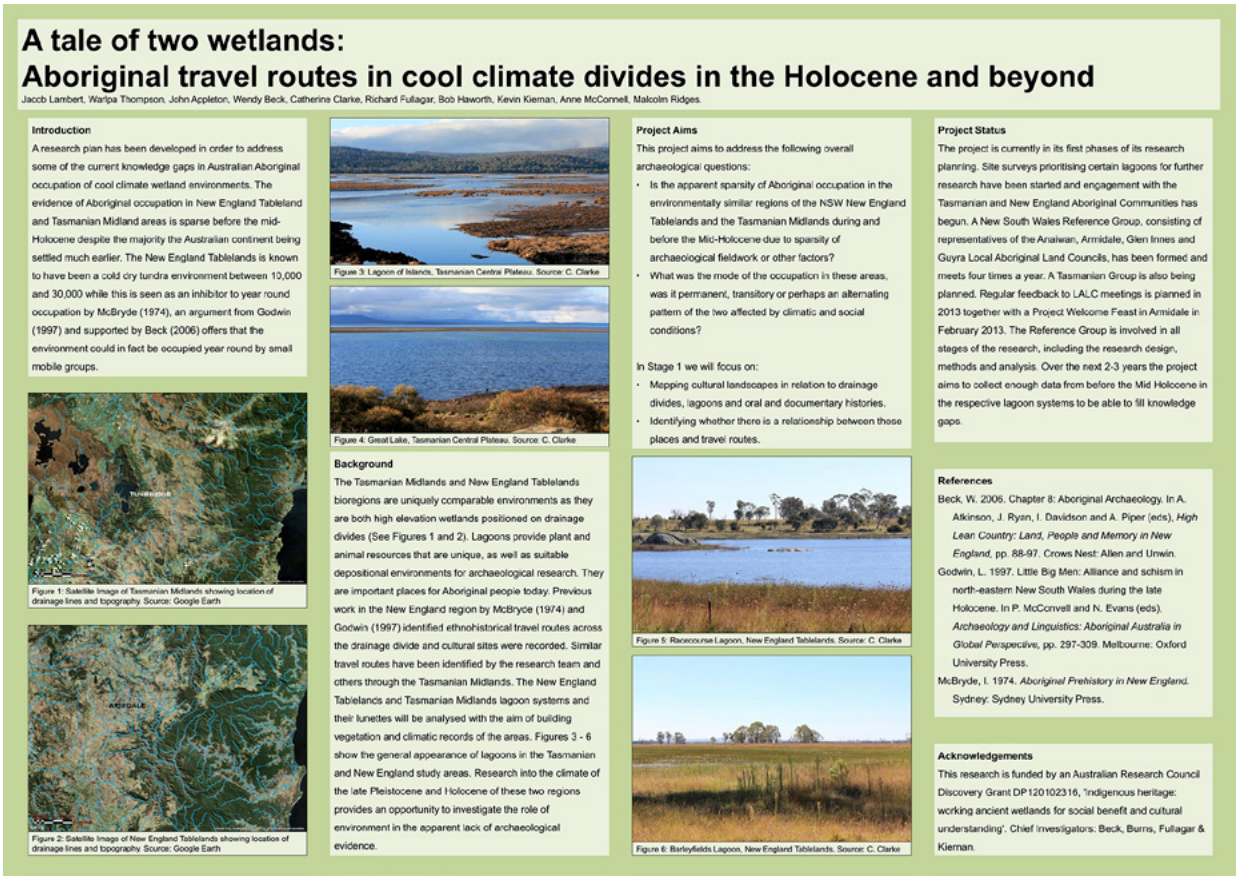


Figure 1.1 *Poster for AAA 2012 conference*

Warlpa: Valuing different types of knowledge

How do we counterbalance the lack of credibility placed on Aboriginal oral history as well as foster more respectful and collaborative discussions around Australian Aboriginal archaeology? Reaching a balance in a place like Australia where Aboriginal people make up 1% to 2% of the total population of their traditional country requires Western society to relinquish a bit of its control. Knowledge has been said to be power but perhaps more significantly, claiming the validity of certain forms of knowledge is a claim to the right to have political power over others – the right to oppress.

There are many types of knowledge of landscape: traditional; memory; intuitive; primary written sources; analysis and synthesis by commentators; material items as evidence; experimental; biophysical; and others. Also, each culture may have a different perspective and give different emphasis to these different forms of knowledge. If we are to truly understand the landscape and see its richness through human eyes of many cultures, we must recognise the validity of all forms of knowledge.

Graham KNUCKEY: I am neither of Aboriginal nor Torres Strait Islander descent, however, as an archaeologist, I have adopted ideas and attitudes from the Aboriginal groups I have had the privilege to work with over the last 20 years as an archaeological advisor/consultant.

The idea of 'landscape archaeology', assessing archaeological sites within the context of the surrounding environment (or landscape), not necessarily as 'stand alone' objects or phenomena' but as components of a bigger picture, is an investigative technique that has been used by archaeologists for many years. Yet in public archaeology, that is consulting, the landscape approach is actively discriminated against by many developers who are more concerned with 'dots-on-maps', individual points in the landscape, and whether they are 'show-stoppers' and how they can be avoided/mitigated.

It does not take much energy to realise that the archaeological technique of landscape archaeology and the Aboriginal concept of cultural landscape parallel one another closely. Time spent with Aboriginal people developing some understanding of Cultural Landscape gives an archaeologist a better appreciation of the importance of the individual archaeological items and/or sites and places she/he finds. To use the example of the river from above, with some knowledge of the way in which different skin groups use the river, with an understanding of the Cultural Landscape, and the context of the river within that landscape, an archaeologist finding archaeological resources within the vicinity of that river can provide a richer interpretation of that material for the short-term past (200-5000 years) and possibly even identify with greater confidence trends and/or patterns that might then apply to material located and dated to a time in the distant past.

2. Poem written for the World Archaeology Conference by Esther Gardiner

A Sunset Sky

A sunset glowing in an evening sky
Beautiful colours I see
Reminds me of a dreamtime sunset
My people would have seen
In Australia the land of dreams

Dancers would have danced
To clapsticks in time
As the didgeridoo its echoing call
Reminds the dancers to be proud and strong

Dance the memories of our people
This land
Created in the dreamtime
On an evening sunset sky

Esther Gardiner 2013

Student interviews

Various interviews were held with the students and staff at and around the field schools according to UNE Ethics Approval (HREC Number.HE12-157). The students also constructed questions and interviewed each other as part of their training in oral histories. Their final presentation was in the form of a poster. Below is an example from Corey and Lex Livermore (NSW) (See Figure 1.2):

Reflections on field school participation

A number of students reflected formally and informally on their field school participation. Dick Blair kept a diary of his experiences (See Figure 1.3). Here is an excerpt from it:

> 6/5/13 Monday started with some theory work which to me is exceptional because it explains with some imagination what the country was like thousands perhaps millions of years ago and how the elements of nature and man changed some aspects for better and worse.

Other Aboriginal participants reflected in formal interviews. Teangi talked about the need to understand workplace organisational values and culture.

Teangi Brown (Museum worker, Tasmania 10/3/14) said:

> Advice to new students is working in hospitality under pressure, being nice to people, cope with stresses. Need social skills. Don't just go for Indigenous jobs- go for all jobs. Go for responsible jobs- those needing tickets.

Andry pointed out the archaeology-specific aspects of what he learnt at the field schools. Andry Sculthorpe (Tasmania 11/3/14) who is an experienced heritage practitioner said

> Over the last week and a half I have been personally involved in these kinds of activities for a while, but room to learn more. Technical things have been learnt. Artefact identification and knowledge of Aboriginal use of the Midlands- have not known very much and how the network of lagoons fits together and about what happened here. Landscape is important.

Discussion

The field-schools and other project learning activities and experiences provided opportunities for a number of important workplace literacies to be investigated and practised. Most importantly, they illustrate the need and advantages of equitable dialogs across and within cultural and social spaces.



Figure 1.2 *Poster by Lex and Corey 2013*

Learning dialogs

Falk and Dierking (2000: 27) point out that learning, including learning about cultural heritage, is not merely the accumulation of information but a 'cumulative transformation' of cognitive frameworks or understandings. These transformations occur through interaction and dialogue. As educational theorist Vygotsky (1987: 107) expressed it, learning is constructed out of 'joint activity and conversation with other people'.

Just as early views on education were based on a belief that the mind of each student was simply a *tabula rasa* or 'blank slate' onto which knowledge as a commodity could be transmitted by set procedure and repetition (Scaife 2008: 73-74), learning from the multiple voices in Indigenous heritage research requires a real commitment to ongoing (iterative) dialogue which does not presume that knowledge is a commodity with a single voice. Dialogue is neither a one-way-street nor a single visit.

It is helpful to see the project as one of learning (or transforming conversations) at multiple levels: cultural landscapes knowledge; research processes; generic educational skills; cultural heritage project design developed from various points of view; Indigenous/non-Indigenous; scientific/subjective; youth/age; past/present; regional/urban are just some of the multi-vocal dialogues that occur.

Practice spaces

As well as conversation (or dialogue), learning involves practice (Keevers & Abuodha 2012); practice not in the sense of repetition but as 'joint activity'. It requires, that is, the creation or utilisation of spaces for 'learning-in-action' or praxis (Freire 2006[1968]). These spaces may be:

- Physical – as in the exploration of cultural landscape environments themselves with questions and purpose in mind, and
- Social and conceptual – as in building a research team, maintaining consultative networks and nurturing opportunities for knowledge partnerships.

It is in these spaces that praxis, or learning in action in the broadest sense, can occur and sustainable transitions emerge.

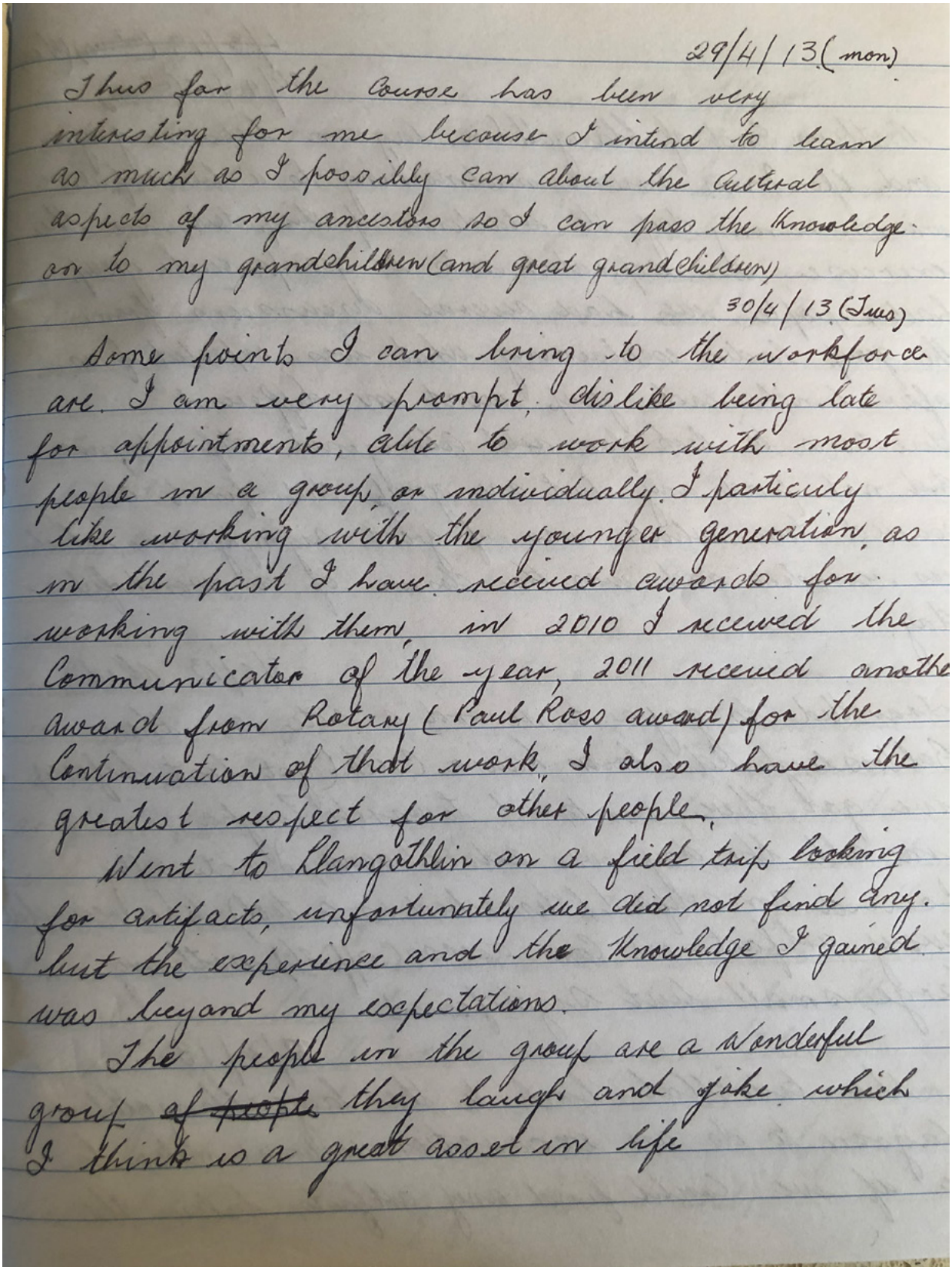
Conclusion: success and its limits

Work integrated learning was very successful as an active site of learning and by including training (partly at University sites, classrooms, college accommodation etc.) and work on country it provided specific skills and encouragement towards Higher Education. Several students did enroll in higher education, at least in part as a result of the project. We collected a number of testimonials, where community members shared aspects of what motivated them to engage with the project and what they got out of it.

The following quote from Larissa Ahoy (NSW student) in response to the question, 'Do you reckon this course is going to help people to know about their culture and history?' illustrates one meaning of heritage:

> *Definitely. Cause it gives people like us a foot in the door. We need to be the ones teaching our kids about our culture and not non-Indigenous people teaching us, how it once was, so once we learn the tools that we need to move forward, we can then pass that knowledge on to the little ones.*

The economic benefits were stated by Lex Livermore (NSW student):



29/4/13 (mon)

Thus far the course has been very interesting for me because I intend to learn as much as I possibly can about the cultural aspects of my ancestors so I can pass the knowledge on to my grandchildren (and great grandchildren)

30/4/13 (Tues)

Some points I can bring to the workforce are I am very prompt, dislike being late for appointments, able to work with most people in a group or individually. I particularly like working with the younger generation as in the past I have received awards for working with them in 2010 I received the Communicator of the year, 2011 received another award from Rotary (Paul Ross award) for the continuation of that work I also have the greatest respect for other people.

Went to Llangathlin on a field trip looking for artifacts, unfortunately we did not find any. But the experience and the knowledge I gained was beyond my expectations.

The people in the group are a wonderful group ~~of people~~ they laugh and joke which I think is a great asset in life

Figure 1.3 *Extract from Dick Blair's diary*

> *Been useful, I would like to become a Sites Officer and would like to help out the community and show people. I enjoyed teamwork and mingling in with the Tasmanian fellas.*

Lee Patterson (NSW Elder) spoke of family and generational connections:

> *Look, one of the things that's important to me as I get older, as I'm getting older, is that I want to share my experiences with my kids and their kids. And let them know that what I did, in my era, in my time, as a kid and as a young adult or a teenager around the waterways and the lagoons around here is one of associating those water bodies and waterways with fun and coming together as a family with all my cousins, my brothers and sisters.*

The effectiveness of the project approaches to working within engaged partnerships in cultural heritage research are demonstrated in the contracts and agreements achieved and in interview comments. The engagement of the community came from a mutual understanding and negotiated agreement of processes— including with regard to finances—and the relevance of the project to local life in the regions. The project gives back to the community most directly in the way we know how, that is, in the way of training and educational and workplace experience. We also argue that this engagement improves the conservation of the cultural resource, through deeper understanding and improved skills in all the participants. Research practice adds to community capacity, not just the academic outcomes. The community, for its part, adds to academics' knowledge, understanding and cultural competence.

Progress in community heritage engagement is strived for, but hard to achieve quickly, especially given the political reality of commercial management versus research. In eastern Australia, the number of funded research projects is very small compared with the numbers of short-term commercial projects. Thus, there is little opportunity generally to carry out long term work in communities. The limitations of the longer-term research approach, however, are that some of the benefits of community archaeology are intangible and not easily measured. In our project, good-will was evident throughout and a real willingness to partner in research was sustained.

Even so, the impacts of over two hundred years of white colonisation cannot be easily addressed in one single project, so disadvantage can only be addressed slowly. This project makes a small contribution to addressing the complex interplay of social, economic, educational, and cultural factors that create obstacles to Indigenous communities playing a greater role in the cultural, economic and social life of the study regions. Alas, inequalities of status between academics and Aboriginal people remain and remain to be addressed further in future projects.

The results of our research do demonstrate a new theory and practice of engagement in community heritage research. Following community defined goals for heritage and higher education studies, groups of young people from eastern Australia successfully participated in work integrated learning at heritage places, where Indigenous knowledge and scientific knowledge were valued and communicated in partnership between elders and academics.

The Lagoons project provided scientific and historical knowledge of landscape change and human environmental interactions in the New England region of New South Wales and in the Northern Midlands Tasmania; knowledge that should aid in managing this landscape into the future. The project combined strong archaeological methodology with participatory heritage research with a view to sustainable and long term social and economic benefits for the local communities.

The design and operation of the project provided opportunities to redefine a contemporary, practical vision of heritage education which can be linked to caring for the land, joining the future of heritage

management to the future social and economic health of the region. Simultaneously, the project partnerships contributed to strong archaeological research and outcomes.

In this project all participants in partnership contributed to creating new knowledges about ancient landscapes in eastern Australia. The definition of 'landscape' used here is that of Johnson, who defines landscape as a 'way of seeing, a way of thinking about the physical world' (Johnson 2007: 4). Equally importantly, participants have been able to assert their presence, and the ongoing presence of their people over millennia, in landscapes from which colonialist discourses have historically erased them (McKenna 2002:205).

In other words, simply describing the physical realities is not enough on its own to explain landscape. As Johnson goes on to say 'For the indigenous peoples of Australia, for example, the notion of distinction between a process of living in the world and one's spiritual or emotional preconceptions about it is a quite alien concept' (Johnson 2007:4). Similarly, Schaama (1995: 3-5) notes that we comprehend personal and social identity through awareness of the past and our construction of the physical world as landscape, mediated through memory, tradition and history.

This can be seen in the poem, '*Australia Land of Dreams*', which Esther Gardiner (elder, Tingha) wrote for us:

A land of dreams and beautiful
Memories Australia so rugged and old

The Aboriginal people were born in
The Dreamtime their footprints on desert
Sands are still shown

The rock engravings of animals and stone tools remain and the dance of the dreamtime is still told today

Walk a little further leaving footprints
In the red dust, and signs of corroborees
That can be seen painted on the rocks

The animals long for the corroborees of our people
In this land
Created in the dreamtime before time began,

As you see a beautiful evening,
Sunset painted in the sky
Remember the dance of the dreamtime
On an evening sunset sky
On dreamtime nights that can be
Remembered in dreamtime dreams
Of a glowing moonlight night

Walk with pride the aboriginal people
Across Australia so old
The first Australians remember in dreamtime dreams

Walk with pride the aboriginal people
Across Australia so old
The first Australians remember
Your heritage in Australia and the dreamtime so old

Esther Gardiner (Kamilaroi/Dhungatti woman and Research Partner)

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Chapter 2:
Connections—Aboriginal Participants' Reflections: a Photo Essay

Compiled and photographed by Catherine Clarke and Wendy Beck

Feeling connections: Signs in place and time

Aboriginal people in the area...left signs, the artefacts and campsites. The artefacts that we're finding now. It's a privilege to walk in the areas that they walked, the Aboriginal people. You feel part of their, a part of their group...



Figure 2.1 *Snapped flake at Barley Field Lagoon, Uralla*

...And being out in the bush I feel at peace with my people, feel part of where they lived and what they did. (Esther Gardiner, NSW)



Figure 2.2 *Little Llangothlin Lagoon, NSW*

Culture and heritage

Project members shared their views on cultural heritage, its meaning and critical value for a sense of self, community and justice.



Figure 2.3 *Isabel Williams*

When I was about six years old, maybe seven, I went to school at Tingha Public, and a young lass, she was non-Aboriginal of course, she said to me, 'Why don't you go back to where you came from?' So, I think, 'Oh, what's going on here?'... I was thinking, 'Did we come from somewhere [else]? I'll have to find this out.' And for a long time, it made me feel like I did come from somewhere else, and maybe I didn't belong here. I knew it couldn't be true. I made it my point to find out about my cultural heritage, and where we came from. So that's what I set about to do ...And then I started, you know, it started, the cultural feel started to come to me. And I wish today that I could see that lass and tell her. (Isabel Williams, NSW)

Cultural heritage is embedded in the land



Well, generally, I think that heritage as an Aboriginal person is your birth right. It's something that's come from your family or your ancestors, so that takes into consideration all of those things: like physical heritage, objects, places, landscapes, land, like land in general - that's Aboriginal heritage. (Adam Thompson, TAS)

Figure 2.4 *Practising knapping, Tasmania*

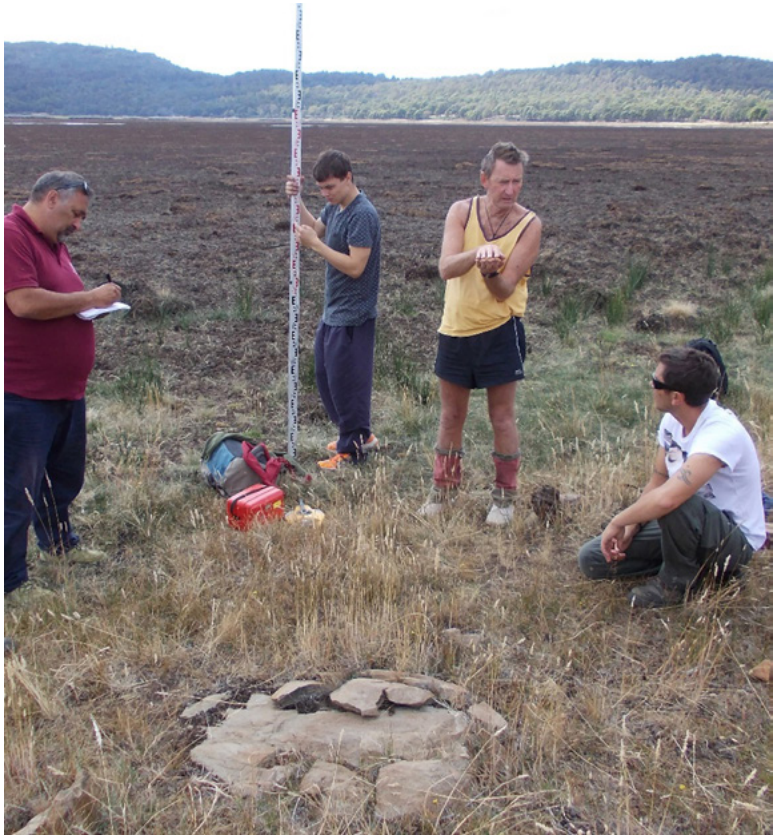


Figure 2.5 *Identifying levels at Lagoon of Islands, Tasmania*

I think that culture is basically the definition of your soul, like without it you wouldn't be anything. It comes from way back, further than anything else you can think of, it's always been in you. It's a very personal thing, we all need it and it's very good to be in touch with your culture. (Jayden Potter, NSW)

Culture is alive

What makes me proud is knowing that we're the oldest culture in the world. ...We're the first ones and yet we still maintain our culture today...[I]f we don't have ceremonies or, you know, initiations, every day of the week, we still practise our culture regardless every day of our lives. (Larissa Ahoy, NSW)

Learning

Experience and tools for uncovering the past and passing it on.



Figure 2.6 *Excavating, NSW*

We need to be the ones teaching our kids about our culture and not non- Indigenous people teaching us how it once was. So, once we learn the tools that we need to move forward, we can then pass that knowledge on to the little ones. (Larissa Ahoy, NSW)



Figure 2.7 *Inspecting a surface scrape for artefacts, NSW*

...I'll be able to take this back. I'm hopefully going to apply for the Aboriginal Archaeology Diploma, so I'll use that for jobs. It would be good just to go back and find sites at home now, and be able to record them. That's why I really enjoyed this, there are a lot of unrecorded sites at home. (Jayden Potter, NSW)

Yeah, it's always good to do a bit of paperwork ... (Lex Livermore, NSW)



Figure 2.8 *In the classroom in NSW*



Figure 2.9 *Sieving for artefacts and other traces, NSW*

...[W]hen you sit down and talk about things it can be hard to get it across, (rather) than if it's actually there in your hands...

... I'd like to become a sites officer or something if I can. ...I'd like to help out and do all that with the rest of the community. Yeah, I've learnt a lot from this, actually. (Lex Livermore, NSW)



Figure 2.10 *Practising pressure flaking in Tasmania*

I found that it's been really interesting finding out more details about artefacts because it's really helped me to be able to form a picture of how the artefact got to be there - material type and how it was manufactured. So, it's raised my awareness in a lot of ways. (Adam Thompson, Tasmania)



Figure 2.11 *Lee Patterson surveying, NSW*



There are many types of knowledge of landscape: traditional; memory; intuitive; primary written sources; analysis and synthesis by commentators; material items as evidence; experimental; biophysical; and others. Also, each culture may have a different perspective and give different emphasis to these different forms of knowledge. If we are to truly understand the landscape and see its richness through human eyes of many cultures, we must recognise the validity of all forms of knowledge. (Warlpa Thompson, NSW)

Figure 2.12 *Learning about plants and the environment*

Working together: Connecting and understanding through teamwork

It's always good to do stuff with people you know but it's also good to do stuff with people you don't know... [Y]ou get to share your experiences with them, experiences that you don't [normally] get to share with people that aren't related to you. (Lex Livermore, NSW)



Figure 2.13 *First Field-School, NSW*



Figure 2.14 *Second Field-School, NSW*

I've enjoyed working with people from another area, and we've been able to compare here to NSW. (Adam Thompson, Tasmania)



Figure 2.15 *Some Tasmanian Field-School Team Members*

And coming to the cultural land down here [Tasmania] is great because we can see the way they control it and look after it. (Jayden Potter, NSW)

They've been telling us about their culture and the ways they live...and about the history that's happened down in Tasmania...It's been good. (Lex Livermore, NSW)



Figure 2.16 *Listening to Elder Clyde Mansell, at trawatha makuminya, Tasmanian Field-School*

Sharing stories

Telling stories and recording oral histories across generations, cultures, and regions is key to valued ongoing connections.



Figure 2.17 *Tasmanian Elder speaking to Field-School at trawatha makuminya, Tasmania*

[S]tories are important because that's how people communicate about land and places and history in Aboriginal culture. And stories about places help people to understand them, they're something that's continuous. Like, in Tasmania, most of the stories about places that have been around for thousands of years have been lost, and when we talk to people from the mainland who are still aware of their stories about places, you really wish that you knew the stories about your own country, it's such a shame that they've been lost. So, the stories that we do have are so important. (Adam Thompson, Tasmania)



Figure 2.18 *Sharing stories at trawatha makuminya, Tasmania*

Jayden Potter: Do you think it's necessary to transfer information from Elders to the next generation?

Tim Levy: Yes, because without transferring it, how would our culture and history be still alive when me and you are dead? If our grandkids were still saying the stories that we are here, I'd be so happy. At least I'd know they'd be learning about our culture and not white peoples' culture.



Figure 2.19 *New England Elders in Tasmania*



Figure 2.20 *Dick Blair*

...[to] pass the knowledge on to my grandchildren and great grandchildren. (Dick Blair, NSW)

Tim: We wouldn't know what we know today without our Elders. Hey, Brother?

Jayden: Yeah, that's it, you need to talk to your Elders just to get the start of your culture, to start off. (Jayden Potter and Tim Levy, NSW)

Water stories: Landscape and its elements in culture, identity and lived experience



Figure 2.21 *Lee Patterson*

[W]e are great storytellers. Even when we are kids, we're great storytellers. I love looking at my kids now – grandkids – and seeing how they tell stories to each other. They're bursting with joy!...And I want to see that again [in relation] to the old places I went as a kid and swam and did other things like skimming rocks. And it was just like a family water cultural thing that we would do. (Lee Patterson, NSW)



Figure 2.22 *Llangothlin Lagoon, NSW*

Isabel Williams: My introduction to water was carrying the stuff, we had to carry it from the waterhole up to the house.

Dick Blair: [W]e had a lot of four-gallon drums. We use to have to fill them up, that was me and my older sisters' job after school every afternoon— to make sure those buckets were full. (Isabel Williams and Dick Blair, NSW)



Figure 2.23 *Change of light at Lagoon of Islands, Tasmania*

[A] lot of the stories that we record are about the elders growing up and mutton birding and things that they did, and that's important for our islands and for us to record them for the future generations of Aboriginal people. Because people, especially Aboriginal children living in our society when they're young and they're at that age where they're trying to form their identity, and they say to themselves what makes me - especially when they don't look that different to other people, and they say – 'What makes me Aboriginal?'...'How am I different to anyone else?' Well often it's the cultural practices and the stories that they're aware of and the knowledge of their family and their past that makes them different. That's why those stories are important, for young people and forming their identity. (Adam Thompson, TAS)

Well, I sit down and listen to the old people, the old Elders, when they tell stories so I can connect the stories to the places and tell other people. So they can feel a connection too. (Esther Gardiner, NSW)

Chapter 3:
Fieldwork, Sampling and Study Areas

Wendy Beck and Robert Haworth

Aims

The aim of this chapter is to explain why the particular sites were chosen for study in the New England Tableland and in Tasmania and how we went about our field investigations. The overall strategy has been detailed in the Introduction, but in this chapter we explain the specific geomorphic and archaeological methods we used to construct past landscapes.

Wetlands

Wetlands have various definitions. In this book we use the terms 'lagoon' and 'lake' mostly according to local naming custom. Lakes tend to be deeper (over 1.5 m) and larger in surface area. Some are permanent but most wetlands are not. 'Temporary wetlands are far more common and widely distributed in Australia than are permanent lakes and swamps' (Bell *et al.* 2008: 475; Paijmans *et al.*1985).

Wetlands are also cultural landscapes. Those that persist to the present day are useful starting points for study because they can preserve long-term geomorphic and archaeological evidence over thousands of years, which enables comparative studies of human interactions. To date, Australian Pleistocene human land-use studies in ancient wetland areas have been focused on riverine lagoons such as Lake Mungo (Fitzsimmons *et al.* 2014) and those in Northern Australia (Bourke *et al.* 2007), whereas this project compares people–land relationships in depressional wetlands in cold, 'harsh' climates with coastal connections.

The ancient wetlands provide opportunities for good Pleistocene sediment records of Aboriginal occupation and climate change to be preserved in periglacial settings (Colhoun *et al.* 2010; Haworth 2006). The 'lagoons' in this study are shallow upland ponds located along the highest parts of the major drainage divides. The 'lakes' in the study are larger and deeper permanent water bodies. Most of these wetlands have wind-formed 'lunettes', crescentic sand dunes or clay mounds, on their lee (eastern) side, suggesting that they were formed under harsher climatic conditions than the present, possibly in the cool tundra type landscape thought to have been present during the Last Glacial Maximum (LGM) in the high country (Galloway 1965; Slee *et al.* 2014; see Chapters 5 and 9). Lunettes provided productive opportunities for finding archaeological sediment and artefact sequences, especially as the granite, dolerite and basalt geology is not conducive to large rock-shelter formation.

In other parts of the world, these wetlands are known as 'depressional wetlands' and are differentiated from those in other geomorphic settings, such as riverine, lacustrine, estuarine and slope wetlands. The basic difference is that they are closed basins where the major water source is rainfall and its evaporation, not rivers or streams. These wetlands occur in North America, Northern Europe, South America, Asia and Australasia (Brinson and Malvarez 2002). Temporary wetlands (lagoons) can occur in 3–5 general forms: near-permanent (rarely dry); intermittent and episodic (often seasonally dry) and ephemeral (only occasionally full).

Intermittent wetlands in New England support the greatest variety of plant species and therefore habitats: 24 species as opposed to only 15 in the near-permanent wetlands, and less than five endemics in the most ephemeral lagoons (Brock 2011). Both near-permanent and intermittent lagoons tend to be shallow and have vegetation throughout their area, but the shallower intermittent wetlands support a greater variety and produce a relatively greater potential habitat area in the seasonal fluctuations of their concentric zones. This abundance of vegetation types and species successions creates a range of microhabitats, which are exploited by a large number of native fauna, most noticeably the waterbird species.

Table 3.1 (Brock 2011) shows that the pattern of water filling and drying for lagoons can be used as a classification scheme, although most lagoons have been disturbed by European agricultural activities. The lagoons vary in size. For example, on the New England Tableland they range from less than 0.5 ha up to 430 ha (the Mother of Ducks Lagoon, near Guyra) (Bell *et al.* 2008) which affects the ecology and drying patterns of these wetlands. However, scholars agree that each lagoon has individual characteristics, such as vegetation, microfauna, and water regimes, which are not tied to landscape level variables and therefore each lagoon is individual and needs to be managed individually. This causes issues for effective conservation (Growns *et al.* 2020, Hunter 2018).

Table 3.1 Types of temporary wetlands by drying patterns (after Brock 2011).

Drying pattern	**Predictability and duration of filling**
Semi-permanent or near permanent	Usually holds some water; annual inflows are greater than minimum loss in 90% of years May dry during extreme drought events
Seasonal	Alternately wet and dry every year according to season Fills during wet season and dries annually Surface water persists for months
Intermittent	Alternately wet and dry, but less frequently and regularly than seasonal wetlands. Surface water may persist for months to years
Episodic	Annual inflow is less than minimum loss in 90% of years Dry for most of the time Only rarely and irregularly flooded, when water may persist for months
Ephemeral	Only fills for a few days after unpredictable rainfall and run-off

Lagoons as Aboriginal Resources

Lagoons were potentially diverse sources of food and fibre resources for Aborigines in the past and provide resource clusters that are not available elsewhere in the region. For further details of species and distribution see Beck *et al.* (2015). The resources of the lagoons generally are water, stone for artefacts, plants and fauna, including birds, mammals, amphibians, crustaceans and reptiles. Eels are the only fish found naturally in large numbers in these cooler waters, and only in the lagoons on the eastern (Pacific Ocean) side of the Great Divide (Park 1986). Small rare native fish (*Galaxias auratus)* are found in Lakes Sorell and Crescent, but not in any other lakes. Many of the flora and fauna are specific to these still-water wetlands and would not be common in other water bodies, such as faster flowing streams and rivers.

Wetland Use by European Settlers-Nineteenth Century

European settlement began in the 1840s in the New England region and around 1800 in Tasmania. Early settlers hoped for immediate and future gains from wetlands as they seemed to promise a reliable water

supply. The natural fluctuations of water levels dashed these hopes and the response was to manipulate water regimes. Modification of water regimes arose from local management action. It occurred in the absence of public policy, agreed values for wetlands, or guidelines on actions. As well as intentional water regime changes many unintentional changes occurred as a consequence of land-use in the wetland catchments. As uses of wetlands became more intensive and often extractive, more was invested in engineering. The basic attitude was 'dam it or drain it' in an attempt to decrease the variability of the wetlands (Brock *et al.* 1999).

Some examples:

Industrial use shaped the landscape in the 1870s. At Lake Llangothlin (410 ha), an account in the local paper in 1939 describes the owner's experiments with waterwheel power:

> Mr. C. T. Bagot was a horticulturist amongt [sic] other things, and was trained at an agricultural college in the South of England ... He was a very optimistic man and could see only a bright future in all his undertakings. He erected a large overshot water wheel over 40 feet in diameter. He had a big lagoon dammed up at the creek outlet and raised the water by several feet. He had a race cut round the hills at the other end of the lake, conveying the water close to the homestead. It was then run into a large flume from the top of the hillside, discharging over the wheel, alongside of which was erected a sawmill, and later on a flour mill was to be erected on the other side of the wheel, which was never finalised ... Unfortunately for Mr. C. T. Bagot in the early eighties, a depression came along and cattle fell to a very low price. Mr. Bagot in his optimism had borrowed a lot of money from a certain bank and this bank saw that it was a promising time to foreclose on such a good property. ('Web' 1939)

However the mill only ran for three years and was then demolished (Connah 1994), and was archaeologically excavated in the 1980s. The waterwheel failure was due to insufficient water, financial problems, and old-fashioned wheel technology. Some of the traces can still be seen in the landscape (Figure 3.1**)** and it was used as a rubbish dump after its demolition.

The largest lagoons were used for recreational boating and swimming between the 1880s and 1930s. For example, boating on Mother of Ducks Lagoon, in the 1880s involved a shallow draft paddle steamer. Even the smaller lagoons were used for picnics and local sports events. This is illustrated in Figure 3.2 which shows a picnic at Dangars Lagoon (55 ha) in 1902.



Figure 3.1 *Remains of Bagot's Mill at Lake Llangothlin, NSW*



Figure 3.2 *Dangars Lagoon picnic, NSW, 1902 HRCP 7312 (New England Archives)*

Wetland Use, overlapping Aboriginal/Settler occupations

It is clear that the lagoons represent a range of values to different groups of people. In some cases continued association between Aboriginal and European uses of the lagoons is apparent. In 1951 Mother of Ducks Lagoon was drained to extend land used as a golf course. Contemporary photos of a local Aboriginal family, the Walkers, (accessioned in the New England Archives as HRCP 1540 and 1541) by an unknown photographer shows continuity of association through time, with the family perched on the newly constructed dam. The drain reduced the outlet level by 1.7 m and was designed to prevent flooding of the golf course and to provide more grazing land in Guyra (Brock *et al.*1999).

At Barley Field Lagoon a modern dam has been built to provide stock water in this Travelling Stock Reserve. The dam is based on the shallow underlying water table. The lagoon is approximately 400m from north to south (6 ha in area). The 1880s railway line and rail cottage are in close proximity as well as the current road motorway, all of which skirt the lagoon and disrupt and reduce its catchment This lagoon was also used in the nineteenth century to provide water to Rocky River goldfields via a channel cut into the hill across the Great Divide. There is a large surface archaeological site on the southern end of the lagoon, with different types of artefact raw material suggesting that stone was brought here by Aboriginal people.

Another example of drainage and cultivation can be seen at Kings Plains lagoon. This lagoon (see Chapter 7) is approx. 200 m from north to south (2 ha in area). In the satellite image, the line across the centre represents a fenced boundary between private land to the north and public Travelling Stock Reserve to the south. Note the difference in land use/cultivation to the north and remnant vegetation to the south. The sloping lunette is also avoided in the cultivated area. A few isolated stone artefacts were found on the surface.

The best preserved lagoon in New England is Little Llangothlin (100 ha). There is evidence of Aboriginal occupation with stone artefacts and scarred trees seen in Figure 3.3. In 1996 it was recognised as an internationally important example of a natural wetland in the New England bioregion.

> At 105 hectares, Little Llangothlin Lagoon is one of the largest examples of these high altitude lakes. It is also rare due to its near-natural condition, as the majority of the lakes have been degraded or destroyed through hydrological modification, grazing and cropping (NSW Department of Planning, Industry and Environment, Little Llangothlin Nature Reserve)

Little Llangothlin lagoon also provides a habitat for threatened plant species and a habitat refuge for waterfowl. Local, regional, national and international awareness of the value of wetlands has increased from the 1970s onwards. The lagoons are protected by recent legislation. They are listed as *Threatened Ecological Communities* under the *Federal Environment and Biodiversity Act 1999* and under the *State Biodiversity Conservation Act (2017) (Upland Wetlands of the Drainage Divide of the New England Tablelands and the Monaro Plateau).*



Figure 3.3 *Scarred trees at edge of Little Llangothlin Lagoon, NSW*

Methods

Initial Reconnaissance for Sample Locations

In 2012 reconnaissance surveys were carried out by the research team in New England and Tasmania. This included both desktop survey and field examination. For New England a preliminary list of sixty lagoons was documented. This document included a satellite photo, altitude, latitude/longitude, substrate, surface area, previous geomorphic research, previous archaeological research and disturbance history. The document was divided into regional zones from north to south: Glen Innes, Llangothlin, Guyra, Armidale/Uralla, Walcha and Liverpool Ranges. A sample page from this document is presented in Figure 3.4. This large survey was possible due to significant previous research on the area (Bell *et al.* 2008). There have been further ecological surveys of the presence of lagoons in New England and the Namoi River catchment since 2012. The number of upland lagoons counted in the New England has risen to 58 (Hunter 2018). In this

10

9. Barley Fields Lagoon, Glencoe

- Altitude: 1146 m—lat./long.: 29 54' 50"/151 44'—substrate: basalt—area: 10 Ha
- Tenure: public land

Geomorphic Research

- Ovoid shape
- Commercial grazing ceased 2007
- Retains geomorphic and ecological integrity, except where highway cuts eastern edge
- Marked by government surveyor Galloway in his 1840 chart

Archaeological Research

- None known

Disturbance history

- Mostly intact—commercial grazing ceased 2007—management authorities will fence and weed to increase ecological integrity.



UNE Wetlands Project—New England Lagoons: Maps, Images and Summary Data---Haworth (Oct 2012)—Project Team Background Data

Figure 3.4 *Sample page from New England lagoon reconnaissance document*

study the smallest area of these lagoons was 0.6 ha and the largest 110 ha with a mean area of 13.6 ha. Generally, most lagoons are smaller than 10 ha in size (81%) and very few are large, that is, over 100 ha (2%) The New England map derived from this work is presented in Figure 3.5.

In Tasmania 24 lagoons were initially listed in the desktop study. These were divided into Central Plateau lagoons, Midlands lagoons and East Coast lagoons. Information about the lagoons was presented in a similar way to the New England lagoons.

Final selection of sites

The final selection of eight wetlands from Tasmania and nine from New England was based on a number of characteristics. First, we looked for sites with visible and reasonably preserved lunettes with stratigraphic integrity and with archaeological evidence, at a range of sizes, and including places in each of the four New England Aboriginal Land Council areas. We also mostly chose lagoons which had surface stone artefacts. We also preferred sites under public ownership (for access reasons). The Tasmanian wetlands are generally larger by orders of magnitude- the largest (Lake Sorell) is over 9000 ha whereas the largest New England wetland (Lake Llangothlin) is only approximately 400 ha in extent. The base geology is variable. The altitude of New England lagoons is also much higher than that of the Tasmanian ones, although latitudes differ by ten degrees, 30 degrees versus 42 degrees. The smallest wetlands sampled are similarly sized at about 2 ha (Kings Plains and Township Lagoons). Three of these lagoons (Rushy & Township in Tasmania and Little Llangothlin in NSW) were only surveyed in the course of fieldwork, and no subsurface samples were taken, although some were used from earlier research for Little Llangothlin. Sediment samples for geomorphological analysis were taken from the others- fifteen in all. The characteristics of the final sample lagoons are shown in Table 3.2.

Permits

A number of regulations govern physical research into wetlands in Australia. We have discussed the formal agreements with Aboriginal communities in Chapter 1 which outline our overall approach to working on wetlands. Specific permission to carry out archaeological excavations on the lagoons in New England required permits from the Office of Environment and Heritage NSW (AHIP no. C0002673) and Local Land Services NSW, Travelling Stock Reserve Use Permit #3 (the major landholder for these lagoons). No subsurface archaeological work was carried out on Tasmanian wetlands, according to TAC practice.

Geomorphic fieldwork

The geomorphic research involved reconnaissance-level observations of bedrock exposures and Quaternary sediments around the perimeter of each selected lake. Records were obtained of slope deposits and alluvial sediments proximal to some lake shores, including the size of constituent clasts, clast angularity and weathering status, the latter being based mainly on the thickness of weathering rinds, assessing those formed on subsurface clasts separately from those on surface clasts. Investigation of in-basin sediments included identification of cobble ridges and beach sands, the depth of organic-rich sediment on some basin floors being determined by hand auguring and examination of artificial drains. The spatial extent, morphology and stratigraphy of lunettes and sand sheets proximal to the lakes were recorded using aerial photography, ground based observations and hand auguring, and their stratigraphy recorded. All sample extraction sites were registered with GPS co-ordinates, and dune features and sizes delineated by field measurements and re-checked on Google maps and relevant 1:25,000 relief maps, and larger scale cadastral maps and plans where available.

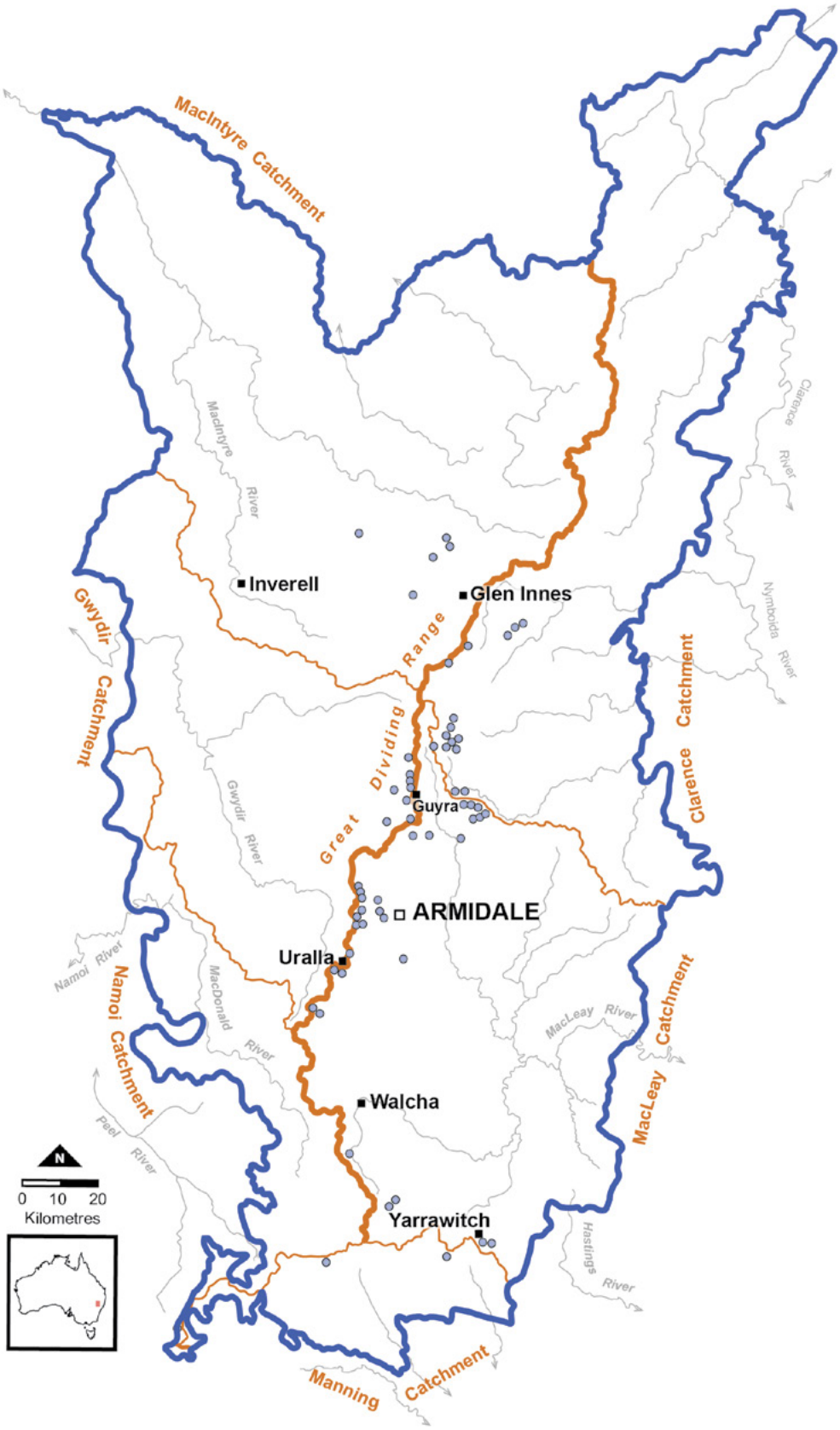


Figure 3.5 *Map of all New England lagoons (K. Newman)*

Table 3.2 Characteristics of lagoons sampled for detailed study after preliminary fieldwork

Name	Size (ha)	Bedrock	Elevation (m)	Lunette?	Archaeology within 100m of waters edge observed in field?	LALC or TAC responsible	European HIstory	Nature of Samples
New England								
Barleyfields (Uralla)	6	Basalt	1069	Yes	Yes	Armidale	Historical drain on west, now blocked by road/rail	OSL, sediment, arch. excavation
Big Llangothlin (Llangothlin Lake)	410	Basalt/granite	1354	Yes	Yes	Guyra	Canal at lagoon outlet	OSL, sedimant, arch excavation
Dangars Lagoon	55	Granite/basalt/ dolerite	1022	Yes	Yes	Armidale	Intense historical recreational use. Small dam	OSL, sediment archaeological excavation
Glencoe Lagoon(Barleyfields)	10	Basalt	1144	No	No	Glen Innes	?Little	arch. excavation, AMS samples
Kings Plains Lagoon	2	Basalt	930	No	No	Anaiwan	Grazing, cultivation, fencing across	OSL, arch. excavation,
Little Llangothlin Lagoon	100	Basalt/granite	1355	Yes	Yes	Guyra	?Little. Drain blocked.	None.
Racecourse Lagoon	20	Granite	1030	Yes	Yes	Armidale	?Little. Intense historical recreational use	OSL, sediment,
Reddestone Lagoon	30	Basalt	1034	No	No	Glen Innes	Drained, dams. Cultivated . Fenced across	arch. excavation, AMS dates
Thomas Lagoon	4	Basalt/silcrete	1034	No	Yes	Armidale	Dam/retaining wall	arch. excavations, AMS samples
Tasmania								
Bells Lagoon	64	Dolerite & sedimentary	257	Yes	Yes	TAC	Canal at lagoon outlet, bunker built	OSL, sediment
Lagoon of Islands	900	Dolerite & sedimentary	758	Yes	Yes	TAC	Water level dammed and drained	OSL, sediment
Lake Crescent	2300	Dolerite	804	Yes	Yes	TAC	Town water supply	OSL, sediment
Lake Dulverton*	233	Sandstone	401	No	Yes	TAC	Dams and bunds	n/a
Lake Sorell	9840	Dolerite	804	Yes	Yes	TAC	Town water supply	OSL, sediment
Lake Tiberias	970	Dolerite & sedimentary	437	Yes	No	TAC	Drains	OSL, sediment
Rushy Lagoon*	40	Basalt & sandstone	383	No?	No	TAC	Drains	n/a
Township Lagoon	2.6	Dolerite & sandstone	199	No	Yes	TAC	?Little evidence	sediment

*surveyed during fieldschools- no subsurface samples take

Archaeological excavations in New England

In the New England region, we excavated at seven lagoons, sampling different altitudes ranging from *c.* 900 m asl to 1360 m asl in a 100 km transect from north to south. These represented a sample of lagoon sizes and lithologies (basalt, granite and silcrete). The excavations were small (less than 10 m^2) at each lagoon for logistic and cultural reasons, and each excavation was carried out by a team of volunteer university students and Aboriginal community members. The position of the excavation squares was determined in part by geomorphology and partly by the presence of surface artefacts, so some were on the lunette and some on the lakeshore. As no visual stratigraphy was present, arbitrary layers were removed by hand and dry sieved. Ironstone layers were common and prevented deep excavations. OSL samples were taken using metal tubes as plastic tubes broke in the hard sediments. In addition, charcoal, where present, was taken at some lagoons, for radiocarbon dating.

As per the Office of Environment and Heritage (OEH) Code of Practice (2010) excavation was carried out by hand in 5 cm layers (or less), in 50 cm x 50 cm squares at several different locations across the lunette and/or lake edge. Each square was sieved and any artefacts found were stored in accordance with the Code. Each excavation square was back-filled and the ground level restored after excavation.

Lagoons are very individual in their characteristics, both biological, palaeoecological and cultural, and this is an important feature when determining methods of analysis and interpretation.

Establishing chronologies

OSL (Optically Stimulated Luminescence) dating of sand samples obtained from enhanced natural exposures and excavated pits. OSL samples were collected from parts of the dune profile that could best pinpoint the age of formation, and the pace and nature of development. Multiple-aliquot age determinations were undertaken at several laboratories (See Chapter 4 for details).

Samples for were also AMS (Accelerated Mass Spectrometry) dating were obtained near or immediately under Aboriginal artefacts not directly linked to the geomorphic work. were taken for archaeological purposes. These determinations, deriving from shallower locations than the OSL samples, were also used to check the sedimentation rates determined for the deeper sites and to see if there was any distorting disparity between near surface rates and those at depth. The sedimentation rates were themselves subject to the caveat that we had no precise means of checking for any variation in sedimentation rates, except that given by the sparse OSL ages with their very broad age ranges, and a general picture that emerged in each sediment column of the degree of overall consistency of grain size and stratigraphy. For further details see Chapter 4.

Particle sizing and sediment descriptions

Pits, measuring at least one metre by one metre, were dug as deep as practicable with appropriate reinforcing, and at the base of these pits further cores were extracted several metres deeper using a three-metre steel auger, in order to extract samples for dating, to check any change in stratigraphy, and locate any Aboriginal artefacts at depth (see Chapter 7). Materials collected from auger corings and pit faces were generally described in terms of:

- field texture,
- colour and field pH, of each
- distinct stratigraphic layer and/or pedogenic horizon.
- sediment classification
- particle size analysis

Particle size analysis was performed at various sections of the dune profile, both above and below areas of OSL dating. This analysis was employed to identify changes in sediment size potentially indicative of changes in sediment provenance, and hence change in the depositing agent, such as wind, water or bioturbation (O'Connor 1990). It was also employed to assess the rate and continuity of sediment accumulation, and to identify any internal disturbance, taking account of the potential for confounding factors such as periods of soil formation with colloidal action producing fine clays, or of periods of deflation, or even anthropogenic disturbance, that might disperse sediment and cause a gap in the profile.

The particle size analysis was carried out using a Malvern Mastersizer 3000, using laser diffraction to measure particle size distribution over most of each core. Skewness of a grain size population is a measure of the predominance of finer or coarser sediment relative to a mean (Boggs 2011). The Mastersizer graphs show the grain size population and, among other things, the degree of skewness in the size distribution.

Dune volumes

Total volumes of sand contained in different dunal zones of the New England lunettes were calculated from field measurements of length and average width and multiple auger probes to estimate the average depth of each feature or accumulation. In extensive and irregularly shaped depositions, such as the north Llangothlin sand field, the total feature was broken into segments for the purpose of measurement for calculations, in order to ensure that the estimated average widths and depths were reasonably accurate. Rates of accumulation of sediment were calculated between points where ages had been determined, and from the surface. While these rates are obviously subject to unknowns, such as possible periods of deflation, over the long periods measured they might give a general guide to age when no radiocarbon ages are available.

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Chapter 4:
Dating and Chronology

Elspeth Hayes, Richard Fullagar, Wendy Beck and Kevin Kiernan

Introduction

One of the important contributions of the Lagoons Project is to provide ages for the archaeology and geomorphology of the study regions. Only one published dated archaeological horizon in the New England Tableland Bioregion (820 BP, at Reddestone Creek megafauna site) existed prior to our study (Horton and Connah 1981). Consequently, we employed a generalised dating program that allowed us to sample the range of lagoon depositional contexts and understand their chronologies. Our approach (see Chapter 3) included the dating of sediment and charcoal samples using single-grain and multi-grain optically stimulated luminescence (OSL) and radiocarbon dating. (see Figure 4.1 for sample locations). In all, nine radiocarbon ages were determined for four sites together with 54 OSL ages (Tables 4.1 and 4.2).

The aim of this chapter is to explain the dating techniques and the general limitations and constraints of the dating methods as well as the resulting chronologies. The implications of the chronologies are more fully discussed in Chapters 5-11.

Sample collection and analysis

As charcoal was not commonly found in the sediments, only nine samples were collected for radiocarbon dating, recovered from contexts associated with the archaeological material from four sites in the New England region: Barley Field, Big Llangothlin, Reddestone and Thomas Lagoons. Charcoal samples were collected during archaeological excavation from the 3 mm and 5 mm mesh sieves and submitted to the Waikato University Radiocarbon laboratory for AMS dating (see Appendix A for a description of sample pre-treatment methods and measurement instruments).

All other ages (n=54) were determined using OSL on sediments collected from relevant stratigraphic levels from ten lagoon sites (see Appendix B). In this method, ages are given as an estimate of the time since the quartz grains within sedimentary deposits were last exposed to sunlight. Based on the depositional age of the surrounding sediment, ages can be inferred for the timing of site formation and cultural activities.

Sediment samples were sent to one of two institutions for multi-grain and single-grain OSL age determinations: (1) the University of Wollongong (UOW), Australia, and (2) the University of Washington (UW), USA. Sediments were collected from excavation pits (dug to depths ranging from 100–200 cm) by driving a 200 mm section of metal or opaque plastic tube (60 mm diameter) horizontally into the sediment profile and then capping the ends with tape as it was removed (See Figure 4.2). This approach ensured that the sediments within the middle region of the tubing were protected from light until the sample was opened and measured in the laboratory under the appropriate lighting conditions. Samples were then submitted to UW and UOW single-grain and multi-grain OSL analysis, respectively.

Samples collected from deposits associated with archaeological materials (n=17) were analysed at UW using single-grain OSL, where OSL ages are determined from measurements made on single grains of

quartz (Appendix C). Samples collected from deposits to assess site geomorphology (including ages of lunette formation, n=34) were analysed at UOW by two analyst teams using multi-grain OSL. In this method, age estimates are determined from measurements made on multiple grains of quartz (~10–100 grains) composed on a single disc ('aliquot') that are measured at the same time (see Appendices B and C).

Following measurement of quartz grains, a single, representative equivalent dose value (i.e., the amount of trapped electron charge equivalent to the time in which the quartz grains were protected from sunlight) for a population of individual grains or aliquots was determined using one of three parametric statistical models: **(1)** the central age mode (CAM); **(2)** the maximum age model (MAM); and **(3)** the finite mixture model (FMM) (Galbraith *et al.* 1999; Roberts *et al.* 2000; Roberts and Galbraith 2012). Where equivalent dose distributions were interpreted to represent a single well-bleached population of grains (i.e., there is a single component equivalent dose distribution), the CAM was used to calculate average equivalent dose values for final age calculation. This model assumes that the equivalent dose values for all grains are centred on an average value of equivalent dose, and the estimated uncertainty takes into account any overdispersion (Galbraith *et al.* 1999). In samples where equivalent dose distributions were thought to represent two discrete dose populations (e.g., when a sample consists of grains that have been fully bleached and is subsequently mixed with younger, intrusive grains), the maximum and minimum age models were applied to determine the maximum and minimum dose rate populations. Under these circumstances, the timing of primary deposition can be estimated from the equivalent dose values of the well bleached, host grains—that is, the grains that with the highest equivalent dose values (Galbraith and Roberts 2012). In samples that had multiple discrete dose populations, the FMM was applied to determine the most likely equivalent dose for the targeted dating event. This model enables the number of discrete dose population components to be recognised and given along with the equivalent dose of each dose component and the proportion of grains belonging to each component. The equivalent dose value for age calculation is selected from the most populated dose component. This model is typically applied to samples that have a scattered equivalent dose distribution that is often typical of mixed sediments.

The resulting equivalent dose values determined from the models were then used in the OSL age equation together with measurements of the environmental dose rates to determine OSL ages. Equivalent and environmental dose values are presented in Appendix C with final age calculations summarised in Table 4.2.

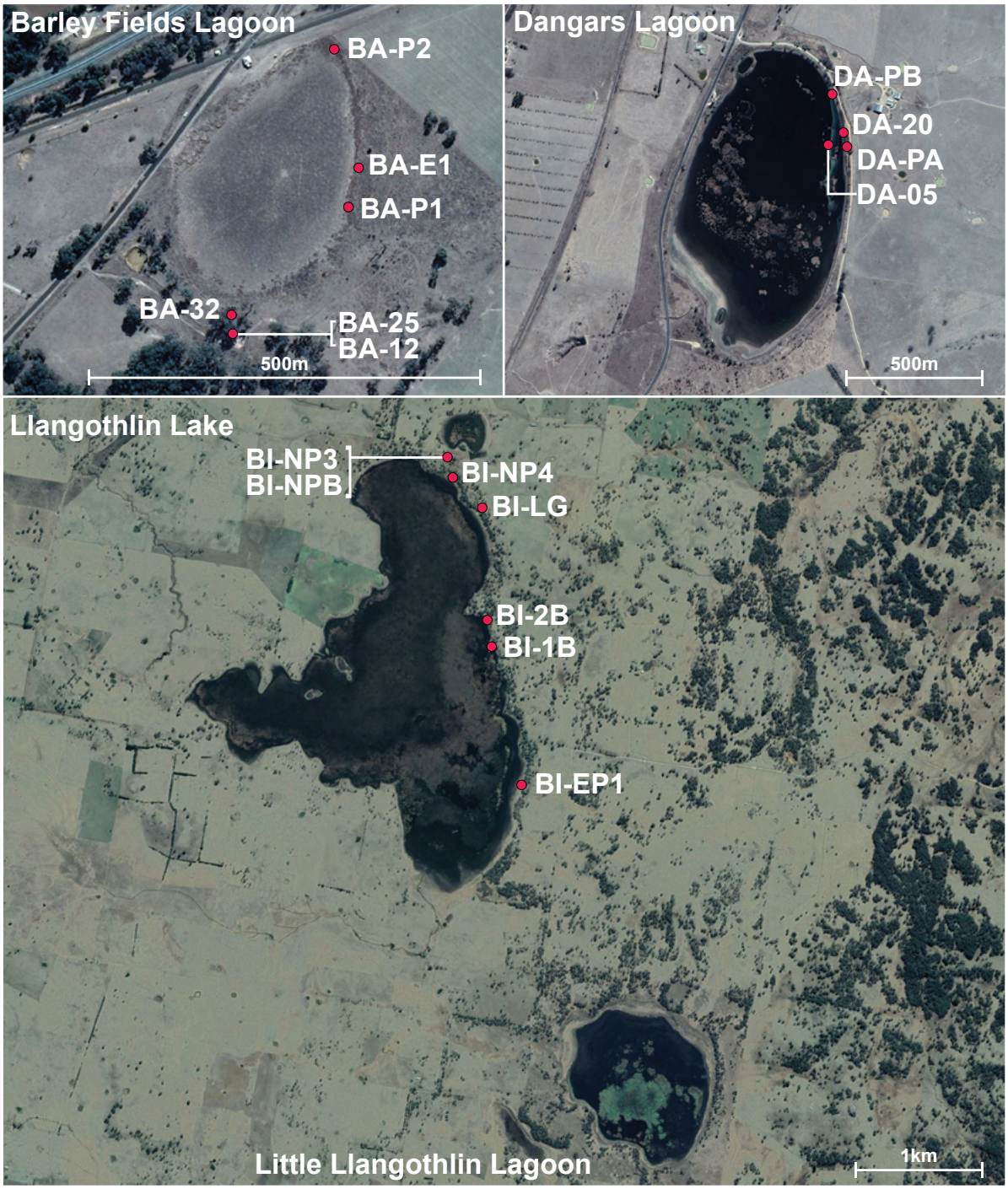


Figure 4.1a *Locations of lagoons and dated samples in New England 1 (K. Newman)*



Figure 4.1b *Locations of lagoons and dated samples in New England 2 (K. Newman)*



Figure 4.1c *Locations of lagoons and dated samples in Tasmania (K. Newman)*



Figure 4.2: *Barley Field Lagoon OSL sampling Barley Field Lagoon Pit 5*

Results

A total of 63 ages were produced across 11 lagoon sites using radiocarbon (n=9) and OSL dating (n=54) techniques (Tables 4.1 and 4.2; Appendix B). The AMS radiocarbon ages obtained from charcoal samples collected from four archaeological sites in the New England region are summarised in Table 4.1. Calibrated ages across all four sites ranged from 2290 and 240 years BP and indicate all dated material (and associated archaeological material) derive from the late Holocene. Single-grain OSL age estimates for sediments collected from archaeological contexts also indicate that the archaeological material mostly derives from the late to mid Holocene (Table 4.2, shaded cells). Multi-grain OSL ages for sediments collected from geomorphological contexts are generally much older than those obtained for sediments from archaeological contexts and indicate that some of the dunes and associated wetlands were extant at the time of earliest human settlement in Australia (Table 4.2, unshaded cells). The implications of these chronologies are more fully discussed in Chapters 5–11.

Table 4.1 Summary of AMS radiocarbon ages.

Site name	Field Sample ID	Location code on Figure 4.1	Depth below surface (cm)	Wk-Lab No.	δ13C ‰ (CRDS)	F14C%	Central Age (ka BP)	Calibrated Age (calBP) 95.4%	On or off lunette, Lagoon Margin
Barleyfields, Uralla1	BFU 32/4	BA-32-11	11-16	44209	-26.2 ± 0.3	75.4 ± 0.2	2269 ± 20	2290-2150	ON, SW
Big Llangothlin	BGLL 2A/1	BI-2A-08	8-12	44209	-26.2 ± 0.3	97.5 ± 0.2	201 ± 20	240-70	OFF, NE
Big Llangothlin	BGLL 2A/4	BI-2A-15	15–19	44211	-25.5 ± 0.3	95.4 ± 0.2	375 ± 20	320	OFF, NE
Big Llangothlin	BGLL 2A/5	BI-2A-19	19–25	44212	-26.1 ± 0.3	95.4 ± 0.2	376 ± 20	320	OFF, NE
Big Llangothlin2	BGLL 2A/6	BI-2A-25	25–30	44213	-25.3 ± 0.3	95.4 ± 0.2	381 ± 20	320	OFF, NE
Reddestone3	R300/2	RE-300-14	14	44214	-25.1 ± 0.3	97.2 ± 0.2	232 ± 20	270–150	OFF, N
Thomas Lagoon	TH 1M/6	TH-IM-26	26	44215	-28.3 ± 0.3	92.7 ± 0.2	608 ± 20	600–530	OFF, NW
Thomas Lagoon	TH 27C/3	TH-27C-05	5–10	44216	-26.2 ± 0.3	97.4 ± 0.2	212 ± 20	250–140	OFF, NW
Thomas Lagoon	TH 27T/3	TH-27T-05	5–10	44217	-26.7 ± 0.3	98.2 ± 0.3	143 ± 20	220–150	OFF, NW

TABLE 4.2 OSL AGES FOR NEW ENGLAND AND TASMANIAN WETLANDS SITES.

Site	Field sample ID	Location code on Figure 4.1	Depth below surface (cm)	Central Age (ka)	Analyst team	Age model	Likely age range (ka)
Barleyfields	KK_BFL_01	BA-P1-32	32	10.5 ± 0.8	EH, ZJ	CAM	
Barleyfield	KK_BFL_02	BA-P2-15	15	14.7 ± 1.4	NJ	CAM	
Barleyfields	KK_BFL_03	BA-P2-57	57	27.2 ± 2.4	NJ	CAM	
Barleyfields	KK_BFL_04	BA-P1-70	70	47.8 ± 2.7	NJ	CAM	
Barleyfields	BFL-E1-01	BA-E1-31 UW3479	31	6.34 ± 0.566	JF	FMM	4.5–7.3
Barleyfields	BLF-E1-02	BA-E1-40 UW3483	40	8.69 ± 0.696	JF	FMM	5.0–9.0
Barleyfields	BFL-E1-03	BA-E1-42 UW3482	42	6.75 ± 0.623	JF	FMM	5.0–9.0
Barleyfields	BFL-E2-01	BA-12-22 UW3484	22	3.23 ± 0.515	JF	FMM	0.6–5.0
Barleyfields	BFL-E2-02	BA-25-24 UW3481	24	3.53 ± 0.447	JF	FMM	1.4–4.6
Barleyfields	BFL-E2-03	BA-25-47 UW3480	47	12.4 ± 1.22	JF	FMM	> 12.0
Barleyfields	BFL-E2-04	BA-25-51 UW3485	51	7.47 ± 0.673	JF	FMM	4.3–10.0
Barleyfields	BFL-E2-05	BA-32-30 UW3487	30	3.14 ± 0.331	JF	FMM	1.8–7.6
Barleyfields	BFL-E2-06	BA-32-47 UW3488	47	8.36 ± 1.19	JF	FMM	3.8–15.4
Big Llangothlin	KK_BL_06	BI-NPB-50	50	29.0 ± 2.0	EH, ZJ	CAM	
Big Llangothlin	KK_BL_05	BI-NPB-65	65	32.1 ± 1.9	EH, YG	CAM	
Big Llangothlin	KK_BL_04	BI-NPB-118	118	60.5 ± 4.1	NJ	CAM	
Big Llangothlin	KK_BL_03	BI-NPB-165	165	72.6 ± 7.3	NJ	CAM	
Big Llangothlin	KK_BL_03	BI-NPB-200	200	26.3 ± 3.1	No data	CAM	
Big Llangothlin	KK_BL_07	BI-NP3-40	40	4.6 ± 0.4	EH, YG	CAM	
Big Llangothlin	KK_BL_09	BI-NP4-43	43	8.9 ± 0.7	EH, ZJ	CAM	
Big Llangothlin	KK_BL_08	BI-NP4-88	88	20.7 ± 1.3	EH, ZJ	CAM	
Big Llangothlin	KK_BL_13	BI-EP1-32	32	2.6 ± 0.3	NJ	CAM	
Big Llangothlin	KK_BL_11	BI-EP1-114	114	12.8 ± 0.8	NJ	CAM	
Big Llangothlin	KK_BL_10	BI-EP1-147	147	15.3 ± 0.9	EH, YG	CAM	
Big Llangothlin	KK_BL_12	BI-EP1-200	200	7.1 ± 0.5	EH, YG	CAM	
Big Llangothlin	BGL-20	BI-1B-20 UW3491	20	1.83 ± 0.203	JF	FMM	0.8–4.0
Big Llangothlin	BGL-50	BI-1B-50 UW3489	50	6.45 ± 0.624	JF	FMM	3.3–6.2
Big Llangothlin	BGL-75	BI-1B-75 UW3493	75	13.0 ± 1.58	JF	FMM	>15.8

Site	Field sample ID	Location code on Figure 4.1	Depth below surface (cm)	Central Age (ka)	Analyst team	Age model	Likely age range (ka)
Big Llangothlin, laterite gully	KK_BG_02	BI-LG-88	88	28.9 ± 1.8	EH, ZJ	CAM	
Dangars	KK_DGL_02	DA-PA-70	70	16.3 ± 1.4	NJ	CAM	
Dangars	KK_DGL_01	DA-PA-112	112	35.8 ± 2.1	EH, YG	CAM	
Dangars	KK_DGL_03	DA-PB-105	105	28.2± 1.8	EH, ZJ	CAM	
Dangars	KK_DGL_04	DA-PB-120	120	48.1 ± 6.1	NJ	CAM	
Dangars	DGL-E2-01	DA-05-38 UW3492	38	1.88 ± 0.247	JF	FMM	0.52–2.9
Dangars	DGL-E1-01	DA-20-42 UW3486	42	6.81 ± 0.630	JF	FMM	4.3–13.5
Dangars	DGL-E1-02	DA-20-43 UW3490	43	7.30 ± 0.875	JF	FMM	5.9–17.7
Kings Plains	KI-RE-12	KI-RE-12 UW3425	12	5.21 ± 0.66	JF	FMM	3.7–9.0
Kings Plains	KI-RE-16	KI-RE-16 UW3426	16	3.76 ± 0.451	JF	FMM	2.3–7.1
Racecourse	KK_RCL_03	RA-PA-35	35	12.9 ± 1.2	EH, ZJ	CAM	
Bells Lagoon	KK_BSLE_02	BE-MP-150	150	18.4± 1.5	EH, ZJ	CAM	
Bells Lagoon	KK_BSLE_03	BE-MP-150	154	17.1 ± 1.2	EH, ZJ	CAM	
Bells Lagoon	KK_BSLE_01	BE-MP-180	180	18.7 ± 1.2	EH, ZJ	CAM	
Lagoon of Islands	KK_LOI_S1	IS-S1-50	50	15.8 ± 0.9	NJ	CAM	
Lagoon of Islands	KK_LOI_S2	IS-S2--60	60	15.6 ± 1.0	NJ	CAM	
Lagoon of Islands	KK_LOI_S3	IS-S3-50	50	13.5 ± 0.8	EH, ZJ	CAM	
Lagoon of Islands	KK_LOI_S4	IS-S4-60	60	16.0 ± 0.8	EH, ZJ	CAM	
Lagoon of Islands	KK_LOI_S5	IS-S5-85	85	16.3 ± 0.9	EH, ZJ	CAM	
Lake Crescent	KK_TLC_1B	CR-P1-120	120	0.1 ± 0.00	EH, YG	CAM	
Lake Crescent	KK_TLC_1A	CR-P1-204	204	16.1 ± 1.1	EH, YG	CAM	
Lake Sorell	KK_LS_02	SO-P-265	265	0.1 ± 0.00	EH, YG	CAM	
Lake Sorell	KK_LS_01	SO-P-315	315	0.5 ± 0.1	EH, YG	CAM	
Lake Tiberias	KK_LT_01	TI-P1-60	60	7.1 ± 0.7	EH, ZJ	CAM	
Lake Tiberias	KK_LT_02	TI-P2-60	60	17.4 ± 1.9	EH, ZJ	CAM	
Lake Tiberias	KK_LT_03	TI-P3-112	112	50.4 ± 4.6	EH, ZJ	CAM	

UOW (multi-grain method) analysts: EH Elspeth Hayes, NJ Nathan Jankowski, YG Yugie Guo, ZJ Zenobia Jacobs
UW (single-grain method) analyst: JF, James Feathers
CAM, Central age model; FMM, Finite mixture model

Discussion and conclusion

The overall dating strategy for the Lagoons Project was to target geomorphologically sensitive locations (e.g., lunettes) to determine the timing of landscape formation, and to produce ages for the archaeological material. Age estimates were produced using radiocarbon and OSL dating of charcoal and sediments that derived from the same depositional context as the landform/archaeological material. The OSL ages are most useful for demonstrating the relative formation chronologies of the lagoons, and for demonstrating that the visible archaeology is most likely Holocene in age. Only one site, Barley Field Lagoon, had samples collected for both radiocarbon and OSL from the same depositional context (BFL, square 32).

As the archaeological material typically derived from shallow deposits, the sediments from these contexts were more likely to be disturbed by bioturbation and other surface disruptions, particularly since European colonisation. OSL analyses confirmed that the sediments collected from the archaeological contexts were more mixed than the sediments collected from geomorphological contexts, which were typically sampled from much deeper deposits, up to 200 cm. Sediment samples targeting the archaeological material were also collected from contexts where wind-blown sediments may not have comprised the majority of sediments. In contrast, water-borne sediments are less suitable for luminescence dating. This could explain the three cases of significant age inversions at Barley Field Lagoon (KK-BFL_02 and BFL-E2-04) and Big Llangothlin Lagoon (KK-BL-12).

The OSL reports of Jankowski, Feathers and Hayes *et al.* (Appendix C) express concern with the significant spread ('overdispersion') of equivalent dose values for some samples, beyond what is statistically expected. Despite using 1 mm aliquots of grains, Jankowski notes that the spread of equivalent dose values in some samples is so significant that he could not resolve this using the multi-grain method, and he recommended making single-grain measurements to determine the true extent of the spread and help give more confidence in the sample equivalent dose determinations. Likewise, 12 samples measured by Hayes *et al.* displayed high overdispersion values (exceeding 20%) that would benefit from single-grain analysis. The single-grain equivalent dose distributions of Feathers also suggest that the spread of equivalent dose values for many samples is also significant. This overdispersion is similar to OSL results obtained by Shulmeister *et al.* (2016: 1440) for the lunette at Little Llangothlin Lagoon in 2016 and may be a feature of the formation processes of these lagoon landforms.

A key advantage of single-grain OSL dating is the ability to identify and discard any grains with aberrant OSL behaviours (e.g., grains with little or no measurable luminescence signal) before final age determination. Multi-grain aliquots can give rise to inaccurate OSL ages if they contain a mixture of grains that have intruded from younger or older deposits, or grains that have not been fully bleached prior to deposition. Because this method measures between 10 and 100 grains at the same time, the equivalent dose is given as an average of all those grains that are present on the disc. The result is that when we come to combining the multiple equivalent doses in each sample into one value for age estimation everything gets drawn towards an average and the spread between the individual data points is much reduced. Unfortunately, single-grain measurements of these same samples have not been possible.

As a consequence of using different methods, different age models, and generally high overdispersion values, comparison of the resultant chronologies at each locality should be undertaken cautiously.

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Chapter 5:
Formation and development of upland lake-lunette systems in northern New South Wales, Australia, and their relation to climate, ecological change and human occupation

Robert Haworth, Kevin Kiernan, Anne McConnell

Introduction and background

In the northern tableland of the New England district of New South Wales, southeast Australia, shallow lakes or ponds, often with an associated sand or clay lunette on their lee (eastern) shore, occur between 1000 and 1400 metres altitude above sea level on the crest of the topographically subdued 'Great Divide' that separates drainage eastwards into the Pacific Ocean from streams that flow westwards into interior Australia (See Figure 3.5). Despite the apparent attractions of plentiful game and edible plant resources, the country around the high-altitude wetlands has revealed little or no evidence of continuous long term human occupation until the mid to late Holocene (Binns and McBryde 1972; McBryde 1974:). This is in sharp contrast to lake-lunette systems of the inland plains such as the Willandra Lakes, which are associated with extensive evidence for Pleistocene Aboriginal occupation (Bowler 1970; Fitzsimmons 2012; Fitzsimmons *et al.* 2014). Understanding this apparent contrast requires answers to such questions as whether the present-day lagoons and lunettes on the tablelands were extant prior to the Holocene, what other resources were present to attract or support human populations in the past, and the environmental conditions to which humans may have been subject to in choosing whether or not to use the Tablelands environment. Hence, the purposes of the study were to assess the origin and age of the present-day Tablelands landscape, the environmental conditions and associated resource opportunities that have prevailed there since the first proven arrival of humans on the Australian continent, and whether geomorphological evidence might be able to shed any further light upon the question of Aboriginal use or non-use of the area including when it first occurred.

Situated on the drier and colder continental side of the 1000 mm rainfall isohyet (BOM 2016) this environment is subject to seasonal extremes of moisture and temperature that lead to volatile soil processes including precipitation of drainage-impeding duricrusts such as silcrete and ferricrete, and heavy black montmorillonite clays. Groundwater sapping from the base of extensive basalt flows nourishes ponding, and ground surface disturbance by periglacial freeze-thaw processes may also have locally trapped drainage. Once the surface area of ponded water is large enough for wind-driven waves to be generated, wave erosion of the shorelines progressively increases the size of lagoons. Ponding of water in wetter seasons alternates with periodic deflation of these small basins in dryer times, any exposed granitic rock providing a supply of quartz sand that allows dune building (Figure 5.1). These shallow lakes or ponds therefore represent non-fluvial, shallow wetlands formed in closed or nearly closed basins. Being located on or near the top of drainage divides on plateau interfluves, they are beyond the erosive reach of first order streams which would otherwise subsume them into larger river systems.

Ever since the advent of Europeans into Australia, interpretation of the eastern highlands has involved conceptual misunderstandings of the Great Divide (for instance, Oxley 1820; Dawson 1830). The dominant landform type of the highlands involves plateaus dissected by deep and often impassable gorges, a

situation that has no analogy in the European homelands. From the first this landscape peculiarity presented difficulties in penetrating to the Australian interior, as the 25-year delay in crossing the Blue Mountains behind Sydney demonstrates. This misinterpretation continues to this day, with frequent description of the steep coast-facing margin of the plateau country by casual observers as a non-existent 'Great Dividing Range'. This is an inadequate descriptor of the mostly flat and swampy drainage divide (referred to henceforth as the 'Great Divide') between the inland continental drainage (the Murray Darling complex of waterways) and the much shorter and steeper coastal streams bound for the Pacific Ocean. This Great Divide is great in its length of over 3000 km, but not especially great in altitude. In our area it averages around 1000 m AHD, while the highest ground of up to and above 1500 m tends to lie on the edge of the plateau land 50 to 100 km to the east of the actual stream dividing line that constitutes the Great Divide. This low and near-level section of the Great Divide (less than 2^0 slope over large portions of its extent: Connelly, 1983) is the prime area of our investigation.

The New England lagoons are today surrounded by concentric zones of marsh and fen vegetation (Bell *et al.* 2008) merging into a landscape of *Eucalyptus* woodland, which latter includes *E. viminalis, E. nova-anglica, E. obliqua,* and the snow gum *E. pauciflora* (Smith and Turvey 1977) with grassy floors of the hillside woodlands broken by open treeless meadows in the frosty hollows. These wetlands seem to have the capacity to maintain productivity under challenging climatic conditions. They can often retain enough moisture, especially when not in lake-full mode (Beck *et al.* 2015), to support islands of biota in cold and relatively dry environmental cycles. They also present satisfactory human occupation sites on their sandy dunes in the drier, less than full lake conditions when the lagoons resembled what 19th century settlers described as 'pernicious swamps' (Gardner 1854). Pernicious, that is, for graziers trying to preserve their sheep from foot-rot and their lumbering cattle from bogging, but perhaps not so malign to hunter gatherers set to cull from the diverse flocks of wild fowl and the multitudinous eels that still swarm in the boggy environment (Beck *et al.* 2015). Local farmers relate the story of the extraordinary mass of eels that vacated Lake Llangothlin for the headwaters of the Mann River in a critical phase of the great drought of the early 1940s (D. Jones, pers. comm.), the same eels that had provided welcome and abundant food for their families in the hard economic times of the 1930s.

No comprehensive, tableland-wide survey of pre-European human occupation has been performed in the northern New South Wales region since the early work of McBryde (1974), who did not look specifically for open camp-sites. The present authors aimed to correct this deficiency by conducting an extensive survey of regional wetlands, with an emphasis on shoreline dunes, mostly lunettes. This formed part of a larger comparison with similar features and topographies in Tasmania (see Chapter 9) to tease out background conditions for possible Pleistocene and Holocene human settlement in the climatically cooler upland regions of Australia. This chapter provides a geomorphological context for the archaeological investigations described elsewhere in this volume. Following this introduction and subsequent statement of our methodology, Part A of the chapter describes the broad environmental setting of the Tablelands; Part B explores the origin and evolution of the basins in which the lagoons have formed; Part C addresses the character, age and likely origin of the sand masses that have accumulated around lagoons; and Part D reviews apparent past environmental conditions and their likely relevance with respect to pre-European human activity in the area.

Methods

Site selection

The geomorphology of numerous examples of the lagoon-lunette systems of the New England Tablelands was investigated at a reconnaissance level, with a number of these sites then scrutinised in greater detail.

Four lagoons on basalt substrates were geomorphically investigated but not studied in detail. From north to south these were: Kings Plains; Reddestone; Glencoe-Barley Fields and Thomas Lagoon. Five lagoons were studied in more detail, namely: Lake Llangothlin and Little Llangothlin Lagoon in the north, and Barley Field Lagoon, Racecourse Lagoon and Dangars Lagoon in the south (See Figure I.2).

The northernmost of those sites that received more concentrated attention, Llangothlin Lake (or lagoon) near Guyra, (Figure 5.2), is situated astride the boundary between Tertiary basalt flows to the west and granitic intrusions to the east. Large quartz sand accumulations occur along its eastern shore. A few kilometres further south lies Little Llangothlin Lagoon. The Little Llangothlin lunette and surrounds have already been thoroughly investigated by Woodward *et al.* (2014), Shulmeister *et al.* (2016) and especially Ellerton *et al.* (2017), these researchers confirming that the lunette building most likely began in the latter part of the LGM. Particular attention was paid by previous workers to an enigmatic berm at the southern end of its lunette that was left undated. However, a hitherto unreported AMS date was in fact obtained by one of us from the berm some years prior to the current research. Because this is the only such result obtained from the base of the lunette landform, its adjusted age is recorded here for the first time, both to confirm previous results by more recent workers from the main Little Llangothlin lunette, and to facilitate comparison with the lunette on the south east shore of Lake Llangothlin.

Three lagoon-lunette systems were also examined 100 km to the south of the Llangothlin lagoons, around the town of Uralla (Figure I.2). These included Barley Field Lagoon lunette 3 km north of the town, and Racecourse Lagoon and Dangars Lagoon lunettes 3 km and 4 km to the south and south east of the town. These lagoons are on or near basalt flows, with the basement rock usually being granitic (adamellite and granodiorite) or in some cases the underlying Palaeozoic metasediments of the New England Fold Belt. There are substantial precipitated duricrusts proximal to all these southern lagoons, especially silcrete, manganese and ferricrete which, along with heavy black montmorillonite clays, represent the erosion products of basalt or the palaeo river beds of underlying Tertiary sediments ('deep leads'). These erosion products have done much to slow natural drainage, and create a landscape which, already of subdued relief, becomes even more prone to the formation of bogs, swamps and either ephemeral, intermittent or permanent wetlands.

Recording of Dune Forms and Composition

Total volumes of sand contained in different dune zones were calculated from field measurements of length and average width of dune areas and multiple auger probes to estimate the average depth of each feature or accumulation. For extensive and irregularly shaped depositions, such as the north Llangothlin sand field, the total feature was broken into segments for the purpose of measurement for volume calculations, a bid to ensure that the estimated average widths and depths were reasonably accurate.

In order to check for stratigraphic variations and extract samples for particle size analysis and dating, pits, measuring at least one metre by one metre, were dug as deep as practicable with appropriate reinforcing. Cores were then also extracted from the base of these pits. All sample extraction sites were registered with GPS co-ordinates, and dune features and sizes delineated by field measurements, re-checked using Google maps, relevant Central Mapping Authority of NSW 1:25,000 relief maps, and larger scale cadastral maps and plans where available. Particle size analysis using a Mastersizer was conducted on selected lunette sediments to identify changes in sediment size, any evidence of changes in sediment provenance, and hence change in depositing agents (e.g., wind or water or bioturbation), to see if accumulation or dispersal had been constant over time (O'Connor 1990: 76), and to assess whether there had been any internal disturbance. Fluctuations in grain size have the potential to allow insight into the dominant formation processes. This involves determining the extent of either aeolian versus

wave deposition by inference from the proportions of the small silt or dust grains in the profile versus large to mid-large grain sizes. However, potential confounding factors might include any period of soil formation with colloidal action producing fine clays, or a period of deflation or even anthropogenic disturbance that might disperse sediment and cause a gap in the sequence. Samples for particle size analysis were obtained from various sections of dune profiles, both above and below areas from which OSL dates were obtained, to establish just how typical or deviant these sites were.

Dating

Optically Stimulated Luminescence (OSL) ages were determined for parts of the dune profile that were assessed as being most likely to allow pin-pointing of the age of dune sediments, and the pace and nature of dune development. An Accelerator Mass Spectometry (AMS) radiocarbon date was also obtained from one site. Some further OSL and AMS ages from near or immediately under Aboriginal artefacts, not directly linked to our geomorphological work but instead obtained during the associated archaeological studies, also usefully facilitated comparisons against the ages we obtained for the aeolian sequences

OSL ages were obtained from lunette and other dune samples, associated with four lagoon-lunette systems. The ages obtained are likely to be reasonably accurate, as over-dispersion rates were relatively low, between 9% and 42%. This compares, for instance, with over-dispersion rates for OSL ages from Little Llangothlin Lunette of between 44.4% and 79.9% accepted by Shulmeister *et al.* (2016) An AMS age determination was obtained from a controversial section of Little Llangothlin lunette.

Rates of accumulation of sediment were calculated between points where OSL ages had been determined, and from the surface. While these rates are obviously subject to unknowns, such as possible periods of deflation, over the long periods measured they might give a general guide to the age of those strata from which no OSL or other dates are available. To cross-check to at least some degree the sedimentation rates interpreted on the basis of the OSL dates obtained to inform this geomorphological chapter, and to assess whether any distorting disparity existed between near surface rates and those at depth, we were further informed by some of the OSL and AMS dates obtained from shallower depths during the associated archaeological research. The sedimentation rates presented here nevertheless remain subject to the caveat that we had no precise means of checking for any variation in sedimentation rates, apart from that deduced from the sparse OSL ages with their very broad age ranges, coupled with the general picture that emerged from each individual sediment column regarding the degree of overall consistency of grain size and stratigraphy.

Part A: Environmental Setting

Geological and landscape history of the New England Tableland

Key elements of landscape history of the New England Tableland began in the Permian between 300 to 250 mya, with folding and inclusion of marine sediments onto the Australian craton (Korsch and Harrington 1981). These elements can be related to the geology surrounding lagoons shown in Figure 3.5, as well as providing stone raw materials. The New England Batholith and other granitic intrusions formed shortly after 250 mya, and a period of extreme erosion followed, which implies the prior occurrence of substantial uplift. The highlands and what became the main continental divide were affected by the breakup of Gondwana and especially a drainage reset following the opening of the Tasman Sea between 80 and 60 mya (Haworth and Ollier 1991). Possibly associated with this, a long period of volcanic extrusion extended throughout most of the Tertiary after 65 mya, and the stripping of the subsequent basalt cover from the last dated flows of 16 mya formed the current landscape. This landscape is dominated by inversion of relief, with basalt residuals often preserving old fluvial

sediments in the highest part of the present-day landscape. Concurrent with this, ferricrete and silcrete and heavy clays developed in the shallow subsurface over wide areas, impeding drainage in an already subdued landscape where all streams tended to be sluggish. Erosion has revealed much of the silcrete at the surface where it forms the most durable of the Tertiary sediments, while nodular ferricrete appears to have been continuously precipitated throughout the landscape, derived from the abundant iron in basalt (~30% iron as measured by us in local basalt flows).

The evolution of passive continental margins such as that of eastern Australia is driven by a gentler tectonic adjustment to rifting and subsequent but more dramatic frontal erosion. Ollier (1982, 1995) suggested that these prominent escarpments initiate when rift flanks are uplifted during continental rifting (which occurred here ~ 60 million years ago with the opening of the Tasman Sea) after which the escarpment has retreated at a rate in the order of one km per million years, while the gorges have been cut back into the plateau by headward erosion at a faster erosion rate of two km per million years (Seidl *et al.* 1996), a rate that appears to be markedly uniform on the New England Tableland regardless of which rock type was being incised.

This history has set up the extreme contrast on the New England Tableland of an interior, low relief, highly weathered upland area which contains the main continental drainage divide, and a deeply incised high relief coastal area, so easily mistaken when seen from the coast as a mountain range rather than the steep, sea-facing front of a plateau. To further this illusion, parts of the tableland cut off by escarpment retreat and gorge incision form giant isolated mesas, which again, from a distance, could be mistaken for the mountains of fold belts, except for their flat tops. It is this fragmented edge of the escarpment that is judged by casual viewers to be the elusive 'Great Dividing Range' though it divides nothing in terms of drainage flow. Popular interpretation is further complicated by the dramatic visual appearance of the eroded remains of the Miocene shield volcanoes (aged between 20 mya to 15 mya) that have extruded through the fault lines that bound the New England Tableland to the east and west. These include the Ebor-Dorrigo volcano parallel to the Guyra plateau but 80 km further east, and the Comboyne volcano further south at the base of the escarpment below the Walcha region. To the west of the Tableland, a chain of higher summits of relatively un-eroded Miocene volcanoes centred around Mt Kaputar (1500 m) rise higher than most of the tableland. These have the climatic effect of blocking the tableland from perturbations in arid zones further inland, minimising dust storms, for instance, compared to other west-facing highland areas.

The eastern edge of the New England Tableland tends to be the highest (almost 1600 m) and faces the ocean, and the consequent orographic rain (over 2000 mm/pa) favours the growth of rain forest on the escarpment and gorge slopes. This is in contrast to the dryer western Tableland, which is covered naturally in open woodland savannah with rainfall of less than 1000 mm p.a. In one area of particular interest to this study, the Guyra/Llangothlin region, the western part of the Tableland is more elevated due to the growth of the late Eocene (~35 mya) Maybole Volcano which has raised the local altitude of the plateau country to over 1500 m in places, almost equal to that of the highest levels of the eastern escarpment. However, because of the lower humidity in the dryer west, the winter cold and frost are much more intense than on the eastern falls of similar altitude, where greater moisture tempers the extremes. This has consequences for the increased development of groundwater-precipitated duricrusts, such as silcrete and ferricrete, in the study area, and their increased role in impeding drainage in the higher areas where altitude and aspect promote temperature extremes and seasonal moisture fluctuations.

Erosional stripping of the basalt cover since the cessation of volcanic flows 16 mya has created the present tableland landscape. Because lava flows seek topographic lows, they tended to block the old river courses, and new drainage had to either cut down parallel to the old drainage, or if the landscape was totally inundated by lava, create an entirely new drainage system. Either alternative led to

widespread inversion of the landscape, where the old river beds often ended up as the highest points in the local landscape, these basalt residuals and associated gold bearing fluvial deposits earning the local description of 'deep leads'.

Local geology

The current landscape of southern New England has been exhumed from a near complete covering of Tertiary basalt flows, active between 40 and 16 mya, and possibly even later. The extrusion of basalt, and subsequent development of indurated deposits of ferricrete and silcrete represent the first significant addition of geological material to the region since the intrusion of granitic batholiths in the late Permian, and following their fate is the key to understanding the present landscape (Connolly 1986).

Palaeozoic meta-sediments (Sandon Beds)

The Sandon Beds comprise Palaeozoic meta-sediments made up of chert, jasper, greywacke, mudstone, volcanics and some quartz (Binns 1967). The beds are easily distinguishable in the field by extreme folding on all scales, including some measures that are almost vertical, but this also makes it difficult to interpret their chronology. Metamorphosis is not consistent, to the point where some younger beds preserve fossils. The lowest measures include sandy greywackes, siltstones, slates or phyllites, with finely laminated cherts, bars of massive jasper and altered basic lava. To the north of Armidale, the Palaeozoic beds include conglomerates (such as the Dummy Creek conglomerates), siltstones, mudstones and interbedded acid lavas and pyroclastics. To the south east of Uralla there are diorites and porphyritic layers, perhaps associated with other intrusive rocks.

Siliceous rocks such as chert are common and quartz occurs, but quartzite is rare to absent, because metamorphosis was weak to absent, especially from the younger upper measures, and in the lower measures metamorphosis mainly affected the argillaceous rocks (shales, siltstones, mudstones) but not the coarser, harder material. The beds were reworked in the Tertiary in some places to form small patches of fluvial conglomerates, preserved under Tertiary basalt as in the Armidale Beds. Extensive Tertiary regolith is preserved as deep lateritic weathering profiles and fluvial and lacustrine sediment. The underlying Palaeozoic sediments were laid down as shallow sea sediments, initially in the early Carboniferous 340 to 300 mya. They were intruded by massive granite batholiths in the Permian between 280 and 230 mya, and possibly later (Brownlow 2010). The region must have been uplifted to form a highland area by at least this time because the intrusive rocks were exposed by massive erosion to reveal the great granite batholiths that dot the Tableland. The products of this erosion, especially quartz sand, were deposited in the adjoining Clarence-Moreton and Sydney Basins throughout the Triassic and Jurassic (230 to 130 mya). Since then, the New England block has continued to be essentially dominated by erosional processes. It is the landforms in the relatively small areas of Tertiary and Quaternary deposits in the highest parts of the block which largely escape this erosional regime that are the focus of this study.

Intrusive igneous rocks

Granitic intrusions fall broadly into two main divisions. The older (260-250 mya) mid Permian Hillgrove Plutonic Suite tend to show evidence of stress, and occupy the east and south of the region. The younger (250-225 mya) late Permian New England Batholith, largely unstressed, occurs in the north and west (Binns *et al.* 1967). There is very little contact metamorphism associated with especially the extensive adamellitic fraction of the Hillgrove Suite. This suite tends overall to manifest as individual intrusions, with abundant quartz that can be bluish in colour. Because of the limited contact metamorphism there is little to no quartzite. By contrast, the unstressed intrusions of the New England Batholith occur as

massive intrusions, and are surrounded by contact aureoles of hornfels where they were emplaced into sediments. They contain less quartz than the Hillgrove Suite, and often lack its blue colouration.

Gibbs *et al.* (1967) classified the major igneous intrusions into three compartments: (i) Acid rocks, with modal quartz greater than 20%, including granite, adamellite, granodiorite and trondhjemite; (ii) intermediate rocks, with modal quartz between 10 and 20%, including syenite, monzonite, tonalite, and diorite; and finally, (iii) basic rocks essentially lacking quartz, such as gabbro. The extensive quartz sand deposits surrounding some of the upland lagoons and ultimately of course, the celebrated surf beaches of northern New South Wales and sand islands of south Queensland, all ultimately derive from these quartz rich rocks of the New England Tableland.

Of special note are several large intrusions of porphyrite, outcropping adjacent to granite intrusions near Uralla and Guyra. An outcrop of this or some associated rock type is the site of what appears to be the most productive Aboriginal axe quarry at Salisbury Waters. It is likely that the rock extends into the catchment of the nearby Dangars Lagoon.

Tertiary and Quaternary sediments

It is the fate of the Cainozoic sediments, which contain both volcanic and non-volcanic materials, that has determined the present evolution of the New England Tableland. The Quaternary sediments of alluvium and colluvium consist of mud, silt, sand dunes and high and low-level gravel deposits. All these tend to be highly ferruginised, with extensive substrates of nodular and other forms of ferricrete (Connelly 1986), especially where subsurface water issues as springs and seepages from under basalt layers. Tertiary deposits include the same types of undifferentiated sediments, including extensive high-level gravels, some named deposits such as the Armidale Beds, but also an extensive variety of unnamed deposits consisting of 'deep lead' gravels, sands and clays as well as thin but quite high quality coal deposits. The most eye-catching features are the ferruginous sandstones and widespread silcrete formations, both occurring in massive forms but also intruding into faults and cracks in granites and country rock (see Appendix E). A human fascination with silcrete is widespread over space and time, the largest prehistoric megalith site in Europe, the great Avebury complex in Wiltshire, England, being composed of hundreds of raw unworked menhirs of silcrete, while nearby Stonehenge contains over 80 dressed silcrete slabs (Summerfield 1979; Ullyot *et al.* 1998; Pearson 2015). Coincidently, these English silcretes (or 'sarsen stones') have also been classified as of lower Tertiary age. Silcrete is sometimes mistaken for quartzite, but the latter is a metamorphic rock and hence it is unlikely to be present in undisturbed near-horizontal Tertiary sediments.

Basalt is of course the dominant rock type over southern New England, with many types of flow, mostly alkaline olivine rich flows that are sometimes highly vesicular and intermixed with gravels. There were at least two phases of massive extrusion of basalts and related volcanics in the Tertiary on the tableland, one from 45 mya to 35 mya, and the other from 23 mya to 16 mya (Wellman and McDougall 1974). One well defined Tertiary measure is the Armidale Beds (Voisey 1942), which consist of fluviatile deposits in horizontal to sub-horizontal sequences containing conglomerates, grits, indurated sandstones on a spectrum of durability from soft sandstone to hardest silcrete, siltstones, mudstones, and plated ironstone. They are found mainly south of Armidale. The Armidale Beds are loosely compacted, no more than 50 m thick, and some exposures show the paling of a laterite profile, indicating iron movement by water table fluctuation. They have been dated by pollen to the Upper Eocene (Slade 1966), around 35 mya. The most interesting result of sediment induration is the common silicification of quartz rich sandstones to form hard, durable beds of silcrete, the hated 'greybilly' of the gold diggers who had to chisel or dynamite through it to get to the gold bearing fluvial deposits beneath. But the most widespread induration is the near ubiquitous presence of nodular ferricrete, an ironstone, sometimes referred to as

laterite. Silcrete is also not restricted to Eocene beds but is found in most Tertiary deposits post-dating basalt extrusions. Most importantly, it survives the erosion of those deposits to act as a marker of the pre-basalt topographic lows.

Part B. Character and Origin of the Lagoon Basins

Lagoon Geomorphology

The New England lagoons occur in a range of geological settings and display a variety of morphologies. Many have been modified from their natural condition since European settlement of the area. Kings Plains Lagoon (Figure 3.5) is a kidney shaped wetland entrenched into a basalt landscape but with deep alluvium on its floor. It is located mostly on public land, except in its north, and is still in fairly good ecological condition. Its outflow is to the south west and there is a basalt ridge bordering its north west. Some kind of lake shadow aeolian feature on its eastern shore is backed by a highly ferruginised basalt ridge, and a low sediment filled declivity lies to the south west. Glencoe-Barley Fields Lagoon lies on the eastern edge of deep basalt flows from the Maybole Volcano, 5 km further to the west. Like Reddestone, Clareveulx, and Dunvegan lagoons, Glencoe lies on the edge the extensive flows from Maybole volcano. It is entirely on basalt and it lacks any lunette. There is some kind of lake shadow on the eastern edge of Glencoe, unfortunately obscured and degraded by highway construction. It drains from its south end to the eastern rivers, though the Great Divide is the ridge only a few hundred metres to the west of the lagoon, and there is a wind gap (shown by the line of trees) to the north west that cuts across the Great Divide. Reddestone Lagoon appears as an area of bare land immediately north of Strathbogie Road, with its northern end now terminated by a dam and bund wall. The deep dam discernible at the southern end collects all water from the inlet stream and would rarely overflow, because much of the water appears to be pumped back south of the road. Thomas Lagoon, southwest of Armidale and set on a flat basaltic plain with several other nearby lagoons (Strahle, Little Thomas, and one unnamed lagoon to the north west) is located within a few hundred metres of the cusp of the Great Divide to the west. Thomas Lagoon has massive outcrops of silcrete to its north and west (see Appendix E, Chapter 8), with ferricrete to the south and east and probably silcrete underlying it. While Tertiary basalt is the visible local bedrock, there is an exposure of Palaeolithic Sandon Beds 200 metres to the east, which probably underlies the whole area. This lagoon is fed by a spring in its southwest corner, made conspicuous due to a triangular reed bed.

Reddestone and Clarevaulx lagoons, north west of Glen Innes (Figure I.2), lie proximal to an area that is known for its extensive and varied megafauna remains (for example, *Diprotodon minor, Procoptodon goliah, Sthenurus pales, Genyornis spp.* Horton and Connah 1981). The consequences of the extinction of the giant herbivore species that are represented among these remains is increasingly regarded as one of the major disruptors of the south-eastern Australian ecology in the last 100,000 years (Johnson 2009; Miller *et al.* 2005; Smith 2013) prior to European settlement. However, no samples for laboratory analysis or OSL dating could be obtained from this locality, due to private property access issues.

Potential modes of lagoon genesis

Widespread induration of Cainozoic sediments, with the attendant blocking of drainage in the high country, appears to be one of the necessary (but not sufficient) conditions for the formation of the upland lagoons that are the focus of this research program. Some conditions that add up to a sufficiency of processes for the formation of lagoons and their closed basins include, beginning with the largest scale:

i. the backward tilting on a sub continental scale of the passive continental margin of eastern Australia (Ollier 1979), itself a consequence of the rifting that formed the Tasman Sea in the early Tertiary;
ii. the outpourings of basalt in the central volcanic province of eastern Australia, encompassing the Tableland, in the mid to late Tertiary, which may have been another partial consequence of rifting and tectonic adjustment;
iii. the erosion and deposition of the weathering products of basalt in a restricted area of landscape that was already in a state of subdued relief common to passive continental margins, and
iv. the more arid and unstable climates experienced as Australia drifted north during the Tertiary into the mid latitudes, when processes of extreme weathering massively indurated the products of erosion and the pre-basaltic sediments of ancient stream beds, producing sluggish drainage both above and below ground;

Induration is common in all the Tertiary and Quaternary colluvial and alluvial sediments in the western part of the New England Tableland. Induration is evident inland of the one metre rainfall isohyet which also marks the boundary of the area of upland lagoon formation above 1000 metres altitude. This tendency to induration appears to be largely absent in the wetter east, although all other conditions, such as widespread basalt and high-altitude low relief plateaus, are present. It seems that massive induration is largely induced by frequent rise and fall of water tables which may precipitate iron, manganese and silica in the regolith. These fluctuations tend to be subdued in the eastern fall country with its high orographic rainfall, but they are widespread in the sub-humid inland of the tableland where conditions can vary sharply between several years of dry conditions and contrary cycles of heavy wets, thereby inducing extreme water table fluctuations.

There is an interesting parallel with the presence of periglacial mass movement deposits and rock glaciers on the New England Tableland (Slee 2016), which are also confined to high altitudes on the more arid side of the one metre rainfall isohyet. The extreme cold needed for these periglacial processes, and their warping of the regolith, occurred only in the extremely dry cold of the western tableland. Extreme cold is muffled by higher humidity on the eastern edge of the tableland. Periglacial processes might conceivably have had the capacity to initiate minor ponding of water. One interesting south-facing escarpment at Urandangie Station a few km south of Guyra, which was the centre of recent periglacial research (Slee 2016), presents a chain of ponds along the base and sides of the basalt slopes in various stages of emergence as fully formed lagoons in locally closed basins. Even in 2015, temperature sensors at one site near Guyra recorded three winter nights in a row of minus 17 degrees Celsius (Slee, pers. comm.) as a result of cold air drainage. Temperatures during the Last Glacial Maximum (LGM) would have been proportionately still more extreme. Small depressions such as this might conceivably develop in response to the out-thrusting of rock material by frost action processes. An alternative possibility, were the periglacial climate sufficiently severe as to produce ground ice, involves warming of the regolith by heat re-radiated from adjacent sun-warmed bedrock surfaces (Kiernan *et al.* 1999). Long-wave radiation penetrating into ground ice, and thereby causing peripheral thawing, can cause sufficient loss of the ice mass as to cause surface subsidence, thereby initiating small depressions and ponding of water therein, this liquid water potentially then causing further thermo-erosion of the surrounding regolith. Seasonal or longer-term drying are likely to have allowed basin deepening by deflation. All evidence suggests that predominantly westerly winds have been sustained throughout the 120,000 year Last Glacial Cycle, with winds possibly being stronger than present in glacial maximums but always dominantly from the west (Shulmeister *et al.* 2016).

Hence, several further factors also warrant consideration as possible influences upon lagoon evolution on the higher uplands:

i. periglacial freeze-thaw heaving and out-thrusting of regolith layers on south facing hillsides, or thermo-erosion of ice-bearing sediments by long-wave radiation emitted from rock surfaces might conceivably form very small closed basins and ponding of water. The action of springs from beneath basalt bedrock and any ground ice would likely continue sapping of the cliff faces thereby extending the lagoon area;
ii. the exposed aspect of the western edge of the Tableland, and the position of most lagoons on the cusp of main drainage divides, which naturally exposed them to the sculpting effect of the prevailing westerly winds;
iii. the potential also exists for other minor perturbations, such as the possibility that some small surface depressions may have been enlarged by wallowing herds of giant herbivores such as *Diprotodon* whose fossil bones litter boggy sediments in parts of the New England uplands (Horton and Connah 1981), any trampling by which would have further decreased the permeability of basin floors thus favouring water retention.

Characterising the lagoon basins

In broad terms then, the lagoons of the New England Tableland can be characterised as being located in exposed aspects confined to altitudes above 1000 m and clustered especially around 1300 m (zones of periglaciation), in areas of low relief exhumed from massive and widespread Tertiary basalt flows, the weathering and erosion of which has provided widespread drainage-blocking products (Figure 5.1). The lagoons have formed in areas subject to strong seasonal and annual rainfall fluctuations, but with annual averages below 1000 mm p.a., which would tend to produce active water table fluctuations of sufficient amplitude to generate indurated lithologies. Wetting and drying of the basin floors, coupled with deflation, would facilitate basin deepening while constant weathering and erosion of massive basalt layers would provide retreating escarpment profiles liable to sapping by subsurface water flow emerging from beneath the basalt flows. Deflation of the weathering products would have allowed sand or clay sediments to accumulate along lee shores. In addition, weathering and erosion of numerous nearby granite intrusions liberated quartz material that was delivered into basins by down-cutting streams, ultimately to be reworked to form lunettes and other sand landforms along the lagoon shores.

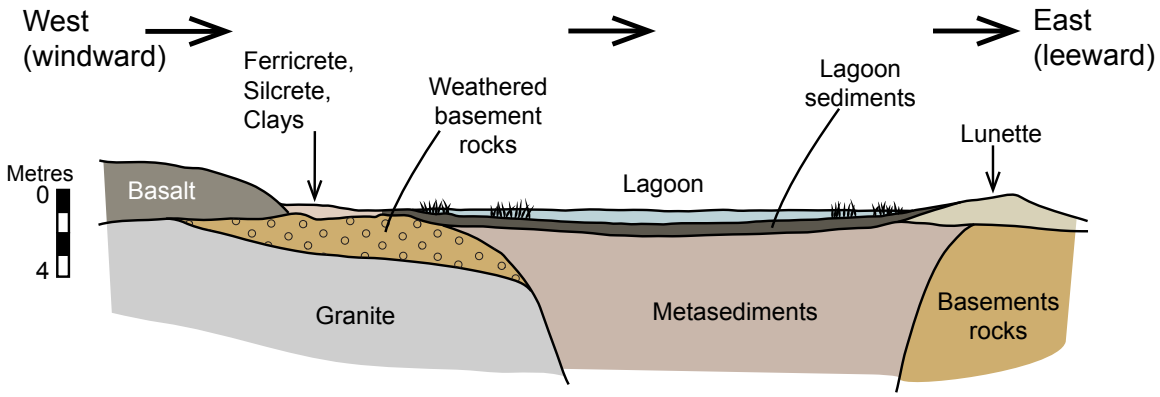


Figure 5.1 *Schematic model of a typical high country lagoon. The catchment geology is usually basalt overlying granite, and sometimes the metasediments of the New England Fold Belt (Adapted by Kim Newman from original by Paul Ashley, UNE Geology).*

The main components of the tableland geology play an important part in the formation of the lagoons, and the three main rock types, broadly the chert-rich Palaeozoic meta-sediments (Sandon Beds, known locally as 'trap'), the Tertiary basalts, and the various granites, occur in different frequencies throughout the lagoon zone. Consequently, the type of lagoon, and especially the presence or absence of sandy lunettes, depends very much on the rock types among which individual lagoons are set.

Some lagoons, especially those in the north west of the study area, are set entirely in basalt; these include Glencoe Barley Field and Reddestone Lagoons, and with Clareveulx and Dunvegan, which are on the edge of the massive basalt flows that were extruded from the Maybole volcano, but also the chain of lagoons set directly on the Main Divide at Guyra, beginning with Dittons and Mother of Ducks Lagoons and including a half dozen other small lagoons to the north set entirely on basalt. These basalt lagoons have no sand lunettes because they have no nearby granitic rocks from which quartz detritus could be delivered (apart from the anomalous lunette at Everetts Flat, where there may have been some river capture in the early Tertiary that cut off a pre-existing sand supply from the more granitic east). However, the commonest situation for lagoons is close to, or on, the basalt-granitic overlap, examples including the Llangothlin Lagoons as well as the Uralla lagoons to the south. All these have well developed sand lunettes, as well as other sand features around their shores.

Part C: Dune geomorphology

To understand the prospects for human occupation, and why the high country may or may not have been attractive to humans, it was thought necessary to get some measure of the geomorphological dynamics and age of the lake-dune systems. Hence, sites were surveyed to assess active and relic human and natural features, OSL and AMS radiocarbon dating were applied to lunette sediment samples (see Chapter 4), and grain size analysis was undertaken to assess whether aeolian or wave action was the dominant factor in lunette development, and to seek evidence for environmental change or disruption that might be indicated by extreme fluctuations in particle size of the dune sediments over time. We were fortunate to be able to set our findings in the context of detailed work (Bell *et al.* 2008; Shulmeister *et al.* 2016; Slee 2016; Ellerton *et al.* 2017) performed recently on the New England lagoons and their environment, as well as by earlier investigators (Briggs 1976; Brock *et al.* 1999; Coenraads 1989; Connolly 1983; Horton and Connah 1989).

Dunes of the northern Tablelands (Guyra Area)

Llangothlin Lake

Description

Llangothlin Lake is 3.3 km long by 1 to 2 km wide with a lake-full area of 4 km^2 and depth of 2-3 metres (Figures 5.2, 5.3). It has 11 km of generalised shoreline, as measured from the 1:25 000 map. It is located at 1350 m altitude and has a catchment of approximately 12 km^2. About 70% of this catchment is covered by basalt and 30% by exposed granitic rocks, although extensive surficial sediment cover including over the southwest sand plain conceals the exact proportion. The basalt occurs mainly in the western part of the catchment but granite is exposed along the eastern lake-shore and in the slopes above, with a few minor basalt residuals. The entire eastern shore is lined with dunes and lunettes, with markedly large sand fields and dunes at the northern and southern ends of the lake. Sand accumulations are completely absent from the long western shoreline, except in the extreme northwest and southeast corners which face the full fetch of the lagoon. Water exits the lagoon from the middle of the western shore to form one of the headwaters of the Mann/Clarence Rivers system (Figure 5.3), the largest in coastal New South Wales. This exit was manipulated in colonial times (*c.* 1870) to provide water for

an industrial mill (Connah 1994; Walker 1963) (See Figure 3.1). It is possible that this outlet has been blocked naturally from time to time in the more distant past, allowing the lake level to rise and sand to be deposited by wave action well above the present lake level, as might be suggested by a 16 metre high dune at the northern end of the lake. The large sand plain to the south of the lake contains at least one remnant lagoon, and shows signs of having been the bed of a formerly much larger lake that included the present Lake Llangothlin, perhaps in the early Pleistocene. In this respect it is similar to all the larger lagoons of the tablelands, each of which displays evidence in its catchment suggests that they have previously been part of more extensive water bodies. They have since been reduced to chains of ponds, often separated by dunes or lunettes, possibly in response to the shoaling process outlined by Lees and Cook (1991) which they deduced from observations of modern day active lake-lunette systems on Cape York in north Queensland.

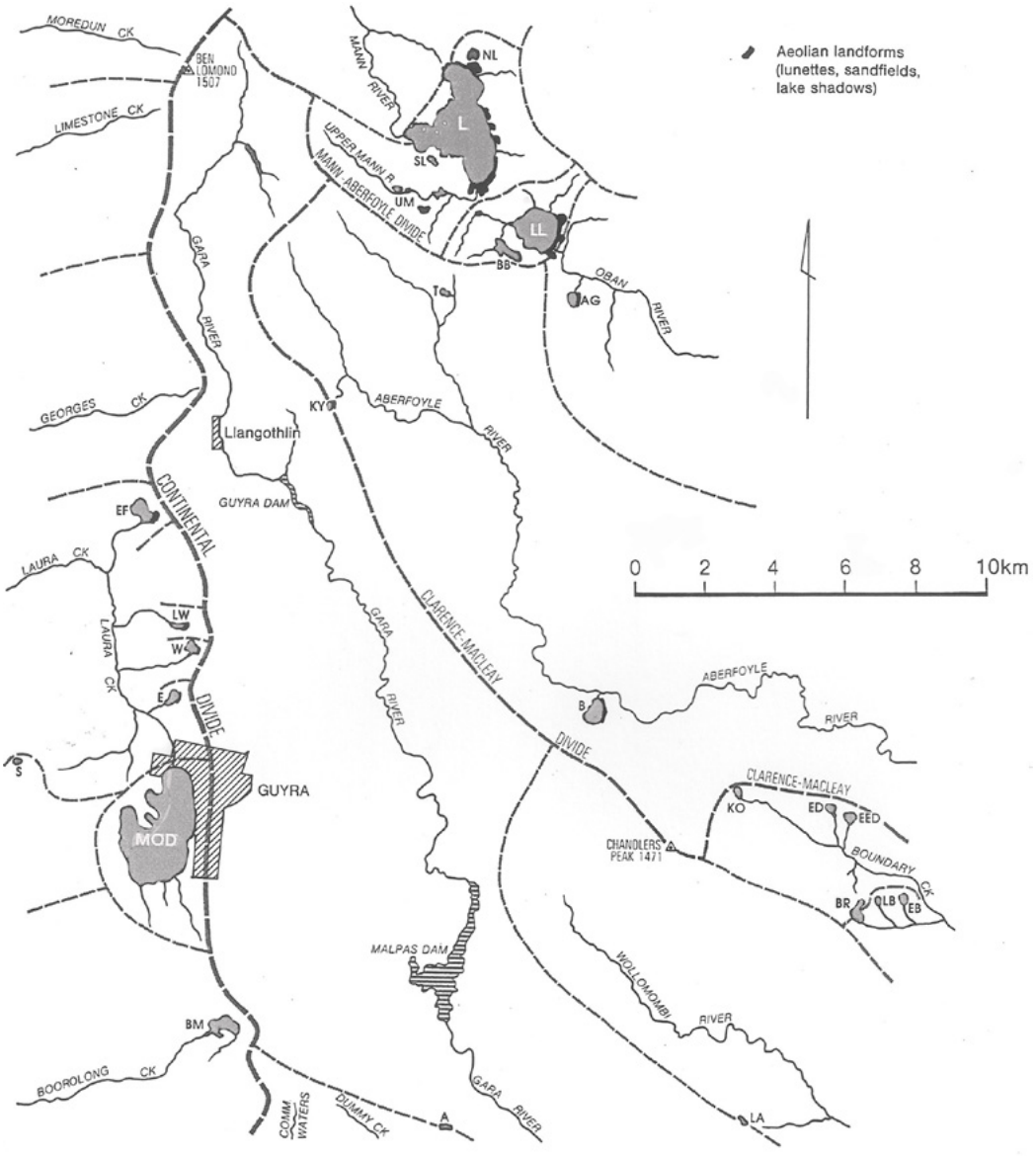


Figure 5.2 *Relationship between lagoons and aeolian features in the Guyra region. Note concentration of lunettes on the lee (eastern) shores (L is Llangothlin Lake, LL is Little Llangothlin Lagoon, AG is Abbey Green Lagoon). (From Haworth (1994) Drawn by M. Roach).*

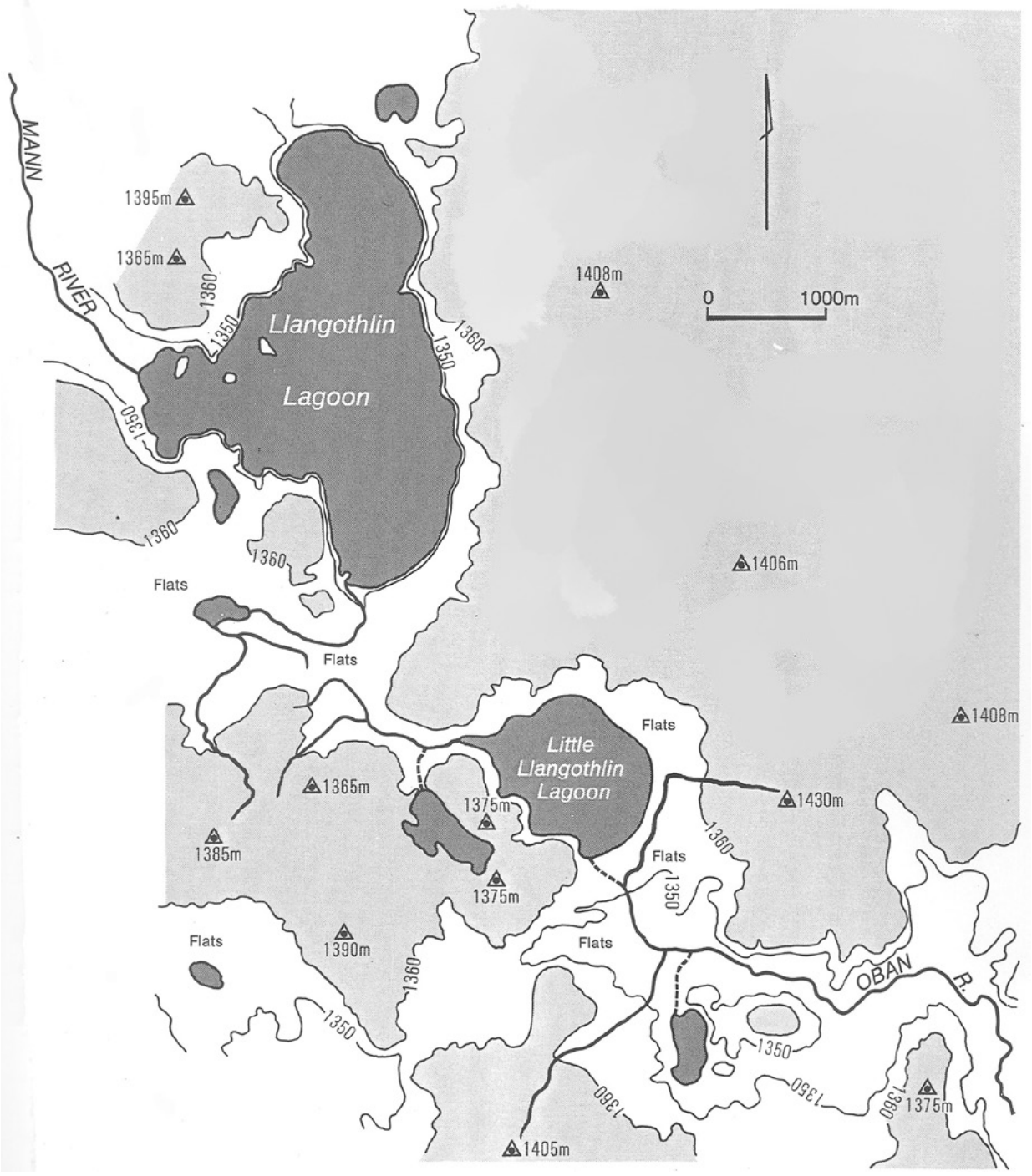


Figure 5.3 *The chain of Llangothlin lagoons showing the tendency of lagoons to occupy cols or gaps on drainage divides. Two principal tributaries, the Mann and the Oban, of the Clarence River, the largest stream system on the New South Wales coast, have their sources in this upland area of indeterminate drainage. (From Haworth 1994, drawn by M. Roach)*

Sand mass morphologies, volumes and composition

The largest of the shoreline sand accumulations at Lake Llangothlin is located at the northern end of the lake. It is not a lunette, but an irregularly-shaped sand mass covering over 20 hectares and at its highest 16 m above the present shoreline. It develops into a linear shore-bordering dune in its southerly extension, where it faces due west (Figures 5.4, 5.5).

The main northern dune has dimensions of approx. 600 m x 250 m x 10 m, giving a volume of around 1,500,000 m^3. A sand sheet extends for about one km to the north east of the main dune over a flat plain. This apparent blow-out measures 1000 m by 750 m, and averages a depth of one metre, giving a figure of around 750,000 m^3. The main north-end sand deposit, extending from the main dune along the lake shore in a south east direction (sites A, B, D in Figure 5.4), is approximately 550 m by 100 m broad and averages 3 m deep, or ~165,000 m^3. The isolated beach dune in the north west cove (site

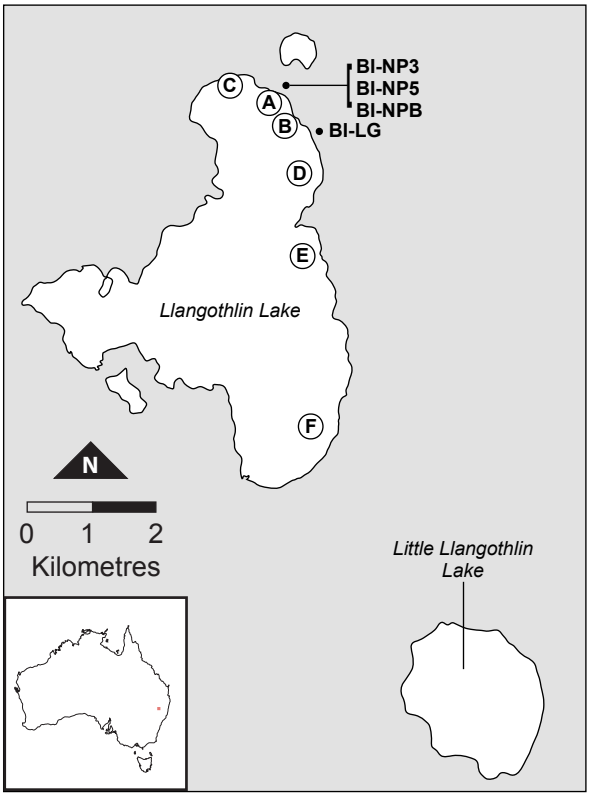


Figure 5.4 *Sand compartments and sampling locations on Lake Llangothlin shoreline (Drawn by K.Newman)*

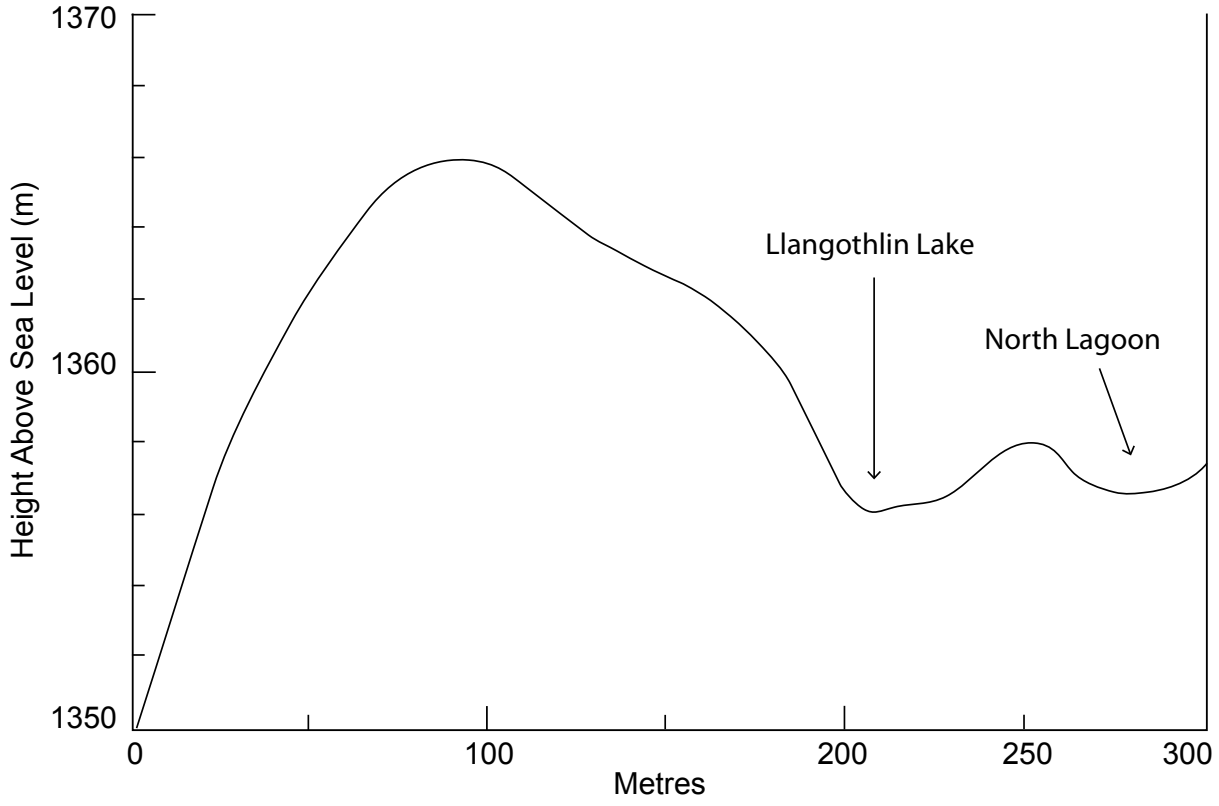


Figure 5.5 *Exaggerated cross section of northern dune of Lake Llangothlin (Drawing by K.Newman)*

C, Figure 5.4) measures 250 m by 30 m and averages 3 m deep, giving a comparatively small volume of 22,500 m^3.

Hence, the total accumulation of sand in the northern end of the lake alone is around 2.5 million m^3. By comparison, the lunette occupying the south east shoreline of the lake (site E-F in Figure 5.4) is 1250 m long, approximately 125 metres broad, and averages 3 m thick, giving a volume of 468,750 m^3, or only about one fifth of the sand that has built up in the northern cove. The main lunette extends along the south-eastern shoreline (Figure 5.4, site F), and terminates in an extensive flat sand plain around the southern end of the lake. It is parallel to and in the same relative location as the lunette in the neighbouring lagoon of Little Llangothlin.

A discontinuous series of small sand accumulations, possibly incipient lunettes, occupies the middle part of the eastern shore, facing the lake outlet 2 km away on the western shore. This series of intermittent dunes is ~500 m long and ~50 m broad, and averages 3.0 m depth, suggesting an approximate volume of 75,000 m^3.

It is likely that there was once also a large sand mass at the far southern end of Llangothlin Lake, where now there is only a broad but shallow sand plain. This area has been intensively farmed and disturbed for 150 years. An indication of its original nature may be in the name of the old homestead: 'Sandy Farm'.

OSL ages (Table 5.1, Figure 5.6) and particle size determinations for the northern sand mass were obtained from one core (site A, Bl-NPB). This was extracted from the highest part of the extant dune in what was judged to be the centre of its area, 16 m higher than the present lake shore and 100 m inland (Figures 5.5, 5.6). No particle size determinations were undertaken on other cores obtained from the northern sand mass other than Bl-NPB, but visual examination indicated similar coarse red-brown sand around 800 microns that made up most of the near surface (that is, within one metre of the surface) dune sands in this area. An overall large grain size, coupled with its topographic position, suggests that the sand mass at the northern end of the lake is likely to have been deposited by wave action rather than by wind, and probably involving processes similar to those described by Shulmeister *et al.* (2016) and Ellerton *et al.* (2017) from neighbouring Little Llangothlin Lagoon.

TABLE 5.1 NORTH END OF LLANGOTHLIN LAKE: CORE 1A--- DUNE GRAIN SIZES VS AGES

Depth of sample	OSL age (see Table 4.2 for details)	Volume weighted mean	Profile
10-20 cm		844 microns	unimodal coarse sand
40-50 cm	29.0+/-2.0 ka BP at 50 cm (BI-NPB-50)	840 microns	unimodal coarse sand
60-70 cm	32.1+/- 1.9 ka BP at 65 cm (BI-NPB-65)	897 microns	unimodal coarse sand
78-83 cm		572 microns	bimodal, coarse sand dominant, small silt (or dust) peak
96-107 cm		809 microns	almost unimodal with coarse sand peak, but with very subdued silt peak
	60.5+/- 4.1 ka BP at 118 cm (BI-NPB-118)		
125-133 cm		293 microns	bimodal/ borderline trimodal, almost equal coarse sand and silt peaks, plus incipient sub-silt bump (clay/colloidal??)
	72.6+/- 7.3 ka BP at 165 cm (BI-NPB-165)		
180-190 cm		806 microns	unimodal coarse sand
280-300 cm		762 microns	unimodal coarse sand, incipient small silt peak.

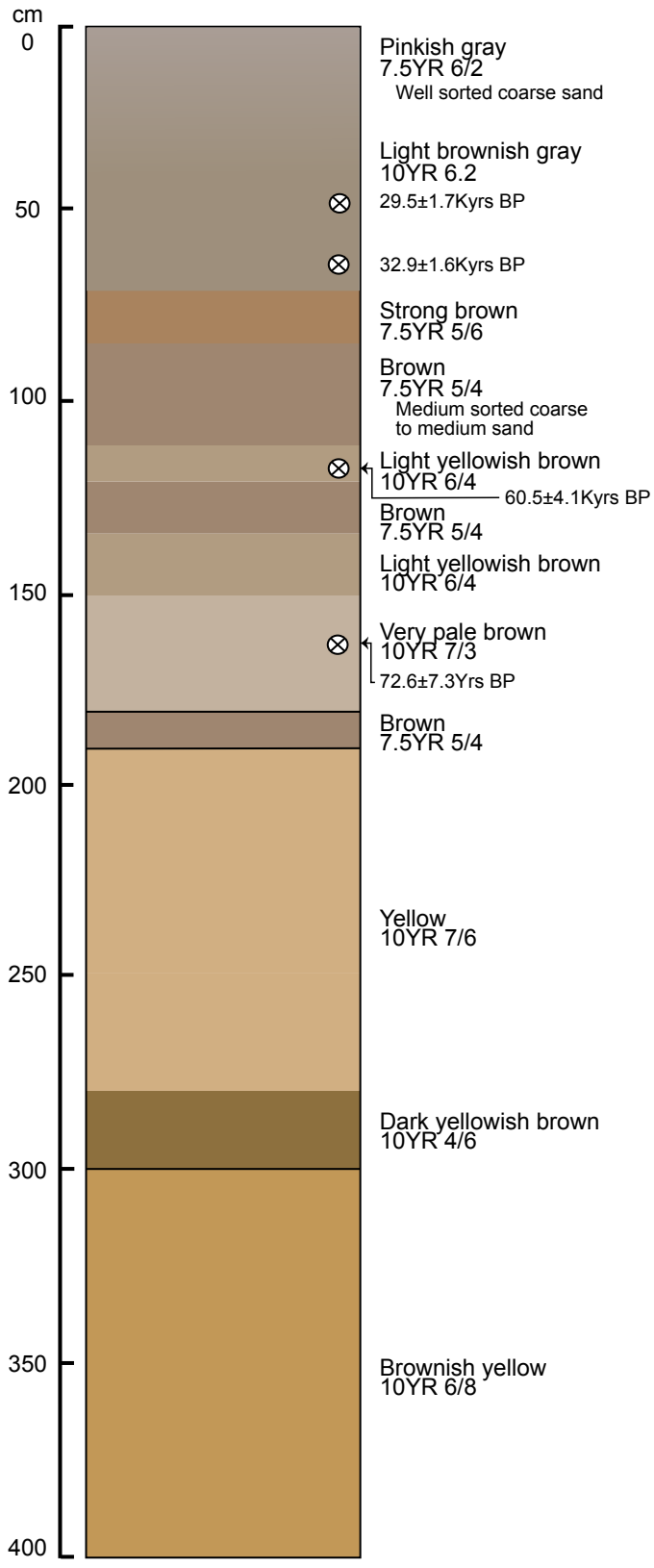


Figure 5.6 *Core profile of Bl-NP3, north Llangothlin sand dune. Note the major change from brown sand to yellow around 40,000 years BP (Drawing by K.Newman)*

Particle size determinations obtained from a single core extracted from the south-east lunette (BI-EP, Figure 4.1a) indicated a mean calibre of 440 microns at 25-35 cm depth, 700 microns at 90-100 cm and 540 microns at 160-175 cm, the latter showing a minor peak at 35 microns (Table 5.2).

TABLE 5.2 GRAIN SIZE OF SOUTH EAST LLANGOTHLIN LAKE LUNETTE CORE COMPARED TO OSL AGES

Depth	OSL Age	Volume weighted mean	Profile
25-35 cm	2.6 +/-0.3 ka BP at 32 cm depth (BI-EP-1-32)	440 microns	weakly bimodal, with medium sand dominant but with subdued silt/dust peak
90-100cm			706 micron unimodal, coarse sand
	12.8 +/-0.8 ka BP at 114 cm depth (BI-EP-1-114) 15.3 +/-0.9 ka BP at 147 cm depth (BI-EP1-147)		
160-175 cm		539 microns	bimodal, with a coarse sand dominant peak, but moderately high silt/dust peak

Dating: Northern and South-eastern sand dunes

Samples for OSL dating were obtained from several places in this sand agglomeration (See Figure 4.1a). Core 1a (BI-NPB) was extracted at the northern limit of the undisturbed part of the dune. Further north it had been disturbed by sand extraction by local farmers. The large pit that sand extractors had created in the back dune area, however, did give us an informative picture of the structure and depth of the dune. Core 1b (BI-NP3) was extracted a few metres from core 1a, and one metre lower in altitude. Core 1c (BI-LG) was extracted 30 m to the east of, and down-slope from Core 1a, and three metres lower in altitude. Finally, Core 1d (BI-EP1) was extracted from a low dune at the far southern end of this northern sand accumulation, named the laterite gully, 400 m to the southeast from Core 1a and about 30 metres inland from the shoreline, at 1362 m asl (See Figure 4.1a). The OSL dates obtained are presented in Table 5.3 and Table 4.2.

TABLE 5.3 SEDIMENT ACCUMULATION RATES INFERRED FROM DEPTH OF DATED SAMPLES AT LAKE LLANGOTHLIN

Period (ka) and location (Figure 4.1a)		Rate (mm/yr)
Start date	End date	
Northern sand mass:		
Core 1a (BI-NPB)		
Present	29.0 ± 2.0	0.02
29.0 ± 2.0	32.1 ± 1.9	0.05
32.1 ± 1.9	60.5 ± 4.1	0.02
60.5 ± 4.1	72.6 ± 7.3	0.04
Core 1b (BI-NP3)		
Present	4.6 ± 0.4	0.09
Core 1c (BI-NP4)		
Present	8.9 ± 0.7	0.05
8.9 ± 0.7	20.7 ± 1.1	0.04
Core 1d: laterite gully (BI-LG)		
Present	28.9 ± 1.8	0.03
Southeastern lunette (BI-EP1)		
Present	2.6 ± 0.3	0.12
2.6 ±0.3	12.8 ±0.8	0.08
12.8 ± 0.8	15.3 ± 0.9	0.11

Three dates were obtained from a pit excavated to 185 cm depth in the south-eastern sand mass (Table 5.3, Core BI-EP1). Sample BL10 from 147 cm depth immediately above a gravelly bed gave a date of 15.3±0.9; sample BL 11 from higher in the same sand unit at 114cm depth 12.8±0.8 and BG13 from 32 cm just above a transition from grey to yellowish sand 2.6±0.3 (See Table 4.2).

Dune evolution

The morphology, internal structure and sedimentary composition of the complex dune features along the eastern shoreline of the lake indicate composite beach and aeolian landforms, deposited by both wave and current and probably reworked *in situ* by small scale aeolian processes such as saltation (movement of large grains up or across a sand dune by leaping and bouncing action). The disproportionate amount of sand in the far northern dunes of the lake compared to the eastern shore indicates that the narrowing northern lake arm has been a long-term sand trap, probably the consequence of waves and currents driven by a fetch extending over the entire 5 km longitudinal axis of the water body. There may have been more wind than wave deposition in the south eastern lunette (compared to the north), expressed as more long tails of fine material mixed with the coarser sands in the grain size profiles than in the north. Newley (1992) undertook a comprehensive physical and statistical analysis of grain size on samples from a 1.5 metre deep pit in the northern dune close to the present pit where our OSL and grain size samples were taken (site A in Figure 5.4). He concluded that most of the material examined is likely to be the result of aeolian reworking of wave and current deposited sediments, the whole tending towards beach sandbank characteristics, though with some obvious outliers in strata with finer aggregations.

In summary, the bulk of the sand that was examined in the northern sand trap by both Newley (1992) and the present authors is of uniformly large grain size, an indication that it most likely derives from beach sands, re-dispersed up the dune slope by saltation or possibly deposited in a period of higher lake levels. The bi- and multi-modal profiles of the southeast lunette, with their greater content of fines, indicate a skewed pattern that is more likely the result of a greater input by aeolian processes (Friedman 1961).

Skewness of a grain size population is the measure of the predominance of finer or coarser sediment relative to a mean (Boggs 2011). The Mastersizer graphs show the grain size population and, among other things, the degree of skewness (summarised in Figure 5.7). A symmetrical distribution, common in the northern cores at Llangothlin Lagoon, as indicated by a uni-modal graph form, indicates an unskewed or negatively skewed profile, where the majority of grains have a similar coarseness. Finer grained material could indicate more aeolian deposition, though some of it could also indicate soil fines produced by vegetation. The lack of bedding that was fairly general in all the cores suggests rapid deposition at times, by whatever means.

There was little evidence for palaeosol development in the Llangothlin dunes and few inclusions of any kind, including artefacts. This suggests reworking of the sand by wave and wind over long periods, and if there were any lag deposits associated with this they were not found. All indications were that the dune sediment was for the most part very well sorted, subject to constant winnowing by wave and current before re-deposition onto accreting beach berms. Sun *et al.* (2002) found that in closed bas*in situ*ations (such as the Llangothlin Lakes) grain-size analysis revealed two types of grain size distribution for the sediments. The first one is composed of two closely overlapping silt components, with a smaller amount of finer grained material. The second type is a coarse component greater than 200 micrometres. The fine component is around 0.2 to 0.4 micrometres, and is interpreted as paedogenic or biochemical. The coarse fraction is consistent with saltation processes in the lake bottom during major storm events. Smaller grain sizes (25-35 micrometres for instance) are compatible with suspension load in lake waters during more minor storm events. One speculation derived from this analysis is that the coarse grain

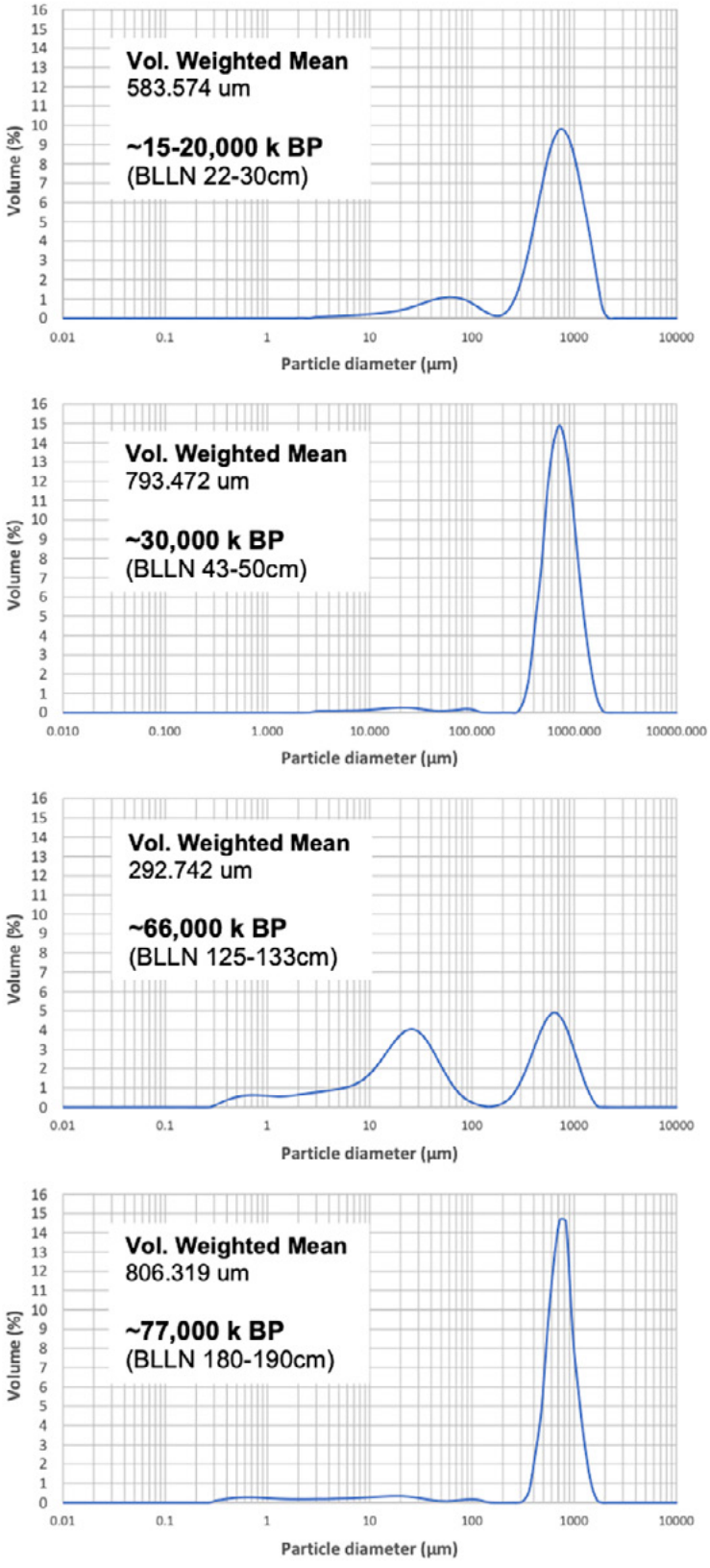


Figure 5.7 *Comparison of fine grain (dust, silt or colloidals: 1-100 µm) peaks at four ages in core profiles from Llangothlin Lagoon, showing marked increase in fine grain in the 66,000-year profile. (Drawn by K.Newman)*

size dominance in the Llangothlin sediments may represent a period of heavy summer rainfall and the finer components a period of gentler (winter) rainfall.

The accumulation rates inferred for each sand unit may give a useful if inevitably coarse proxy of environmental conditions during past deposition. The accumulation rates inferred for the Lake Llangothlin sand masses are given in Table 5.3. The sedimentation rate inferred for the south-eastern lunette is an order of magnitude greater than that for the northern sand dune over the same age range.

The first thing to query is: how reliable are these rates? One can never be sure if something has been deflated from the sediment columns in question. In the northern cores this seems unlikely, as the three cores for the most part appear markedly uniform in both accumulation rate and well sorted particle size, despite having been extracted from three very different locations. One important exception is the deep dust layer and markedly smaller median particle size in Core 1a, below 1.45 m and therefore between the ages of 60 ka and 70 ka. Here the grain size median is 295 microns versus a median above and below of coarse sand particles at ~800 microns. Large sized sand grains would not so easily be deflated. However, there is an apparent break-out beyond the northern dune to the sand plain to its north east. This could also have received sand directly from the erosion products of the high granite ridge behind it. The lake could also have extended to the north east at some earlier time, as it is hard to judge just how deep the sand plain

is, but the far northern lagoon (North Llangothlin Lagoon) appears to be perched on a deep sand deposit 8 m higher than Lake Llangothlin, maintained by a humicrete of organic cemented sand. If so, there could be even more sand trapped in the north than calculated.

The particle size of the material from the southeast lunette is notably more variable than that in the northern sand dunes, fluctuating from a median 440 microns between 25-35 cm (around 2600 years ago) up to a median of 706 microns at 100 cm depth just after 12,800 years ago, falling to 539 microns at 160-170 cm some time after 15,700 years ago. The particle size variation in the south east lunette and its apparent markedly more rapid sedimentation rate could be a function of it being younger, such that less time has been available for it to be subjected to deflation events.

Alternatively, it could represent a genuine increase caused by a different sediment delivery process as opposed to the much larger sand accumulation in the north of the lake. One key clue perhaps is the much greater degree of sorting in the northern sands, expressed as a much more uniform particle size of coarse sand throughout, with the one exception at great depth in Core 1a. A greater degree of sorting, and a much greater amount of sand delivered at a lower rate but over a much greater period of time, strongly suggest a persistent mechanism of wave action being responsible for the agglomeration of sand in the north. Looking at the relief surrounding Lake Llangothlin, it is obvious that the form of this lake is much more structurally controlled than most of the surrounding lagoons (for instance, Little Llangothlin). High rocky slopes protect much of its shoreline from the full strength of prevailing winds, except for two instances: a wind gap in the south of the lake and the two km wide east-west bay facing the lunette. This bay provides an open corridor for the prevailing westerly winds. Coenraads (1989) suggested that the Llangothlin lagoons have formed on the remnants of a river palaeo-channel exhumed from beneath the basalt, thus accounting for the 'fossil' wind gaps. The west wind is dominant in the winter (BOM 2016) when, as pointed out by Shulmeister *et al.* (2016) the otherwise choking reed beds of these lagoons have withered back and allow lake sedimentation processes of wind, wave or current much greater efficacy.

The sand accumulation in the north, on the other hand, cannot be a result of the prevailing westerly wind (except in part of its southern extension) because of its location in the northern tip of this elongated water body, with a higher rocky ridge to the immediate west of the main sand body. The most likely process of accumulation is wave action driven by wind on the 3 km fetch from south to north, followed by wind transport from the beach by saltation and related processes to form the higher parts of the dune. The fetch from south to north would be more powerful than its opposite because of the wind gap at the southern tip of the lake, behind which to the south are a series of small remnant lagoons that may have been part of a much larger proto Lake Llangothlin. Unfortunately, this area has had extensive agricultural modification, with kilometres of drains dug (and continuously re-dug, as the area tends to quagmire) and land flattened.

Wave transport of sediment could only have occurred under lake-full conditions. This appears to have been the case in Llangothlin Lake to a much greater extent than most of the surrounding lagoons. It is both larger and deeper than all but the Mother of Ducks Lagoon at Guyra township to the southeast, but unlike that lake, Lake Llangothlin is much better protected from wind evaporation by the surrounding topography. A characteristic of Lake Llangothlin's circulation when full is a strong current running south to north along the eastern shoreline as part of a counter-clockwise gyre. This would be capable of carrying sand eroded from the granitic outcrops of the eastern shore to the north, although there was probably a much more thorough sorting over the great periods of time available. As detailed above, there are over 2.5 million cubic metres of quartz sand trapped at the northern extremities of the lake compared to the comparatively restricted amount contained in the lunette along the south eastern shore of around a half of a million cubic metres, or a five to one ratio.

Episodes of wave driven sand actively accumulating on the northern shores to form dunes may serve as a proxy for periods of dominantly lake-full conditions. These lake-full periods must have occurred on and off for at least 70,000 years given our deepest OSL age. This may barely scratch the surface in exploring the true age of this giant dune which as far as can be seen extends at least another 14 metres to water level with no intervening rock substrate. The possibility is that it has been accumulating, assuming the mostly stable sedimentation rate of the top two to three metres, for over 300,000 years. This, of course, is only a possibility if there were a uniform rate of deposition through the entire core, and unfortunately we have no way of testing variation in sediment rates for the entire core. However, we can certainly say it has been accumulating for much longer than 70,000 years.

The accumulation of sediment to form the dune from the beachside deposits over a long period of time infers that the lake floor itself was accumulating and recycling sediment over a similarly long time period. This suggests that it would be a rewarding location from which to recover lacustrine deposits for pollen and other palaeo-environmental analysis, although the lake floor contains large areas of treacherous sinking sands.

Little Llangothlin Lagoon

Woodward *et al.* (2014) sketched in the environmental history of the neighbouring Little Llangothlin Lagoon, 1 km to the south east of Lake Llangothlin, (See Fig 5.8) and depicted alternating periods of dominantly lake-full and non-lake-full periods. It may reasonably be assumed that this was also reflected in the history of the larger Lake Llangothlin, notwithstanding the possibility that its greater size and depth may have allowed it to retain water longer in drought conditions.

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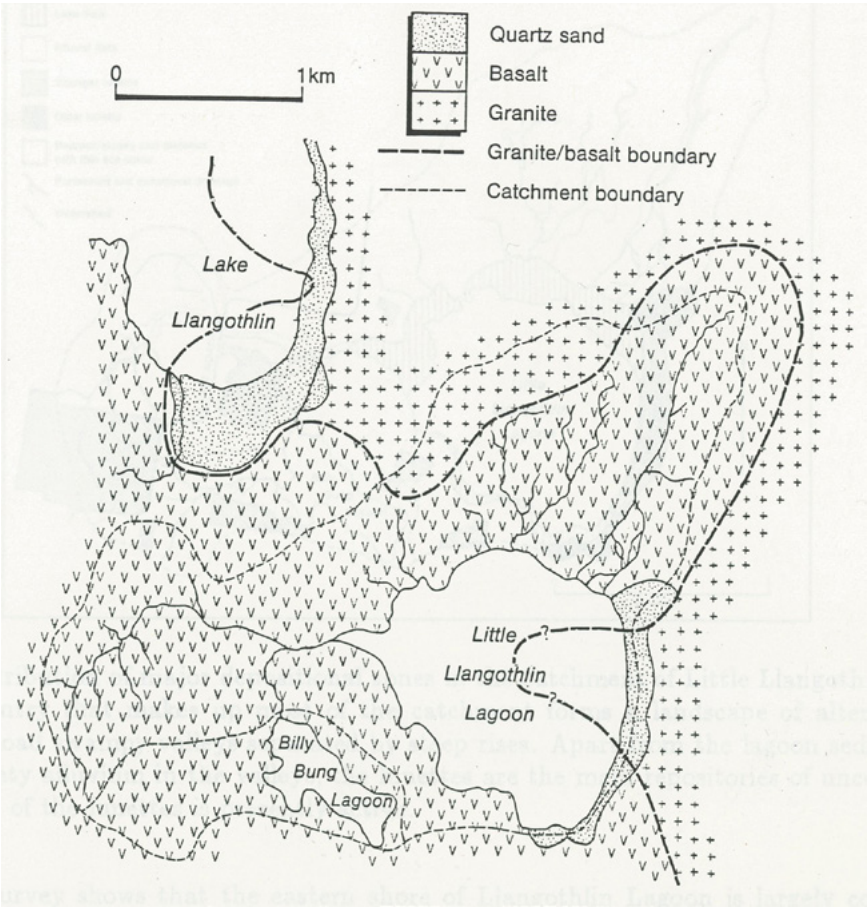


Figure 5.8 *Little Llangothlin, showing its relationship with the neighbouring southern part of Llangothlin Lake, and their relative accumulations of dune sands. The berm under discussion is at the bottom (far south) of Little Llangothlin lunette. (From Haworth 1994. Drawn by M. Roach)*

for pollen and other palaeo-environmental analysis, although the lake floor contains large areas of treacherous sinking sands.

Description

Little Langothlin Lagoon is located 2 km southeast of Lake Llangothlin (Figures 5.3, 5.8). It lies about 14 km east of the Great Divide at 1355 m altitude, on the eastern boundary of basalt flows from Ben Lomond volcanic vent. Granitic rocks (adamellite) are presumed to exist beneath its eastern margin and lunette (Haworth 1994). It is ovoid in shape, about 105 ha in extent and reaches 2 m depth. In contrast to most of the other lagoons on the New England Tablelands, it retains water throughout the year except during times of extreme drought. This makes it a particularly important refuge for waterfowl when other lagoons dry out, and it has been listed as a Ramsar site. Apart from a shallow artificial outlet drain, constructed about 1916 but closed in 1989, Little Llangothlin Lagoon has been little modified since European settlement.

Sand mass morphologies, volume and composition

The lunette that borders the eastern side of Little Llangothlin Lagoon is approximately 1000 m long by 125 m broad. It is comprised of quartz sand that averages 2 m deep. The volume of sand in the Little Llangothlin lunette is therefore approximately ~ 250,000 m^3, which is a little over half that of the southeast lunette of Lake Llangothlin (468,750 m^3). The Lake Llangothlin lunette, is deeper and longer, but is narrower due to the lack of blow-outs, and better preservation. Part of the Little Llangothlin lunette has been constructed upon a gravelly beach berm, which Shulmeister *et al.* (2016) surmised as likely to have originated 'as a spit that developed from the basalt ridge on the SW edge of the lake, with basalt gravels being moved along the shoreline by longshore drift' (Figure 5.8).

In contrast, the lunette consists of quartz gravels derived from granite. Particle size analyses presented by Shulmeister *et al.* (2016 – figure S1) from four sites along the length of the lunette indicates that poorly-sorted medium sand at depth in the lunette grades upwards into fine sand with accessory silt and clay content of 3-15%. Given these already-existing particle size data, and the fact that the latter authors had also determined a weighted mean OSL age of 20,400±800 years for the base of the lunette, the present research concentrated on the gravelly berm or spit upon which may underlie part of the lunette.

To explore the origin and development history of this feature, a pit 1.5 m deep was excavated.at the extreme southern section of the lunette/berm complex, on the lowest topographic part of the barrier, close to the natural overflow point. This revealed the berm to consist of pea sized gravels and a finer sandy matrix. A manganese duricrust encountered at the base of the pit may have been precipitated post-deposition: the berm material is full of iron and manganese nodules, probably because of iron-rich groundwater from the lagoon that appears to be filtered through this part of the dune to join outlet streams.

Dating

A peaty sediment sample was obtained by Haworth from 1.5 m depth below the crest of the berm, judged to be at the berm's base. AMS radiocarbon dating agave a conventional C^{14} age of 16,200 ±70 years BP, and a calibrated age of 19,500 ± 123 cal. years (95.4% probability 19, 721—19,247 cal. years BP: 68.2% probability 19,613—19,388 cal. years BP).

Dune evolution

The radiocarbon age obtained from the apparent base of the berm indicates that berm development commenced in the latter part of the LGM. This is broadly consistent with the ages obtained by Shulmeister *et al.* (2016) for the formation of the main lunette (19,000-24,000 years BP) part of which apparently lies on the berm. The present lunette cuts off an area to the east leaving what is now a back swamp. This may have been part of an older palaeo-lake, hence the lunette could reflect shoaling to the windward having formed a smaller water body, as suggested by the Lees and Cook (1991) model of lake-lunette evolution.

Woodward *et al.* (2014) demonstrated that Little Llangothlin Lagoon has been intermittently active most of the time as some kind of wetland, especially in the latter part of the LGM. Ellerton *et al.*'s (2017) core LL9 from the other side of the lake basin from the lunette at 2.14-2.17 m below the present lake sediment surface was dated to 20,110 ± 290 years cal. BP, comparable to the age of 19,500 ± 123 cal. years BP we obtained from the base of the lunette's berm. The lacustrine clay age marked the base of a unit of un-mottled grey clay that was deposited until about 15 000 years ago, interpreted by Ellerton *et al.* (2017) as the product of lake-full conditions. This would account for the formation of the Little Llangothlin sand lunette by wave driven sedimentation (Bowler 1970) after this date. The base of the grey clay is at least 2 metres below the altitude of our dated sample from the base of the berm, albeit on opposite sides of the lagoon. This suggests a good fit between the potential water level and hypothesised lunette genesis, the lagoon when full seemingly close to its average depth today of about two metres. This in turn suggests very efficient mixing mechanisms at work in Little Llangothlin Lagoon.

Eighty per cent of the lagoon catchment is basalt, presumably the source of the fine lacustrine grey clays evident in core LL9 Ellerton *et al.* (2017). Where then have the abundant quartz sands of the lunette been generated? The 20% of the catchment that is granitic, and the only likely source of quartz sand, is far away along the northern watershed of the lagoon, and most of its sandy sediment is today trapped in bogs in the valley of the north-eastern tributary stream of the lagoon. However, there is abundant quartz sand material from granitic lithology on the far landward side of the lunette, in the area that is now back-swamp and not connected hydrologically with the lagoon. The strong inference is that at some time in the past (pre-LGM) this back-swamp area was part of the lagoon, forming a larger ancestral lake where over a great period of time sediments were thoroughly sorted by wave and current action.

The fine sediments were deposited on the lagoon floor, or blown away, and the coarse sands accumulated on the lee shore where they could be reworked in cyclic reconstructions of the lunette. There are sandy mounds in this back-swamp that could possibly be parts of an earlier lunette, just as there are on the landward side of the southeast lunette at Lake Llangothlin. Both lunettes have swampy flatlands behind them where their respective lakes may once have extended, later to be truncated by shoaling to windward and formation of new lunettes on the shoals (Lees and Cook 1991).

That the size of the Little Llangothlin lunette and its approximate volume of sand (250,000 m^3) are comparable to the south eastern lunette at Lake Llangothlin (468,750 $m^{3)}$ raises the possibility that they may have been formed about the same time, although the greater depth of sand under the last age indicator at Llangothlin Lagoon lunette suggests that it might be older. However, given that the ages from the northern dune at Llangothlin Lake of ~ 70,000 years BP suggests that lake could be much older, there may have been ample time for a succession of lunette-lake cycles, of which the most recent formed during the or near the LGM, as at Little Llangothlin.

Lagoons of the south-central New England Tableland (Uralla area)

The three Uralla lake/lunette systems investigated in detail (Barley Field, Racecourse and Dangars lagoons) are situated 80 km south of the Guyra sites (Figure I.2), and at a lower altitude of ~1000 m. All three sit on cusps of the Great Divide, with occasional overflow to the east from Barley Fields and Dangars lagoons. Racecourse Lagoon is completely closed for surface, but not sub-surface drainage (Haworth 2006). Both Barley Field and Dangars lagoons have had water diverted by artificial channels to west of the Divide for mining purposes during the 19th century. They all have sufficient granitic rocks in their catchments to provide quartz sand for shoreline sand features, and all have lunettes, or in the case of Dangars Lagoon a remnant of the original lunette, on their eastern shores.

Sand mass morphologies, volume and composition

An estimation of bulk volume of material in each lunette gave approximately 51,000 m^3 of mixed sand and clay for Barley Field lunette (340 m long, 150 m broad, and average one metre depth), 100,000 m^3 of mostly quartz sand for Dangars lunette, and a much greater volume of 2,250,000 m^3 for the Racecourse Lagoon lunette (1000 m long, 300 m broad, average 7.5 m depth), which is a mixture of quartz sand and clay. Of these only Barley Fields was precisely surveyed with dumpy levels and Racecourse was more broadly estimated from a number of measured cross sections in the field. All but a small section of Dangars lunette had been altered or destroyed so we extrapolated from the surviving sample. Nonetheless the figures probably fairly accurately show the order of magnitude difference between the enormous bulk of Racecourse lunette compared to the other two.

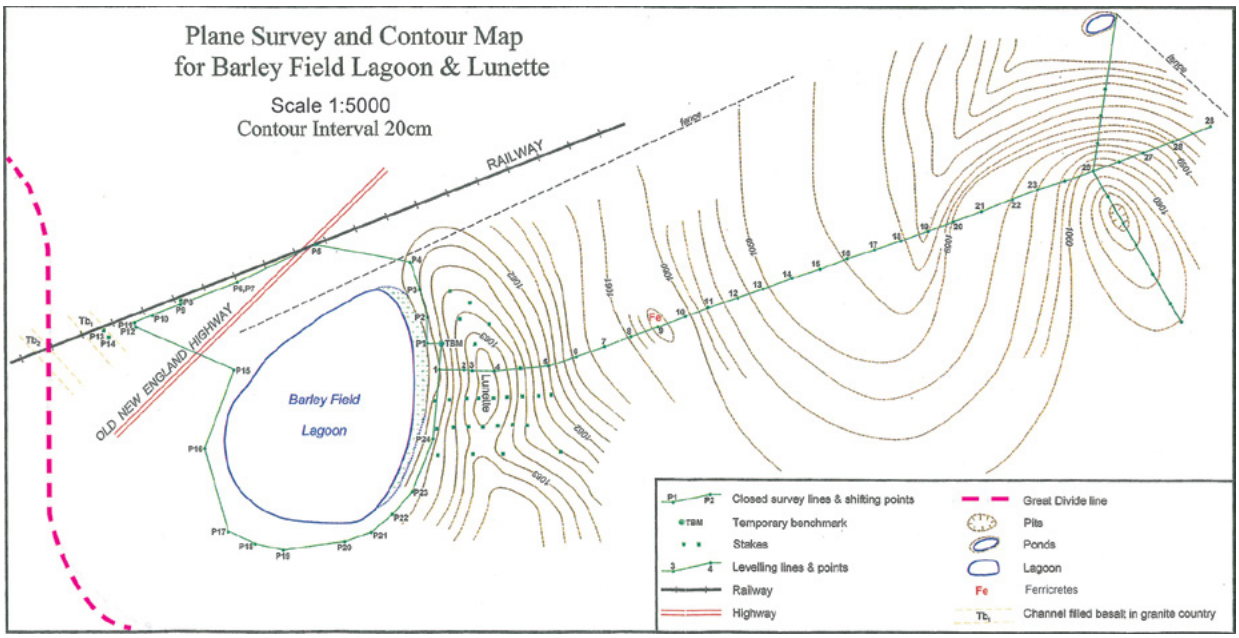


Figure 5.9 *Field survey of Barley Field Lagoon and surrounds c. 1995 Field survey of Barley Field Lunette and surrounds c.1995. The lunette blocks a natural drainage fall to the east, where what may be the remains of a remnant lunette can be seen, perhaps from a time of a larger, older lake. A recent headward erosion gully has cut into what may be an older lake-bed in the top right of the diagram. (Drawing by Tony Pearson 1995).*

Barley Field Lagoon

Description

Barley Field Lagoon lies at 1069 metres altitude 3 km north-east of Uralla, and has a basin area of six hectares. It is the smallest of the three lagoons, standing alone on the cusp of the Great Divide 40 m higher than the other two lagoons and ~ 5 km to their north. A broad, low 340 m long lunette only a little over one metre high blocks drainage to the east. Barley Field Lagoon thus sits near the crest of the Great Divide, which in this region of upland plains and swamps could in no way be described as a 'range'. The lagoon has a 90 ha catchment over granite (specifically, adamellite and granodiorite of the New England batholith) that is overlain in its western portion by basalt flows. There are numerous silcrete outcrops near the southern shore of the lagoon (See Figure 5.9).

In the 19th century a channel was dug to drain the lagoon's water to the goldfields located 4 km to the west of the Divide. The western catchment of the lagoon, largely basalt, was cut off by the excavation of a railway culvert in the 1880s and in the 1960s by an entrenched re-alignment of the New England Highway. This left only the granite and silcrete dominated eastern half of the catchment to provide runoff into the lagoon. While this now masks the much greater likely incidence of full water conditions in the lagoon before developmental disturbance, in the 19th century it was obviously sufficient to serve as a major supply for industrial mining in the goldfields. The area has also served as a Travelling Stock Reserve (TSR).

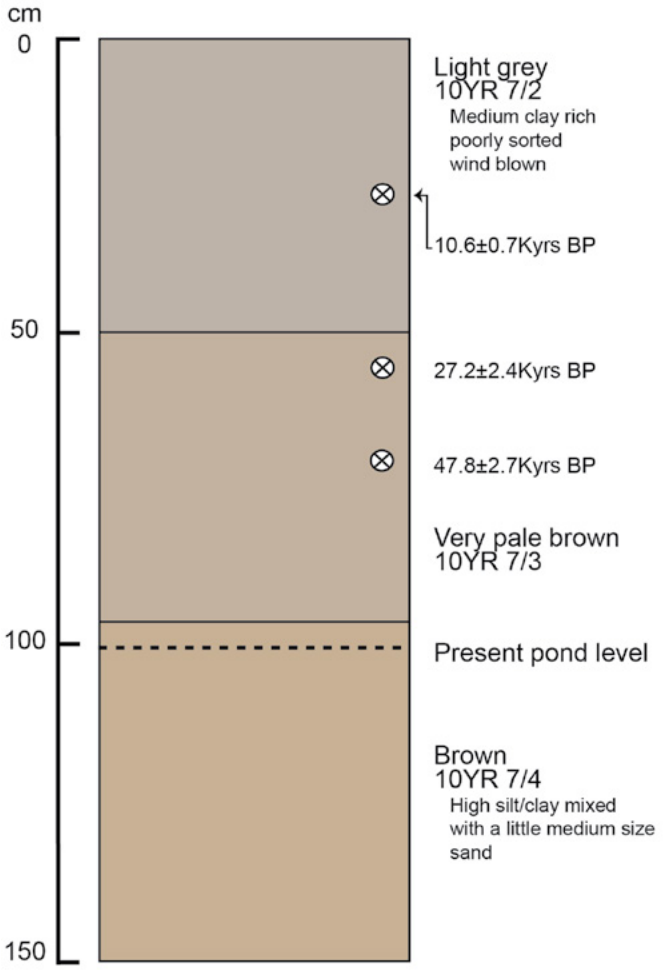


Figure 5.10 *Generalised stratigraphic column from the two adjacent Barley Field lunette cores to show the structure of this mainly clay lunette (Drawn by K. Newman)*

Natural drainage to the eastern seaboard was cut off by the low, sandy, but in parts clay-rich lunette. The lunette is approximately 340 m long and 120-150 metres wide and has a maximum height of 1.2 m (see Figure 5.9). There is a remnant of what may be a parallel earlier lunette 400 metres to the east (shown in the far right of Figure 5.9 - the intervening depression is the result of recent headward gully erosion) - suggesting that, in common with many of the lagoon-lunette systems examined, the present system may be a truncated remnant of a formerly larger lake.

Two pits were dug and augured in the lunette, one on the lunette crest (Pit 1[BA-P1]) and the other on the lagoon margin nearer to the subdued peak of the lunette (Pit 2[BA-P2]). These revealed the lunette to consist of a mixture of quartz sand from the underlying granite and clay aggregates probably derived from erosion products of the basalt in the western segment of the catchment. Ferruginous nodules are

common towards the base of the lunette sediment and at least the uppermost part of the less readily permeable subjacent clay unit (Figure 5.10).

Auguring at 46 sites revealed heavily weathered clay, generally within 1 m of the surface in the case of the lunette, and immediately beneath a thin layer of organic material on the lagoon floor. (Figure 5.11). The fine-grained material below one metre in the lunette is probably old lake floor deposits. No material of comparable grain size to that which forms the lunette above lake floor level was detected in any of the 12 augur holes into the base of the lagoon.

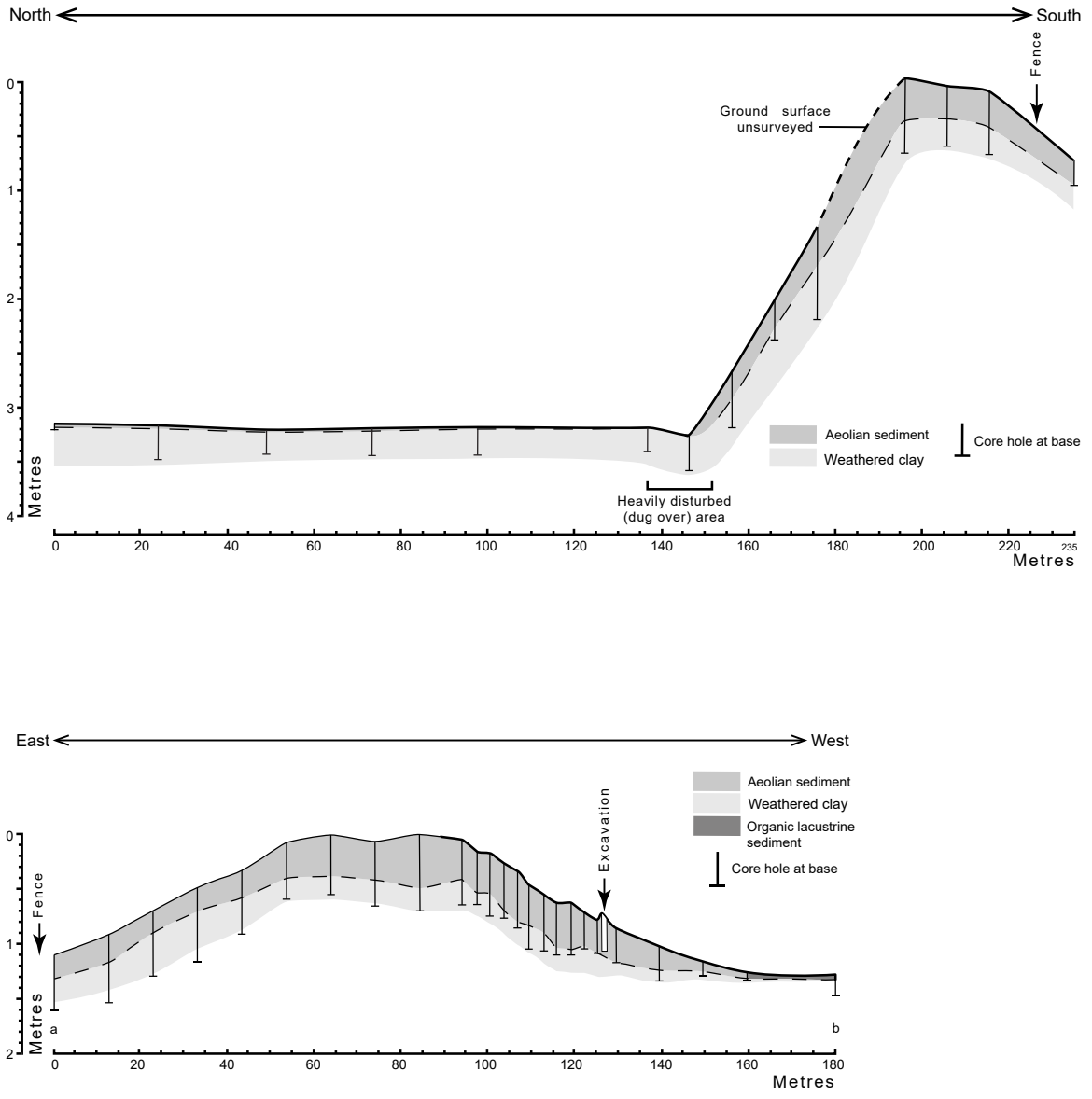


Figure 5.11 *Detailed topographic profiles across Barleyfields Lagoon showing the relative location of the main sedimentary units (the vertical distance is exaggerated). The top profile is a north- south profile which runs from the RHS south (left) across a low ridge crest with archaeological material (excavated in 2016) and across the lagoon floor to a central point (RHS). The lower profile is an east-west profile which runs from the LHS west (right) across the lunette main crest and down across lagoon floor to the same central point (LHS) as the lagoon floor central point in the upper profile. The profiles are based on project coring (auger holes shown) undertaken in the 2013 fieldwork. Location of profiles shown in Figure 7.3. (Drawn by A. McConnell and K. Newman).*

Dating

OSL dates obtained from samples taken from the sediments revealed in Pits 1 and 2 are shown in Table 5.4. Particle size analyses are presented in Table 5.5. These analyses indicate that sediments are all of Pleistocene age. Further OSL dates obtained from shallower pits excavated as part of the archaeological component of the lagoon studies reported in this volume (see Chapter 4) are all younger than, but stratigraphically consistent with, the dates returned from our Pits 1 and 2. Three OSL dates obtained from archaeological pit E1 indicate ages of 6,340 ± 560 years at 31 cm depth to 8,750 ± 630 years at 42 cm depth. Six OSL ages obtained from archaeological pit E2 ranged from 3,140 ± 330 years at 22 cm depth to 12,400 ± 1220 years at 51 cm depth. An AMS radiocarbon result of 2,269 ± 20 cal. years BP obtained from 11-16 cm depth at the base of an artefact layer was also broadly consistent with the pattern of significantly younger sediment forming the upper few centimetres of the lunette (Figure 5.12).

TABLE 5.4 OSL DATES FROM THE PITS A AND B EXCAVATED AT BARLEYFIELDS LAGOON.

Field ID	Lab ID	Depth (cm)	OSL age (ka)
BF Pit 1			
KK BFL 01	BA-P1-32	32 cm	10.58+/-0.8
KK BFL 04	BA-P1-70	70 cm	47.8 +/- 2.7
BF Pit 2			
KK BFL 02	BA-P2-15	15 cm	14.7+/-1.4
KK BFL 03	BA-P2-57	57 cm	27.2+/-2.4

TABLE 5.5 SHOWS THE GRAIN SIZE OF THE BARLEY FIELD LUNETTE SEDIMENT (BA-P1)WITH DEPTH ASSOCIATED WITH THE SAMPLES THAT GAVE THE OSL AGES.

Depth	OSL age (Pit BA P1, Figure 4.1a)	Volume weighted mean	Profile
0-17 cm		286 microns	bimodal, dominant medium size sand, secondary silt/dust peak, long silt tail
17-50 cm		432 microns	bimodal, dominant coarse sand, subdued silt peak with a long sub-silt tail
	10.5+/- 0.8ka BP at 32 cm (BA-P1-32)		
50-91 cm	47.8+/-2.7 ka BP at 70 cm (BA-P1-70)	510 microns	bimodal, dominant coarse sand peak, subdued silt peak with long sub silt tail
130-140 cm			224 microns bimodal, equal silt and coarse sand peaks, with sub-silt tail
150 cm		283 microns	bimodal, coarse sand dominant, but large silt peak
190-200 cm		166 microns	bimodal, dominant extreme silt peak, smaller coarse sand peak.

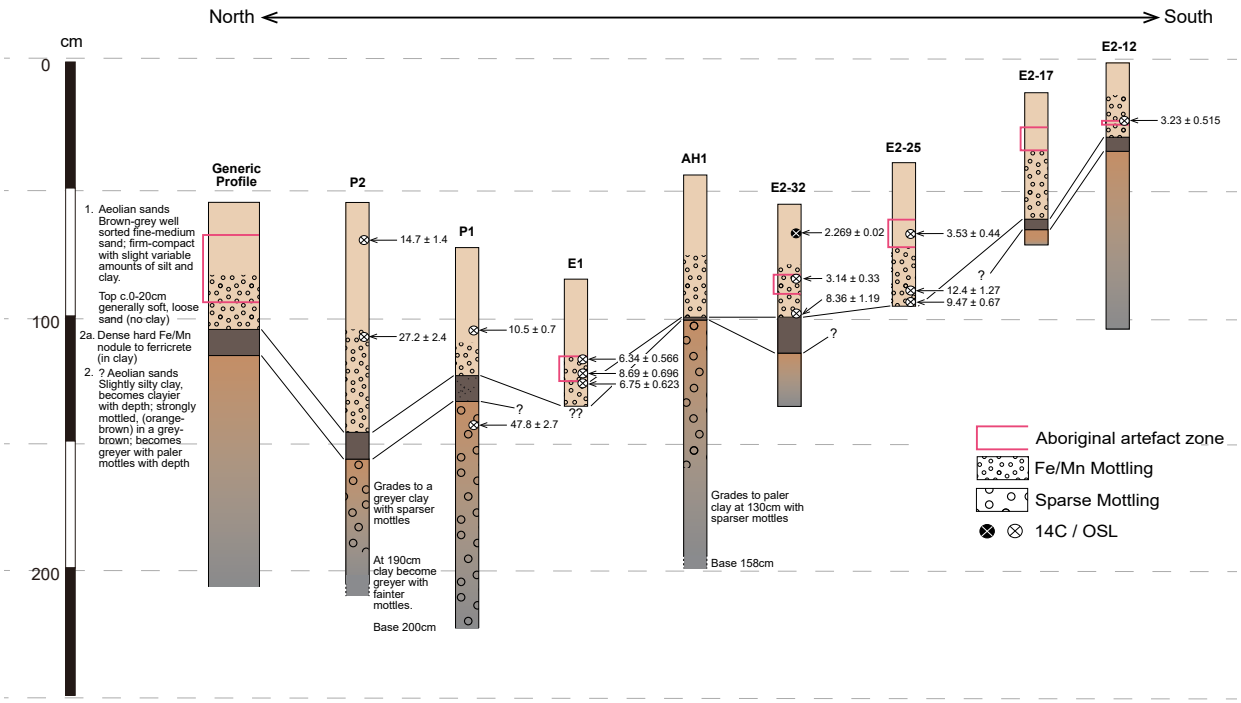


Figure 5.12 *Barleyfields Lagoon stratigraphy details. Columns P2, P1 and E1 are on lagoon facing west face of the main lunette, and the other columns are on the lagoon facing north face of the southern low ridge (locations are shown in Figure 7.3). The 'generic profile' depicts the main sedimentary units and their key characteristics. The column stratigraphy is derived from the stratigraphies of a selection of 2013 auger profiles and 2016 excavation squares. The relative height of the columns is accurate, and the vertical distances are accurate but exaggerated. (Drawn by A. McConnell and K. Newman).*

Dune evolution

The basal clayey unit has probably resulted from the accumulation of weathering products of rocks occurring in the Barley Field Lagoon catchment, with limited and possibly only latest-stage admixture of any sand. A relatively stable land surface would seem to be implied. The older OSL dates imply that the period over which this unit accumulated included part of MIS 3 and that it may have extended into the earliest part of MIS 2.

The loosely textured sand that comprises the upper part of the Barley Field lunette is generally less than 1 m thick and is of Holocene to late Pleistocene age. Its accumulation is likely to have required destabilisation of nearby land surfaces and drying of the lagoon itself, sufficient to allow deflation to occur. Once again, the topographic position of the Barley Field lunette implies its deposition by winds that came predominantly from the westerly quarter. The earliest of the Holocene dates obtained suggest this stability persisted for some time, or that instability recurred. However, scattered Aboriginal artefacts in the upper few centimetres of the sand imply some more recent ground surface instability that seems likely to have been anthropogenic. To this likely Aboriginal impact should be added some inevitable disturbance likely to have been caused when the site was used as a TSR for grazing.

The single AMS date from 11-16 cm depth suggests a sediment accumulation rate since that time of around 0.06 mm/yr. To judge from debris brought to the surface on the roots of wind-thrown trees, trees now growing on the lunette sands are only shallow-rooted, with these roots expanding laterally around the sand-clay interface. Nonetheless, they typically extend at least a short distance into the

underlying clay such that sometimes-large slabs of this material can be brought to the surface or the sediments otherwise disturbed when wind-fall occurs. Presumably a similar process has been occurring throughout much of the Holocene, potentially further complicating the stratigraphic record that might be suggested by findings from isolated pits and cores. The transition from fine silt and clays suggestive of lake bottom sediments to the coarser sediments of the lunette indicates that lunette formation began 25 cm below the last OSL age of ~ 47,800 +/-2700 years ago. If the sediment accumulation rate to the base of the lunette from this last date is approximately the same as that between the lowest two ages, this would push the age of initiation of the lunette to as much as 36,000 years earlier! This a very tenuous calculation, given the uncertainties involved based on too little data, but it certainly suggests a considerable age since lunette initiation, maybe sometime before 70,000 years ago.

Racecourse Lagoon

Description

Racecourse Lagoon has been etched out of a granite ridge and has granite basement rock projecting as small islands in its basin, with a small remnant of basalt on the western watershed of its catchment (See Figure 4.1b). It is about 25 ha in area and its surface catchment extends over only about 100 ha (or 1 km^2), being almost entirely restricted to the slopes around the lagoon, the western boundary forming part of the Great Divide. However, a hydrological connection to Dangars Lagoon is illustrated after flooding rains terminate lengthy droughts, when the lagoons fill up consecutively, with the slightly lower Dangars Lagoon filling first. Only after Dangars Lagoon fills does Racecourse Lagoon also fill, and often to a great depth because the water cannot escape through the impermeable rocky ridges that make up the other three sides of the basin. This subsurface hydrological flow appears to be two way, with water draining from Racecourse to Dangars through the base of the lunette on its eastern side as revealed by drilling (Haworth 2006), again demonstrating a co-dependence on the fluctuations of a common water table.

Sand mass morphologies, volumes and composition

The large lunette making up the entire eastern boundary of Racecourse Lagoon. One km long, 300 metres wide, and 10 metres high. The floor of the lagoon and base of the lunette are both around 1023 metres asl. The sedimentary nature of the Racecourse lunette is disguised by extensive vegetation, large trees and houses. It might easily be judged a structural ridge separating Racecourse Lagoon basin from Dangars Lagoon to the east, had it not previously been cored to its base to reveal that it consisted of semi consolidated clays and sand (Haworth 2006). The lunette from its crest to its base measured 10 metres. Granite bedrock was encountered at the level of the adjacent lagoon floor and less than half a metre above the level of the floor of nearby Dangars Lagoon. A water rich ferricrete nodule stratum was encountered at the very base of the Racecourse lunette, consistent with a groundwater connection between the Racecourse and Dangars Lagoon basins.

A pit was excavated to 60 cm depth at a site about 50 m from the lagoon edge and 100 m from the lunette crest. The upper 40 cm comprised grey brown (10YR6/3) well-sorted fine-medium sand, with very minor silt and clay. This was slightly loamy and humus rich only in the upper 1 cm tending to a more brownish colour towards the base. Beneath this unit lay very dense silty clay with orange mottling in its uppermost part.

Dating

The only OSL date obtained from this site came from a sample obtained at only 35 cm depth near the base of the loosely-textured sand. It gave an OSL age of 12,900 ± 1200 years ago. Even allowing for the

likelihood that the surface has been eroded, on this windward-facing sometimes-shoreline, this date suggests that the majority of this massive dune mass is likely to considerably predate the LGM.

Dune evolution

The exceptional area and volume of the Racecourse Lagoon lunette is partly a result of the erosion of the extensive granitic rocks in the lagoon and its catchment, but given the small size of the local catchment there is also likely to have been a major contribution by reworking of material derived from elsewhere.

Once again, the position of the dune, on the eastern side of Racecourse Lagoon, coupled with the absence of any similar sand accumulation on any other aspect, implies a persistence of predominantly westerly winds during dune formation. The single date obtained again shows that the loosely textured sand that forms the uppermost part of the lunette dates back into the late Pleistocene. As at Barley Field Lagoon, this sand overlies dense, deeply weathered clay that is entirely dissimilar to the surface unit and which appears to have perched moisture, favouring the build-up of ferruginous material at the base of the overlying sand. The heavily weathered condition of the clay unit suggests that it is of considerably greater age than the overlying sand. Given the massive thickness of lunette material at Racecourse Lagoon, it seems likely that the foundations of its lunette are relatively ancient.

Dangars Lagoon

Description

Dangars Lagoon is located 5 km southeast of Uralla. It lies on a flat swampy plain near the crest of the Great Divide (See Figure 4.1a). It is presently 50 hectares in area with a catchment of 9 km^2, the geology of which is diverse, including granite, Tertiary basalt and Palaeozoic acid volcanics. Deep alluvial flats conceal much of the bedrock. It lies one km to the east of Racecourse Lagoon, at a slightly lower (< 1 m) altitude of 1022 metres asl, and is separated from it by the extensive 10 metre high Racecourse Lagoon lunette. As indicated earlier, previous research has demonstrated the existence of a groundwater connection between Racecourse and Dangars lagoons *via* a shared aquifer that extends underneath the intervening Racecourse lunette (Haworth, 2006).

Dangars Lagoon was substantially altered by 19th Century gold diggers when its level was temporarily raised in an effort to transfer water across the low wind-gap in the Great Divide into the west-flowing Rocky/Gwydir River where the main gold workings were located (Bell *et al.* 2008: 481). Despite this and other damage, a substantial amount of its original lunette has fortuitously remained intact, adjacent to the north eastern corner of the lagoon, on both private property and a public road reserve.

Sand mass morphologies, volumes and composition

The Dangars lunette extended for approximately 1000 metres along the eastern shore of the lagoon. In view of the damage previously caused to much of it, our investigation was limited to a short area near its northern end. Pit A (DA-PA), located near the crest of the dune was excavated and then augured to 170 cm depth. This revealed very fine sand to a depth of 70 cm, then fine to medium sand, and finally silt at 170 cm. Pit B (DA-PB) was excavated about 5 m closer to the lagoon edge in a more disturbed area at an altitude judged to be approximately coincident with the base of pit Pit A. The base of this pit was also cored. It revealed loose fine brown sand to 15 cm depth, and an increasing yellow-orange colouration from 150-120 cm with soft nodules beginning to occur. Clayey sediment then became progressively darker with orange-brown mottles to the base of the pit at 177 cm depth.

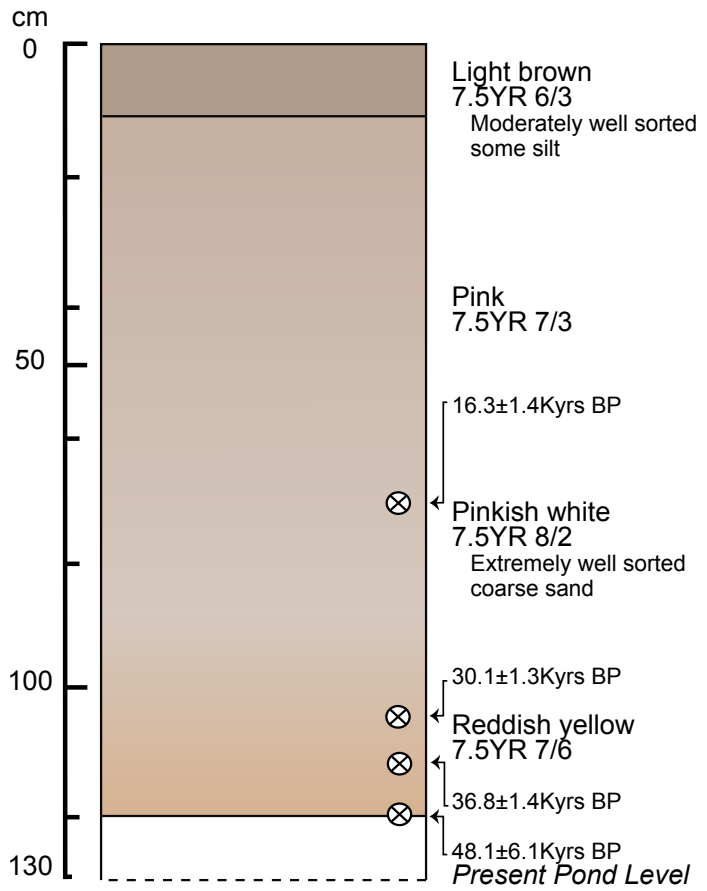


Figure 5.13 *The generalised column profile of Dangars Lagoon depicting the main sedimentary units and their key characteristics (Drawn by K. Newman)*

Coring down the lagoon-proximal flank of the lunette 50 metres further south revealed the loose upper sandy unit to consistently overlie clayey sediment similar to that encountered in Pit B. Iron-rich nodules occur around the interface between the two (Figure 5.13). As at Barley Field Lagoon, coring into the lagoon floor revealed no sand between the few centimetres of organic-rich, dark lagoonal sediment at the surface, and the nodules heralding the upper surface of the less readily permeable clay.

In Pit A median particle size is generally in the range of 570-660 microns but is only about 320 microns at 50 cm depth. Median particle size in Pit B ranges from 750 microns at 2 cm depth, 680 microns at 10 cm, 400-780 thereafter until the pit base at reaching 836 microns at 105 cm.

Dating

A sediment sample from 70 cm depth in Pit A yielded an OSL age of 16,300 ± 1400years ago. A sample from 105 cm depth in Pit B gave an age of 30,100 ± 1,500 years ago while another from 120 cm depth dated to 48,100 ± 6,100 years ago. These ages imply that these horizons of the dune accumulated during MIS 3 and MIS 2. In addition to these ages our archaeological colleagues obtained three further dates from their shallower pits excavated about 100 m further south from Pits A and B. Sand from 42 cm depth in archaeological pit E1 gave an age of 6,810 ± 600 years ago and another sample from 43 cm depth was dated to 7,700 ± 900 years ago. Sand from 38 cm depth in archaeological pit E1 gave a date of only 1,880 ± 200 years ago. These latter dates indicate that sand continued to accrete, or surface disturbance occurred, during the Holocene (Figure 5.14).

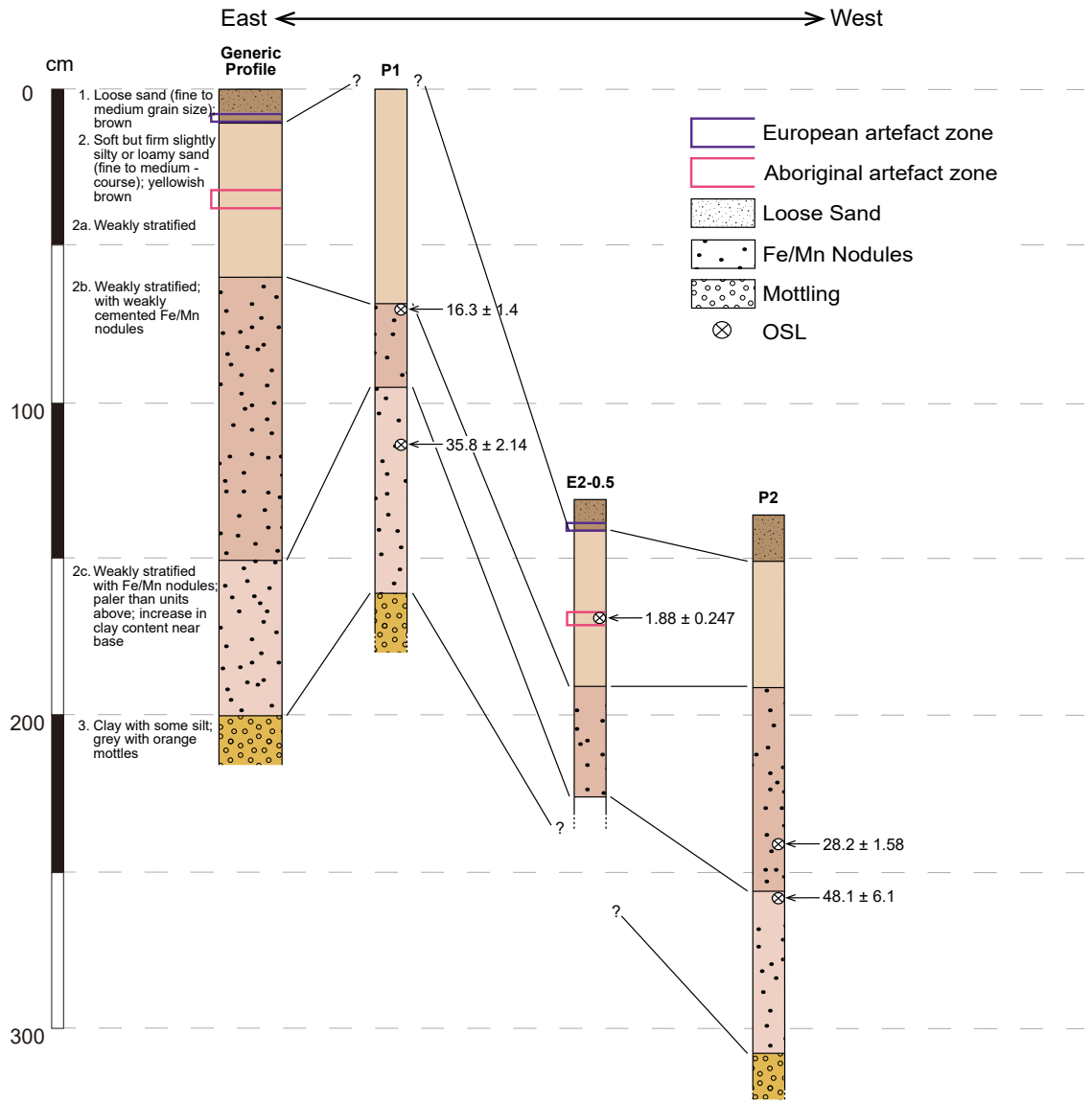


Figure 5.14 *Detailed Dangars Lagoon lunette stratigraphy from the crest (P1) west towards the lagoon.. The column stratigraphy is derived from the stratigraphies of a selection of 2016 auger profiles (P1 and P2) and excavation squares (E2-0.5) (locations are shown in Figure 7.1). The relative height of the columns is accurate, and the vertical distances are accurate but exaggerated. (Drawn by Anne McConnell and Kim Newman).*

Dune evolution

The Dangars lunette has formed exactly parallel with the Racecourse lunette. It is parallel in turn with what appears to be a remnant lunette on the far east of the depression in which both occur. Their form, orientation and juxtaposition suggest that they were formed by the same set of processes and under the same conditions. This partly fits the model (Lees and Cook, 1991) of lake-lunette water bodies shoaling from their lee (eastern) perimeter as water yield declines under a progressively drying climate, in this case giving three residual lake lunette systems (now reduced to two). However, the most westerly lunette, Racecourse, seems to be much older than Dangars lunette, so there is probably more than one cycle of lake/lunette evolution involved. The furthest east lunette remnant has been isolated by recent (that is, historical) headward erosion working up from the Gap, a geologically ancient wind gap in the

eastern bed-rock ridge that borders the old basin. Hence, several palimpsests of ancient landscapes have been imposed one on the other across the basin over an indeterminate time period. One age that we have determined is that of the approximate formation of the central lunette at Dangars Lagoon: close to its base it gives an OSL age of 48,100 ± 6,100 years ago.

The relatively recent dates obtained from the archaeological excavations imply the probability that, as at Barley Fields Lagoon, there was significant instability of the sand surface subsequent to climatic amelioration at the conclusion of the LGM. A date of only 1,880 ± 200 years ago from 38 cm depth raises the possibility that gold miners may not have been the first humans to have disturbed the Dangars Lagoon lunette.

Part D. Synthesis: Character, origin and likely age of the sand masses

Varying ages of lagoon and lunette formation on the Tableland

The lunettes around Guyra in the north have little in common with the lunettes further south around Uralla. There is also internal variation within the Guyra systems. One outstanding feature shown by the ages presented here is that the lunettes and other dunes associated with the lagoons of the tableland are not the product of one climatic period, but range across much of the late Quaternary, with the associated lagoon inception potentially being ancient.

The sand agglomeration at the north of Lake Llangothlin is certainly much older than the OSL age range of 61,000—79,000 years ago, given the depth of the sand beneath. Significantly, it is in a location where it is difficult for its material to be reworked *in situ*, however much it must have been reworked in the lake previously to produce its largely well-sorted attribute. This may be a significant indicator of it potentially offering a record of past environmental proxies. This large dune, enmeshed in the sand trap of northern shore of the Llangothlin Lake, probably contains useful evidence from the very extensive period over which the lakes have been functioning as dune-creating bodies and all that implies about lake-full conditions and functioning wetland biomes. The north Llangothlin sand mass suggests that the lake-full conditions needed to establish these dunes were present for much of the late Quaternary at least.

The OSL ages obtained from the greatest depths at Lake Llangothlin, 72,600 ± 7,300 and 60,500 ± 6,500 years ago, correspond to MIS 4 (75,000 to 60,000 years BP), which was a period of fluctuating lake-full and dune-building activity further inland in SE Australia (Cohen *et al.* 2012; Magee *et al.* 2004). However, Hesse *et al.* (2004) note that MIS 4 was one of the few times in the last 100,000 years when the Sandy Gum palaeo-channel in the Murrumbidgee River did not form dunes. This suggests that something anomalous was occurring at this time, and it may also have applied to the northern tablelands. Kershaw (2007) and Johnson *et al.* (2016) both point to anomalies in pollen counts, especially sudden declines in *Sporormiella,* whose presence is an indicator of megafauna abundance*,* in the environmentally similar site of Caledonia Fen around 70,000 years BP.

The sand deposited above and below the older date in the core from the north Llangothlin dune (which with its error bars may overlap into MIS 3) is very coarse, strongly suggestive of deposition having been influenced by internal lake hydrology (waves, currents) under lake-full conditions. The *c.* 60,500 year age, however, is from directly above material of completely different size and structure, and with a large dust component, suggestive of widely fluctuating conditions. Such a situation may be indicative of aeolian dust deposition of material either from the desiccated lake floor or from further afield (McTainsh 1989). There was a higher dust flux to the Tasman Sea during MIS4, and suggestions of greater glacial

and periglacial activity in south east Australia at this time, but the evidence for conditions during this period is too sparse and contradictory to confidently reconstruct conditions (Hesse *et al.* 2004).

Net deposition at the northern end of Big Llangothlin lagoon of almost half a metre (47 cm) of sand over 12 ka (4 cm per millennium) indicates low to moderate activity, whether by wind or water (Table 5.3). Nevertheless, this is twice the rate of the ~2 cm per millennium suggested for the next 27,500 years. Some kind of marked environmental perturbation thus appears to have occurred between ~60,000 and 70,000 years ago, and a less marked disturbance later, shortly before ~33,000 years ago. This contrasts with an overall core persistence of coarse-grained sand, the consequence presumably of largely stable lake-full conditions. It is striking that there is a uniformly large grain size (coarse sand) in the well-sampled profile above (that is, younger than) the age of ~30,000 years, which includes the Last Glacial Maximum around 20,000 ago. This is consistent with the findings of Woodward *et al.* (2014) from nearby Little Llangothlin Lagoon that indicated moist and possibly full lake conditions from 20,000 to 15,000 cal. years BP and possible lunette building through the LGM (Shulmeister *et al.* 2016).

Nonetheless, it is curious that the lake system should have survived the LGM with little effect and yet show marked environmental disturbance between 60,000 and 70,000 years ago with no extreme climatic stress apparent for the period (Cohen *et al.* 2011). The overall conclusion from the particle sizes and chronology of core 1a (BI-NPB) at North Llangothlin is of relatively stable sedimentation of coarse sand from beach deposits over most of the period, including the LGM, except for an anomalous period of fine dust deposition sometime between 60,000 and 70,000 years ago, with a smaller but still marked period of higher dust deposition shortly before 33,000 years ago. Lake Llangothlin and at least some of its source bordering dunes have probably been present for much of the late Quaternary.

The earliest oldest date we obtained from Barley Field Lagoon is significantly younger than our earliest date from Lake Llangothlin, although we acknowledge that the greater depth from which we were able to retrieve date-able sediment at the northern end of Big Llangothlin (BI-NPB) may have played some part in this apparent discrepancy. Our earliest Barley Field date is broadly similar to the age of the sediments at the base of Pit DLB, at Dangars Lagoon 5 km to the south, but half a metre of basal dune below the Barley Field date could mean that it is considerably older than the Dangars dune. The Dangars lunette had little dunal material below it to the present lake level, and appeared to have a more rapid sedimentation rate than Barley Field, so *c.*48,000 years ago may be reasonably close to its age of initiation, whereas Barley Field is probably considerably older than its oldest age of *c.* 48,000 years. Although the two lunettes are only a few kilometres apart they are in geomorphically separate basins, so perhaps this is not so surprising.

However, there is apparently a much greater age discrepancy between Dangars and Racecourse lunettes, which are in the same geomorphic basin. Racecourse lunette has an ill-sorted mixture of sand and clay, similar to Barley Field but quite dissimilar to the predominantly well-sorted quartz sand of Dangars. Its overall lunette size is much larger than the other two. This may have to do with the rock type rather than the size of their respective catchments and lagoons. Dangars Lagoon is presently 50 hectares in area with a catchment of 9 km^2, or 900 ha, giving a ratio of 1 to 18 of lake-floor to catchment area. Racecourse Lagoon is 25 ha in area, with a catchment of only 100 ha, and but with a lunette that is much larger. Racecourse has, rarely for a New England Lagoon, a catchment almost entirely made up of granite, with granite islands in the lake floor, and thus a plentiful available supply of quartz sand, but Dangars Lagoon catchment though much more diverse in its lithology still has a high proportion of granite, as well as both Palaeozoic and Tertiary volcanics. One curious anomaly is that the Dangars lunette with a variety of rock types in its catchment is made up almost entirely of quartz sand as far as we could see from the surviving section, whereas the Racecourse lunette is a mixture of clay and sand, despite its catchment being entirely on granite.

Windblown sand from further afield may have nourished the much larger Racecourse lunette, as there are isolated sand dunes along the top of the Great Divide south of Uralla which could only have come from long distance wind transport, and the Racecourse Lagoon basin may have formed an increasingly effective trap for aeolian sediment as its lunette grew. However, the much greater size of the Racecourse lunette may also be a result of much greater age. Even though the catchments and lithologies of all three lunettes are different in size and lithology, they all apparently formed before 48,000 years ago, though Dangars appears to be relatively younger. This suggests that similar forces acting on dissimilar material triggered lunette growth, but at different times. Both Barley Field and Dangars have what appear to be stranded lunettes further to their east, suggesting that in both cases there may have been a larger water body present prior to a later phase of lunette construction. If a rough accumulation rate was inferred from the single date obtained from the slope of Racecourse Lagoon's lunette and it were even approximately typical of the full ten metre depth of the lunette at its crest, it would suggest a very early age for inception of that dune and therefore for any palaeo-lake that might have co-existed with it at the commencement of lunette formation.

Active deposition of lunette material during the LGM is evident from all the sites we dated. The Little Llangothlin lunette is certainly a product of the LGM and later (Ellerton *et al.* 2017), and the neighbouring Llangothlin Lake lunette seems to have formed at broadly the same time, though the sediment accumulation rate inferred from the last OSL age of around 15,000 years ago would suggest a formation date closer to 30,000 than 20,000 years ago. A more than slightly hazardous estimate of mean sediment accumulation rates, based on the sparse dating from Dangars pits DLA and DLB, might suggest that the sediments there accumulated at a rate of about 0.04 mm/year over the last 30 millennia (MIS 1 & 2) compared to about 0.01 mm/year over the preceding 18 millennia (MIS 3).

Hence, all the lagoons investigated show evidence that suggests that there were earlier cycles of lagoon-lunette formation taking place as part of larger palaeolakes earlier in the Pleistocene and perhaps Tertiary, certainly extending into early MIS 3 (80,000 to 40,000 years ago). Coincidentally perhaps, this covers the period of human encroachment onto Australia (Balter 2011; Roberts *et al.*1994). However, perhaps the reason little evidence for early human occupation has been found on the tablelands is that it has been sought in the wrong place, on existing lunettes, rather than the dune remnants and possible lag deposits buried in the back-swamps of the current lagoons.

Upland environmental changes after 74,000 years BP

The most important environmental perturbation found in the upland lunettes is the dust deposit in the northern Llangothlin dune, dated to between 65,300 and 79,900 years ago. Given its location in the upper part of the dune this material is unlikely to be flood-deposited silt, and there was no sign of pedogenesis around the unit to suggest that it was colloidal. There is room for speculation as to what could have caused such a deposit. Both before and after this anomalous unit, there is an otherwise fairly uniform profile of deposition. Was this dust unit a product of a local lake bed desiccation, or a more far off wind-driven event from perhaps an inland lake system collapse? Was it likely to be a response to regional or continental climatic fluctuation or to some more autochthonous cause?

It is worth considering what major events occurred during the deca-millennium and a half within which the north Llangothlin dust anomaly accumulated in otherwise consistently large grain sandy sediments. Firstly, the onset of glacial marine isotope stage 4 (MIS4) was accompanied by the Toba eruption around 74,000 years ago in nearby Indonesia. Northern NSW is on the edge of the same monsoon system that is centred on Indonesia. Secondly, recent research suggests that at least some humans reached Australia around 65,000 years ago (Clarkson *et al.* 2015). Thirdly, and possibly related to the last, the megafauna were on their march to extinction. The postulated age for the megafauna extinction is somewhat later,

around 46,000 years ago (Roberts *et al.* 2001). However, Kershaw *et al.* (2007) noted an earlier decline around 65,000 years ago in the pollen spore used as a marker for the presence of giant herbivores in a similar high altitude site to ours in the Southern Alps in Victoria.

Possible climatic drivers

Unfortunately, the climatic record for early MIS4 is not well defined and seems to vary by region. Petit *et al.* (1999) derived Pleistocene dust fluxes for the Southern Hemisphere from the Vostok ice core that demonstrated much higher fallout during cold glacial periods than during interglacials, and somewhat higher dust fallout in the last long glaciation series (70-55,000 and 35-15,000 years BP) than previous extended glacial periods of the last 420,000 years. Martin (2006) describes a generalised trend of the replacement of forest by open heath, shrublands and grasslands following the last interglacial (*c.* 125,000 years ago) in south-east Australia, interrupted by brief expansions of eucalyptus between 40,000 and 25,000 years ago. This was followed by expansion of open heath and grasslands as the final glacial stage (MIS 2) developed after 25,000 years ago. How this was expressed in the high altitude of the Tablelands, on the sub-humid and semi-arid fringe, is difficult to accurately surmise, as there are no present day analogues (Dodson and Wright 1989). More locally, dusty conditions have been noted for the general period around 75,000 ago, with evidence for dust deposition at this time on the coast of northern New South Wales (Williams *et al.* 2006), and in the general region in the North and South Islands of New Zealand (Shulmeister *et al.* 2004) as well as the Tasman Sea (Hesse 1994). However, Kershaw *et al.* (2003) noted a decline in the monsoon system over Australia only after 48,000 years BP. Even after MIS 5, summer monsoon rainfall was more effective than today in the interior, and it did not collapse until after 45,000 years BP.

Although the climatic evidence appears to be ambiguous (Petherick *et al.* 2008; Petit *et al.* 1999) research to date has not been sufficient, and there does not appear to be any outstanding climatic reason for the environmental disturbance evident in the Guyra area prior to *c.* 65,000 years ago in the Guyra region, nor for the commencement of lunette building in the Uralla region sometime before 48,000 years ago.

Hesse and McTainsh (2003) described similar accumulations of sand on the inland side of the Blue Mountains at similar altitudes, and noted that unrealistically drier conditions would have to be invoked to account for such dunes by wind transport. Shulmeister *et al.* (2016) have determined that the New England Tableland was not especially arid around even the LGM, with evidence even of some rain forest taxa at this period in the Pleistocene vegetation record at Little Llangothlin Lagoon.

It is difficult to extrapolate back from the present interglacial climate to the very different conditions of the Pleistocene, for which there are few or no modern proxies (Dodson and Wright 1989). The ecotone of the more arid or sub-humid western side of the eastern highlands would always have been in some state of savannah transition between woodland and grassland, with much lower carbon dioxide levels probably inhibiting woody growth even when there was sufficient moisture (Bond and Midgely 2012). High altitude and lower temperatures would have exacerbated any effect on vegetation change, especially given widespread evidence in the New England region for Pleistocene periglacial activity above 1000 m (Slee and Shulmeister, 2015).

Possible non-climatic disruptors: megafauna and humans

Leaving aside climate, the major ecological disruption in the period between 40,000 and 70,000 years ago was probably the demise of the herbivorous megafauna (Johnson 2006; 2009), a critical change that was capable of setting off a cascade of continent-wide environmental effects, independent of but intermeshed with the cyclical orbital changes that trigger glacial, interglacial and stadial stages. The

New England region has a rich record of megafauna fossil sites (Gorecki *et al.* 1984; Horton and Connah 1981) dominated by *Diprotodon*, the largest extinct herbivore. A terminal date of 46,000 years BP (Roberts *et al.* 2001) has been given for the extinction of the megafauna, but this is contested (Field *et al.* 2008). Size-selective extinction of the largest mammals would have tended to remove *Diprotodon* first, so the largest environmental impact may have come earliest in the process of ecosystem homogenisation during the Pleistocene (Smith *et al.* 2018). By the last interglacial (~125 ka), significant guilds of dryland megafauna were restricted to the southern part of the Lake Eyre basin, such as around Coopers Creek (Smith 2013). This regional fauna (Katapiri formation) collapsed around 65 ka and contracted to the margins of the desert (for example, the New England Tableland) where some megafauna species persisted until 50-45 ka (Smith 2013).

The MIS 3 and MIS 4 boundary is between 65,000 and 45,000 years ago. This is around the time that the Uralla lunettes (at Barley Field and Dangars Lagoons) appear to have been initiated. Perhaps their formation was triggered by altered fire regimes that may have followed the demise of the local megafauna: the possible acceleration of wild fire following the loss of the vegetation control performed by giant grazers such as the *Diprotodon* (Johnson 2009). Miller *et al.* (2005) found evidence for a major reorganisation of vegetation coincident with megafauna extinction in the southern mainland of Australia, with a habitat change after 45,000 years ago from a mosaic of trees, shrubs and grassland to a more uniform and fire prone shrub steppe (Kershaw *et al.* 2002). Johnson (2006) also, on reviewing long pollen records between 45,000 and 50,000 years ago, noted some evidence for post-megafauna expansion of shrubland in mainland Australia. Even though the pollen evidence is dispersed over a long period, both concurred that climate alone could not account for these changes.

The formation of the Uralla lunettes commenced, and the disturbed stratum in north Llangothlin coincided with, what may have been an ecologically disruptive period, possibly associated with changed fire regimes as plant communities simplified in various stages of relaxation from megafauna-conditioned to megafauna-absent states (Smith *et al.* 2018). This would have been especially critical on the inland side of the Eastern Highlands, where our sites are located, where over the glacial/interglacial cycles the boundary of the humid/arid interface would have fluctuated between periods of vegetation growth and cyclic denudation. Within 30 km of the Guyra Lagoons is one of the most extensive sites of megafauna bone accumulation in Australia, including *Diprotodon* (Horton and Connor 1981), with another extensive site 150 km to the south at Lime Springs (Gorecki *et al.* 1984).

An attempt was made to re-examine and date the Horton and Connor (1981) megafauna site, but the area was closed to investigation by mining and other issues. However, by interviewing local small-scale miners and fossil collectors we were able to get a better idea of the sheer size of the area containing *Diprotodon* remains and their relation to nearby lagoons. Horton and Connor dug in the bed of Reddestone Creek itself, but the most extensive cache of megafauna bones is found in a parallel and slightly higher wetland called Hamels Gully. This is a low boggy u-shaped valley stretching from the presently dry basin of Reddestone Lagoon almost to the shores of Dunvegan and Clareveulx Lagoons. It contains a very extensive assemblage of megafauna bones for its full 5 km length, unfortunately much disturbed by fossil hunters and mining. What is exceptional about this wetland is that it has very little catchment behind it, so it is likely that the megafauna mortality occurred in or close to the gully, that is, there is little upper catchment from which they could have been transported and re-deposited. Horton and Connah (1989) also noted that most of their bones appear not to have been transported very far. An attempt to obtain an age of some sample *Diprotodon* teeth and bone was unsuccessful, as the collagen was either too degraded or was beyond the 40-50,000 year limit of effective AMS dating. However, the main point is that *Diprotodon* were roaming the area of interest in sufficiently large numbers to leave an abundance of bones in some of the local wetlands, and there is a possibility that they or the effects of their disappearance led to serious soil disruption such that it left its mark in the dune profiles.

Whether the arrival of people in Australia around 65,000 years BP (Clarkson *et al.* 2015) had anything to do with megafauna extinction is unknown, though it has been proposed by some (Miller *et al.* 2005). Whatever may be the case for other parts of Australia, we have found no evidence yet in our excavations for any human occupation of the Northern Tableland before the Holocene. Lack of evidence is not always evidence of lack, but when compared with the abundance of Pleistocene artefacts and human remains in such sites as the Lake Mungo lunettes in inland New South Wales (Bowler 1970; Fitzsimmons 2012), for instance, it is at least suggestive that these highlands were unattractive to humans in hunter-gatherer mode. The only hint of any early human presence is the artefact rich layer directly above the megafauna bone layer in Horton and Connah's (1981) undated Reddestone Creek site. In this layer was a small overlap of Aboriginal artefacts and megafaunal bones which the researchers interpreted as post-depositional *in situ* mixing. The accumulation rate of sediment is so modest in these swamps in low relief landscapes that it is often difficult to disentangle boundaries and establish clearly defined strata.

Biogeography of inland aquatic food resources

One striking feature of the recent catastrophic fish kill in the inland Darling River (Nature Bulletin January 20, 2019) was its demonstration to astonished onlookers the richness of the fish biota of inland waters, even after 200 years of rapacious exploitation and destruction of riverine habitat. How much more abundant must the western rivers have been in large and succulent fish in their pristine, pre-1788 condition! In contrast, while the upland lagoons represent isolated islands of biota with plentiful wild fowl and terrestrial grazers on the surrounding land, they are deficient in fish and bivalves, but for the migratory eel, one small 5 cm long gudgeon (*Hypseleotris* spp*)* and fingernail size clams (*Corbicula* spp), as opposed to the dinner plate size mussels (*Velesunio* spp) of the inland lakes and rivers. This is because the cold-water upland streams of Australia, that is those above 1000 m in the southeast, are regionally isolated from each other, and no complex cold water fish biome has been able to develop. During the colder parts of the glacial cycle, this depauperate cold water fish assemblage would probably trend well below its present 1000 metres altitude limit, restricting further the habitat range of apex species such as the large (over 20 kg for mature adults) Murray cod and perch (*Maccullochella peelii* and *Macquaria ambigua*) that make river fishing so rewarding in the lowlands.

That this probably had an effect on the numbers and health of Tableland Aborigines was first remarked upon by Oxley (1820) observing the poor physical condition of those people he first met on the tableland. The symptoms he described suggest iodine deficiency, see entry for September 7, 1818, in Oxley, 1820, and goitre was also noted in the Armidale area during the mid-20th century (Barbato 1976). Oxley compared tableland people to the good health and physique of the Aborigines he had passed on the lower inland rivers. The first government agent in New England, G.J. MacDonald (1840) also expressed surprise at the small population on the Tableland compared to both the inland rivers and the coast.

The one abundant fish resource on the highlands, concentrated especially around the larger lagoons, is the migratory long-finned eel (*Anguilla reinhardtii*), bringing welcome and nutritious trace elements from the distant ocean, and can be up to 1.7 m in length and over 20 kg. The main route of the eel migration from the Coral Sea to the eastern Australian uplands is the warm oceanic East Australian current. The possibility that this was disrupted at stages of the glacial cycle (Bostock *et al.* 2006) might also have constrained permanent human settlement of the tablelands. Also, although eels can travel at night or in wet weather over land from pond to pond, they are tightly constrained in the tablelands to the rivers, ponds and bogs on the east of the main divide, even though there is no physical barrier preventing them from entering the western river systems. How they know where not to go is a mystery, but extensive questioning of local fishers confirmed this boundary to their distribution. This means that west of the Great Divide, at high altitude, there was only one species of tiny gudgeon in the lagoons

and streams (exotic cold-water trout have now been introduced to all these streams), and only two species of crustacean (*Cherax destructor* and *Euastacus* spp) to support Indigenous fishers.

So we are left with a puzzle: the lagoons of the uplands could have (and later in the Holocene did) support what was probably a meagre population, but seemed not to most of the time, when there were better options to the east and west, especially the west. In cooler times of high snowfall on the tablelands the western rivers were swollen every year by snow melt, so what was lost from the high country enhanced the resources of the inland rivers (see also Williams *et al.* 2013, about location of LGM human refugia in this region).

Conclusions

OSL and AMS ages taken from shore-bordering dunes of six lake-lunette systems in the Northern Tablelands of New South Wales show that some of the dunes and associated wetlands were extant at the time of earliest human presence in Australia. However, in contrast to the abundant evidence for Pleistocene occupation of similar lake-lunette systems in the lowlands of the Murray-Darling river basin, little evidence for early human occupation has been so far found in these highland systems. An OSL age from the deepest dune sediment sample at Lake Llangothlin ranges from between 65,300 and 79,900 years BP, while the base of two lunettes bordering two lagoons 100 km to the south produced ages ranging greater than 48,000 years BP. Lunette formation therefore began at these sites long before the Last Glacial Maximum (LGM) around 20,000 years ago. However, one AMS age from Little Llangothlin lunette agreed with results from earlier work at this site, confirming that the present lunette formed at the nadir of the LGM. OSL results and assumed sedimentation rates from the lunette on the south-eastern shore of Lake Llangothlin also suggest a formation date near to or just before the LGM. It is noteworthy that there is little evidence at any of these sites for extreme sedimentary disturbance of the dunes during the LGM. However, large dust units in the oldest part of one sediment profile at Llangothlin Lagoon suggest some extreme conditions much earlier, before ~50,000 years ago and especially between 60,000 and 70,000 years ago.

It seems unlikely that a region that escaped extreme environmental disturbance in the LGM should be affected by the less harsh climate of this interstadial period, so the knock-on effect of non-climatic factors might be considered, such as the arrival of humans or the demise of the megafauna. While the highland region appears to have been open shrub-land steppe or savannah often close to the high altitude tree line over most of the glacial cycle, multiple lines of evidence, especially the probably intermittent process of lunette and dune building by wave action, suggest that the overall water balance produced either regular lake-full conditions or in-between swamp lands, adequate to support humans if any were present. Another possible non-climatic explanation, the demise of the megafauna, may have affected the stability of vegetation and soils at these liminal upland sites. Wetland deposits adjacent to some of the large lagoons contain extensive skeletal remains of the giant herbivore Diprotodon. Teeth and bone sampled from these remains proved to be beyond the 40,000-50,000 year range of effective AMS radio carbon dating.

The overall impression is that dune building commenced at different times in different locations, suggesting that local processes and physical configurations were at least as important as any region-wide climatic forcing, with the cause of the major disruptive sedimentary event near the oldest age at Llangothlin Lagoon open to speculation.

It may be that evidence for Pleistocene human occupation will be found associated with the remnants of earlier lunette sites where developed sediment strata may have been inadvertently preserved out of phase with the present landscape. Any formerly sheltered occupation sites in the lee of lunettes

that provided shelter from cold winds are potentially prone to burial in the event of later down-wind migration of the sand mass. It is also possible that more enticing campsites may have been available within vegetated upwind margins of lagoons that were not subject to cold winds blasting across the open expanse of the lagoon surface, and hence did not require huddling in the shelter of a lunette with a potential nuisance caused by blowing sand. A better understanding of lagoon-lunette movement, deflation and re-formation over time might conceivably improve the potential for finding any archaeological sites older than those so far revealed.

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Chapter 6:
A Review of the Archaeological Record of Surface Sites, New England Bioregion

John Appleton and Wendy Beck

Introduction

The primary focus of this research was to find and interpret surface archaeological evidence for gatherings of Aboriginal people and the use of resources that would have been available in and around lagoons. As a comparison we also looked for sites away (over 400 m) from lagoons. We also aimed to summarise the stone artefact technology and the general nature and pattern of sites in the New England region. This should lead to a better understanding of the nature of Aboriginal settlement in New England. A map showing the sites referred to in this chapter is included below (Fig. 6.1).

Most of the places discussed in this chapter are stone artefact scatters. The New England Tableland Bioregion is dominated by basalt and granite and interspersed with exposures of the estuarine sediments of the Armidale Beds and the marine sediments of the Sandon Beds and the most available and at the same time preferred material for manufacturing small sharp tools was silcrete that frequently occurs at the contact zone between the basalt and the estuarine sedimentary rock of the Armidale Beds.

The archaeological record of surface sites in the New England Bioregion

Research 1974-1990

Several small or specialised Tablelands surveys were done in this period. With the enactment of the National Parks & Wildlife Act 1975 archaeologists throughout New South Wales began to record surface sites but predominantly, sites with cultural significance to Senior Men and Knowledge Holders, which for the most part are art sites, stone arrangements, carved trees and burials. An early map of New England archaeology, which includes open sites, suggested that, 'the highest areas of the Tablelands were sparsely peopled and perhaps only during the summer months...dense settlement on the western slopes and sparse settlement on the Tablelands', Connah, Davidson, Rowland (1977: 130). Very little attention was paid to surface stone artefact scatters or artefact technology with the exception of ground edge axes and axe grinding grooves. A sample of over 500 axes was examined petrologically and some of these axes were found to be traded 600 km to the west and found at Wilcannia, Bourke, Cobar, Inverell and the Liverpool Plains, but none had been found in sites to the east of the Tablelands (Binns and McBryde 1972, Connah, Davidson and Rowland 1977). Also, the relatively high frequency of bora rings (raised earthern circles) and stone arrangements in the New England is noted (Connah, Davidson and Rowland 1977: 133). Lagoons are not mentioned in any of this research, the resources which are the focus are kangaroos and grass seeds.

Following on from McBryde's (1974) early excavations in the 1960s, Bowdler's (1981) excavations at Church Gully in 1979, and Williams' (1980) excavations in shelters at Mount Yarrowyck stimulated new interest in questions on where, when and how Aboriginal people had lived on the Tablelands. Further stimulation came from Connah's recording of artefacts at Reddestone Creek and there became a greater

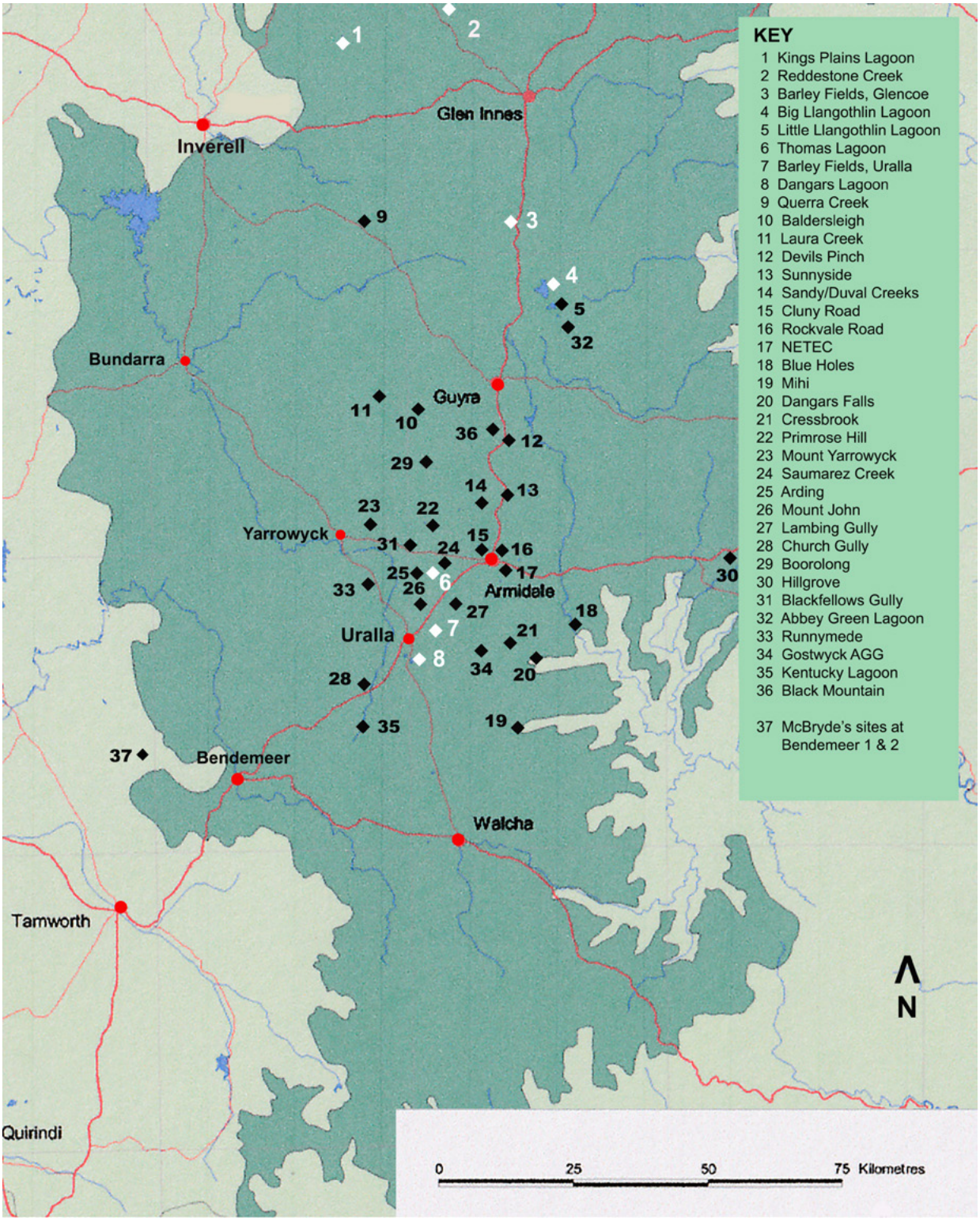


Figure 6.1 *Map showing the location of sites referred to in this chapter*

awareness of the surface archaeology on the Tablelands and its potential research possibilities (Horton and Connah 1981).

A speculative view of New England occupation was put forward by Bowdler (1981) as part of a wider Australian montane economic model, which did not feature lagoons as food sources, but whereby daisy yams (*Microseris scapigera*) were the low-key staple food, and net-caught kangaroos used for ceremonial food for large gatherings. She proposed that the zone above 1000m was not occupied but instead were used solely for ceremonies. Adapting Flood's models for the southeast NSW high country, she suggested that the largest base camps might be found at lower altitudes, with smaller summer camps in between. Bowdler also connects this hypothesis with stone artefacts, "I have argued that the Australian Small Tool Tradition appears to be associated with the first successful exploitation of the Highlands regions of eastern Australia" (Bowdler 1981: 110).

Archaeological attention started to be paid to lagoons in 1982. Davidson recorded artefacts at (Big) Llangothlin Lagoon at 1,300 m AHD, including small artefact scatters in plough zones together with six ground-edged axes and four basalt mullers, but he concluded that there was evidence of only moderate Aboriginal activity on the Tablelands (Davidson 1982). Davidson also investigated the sighting by others of artefacts at Little Llangothlin Lagoon (Davidson 1983). He reported that a hatchet re-sharpening flake was found on the lunette, and there were, '... scatters (of artefacts) at Big and Little Llangothlin Lagoons'. Some of these artefacts are illustrated in Davidson (1982).

Some years later Byrne undertook an overview of Aboriginal sites recorded in the northern NSW including the NEB) listed in the Sites Register (Byrne 1989). He also noted the large proportion of Tablelands sites associated with ceremony — a total of 61 out of 132 sites recorded (Byrne 1989:14). In generalising what types of occupation sites were identified he stated,

> ...major camps in favoured habitats where large numbers of people stayed for long periods to very minor camps used by only a few people perhaps for only a single night. In between these extremes are the thousands of sites used as home bases for a few days or weeks and returned to regularly as groups moved around their territory in response to seasonal changes in the availability of food and water" (Byrne 1989:10).

Godwin (1983) reported on archaeological surveys he undertook on the tablelands and, in the light of his finds of occupational debris, concluded that Bowder's suggestion that the area above 1,000 m AHD was used for ritual purposes only, needed to be reconsidered (Godwin 1983:42-43). Later, he undertook a larger study for his PhD thesis in which he examined the ethnohistory and archaeological sites to provide a basis for a study of settlement patterns and alliances in the Late Holocene in north-eastern NSW (Godwin 1990). For this study he surveyed 12.78 sq km in different contexts — woodlands, wetlands (including five lagoons) and river corridors between 900 and 1500 asl in the New England area and reported on over 900 artefacts from 45 sites (Godwin 1990: 353). The density of artefacts estimated by Godwin in these sites varied from the 7 to hundreds to thousands of artefacts/sq km. The numbers of artefacts at each site varied from 324 to 1 with a median of 15. His conclusion about the settlement patterns was that the Tablelands were occupied all year round, were not just used for ceremonial purposes, and that food and water resources were fairly evenly distributed within the zones whereas stone resources were more unevenly distributed He made note of the existing resource concentrations at lagoons– waterfowl, crayfish, eels and plant foods (Godwin 1991:172) and recorded small artefact scatters at five lagoon sites (Big Llangothlin, Dangars, Racecourse, Saumarez, Thomas).

Generally, he found that most sites were located within 500 m of water (Godwin 1990:361) and in areas close to rich or diverse resources, but there were both larger base camps and smaller special

purpose sites (Godwin 1990: 300). Sites' functions were interpreted from their size, location and artefact technology. Silcrete was the most common raw material and, despite relatively free access with differin Silcrete was the most common raw material and, despite relatively free access with differing distances to the source, was highly reduced (Godwin 1990: 377). Godwin interprets this as due to the prolonged use of cores, because the sources were not being revisited regularly. A very small number of formal tools were found (*c.* 3% of the total recorded). The focus of his theoretical work was the development of information processing systems and of different social networks between the eastern and western New England areas (Chapter 7, Godwin 1997).

In 1990 (and refined in 2015) Appleton developed a Predictive Model (see Table 6.1) for locating Aboriginal sites on the Tablelands and Western Slopes in his BA (Hons) thesis, (Appleton 1990a) based on resource distribution and behavioural models. This model lays out nine expectations for site locations.

Table 6.1 Appleton's model for predicting site location in New England

- Isolated artefacts may be present, but if they are, they are most likely to occur randomly in disturbed contexts and will only be found opportunistically.
- Low-density artefact scatters are unlikely to be visible generally but may be observed in overgrazed or stock-worn areas near water, or in saddles or on ridges or crests.
- It is unlikely there will be any new art sites, not already known.
- There is some potential for new quarries to be found particularly where there are silcrete exposures or previously unidentified metamorphosed rock exposures
- There will be no visible burials
- It is unlikely there will be any new Bora grounds that are not already known and recorded.
- There is a potential for stone arrangements to be found on flat surfaces anywhere in the high country
- Given that there is a surviving Anaiwan community there is some potential for new sites to be identified by Indigenous stakeholders as being sites of cultural significance
- High density artefact scatters are most likely to be found on relatively large areas of level ground in the close vicinity to reliable water source such as waterholes and lagoons
- One in two artefacts will be manufactured from silcrete
- That silcrete exposures most frequently occur between 1020 and 1040m AHD, so most artefact scatters are likely to occur below 1020 to 1040m AHD

From the summary above it is clear that until the late 1980s the NSW State Register for recorded sites carried a heavy bias towards art sites, bora rings; ceremonial and religious sites and that very few open artefact scatters and isolated artefacts were listed. Naturally such a bias can easily be interpreted to indicate that only special purpose sites exist. However, with an increase in commercial surveys for optical fibre cable routes, power-line corridors, bridge replacements and road re-alignments in the early 1990s archaeological consultants began to record numerous stone artefact scatters and isolated stone artefacts providing a much broader data base on which to base interpretation of the archaeological record; and both ceremonial and 'residential' use of the Northern Tablelands. In 1990 Godwin and Appleton produced the first settlement models for the Tablelands, which suggested that the region had been settled year-round in the recent past, due to the number of open artefact scatters found, and

their clustering on good soils or near the boundaries of a range of soil types, rather than just near stone sources or ceremonial sites.

1991-present

After 1990, numerous isolated artefacts and surface scatters were recorded as a result of investigations for development projects but there was no comprehensive overall interpretation for the region. First, it is important to recognise that isolated artefacts may be just the "tip of an iceberg", being the only artefact of a number of artefacts at that location that is visible above ground. In experiments conducted by others it was found that single artefacts in plough zones might be the only visible evidence of a number of artefacts that are concealed beneath the disturbed soils (Roper 1975, Ammerman 1985, Dunnell and Simek 1995, Frink 1984, Mallouf 1982, Yorston, Gaffney and Reynolds 1990. Yorston, Gaffney and Reynolds (1990) found that in many instances an isolated artefact on a ploughed surface might be all that is visible of at least eight subsurface artefacts, and could be as many as twenty. Extending that further, a surface site of ten artefacts in a plough zone could be overlying a subsurface assemblage of 80 to 200 artefacts. So, this problem must be taken into account when considering artefact numbers.

In 1991 Appleton began an archaeological consultancy company in which he was to complete over 650 commercial projects, and at least 40 projects were undertaken in and around the Armidale CBD within a 15 km radius, in which in over 30 of them there was at least one artefact scatter site (See Table 6.2). While most sites comprised of only one to five artefacts, some, such as at the highway overpass on Cluny Road (Davidson and Appleton 1990a, 1990b), and two sites midway between Armidale and Hillgrove (Appleton 1991a), and at Blackfellows (now Iwata) Gully (Appleton 1992a), and at Rockvale Road, Armidale (Appleton 1994) where there were at least twenty artefacts in each site. The majority of the sites consisted of isolated stone artefacts but, one site consisted of two axe-grinding grooves in a sandstone block that had been used as a corner-stone in the construction of a cottage in the 19th century at Saumarez Ponds (personal observation), and one a boulder with two axe-grinding grooves downslope of the northern end of the Armidale airfield on the route of the Armidale Bypass for the New England Highway (Davidson and Appleton 1991b).

Table 6.2 Showing the altitude, distance to water and tool types present in a cross-section of sites in the NE Bioregion

Site location	AHD	AREA	Distance to water	Water body	No. of artefacts	Density of Artefacts /100sqm	Observed contents
High Altitude (over 1100m)							
"Boorolong"	1,120m	not determined	40m	Boorolong Creek	21	na	Retouched flakes & flaked pieces
Devils Pinch, Guyra (Appleton 2001)	1,325m	40 x 30m lozenge	20m	Tributary at head of Tilbuster Ponds	11	0.9	Retouched flakes & flaked pieces
Medium altitude (1000m-1100m)							
Baldersleigh (Appleton 1991c)	1,000 - 1,060m	3,000 x 40m linear	10-80m	Reedy Creek/ Spring Creek	1790	1.5	mullers, g/e axe, Bondi points, microliths
Sunnyside (Appleton 2005 & 2009)	1,000 - 1,020m	600 x 50m elliptical	20-250m	waterholes Tilbuster Ponds	235	0.8	Bondi points, microliths
Primrose Hill	1,040m	80 x 50m	10-50m	Saumarez Creek	164	4.1	Bondi points, microliths

Site location	AHD	AREA	Distance to water	Water body	No. of artefacts	Density of Artefacts /100sqm	Observed contents
Barley Fields Lagoon, Uralla	1,020 - 1,040m	250 x 60m crescent	10-100m	Barley Fields Lagoon	109	0.7	Bondi points, micro blades, muller
Saumarez Creek (NE Highway)	1,015m	50 x 30m linear	10-40m	Saumarez Creek	108	7.2	Bondi points, microliths
Lambing Gully (axe grinding-groove site)	1,040m	60 x 40m	100m	tributary of Saumarez Creek	94	3.9	Bondi points, micro blades, axe trimming flakes
Hillgrove (Appleton 1991a)	1,000m	50m dia. circular hill top	350m	Commissioners Waters	26	1.3	Bondi Points, Retouched flakes & flaked pieces
Cluny Road, Armidale (Appleton 1990a & 1990b)	1,005M	40 x 25m lozenge	30m	Spring tributary of Dumaresq Creek	22	2.2	Bondi Points, Retouched flakes & flaked pieces
Lower Altitude (below 1000m)							
Dangars Falls (BBQ area)	960m	250 x 50m linear	20-80m	Salisbury Waters	72	0.6	Bondi Points, Retouched flakes & flaked pieces
Rockvale Rd. Armidale (Appleton 1994)	900m	40 x 40m irregular	5-50m	Spring tributary of Dumaresq Creek	53	3.3	Bondi Points, Retouched flakes & flaked pieces
Blackfellows (Iwata) Gully Invergowrie (Appleton 1992a)	950m	40 x 30m oval	20-50m	Blackfellows Gully	29	0.08	Bondi Points, Retouched flakes & flaked pieces
Laura Creek	940m	40 x 40m irregular	10-40m	Laura Creek	24	2	Quartz thumbnail microliths
N.E. Traffic Education Centre (Appleton 1990c)	980m	60 x 30m parallel to creek	5-30m	Spring tributary of Dumaresq Creek	22	1.2	Bondi Points, Retouched flakes & flaked pieces

The next of the significantly large sites, comprised a number of discrete artefact scatters extending in a continuous strip for over 3 km along the southern bank of Reedy and Spring Creeks southeast of Baldersleigh, 57 km north west of Armidale (Table 6.2). Despite less than 10% average archaeological visibility, over a thousand artefacts were recorded in stock-eroded pads and slumping creek banks within a 40 m wide strip adjacent to the creek, which contained several near-permanent waterholes in its basalt riverbed (Appleton 1991c). The artefacts were exposed in stock and vehicle wear pads and the depositional horizon was probably between 10 and 20 cm below the surrounding surface level.

Also, in 1992 Appleton found a site at Blackfellows (now Iwata) Gully, 20 km west of Armidale, where 26 of 28 artefacts are of silcrete including a backed blade and an asymmetric Bondi point (see Holdaway and Stern 2004: 81, 261 for artefact definitions). The site is in a highly disturbed TSR adjacent to the creek. It is possible that the site was originally much bigger but cattle have significantly altered the creek banks and bed (Appleton 1992a) (Table 6.2).

The characteristics ‘distance from water’, Bondi points and microliths are present in the sites in the New England bio-region (NEB) regardless of the altitude at which they occur, which varies from 900 to

1350 m AHD (Table 6.2). The single factor common to all of these sites (there are many more examples but these were selected because of the diversity in elevation and environmental context of the sites) is that they all occur in those parts of the New England Bioregion where the majority of development projects have occurred and therefore the area in which most archaeological investigations have been undertaken. We do not doubt that there are bigger, less disturbed, sites elsewhere in the NEB that have so far have escaped detection.

Another very large site found in the 2000s was recorded at the junction of the New England Highway and Sunnyside Road, 17 km north of Armidale (Table 6.2). The artefacts were mostly exposed on bedrock exposed by slope wash, but some were recovered at levels between 5 and 20 cm below the surface where a scraper and water-truck were used to recover additional artefacts not visible on the surface (Appleton 2005).

By 2012 there was sufficient archaeological evidence to consider that other sites might exist where no previous investigations had occurred if they were searched for using the predictive model (Table 6.1) that Appleton (1990a) had developed for the Northern Tablelands. This includes places that have previously been noted by the authors, but never fully investigated and other locations not previously investigated but having the potential to contain archaeological material. These sites were found and recorded during the fieldwork for the Lagoons project.

An important factor affecting the presence of sites is the in the New England Tableland Bioregion is the location of silcrete which occurs at the contact zone between the basalt and the sediments of the underlying Armidale Beds (Table 6.1). This generally occurs between 1,020 m and 1,040 m AHD in the southern part of New England, and therefore most silcrete artefacts will occur at this altitude or just below where silcrete outcrops occur (see Chapter 8). By 2012 the list of known artefact scatters had grown but there was still no larger archaeological context in which they could be compared, analysed and reported. A few axe-grinding grooves had been recorded 30 km SW of Armidale at 'Chiswick', a few minor artefact scatters had been recorded and an *in situ* scarred tree was recorded to the east of Lambing Gully, but there were too many gaps in the record of other site types that might explain where the ground-edged axes were coming from, what activities the sites represented and where would they be found. However, that was to change with finds of more grinding grooves and large artefact scatters, as well as scarred trees, and (rarely) stone quarries.

Each of the sites discussed above were initially observed while undertaking commercial archaeological consultancies or academic research (Table 6.2). Among the many open sites we have recorded there are several that stand out as being both very large in area and containing large numbers of artefacts, and it is the significance of these large sites that we return to later. However, it is also important to describe smaller sites found during 1991-2012 to gain a comprehensive picture of the regional archaeology.

Some of these smaller sites close to Armidale and referred to previously, include a scatter of 26 artefacts (all of silcrete) on the summit of a rounded knob adjacent to the Grafton Road between Armidale and Hillgrove (Appleton 1991a); a concentration of 28 artefacts (including a Bondi point) in the TSR at Blackfellows (Iwata) Gully, Invergowrie (Appleton 1992a), a scatter of 17 artefacts (including a Bondi point) at the highway overpass on Cluny Road (Davidson & Appleton 1990b); a scatter of 14 artefacts at the New England Traffic Education site (Appleton 1990c), and an extended scatter of two discrete scatters comprising 42 artefacts adjacent to an unnamed tributary of Dumaresq Creek, Rockvale Road (Appleton 1994).

During, and in preparation for, the project field-schools held in 2016 (Chapters 1 and 2), five new sites were recorded. The first of the locations, was Lambing Gully, on 'Chiswick', a CSIRO grazing research

property midway south between Armidale and Uralla, where a corroboree was observed by surveyor Henry O'Sullivan White in 1850 (O'Sullivan White 1934) and where there are axe-grinding grooves (Table 6.2 and Chapter 8). The 43 grooves occur on floaters (large rock fragments unattached to bedrock) and exposed silcrete bedrock, together with 94 stone artefacts scattered between and around the axe-grinding grooves at a density of 3.9/100 sq. m. It is clear that many more grooves continued beneath the accumulated grass and loose soil. Forty-one of the artefacts are axe-trimming flakes produced during the final reshaping of the axe-blanks prior to grinding, and the other 51 artefacts are of both igneous and sedimentary origin. The presence of artefacts adjacent to grinding grooves was also noted while investigating axe-grinding grooves at 'Cressbrook' to the southeast of Uralla (Chapter 8). Another small site was recorded 40 km northwest of Armidale at Laura Creek, where 24 artefacts were recorded exposed in vehicle tracks on the bank on the outside of a sharp bend of the creek.

Two other large sites were found as a consequence of investigating potentially sensitive archaeological areas for field-schools. The first of these was upstream of the Saumarez Creek site, in an area approximately 80 m x 50 m to the north of Primrose Hill (14 km west of Armidale) where164 artefacts were recorded in stock-pads in the TSR adjacent to a deep and permanent water hole (See Table 6.2). While most of the artefacts were observed in areas that had been denuded by stock use, a few were recorded in the intervening grassed areas where there was total grass cover. Over one hundred artefacts were recorded despite the archaeological visibility being less than 10% in most of the area, at an artefact density of 4.1/100 sq. m. Interestingly, Frost (1983) wrote that nulla nullas, spears and shields and a Bora ring were found by Thomas Frazier the first owner of the land on which they were found immediately to the west of Saumarez Lagoon. The lagoon lies 4 km to the northwest of the Primrose Hill extended scatter.

Another recent large study by Desic (2018) surveyed 5.6 sq. km of rocky hills, between 1020 and 1080 AHD, 30 km south of Armidale, for a solar farm project. The team recorded 235 artefacts in 25 open sites and 46 single artefact sites, together with six grinding groove complexes, 13 scarred trees and five quarries. The sites were small (1-19 artefacts per site), and located on average 200 m from 1st or 2nd order streams. There are several raw materials but silcrete and chert dominated. Some retouched artefacts are present in small numbers. Desic also recorded a silcrete outcrop with over 250 axe-grinding grooves, which we excavated in 2020 at the request of the Traditional Owners. The outcrop has been in use for *c.* 2300 years (Ryan Desic pers. comm. 2018, see also EMM 2018; Appleton 2020). The percentage of cores in the overall survey assemblage is very high (31%) due to the proximity of source materials.

In summary, between 1974 and 1991 many sites above 1,000 m elevation were interpreted to be either associated with, or directly connected with ceremonial sites, but relatively few stone artefact open sites had been recorded. Prior to 1991 the only large site recorded (i.e., containing in excess of an estimated 1,000 artefacts) in the AHIMS (Aboriginal Heritage Information System) Site Register was the extended scatter in the area exposed by stock treadage along the southern bank of Saumarez Creek opposite and to the south of Saumarez House 13 km southwest of Armidale (Godwin 1990). Sites recorded after this period and up to 2018 include a large number of open sites over 1000m as well as some lower sites. The open sites in Table 6.2 are similar to those observed by Godwin (1990) and Desic (2018) ranging from 10 to over 1000 artefacts, but they are mostly small assemblages within 150 m of water sources, and containing low numbers of retouched artefacts, such as Bondi Points. The density of the artefacts ranged from low - less than 0.09/100 sq. m at Blackfellows (Iwata) Gully, to denser scatters over 4/100 sq. m at Primrose Hill, Lambing Gully and Saumarez Creek scatters. These are interpreted as being traces of small mobile groups who occupied the higher altitudes year-round with stone procurement being part of their normal resource round. The large numbers of recently recorded silcrete axe grinding grooves, together with axe blanks (Desic 2018 and our team), add another dimension to Aboriginal movement

suggesting targeted industrial places are also part of the settlement pattern of the New England high country.

Lagoon site survey 2012-2016

However, none of these large surveys have carried out comprehensive archaeological work at lagoons or investigated their potential connection with the large number of ceremonial sites in New England. In 2015 we surveyed the potential biological resources available at high country lagoons and suggested that in the last 1000 years, the higher Aboriginal population, with greater, socially regulated contact and exchange between regions could be related to high water lagoon resources of waterfowl, eels, yabbies and water plants (Beck *et al.* 2015). So detailed surveys of the lagoons were undertaken in 2012-2016. The general results of these surveys are shown in Table 6.3.

Table 6.3 Lagoon sites, altitude at which they occur, and environmental context

LOCATION	SITE TYPES	Artefact No.	AHD	WATER SOURCE	SITE DIMS. L x W m	Density	CONTEXT
BARLEY FIELDS LAGOON, URALLA	Open artefact scatter	80	1,040	LAGOON	250 X 50	0.64	Open site parallel to shore & lunette
BIG LLANGOTHLIN	Scarred trees, artefacts, grindstone	18	1,360	LAGOON	1,000 X 20	0.09	Parallel to shore line
DANGARS LAGOON	Open artefact scatter	12	1,020	LAGOON	60 X 10	2.0	Lunette
BARLEY FIELDS, GLENCOE	Open artefact scatter	3	1,150	LAGOON	100 x 100	0.03	Variable
REDDESTONE CREEK	Scarred tree, open artefact scatter	2	1,030	CREEK	40 X 2	2.5	Variable
KINGS PLAINS LAGOON	Isolated artefacts	2	810	LAGOON	30 X 50	0.13	Perpendicular to shore
LITTLE LLANGOTHLIN	Scarred trees & artefacts	1	1,350	LAGOON	800 X 25	0.005	Lunette

Barley Field Lagoon, Uralla

Yet another significantly large (80 artefacts, Table 6.2) site was recorded in a vehicle-worn strip in a Travelling Stock Reserve skirting the southern edge of Barley Field Lagoon, 20 km southwest of Armidale in an area 200 m long and up to 60 m wide with an artefact density of 3.2/100 sq. m. In addition to the surface artefact scatter, several boulders of silcrete were found 200 m to the south that exhibited scars where large flakes had been removed, and a granite muller was found nearby exposed in a vehicle track in woodland 100m to the east of the lagoon. Excavations were carried out at two locations skirting the lagoon – see Chapter 7.

Thomas Lagoon

Another site (directly associated with axe-grinding grooves) occurs to the west of Thomas Lagoon,15 km southwest of Armidale. The surface artefacts were at a density of 0.62/100 sq. m. Excavation at the site revealed over one hundred artefacts adjacent to the grooves (See Chapter 7 for details). When we investigated further, we found 22 grooves on floaters and outcropping silcrete bedrock to the northwest of Thomas Lagoon. The paddock in which these grooves occur are part of a nearby property, and the owner, drew my attention to more grooves on outcropping silcrete bedrock close to the homestead, as well as several axes. Another 48 grooves were recorded in that location, together with a few large silcrete scrapers. At both the Thomas Lagoon and the owner's sites the grooves were partly concealed by accumulated deposits, that is, by flood-plain deposits, by slumping slope deposits, encroaching grass and sheep dung, and it is probable that more grooves are concealed from view.

We had also previously heard of axe-grinding grooves at 'Chiswick', the CSIRO establishment in Lambing Gully midway between Armidale and Uralla, and so we sought permission to view and record the grooves. During a visit to the site we observed that there were many stone artefacts of various materials scattered amongst the grooves. Subsequently this site was visited as part of our training program in 2014 (see Chapters 1, 2 and 8). While axe-grinding grooves are discussed in a separate chapter, the site is relevant to this chapter in that, from the number of visible grooves, this site might represent an axe manufacturing site in which large quantities of axes were prepared for trade and exchange with visiting tribes at ceremonies (corroborees). Lambing Gully is only 7 km to the northeast.

There is mounting evidence to indicate that other groups of axe-grinding grooves might occur in other silcrete outcrops together with both large and small artefact scatters occurring *throughout* the Armidale area on private property yet to be observed and recorded.

Other Lagoons

North of Armidale at Kings Plains Lagoon, two artefacts were recorded in the table-drains in the road easement of Kings Plains Road, and two others were recorded on the edge of a plough zone adjacent to the TSR. A single artefact was recorded in a narrow exposure in a track through dense woodland at Reddestone Creek, and two artefacts recorded in mechanically formed shoulders to Lights Road within 50-80 m of Abbey Green Lagoon. A grinding slab was recorded on the eastern shore of Big Llangothlin Lagoon where it had become exposed by recent mechanical clearing of fallen branches.

South of Armidale at Dangars Lagoon, 12 artefacts were recorded over a 24-month period in a graded track through the lunette bordering the lagoon. Three artefacts were recorded on the mown strip bordering Racecourse Lagoon, and four retouched clear glass artefacts were recorded on a granite platform immediately adjacent to the lagoon. Two artefacts were recorded on the surrounding bank of a dam opposite the road that becomes Big Ridge Road midway between Barley Fields Lagoon and northern Uralla.

Lagoon versus non-lagoon sites

So, the overall patterning in Table 6.3 is that lagoon sites are generally small, with few, scattered. This is similar to Godwin and Desic's findings of under 20 artefacts in sites near lagoons. Lagoon sites are all at high altitudes. The sample sizes are too small for a meaningful comparison with the non-lagoon sites, but the lagoon sites seem to have a more diverse range of other site types nearby- scarred trees, axe grinding grooves, with a very rare Tablelands grindstone find at Big Llangothlin Lagoon. In order

to investigate whether there are other differences, we next consider the assemblage content in more detail, and then how the sites may fit into an overall pattern.

Overall variations in assemblage content

Tables (6.4-6.6) deal with a range of variables about assemblages in the lagoon sites and non-lagoon sites. Each table will be discussed in turn.

In Table 6.4 nine variables are listed for both lagoon and non-lagoon site assemblages. However, the sample sizes are different, with only 292 artefacts in six lagoon sites compared with 2506 artefacts in 16 non-lagoon and so comparisons should be treated with caution.

Table 6.4 List of technological variables in lagoon and non-lagoon sites (ARTS = Artefacts; Fl = Flakes; FL P = Flaked Pieces)

	ARTS	CORES	FL	FL P	CORE TO FL/FLP RATIO	TOOLS	TOOL TO ART RATIO	Arts with cortex	% of artefacts with cortex
LAGOON SITES									
BARLEY URALLA	80	1	62	16	1 : 108	10	1 : 11	34	43.2
DANGARS	12	0	6	6	0	1	1 : 12	2	16.7
BIG LLANGOTHLIN	18	0	6	12	0	6	0	9	50
KINGS PLAIN	4	1	2	1	1 : 28	5	1 : 6	1	20.7
BARLEY GLENCOE	3	0	0	3	0	0	0	0	0
REDDESTONE	2	0	1	1	0	0	0	1	50
TOTAL Lagoon sites	292	5	183	104	1 : 58	30	1 : 9.7	90	30.8
Overall %		1%	63%	36%		10%			31%
OTHER SITES									
SUNNYSIDE	235	9	135	91	1 : 25	42	1 : 6	27	11.5
PRIMROSE HILL	164	5	104	55	1 : 32	8	1 : 20	20	12.2
LAMBING GULLY	94	2	34	58	1 : 46	9	1 : 10	11	11.7
BALDERSLEIGH	1,790	192	823	775	1 : 8	134	1 : 13	244	13.6
LAURA CREEK	24	0	16	8	0	3	1 : 8	7	29.2
SAUMAREZ CREEK	108	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
DANGARS FALLS	72	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
“RUNNYMEDE”	17	1	8	7	1 : 17	1	1 : 17	7	41.2
CLUNY ROAD	22	1	18	3	1 : 22	1	1 : 22	n/a	n/a
DEVILS PINCH	11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
BLACKFELLOWS GULLY	29	1	14	14	1 : 29	2	1 : 14.5	n/a	n/a
HILLGROVE 1	26	n/a	n/a	n/a	n/a	3	1 : 8.7	n/a	n/a
BLUE HOLE	39	n/a	n/a	n/a	n/a	3	1 : 13	n/a	n/a
HILLGROVE 2	56	9	23	24	1 : 6.2	n/a	n/a	n/a	n/a
ROCKVALE ROAD	53	2	29	22	1 : 26.5	3	1 : 17.7	n/a	n/a
NETEC	22	14	8	0	0	0	n/a	n/a	n/a
TOTAL Other sites	2,944	236	1,212	1,057	1 : 13.1	211	1 : 13.1	316	12.8%

	ARTS	CORES	FL	FL P	CORE TO FL/FLP RATIO	TOOLS	TOOL TO ART RATIO	Arts with cortex	% of artefacts with cortex
Sites with data overall %	2,506	9.4%	48%	42%		8%			12.6%
All sites	3,236		1,395	1,161		241			

KEY: n/a = data not recorded

The proportion of formal tools in lagoons and non-lagoons is similar 10% and 8% but other variables measured are not similar. Core percentages are different: 1% vs. 9.4%. This is the most obvious difference between the assemblages. For example, in the largest site, Baldersleigh, the cores comprise 10% of the assemblage, while at another large site, Primrose Hill, the cores are 3%; and at Barley Field Lagoon, Uralla, the cores are only 1%. Generally, a low core count may be interpreted as indicating that the site is a relatively long distance from material source and in this instance such an interpretation is borne out by close stone sources at Baldersleigh. The ratio of 1:10 may indicate that the material sources are nearby.

The proportions of artefacts with cortex are also different at 31% and 12.6%. In contrast to the core ratios, it might be expected for there to be a higher percentage of artefacts exhibiting cortex with more cores being near the source and therefore more readily discarded and replaced. However, the numbers do not show such correlation. At Baldersleigh where the core ratio is 1:8, 13.6% of the artefacts exhibited cortex; whereas at Barley Field Lagoon where the core ratio is 1:108, 43.2% of the artefacts exhibited cortex. At Sunnyside, where the core ratio is 1:25, 11.5% exhibited cortex. With such variation in sample sizes, the data might merely be related to sampling size but possible other reasons include past and current land use affecting flake visibility.

The core to flake ratios vary from highs of 1:108 at Barley Field Lagoon and highs of 1:46 at Lambing Gully a non-lagoons site. It is interesting to note that despite the big differences in core ratio that the tool to assemblage ratios for all of the sites fall between 1: 6 and 1: 22. Typically, in sites that we have recorded on the Tablelands the core to flakes and flaked pieces ratio falls to between 1: 10 and 1: 20, and so some of the ratios in Table 6.3 were surprising. At Barley Field Lagoon, Uralla, the ratio is a remarkable 1: 108, and at nearby Lambing Gully the ratio is 1: 46, and the ratio for the total of both surface and subsurface artefacts in all of the seven lagoon sites is 1: 58, but at Baldersleigh, where there is a large sample size, the ratio is 1: 8.

That might indicate that part of the problem in many of the sites is the small size of the sample. Unfortunately, Tableland sites tend to be either of very low density, or an extended area in which discrete clusters are linked by low density distribution, which if fewer than a hundred can produce misleading percentages, and so ideally only sites with more than 100 artefacts are likely to produce representative percentage values. At Barley Fields the sample size is 108; at Lambing Gully the size is 93; at the lagoon sites the sample size is 291; whereas the sample size at Baldersleigh is 1,789. At Sunnyside with a sample size of 234 the core ratio is 1:25.

Given that Baldersleigh is the largest sample, we interpret the anomalies in the other sites to primarily be a consequence of small sample sizes, although the absence of visible conglomerate outcrops in the region might support an alternative explanation that with a limited supply of locally sourced ‘exotic’ stone, knappers were taking the cores with them.

Tool types

Given the small sizes of the different assemblages there is only limited value in trying to analyse the percentages in Table 6.5, but firstly we should look at the relationship between retouched flakes and flaked pieces, and formal tools collectively to the size of the assemblage in which they occur.

Table 6.5 Percentages of formal tool types in assemblages

SITES	Arts	Flake	Flaked piece	Core	BB	PT	G	M	Axe	SCR
LAGOON SITES										
BARLEY FIELDS U	80	62	16	1	5	1		1		2
%		79%	20%	1%	6%	1%		1%		2%
DANGARS LAGOON	12	6	6		1					
%		50%	50%		8%					
BIG LLANGOTHLIN	3	1	1				1			
%		33%	33%				33%			
KINGS PLAINS	4	2	1	1	1					
%		50%	25%	25%	25%					
Lagoon site totals	99	71	24	2	7	1	1	1		2
		72%	24%	2%	7%	1%	1%	1%		2%
OTHER SITES										
SAUMAREZ CREEK	108	70	35	3	8	5				5
%		64%	33%	3%	7%	5%				5%
SUNNYSIDE	235	135	91	9	18					24
%		57%	39%	4%	8%					10%
PRIMROSE HILL	164	104	55	5	5					3
%		63%	34%	3%	3%					2%
LAMBING GULLY	94	34	58	2	2					7
%		36%	62%	2%	2%					7%
BALDERSLEIGH	1790	948	644	179	37	29	1	2	7	72
%		53%	36%	10%	2%	2%				4%
Other site totals	2391	1291	883	198	70	34	1	2	7	111
		54%	37%	8%	3%	1%				5%

KEY				
	A	Artefacts	BB	Backed blade
	F	Flake	PT	Point
	FP	Flaked piece	G	Grindstone (slab)
	C	Core	M	Muller (top grindstone)
			Ax	Ground-edged axe
			SCR	Scraper

Retouched artefacts-function

Table 6.4 lists New England sites in various contexts and at various altitudes that all contain retouched artefacts as defined by Holdaway and Stern (2004). Regardless of size and altitude, there is a continuous theme running through all of the sites, namely the prevalence of Bondi points in 14 of the sites and other microliths in at least seven sites, some sites having both.

Retouched artefacts are thought to be used as scrapers, knives and engravers (often hafted) to work many types of materials- wood, bone, plant, skin and feathers (Robertson *et al.* 2009). Recent research with usewear and residues shows that backed artefacts were produced for use as multipurpose and multifunctional tools that were used repeatedly or used regularly. This contrasts with unbacked artefacts which may have been retouched expediently and then used briefly before discard (Robertson et al 2019).

Artefacts that have been retouched have been done so to enhance a particular attribute or improve its efficiency in fulfilling a particular role or task. Retouching a flake or flaked pieces might be to modify the flake or flaked piece to make it more suitable for a particular use. The significance of retouch is that it indicates that the person retouching the item was doing so to prolong its useful life, or that the artefact was being resharpened after prior use, or to enhance the effectiveness of the tool. It is at least evidence that a specific technique was being used in tool or weapon manufacture and therefore a reliable indicator that some sites were likely to have been used for typical subsistence activity.

Retouched artefacts as percentage of assemblage size

For this relationship I have limited the sample sites chosen to those with around 100 or more artefacts but, to increase the sample, have also included Lambing Gully with only 94 artefacts and Barley Field Lagoon, Uralla, with 80. We can conclude that on the evidence of the larger sites retouched items (backed blades & points and scrapers) vary from between 5% to 18% of an assemblage (Table 6.5). This is consistent with percentages found by other New England researchers (Godwin 1990, Desic 2018).

Formal Tools as percentage of assemblage size

The second relationship to consider is whether there is a correlation between the number of formal tools (including equipment such as retouched artefacts, axes, grindstones and mullers (See Figures 6.2a-c*) present in an assemblage with the size of the assemblage. In Table 6.5 the largest assemblage has 8% formal tools and the smallest one 9% tools, so that the size of the assemblage in this sample is not clearly related to the assemblage diversity.

Comparing these results with previous researchers, Godwin (1990: 231) observed that the assemblages in his New England survey did not fit the classic stone rationing model which states that there is a clear trend for increased curation and rationing as one moved away from raw material source. Instead, he found that the size, proportion of retouch and proportions of raw material did not fit the expected patterns. He argued that that reasons for this could be related to stone material quality and, as well, it could also represent the rapid transit of groups through some areas using stone in an expedient manner (Godwin 1990: 313). So, he concluded that stone availability does not play a major part in the logistics of resource exploitation on the Tablelands. This could be part of the wide range of values shown in Table 6.4. Research into understanding the technology of Australian stone artefacts since Godwin's work suggests that flakes, not retouched tools (or cores) were chosen for transport and future use (Douglas and Holdaway 2011). Flakes also have a highly efficient mass to cutting edge ratio (Kuhn 1994). This might explain the low numbers of retouched artefacts and cores in the New England assemblages. Many ethnographic accounts of Aboriginal knapping describe the casual nature of knapping, which required



Figure 6.2a *Formal tools: A range of retouched tools from Baldersleigh*

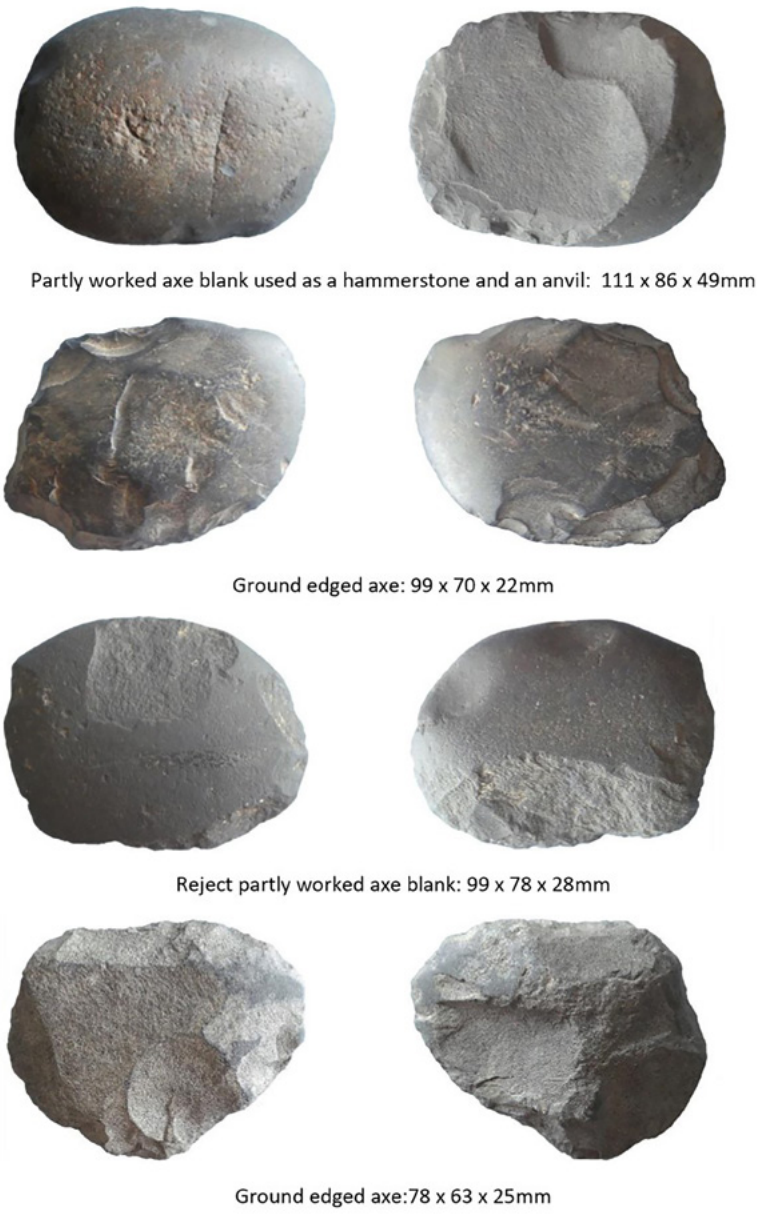


Figure 6.2b *Views of axes and axe blanks from Arding*

less time and energy to produce (Hayden 1977). This might explain low numbers of formal tools and high flake ratios.

These overall results are similar to Desic (2018) and Godwin (1990) with regard to low percentages of formal tools, although the core percentage in Desic is much higher at 31% but this is likely due to the immediate proximity of silcrete outcrops to the sites. The flake to core ratios fall within the same range as Desic (2018) found at 1:68 and Godwin found that cortex percentages varied from 59-10% in his sampled sites. In summary, the range of variables are within the same ranges for both lagoon and non-lagoon sites.

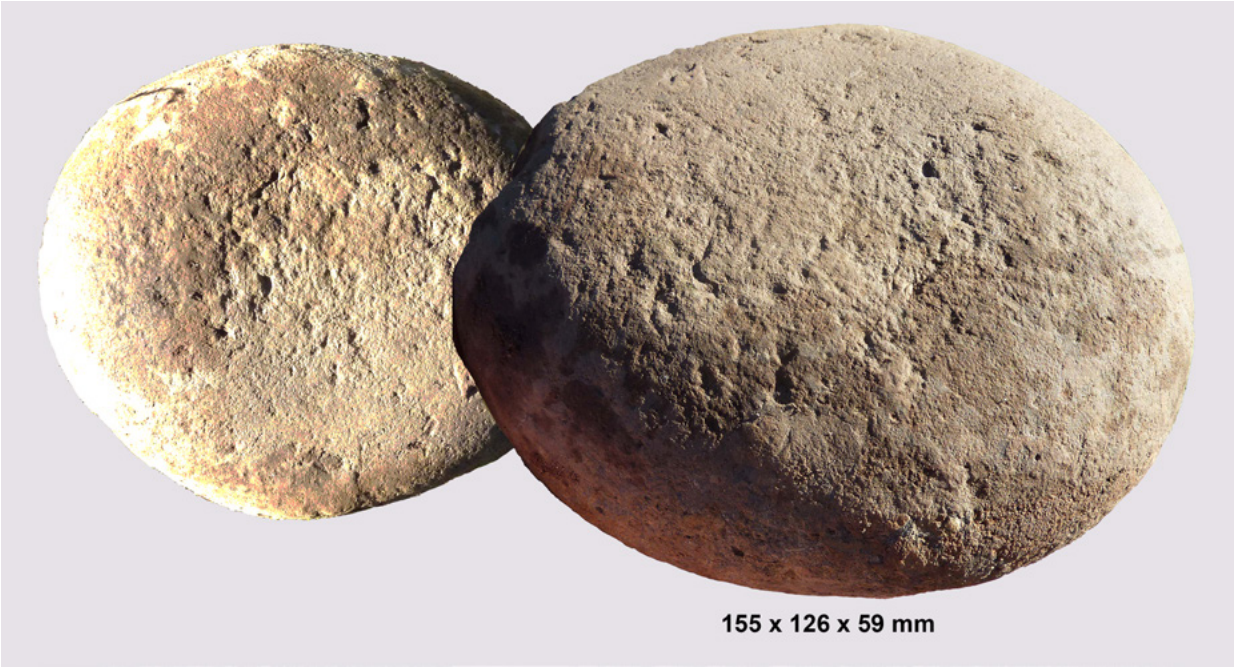


Figure 6.2c *Upper and lower surfaces of muller from Barley Field lagoon (500m south of lagoon). Localities shown on Figure 6.1.*

Stone raw material

The third characteristic common to all but one or two of the sites in the New England Tableland Bioregion is that silcrete is by far the most frequently used material found in surface sites sample (Table 6.6). Table 6.6 lists a sample of 21 sites that have been recorded in various contexts regardless of the differences in land forms, rock type or elevation at which they occur; the sites chosen are those for which we have detailed comparative information. Those sites in which the name is followed by "(LG)" denote the sites and information reported by Luke Godwin in 1990. All of the other sites were recorded by Appleton between 1991 and 2012.

Table 6.6 The use of stone raw material in surface sites in New England (FG* later identified as ignimbrite).

SITE	A	SIL	CHE	B	Q	FG*	MET	GR	CS	ARG	IGN	MUD	CHA	JAS
LAGOON SITES														
Barley Fields Uralla	80	35	3		20			1	18		2		1	
%		44%	4%		25%			1%	22%		3%		1%	
Thomas Lagoon (LG)	13	12			1									
%		92%			8%									
Dangar Lagoon	12	4			5		1						2	
%		33%			42%		8%						17%	
Big Langothlin	3	1					2							
%		33%					66%							
Reddestone Creek	1				1									

SITE	A	SIL	CHE	B	Q	FG*	MET	GR	CS	ARG	IGN	MUD	CHA	JAS
%					100%									
Kings Plains	4	2									1	1		
%		50%									25%	25%		
Lagoon Site Totals	113	54	3	0	27	0	3	1	18	0	2	1	3	0
		48%	3%		24%		3%	1%	16%		2%	1%	3%	
OTHER SITES														
Saumarez Creek	108	75		1	9		10		13					
%		70%		1%	8%		9%		12%					
Sunnyside	235	122	12	3	52		6		24	2	8			6
%		52%	5%	1%	22%		3%		10%	1%	4%			2%
Primrose Hill	164	109	10	4	15		4		1		20	2		1
%		66%	6%	2%	9%		2%		1%		12%	1%		1%
Lambing Gully	94	37		41	3				11		2			
%		39%		44%	3%				12%		2%			
Baldersleigh	1790	648	61	185	215	248	337	2	58	10	1	20	2	3
%		37%	3%	10%	12%	14%	19%		3%	1%		1%		
Cluny Road	27	17	2	2	2		2					2		
%		65%	7%	7%	7%		7%					7%		
Laura Creek	24		7		5		2				10			
%			29%		21%		8%				42%			
Rockvale Road	40	37			1				2					
%		93%			3%				4%					
NETEC	24	19	2						3					
%		79%	8%						13%					
Dangars Falls (LG)	12	9			1		2							
%		75%			8%		17%							
Emu Creek (LG)	297	56	165		7		11				4	54		
%		19%	56%		2%		4%				1%	18%		
Gostwyck (LG)	35	23					12							
%		66%					34%							
Boorolong Creek (LG)	21	1			16						2	2		
%		1%			81%						9%	9%		
Blue Hole (LG)	40	39									1			
%		98%									2%			
Other sites total (n)	2911	1192	257	236	326	248	386	2	112	12	48	80	2	10
%		41%	9%	8%	11%	9%	13%		4%		2%	3%		
No of site occurrences	21	19	9	6	16	1	12	2	8	2	11	7	3	3

A= Artefact Nos; SIL= Silcrete; CHE= Chert; B= Basalt; Q = Quartz; FG= Finegrained; MET: Metasedimentary; GR= Granite; CS= Conglomeritic silcrete; ARG= Argillite; IGN= Igneous:, MUD= Mudstone; CHA= Chalcedony; JAS= Jasper

There are 14 raw material types recorded in our sample. Table 6.6 shows that silcrete is the dominant raw material in 41% of the total of all assemblages; followed by quartz at 14%; meta-sedimentary at 13%; then chert and ignimbrite (a pyroclastic igneous rock) - both at 8%. A total of 84% of the assemblage is comprised of five materials. However, if we look at the number of sites in which each material occurs, silcrete was present in 19 of the 21 sites; quartz in16 sites; meta-sedimentary in 12 sites; igneous in 11 sites; and coarse silcrete in nine sites. The remainder of stone raw materials are present in low quantities.

Silcrete artefacts are generally a glossy grey or fawn and are easily identifiable against the background of red basalt soils or yellow-red soils derived from decomposing granite. The sources of the silcrete are widespread and generally occur at or just above or just below the 1,040 m contour. As might be expected, where granite occurs, quartz is the second most frequently used material, closely followed by metasedimentary material probably sourced from the older creek-beds. Some artefacts were manufactured from crystal quartz which retains both form and sharpness. The local conglomerates include chert, mudstone, chalcedony, basalt and jasper. Some of the small quantities of exotic material may have come from the pebble bars in the gorges that they would have crossed over on their way up via Dangars Falls and Salisbury Waters, picked up by visitors on their journey to the New England or by Tableland residents returning from visiting the coast. Based on the amount of ignimbrite represented by 253 artefacts, the source is probably nearby but was not visible at the time of the survey.

Glass has not been mentioned yet but is of much significance simply because it tells archaeologists that regardless of when the site was first used it must have been in use at the time of European settlement. Small numbers of retouched glass were recorded at Racecourse Lagoon, Reddestone Creek and Barley Field Lagoon, Glencoe.

The ages of the open sites

Based on geomorphic context and formal artefact types, the sites reported here are assumed to be Late Holocene. Unfortunately, none of the surface sites mentioned in this chapter had any dateable material because there was no non-lithic material that could be dated. In most cases the sites were actively degrading and the surfaces on which the artefacts were found was an eroding one. Archaeologists working in sites on the east coast of New South Wales have observed that Bondi Points like other backed artefacts, were generally expanding in numbers between 4,000 BP and 1,500 BP (Attenbrow *et al*. 2009: 2769) but they do occur in Late Holocene contexts as well (Hiscock 2002, Hiscock and Attenbrow 1998) and have been observed in the most recent layers of excavated sites such as Bendemeer (McBryde 1974)

Conclusions about assemblage variation

The major difference between lagoon sites and non-lagoon sites is the size and artefact density of the sites. While all of the New England sites tend to be small, there are greater numbers of larger and denser sites away from lagoons (Tables 6.2, 6.3). The technology and raw material at both site locations is quite similar, with slightly larger proportions of silcrete artefacts and artefacts with cortex at lagoon sites (Table 6.4). This might be due to the location of silcrete outcrops closer to lagoons, but the sample size is very small. The number of formal tools at both sites is also very small.

Godwin (1990: 176) found some differences in site form related to function and differences between sites found around the edges of lagoons and swamps and those in woodland environments. Based on a relatively small data set he identified, '... low levels of discard of amorphous assemblages of artefacts' at eight lagoons, comprising, '... cores, unretouched flakes, the odd blade and some retouch'. In contrast, assemblages in woodland environments 'were dominated by blades, backed blades and distinctive blade cores at greater densities'. In interpreting his results Godwin suggested that exploitation of lagoon

and swamp resources required fewer tools made of stone, whereas hunting/gathering in woodland environments required tools such as stone blades, points and scrapers (Godwin 1990: 176). Our results show almost identical proportions of retouched tools at lagoon and non-lagoon sites (Table 6.5) but this idea about organic tools is worth further investigation.

Ceremonial activity in New England

Having established that there are large sites away from lagoons and smaller ones nearby, we return to a theme that has been part of the distinguishing feature of New England archaeology- ceremonial activity. A number of authors (McBryde 1974, Bowdler 1981, Gollan 1989, Godwin 1990) have commented on the high frequency of archaeological ceremonial sites (bora grounds, art sites, stone arrangements, carved trees) on the Tablelands in comparison to other parts of NSW. Ceremonial sites are also associated with the other high-altitude uplands in southern NSW (David *et al.* 2020; Bowdler 1981). Godwin (1990) commented on the locations of these New England sites and found that of the total of 129, 49 were clustered within five kilometres of each other, forming six clusters altogether (Beck 2006). 'Some ceremonial places were probably visited and re-visited by large groups being parts of a landscape imbued with meaning' (Beck 2006: 97). For example, within a 50 km radius of Armidale there are 19 lagoons together with eight bora grounds reported and one stone arrangement (Beck 2006, Bell *et al.* 2008). Could these ceremony clusters be related in some way to the small lagoon and larger non-lagoon artefact scatters?

Ethnohistory: who, when and why gatherings took place

Not all stories agree or correlate increased ceremony and travel with the increased availability of resources. Aboriginal people on the tablelands were said to migrate to coastal areas during the winter months (Hobson 1978: 82); while Gardner (1842-54) in Pearson (1973: 70) stated that people moved to the west in February and March to escape the March fly. Marchment (1983) includes a reference to a group of 60-70 Aborigines from the Tablelands reciprocating past visits with the coastal peoples from Wilson River, Pappinbarra and Forbes River tribes. McIntyre, who spent early years at Kingsgate (140 km northeast of Armidale), reported that a corroboree of "New England Blacks" included Aborigines from Bellinger, and the Clarence and McIntyre Rivers where they exchanged artefacts (McIntyre 1924 cited in Pearson 1973: 66).

McIntyre's records for the 1870s and 1880s (McIntyre 1924) state there was a corroboree of 700 people at Inverell (125 km northwest of Armidale) attended by people from south of Armidale, from New England, Clarence River, Bellinger River and the Macintyre River area on the north coast. Calvert (1855?: 44) recorded that, '...tribes of Blacks on the McIntyre Brook were at Myall Creek (170 km northwest of Armidale) on the Big River in four days to attend a Durally or fight in February 1846'. Other gatherings occurred at Toondoo and Gedda at the junction of the Sovereign and McIntyre Rivers (90 km nw), at Bora Gap near the Manilla River (140 km west), and near Moon's Creek on the Peel River 110k sw). One of the great gathering centres was at Kentucky (42 km southwest of Armidale) which the Aborigines called 'Boembella' (Calvert 1855?: 44). Note that Kentucky Lagoon and Taylor Lagoon are two small lagoons nearby. O'Sullivan White, a licensed surveyor born in 1831 (1934) recollected observing a corroboree of 600 people including tribes from Macleay and Clarence Rivers (near Armidale) in November 1850, and McIntyre (1924 cited in Pearson 1973: 66) a Glen Innes resident, reported seeing a gathering at which there was a central pole onto which were fastened huge strips of bark on which, '... figures of all sorts of animals were painted in a clumsy fashion with different coloured clays'. He saw, 'four or five hundred men fantastically painted and decorated, stepping in time to a weird song from the females' section who beat time with a waddy on a doubled opossum rug'.

Cohen and Somerville (1990) suggest from oral history that some boras (or 'burbungs') would have been sites for secret/sacred ceremonies specific to women (Cohen & Somerville 1990). Halliday (1988) reported that in the Tenterfield area (190 km north of Armidale) female initiation included cicatrice (body scarring) of the breasts and body; and that male initiation included circumcision and a cut on the abdomen producing a kind of pouch in which to carry a message stick.

Hoddinot (1978) based on linguistics and ethnography suggested that the Northern Tablelands was the harshest environment in New South Wales with an Aboriginal population of perhaps 600, but that the northern areas tended to be occupied only during summer months by Aborigines from the Western Slopes, and that the southern section was occupied by people from both the Western Slopes and the coast. He also suggested that with the onset of colder weather, the Aborigines were forced to move into less harsh areas. Pearson (1973: 70) reviewing the ethnohistory said that 'The blacks abandon the range during the fly months and retreat to the Byron Plains and Bundarra country' (84 km northwest of Armidale). O'Sullivan-White (1934) recorded a corroboree two miles (3.2 km) south of Armidale (Lambing Gully) attended by people from the Macleay River, the Clarence River and New England (Clayton-Dixson 2019: 126-127). McBryde (1974) based on regional ethnohistories stated that people moved to the tributaries of the Clarence in the north, and through the gorge system to the Macleay in the south.

All of these observations support a picture of fluidity and interchange of the NEB Aboriginal groups with those from surrounding regions and that at any meeting there were at least three if not four or five tribal groups present. It follows therefore that the large gatherings were attended by people from different regions, exchanging goods, and sharing common ceremonies, while speaking various dialects. Calvert (1855?) noted that the New England tribes of New England, Beardy Plains and the tribes of Bundarra spoke the 'Ennewan' language - which might indicate a certain permanence in their occupation of the New England area and that they never strayed too far from home, and Mrs McPherson said that Inuwon or Nee-inuwon was spoken west of the range from Bundarra to Uralla, and at Cope's Creek Tingha, Wandsworth, Ollera, Bolorolong Creek, Black Mountain and Guyra (McPherson 1860). Crowley (cited by Hoddinott, 1978) suggested that Anewan had undertaken drastic phonological changes setting it apart from neighbouring languages. Byrne in reviewing the region wrote that there were two languages, Yugumbal and Anaiwan (Byrne 1989, Godwin 1990, Tindale 1974). A comprehensive language map can be found in Clayton-Dixon 2019:17).

Much of this chapter has been focussed on Lambing Gully, Thomas Lagoon, and Barley Fields Lagoon, but it is interesting to note that at the time of contact Calvert (1855?) observed that, 'the great centre was at Kentucky', and that two other central places for meetings were at the junction of the Severn and McIntyre Rivers, and Burkanbandean Mountain near Moore Creek. It underlines the fact that there were numerous ceremonial places in the NEB, some of which have been referred to previously. There were bora grounds at Saumarez Lagoon, Mount Yarrowyck, Ingelba (Cohen and Somerville 1990), and Black Mountain, Moonbi, Kentucky, Wards Mistake, Stonehenge and Hillgrove; and corroborees were held at Lambing Gully, at the River Styx in the Big Hill area of Yarrowitch. Schofield (1979) wrote that corroborees were also held at Mt Yarrowyck.

When we were undertaking a project at Bowraville, an Aboriginal Elder pointed out the peaks and ridges to the west along which he said the Aboriginal people from Bowraville used to travel to ceremonies in the Armidale area. However, that raises the question of whether observations of Aboriginal people from the Tablelands moving down to the coastal strip were all of Anaiwan people travelling to the coast, or whether some were of coastal people returning home from ceremony on the Tablelands.

Marchment (1983) in the Hastings Gazette wrote of observation, made by landholders during the early days of European settlement, of a group of 60 or 70 Aborigines said to be from over the range in the New England area that was expected to camp and renew friendships, and marriages were promised, reciprocating past visits with the Wilson River, Pappinbarra and Forbes River tribes.

Many of the observations and statements in the past were based on very limited information, and without training to observe and record, and often made without thought as to the implications - even with hindsight, we realise that even as we record and interpret what we find today we still make

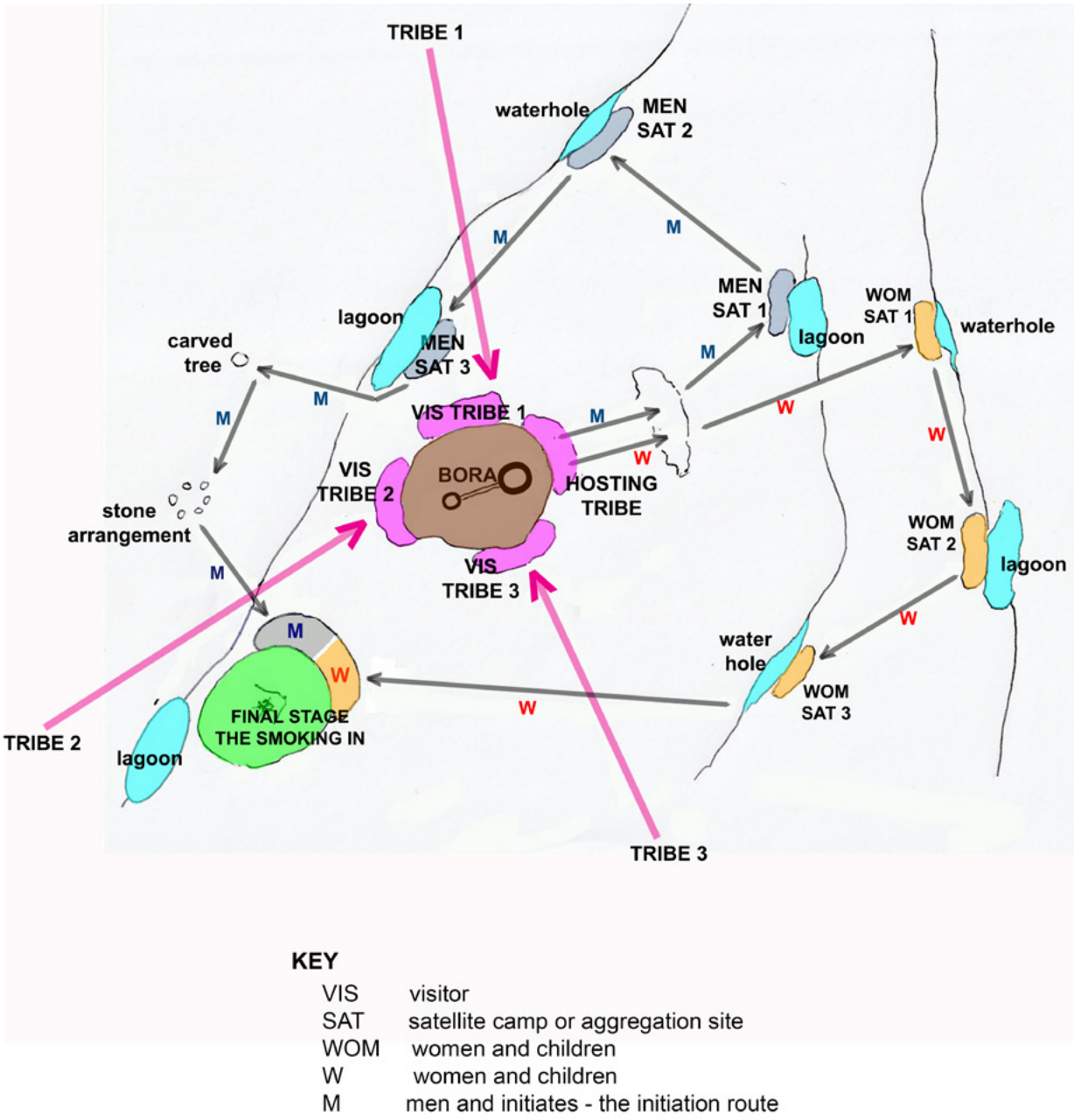


Figure 6.3 *Spatial interpretation of Mathew's description of the Ritual Circuit*

incorrect assumptions. For example, McBryde (1981) said that as there were no grinding slabs at Bendemeer therefore there was no archaeological record of their use on the Tablelands. Since McBryde's work numerous grinding dishes and fragments of grinding 'dish' and mullers have been recorded at Baldersleigh, Big Llangothlin, Little Llangothlin and Barley Field Lagoon, Uralla. Any interpretation can only be as good as the information on which it is based, and it is only in recent years that we have had a greater range and content of information on which to base our interpretations.

In 1995, Fife proposed in his BA (honours) thesis on bora ceremonies in historical records of New England that, while there are numerous sites identified as ceremonial grounds in the historical literature, there is also potential for archaeological traces (Fife 1995). His work was based around observations of R.H. Matthews who was a land surveyor in New England in the 1870s. He also proposed, based on R.H. Mathews first hand observations of the area in southern New England (Mathews 1917, 1896), that sites could be identified as comprising a 'ritual circuit' associated with 'the central place' that might be located within 15-20 km of the ceremonial ground. The 'ritual circuit' for male initiation comprised temporary occupation of sites in a predetermined sequence of sites that terminated at the final 'smoking ceremony'. Figure 6.3 is our interpretation of how this ritual circuit might be arranged in the landscape, with the ceremonial bora ground and smoking ceremony at the centre, and smaller men's and women's camps some distance away but close to lagoons, waterholes and woodland areas for yams and kangaroo hunts. The exchange of trade goods, such as stone axes, may also have taken place.

The following comprises extracts from Mathew's reports in which the more detailed descriptions of the ceremonies have been omitted, but in which the impact on the environment in terms of where the camps were located relative to resources is important.

Mathews' description (1896: 300) is summarised as follows:

Prior to the appointed time for the initiation ceremony which had been determined by the Elders in a previous ceremony (*the year before*) the host group had to prepare the assembly areas, the bora ground and accompanying paraphernalia, and cleared areas in which the various groups would camp upon arrival. If four different tribal groups were coming, then the hosts would prepare five cleared areas - the camping area for each of the groups as well as for themselves.

Mathews continued that the Aboriginal men would then have to prepare the bora ground, usually comprising two earthen circles connected by a pathway, and the associated paraphernalia such as earthen ground sculptures of totem figures of echidna, kangaroo etc, and trees carved with images of totem animals. This preparation period might take several weeks to complete (Mathews 1917, 1896), during which time those preparing the area would be utilising the resources of that area.

Significantly, Mathews refers to the host group, the *Anaiwan,* as being the occupants of the area in which this particular ceremony occurred (Matthews 1896). The *Anaiwan* are believed to have numbered as few as 600 across their entire tribal area, but it is unlikely that all 600 attended the ceremony. Even if there were as few as 100 *Anaiwan* (most likely a single clan) involved in site preparation, sufficient resources to support them would be needed. The average population density in New England is thought to be 25-30 sq. km /person (Godwin 1990: 97), so these groupings are much denser.

Wyndham (1889), who lived and worked on the northwestern Tablelands, described a bora ceremony (probably near Bolivia 160 km north of Armidale) attended by groups from the *Enuin*, *Ucumble*, *Quieumble* and the *Bigumble*, who each had their own camps, and each faced 'towards' their own territory. Not all of the attending groups would have arrived at the same time having travelled different distances to get

there, and so the aggregation areas had to be located near a reliable water source and within a practical distance from food resources sufficient to support the hosts and the early arrivals.

Initially the men, women and children coming from the west or east (seldom from both at the same time for the same ceremony because the coastal Aborigines and those from the Western Slopes were said to be antagonistic towards each other (Godwin 1990:123)) arrived at the assembly or aggregation area and camped at the grounds that had been prepared for them. At this stage as many as 600 people converged upon the aggregation area chosen for the start of the ceremony (Matthews 1896: 123). Once everyone who had previously arranged to be there had arrived and welcoming formalities, feasting and dancing were over, the women and children left to set up camp adjacent to a reliable water source such as a lagoon, waterhole, spring or stream located elsewhere. Meanwhile the men and initiates left the main camp to set up another camp near another reliable water source. It is reasonable to suppose that there could be in the order of 200-300 people at each of the two 'satellite' or 'dispersal' camps.

After several days at their individual camps the men and initiates, who no doubt had significantly depleted the natural resources available to them at that place, moved on to other sites, before moving to the last of the sites on the 'ritual circuit' which they 'prepared' for the final 'smoking' ceremony, by constructing screens of saplings and totemic mounds of soil. The women and children joined them soon afterwards. By now at least four camps have been used (Figure 6.3) and more if the resources at either of the dispersal camps to which they had first moved were no longer able to support the group. Interestingly, in an environment in which reliable, clean drinking water was somewhat limited Mathews (1896: 124) stated that a place for bathing was set aside and was used for no other purpose.

As the total number of those attending the ceremony was in excess of 600 people (which would suggest that perhaps only 200 or less *Anaiwan* attended), it was important that the camp sites were located near reliable water and sufficient food resources to support the group, and so the timing of when the ceremonies took place was determined by the availability of food resources. That might indicate that the ceremonies took place after November rains when the warm nights stimulated vegetation growth and replenished the waters of the creeks and lagoons.

At this point the amount of resources necessary to support 600 people should be considered in greater detail. Naturally the most accessible water sources were waterholes – such as those at Baldersleigh, both Saumarez Creek sites, Sunnyside, Tilbuster Ponds and Wyoming Falls; and lagoons such as the Llangothlin Lagoons, Barley Fields, Dangars and Thomas Lagoon. Food to feed 600 would have depended upon the season and whether plants were carrying fruit and seeds, and tubers, but also on the availability of kangaroos, possums, koalas, birds and turtles. Bowdler (1981) thought that yams were a major constant source of carbohydrate food for ceremonies, but kangaroos and wallabies were probably also an important food source and were a source of protein. Kangaroos were caught efficiently by groups hunting with long fixed nets strung between trees (Gardner 1854: I:18b, Godwin 1990: 151). Kangaroos were probably present in far greater numbers than today and a measure of their abundance was reported in 1884 when 260,780 kangaroo scalps were exchanged for bounty in the Tamworth district, and by the mid -1890s bounties were being paid on 100,000 wallabies a year (Waters 2012).

In the absence of a reliable sequence of dates for the various ceremonial sites, we can assume that many of the aggregation sites were in use at the time of European settlement. We have also been told that initiation ceremonies continue until today, for instance, Appleton was told by an Initiated Elder some twenty years or more ago, that he had been initiated in a secret ceremony in 1944. And a recent men's initiation camp was held in June 2021 at Mt Duval 15 km north of Armidale (Arundale 2021).

We return to the point that there had to be sufficient resources to support 600 people and that visiting groups had to be able to rely on those resources being available when they set out from their own tribal area. Prior to European settlement on the Tablelands and the impact on the vegetation and waterways from sheep and cattle, resources may have been more abundant but even so the open dry eucalypt woodland would only have been capable of supporting a limited number of people for a limited time.

Analysing the content of only one site cannot produce a realistic and reliable picture that can be extrapolated for the whole of a region, and prior to the 1990s there was insufficient evidence of large sites to analyse. Prior to the 1990s most research was directed to where visiting groups of Aboriginal groups had come from, and what they did during the corroboree or ceremonial activities but no-one had seriously considered what those groups did during their journeys to and from the tablelands. Some groups would journey for 15 days or more to reach their destination but how did they survive their journey in unfamiliar country?

Water

Throughout this chapter there has been an underlying reference to the need for sufficient water to support as many as 2-300 people at any one time in any one place and the fact that it needs to be a reliable source not a resource only available after a heavy storm. Those Elders that planned ahead to 'set' a time when all of the visitors would have access to water during their journey, but also for the several weeks they would be on the Tablelands attending ceremony or corroboree had to be reasonably certain of when the meeting should take place. As Beck (2006) stated in reference to the inhabitants, but which applied equally to visitors to the tablelands, 'movement was not random but socially determined within environmental limits. For example, access to water was a prerequisite for journeys of any length' (Beck 2006: 100).

Large sites and aggregation sites

So, can the ethnohistory of large ceremonies on the Tablelands be linked to the archaeology- what is the importance of large and small sites in the New England and can they be linked with ritual and lagoons?

The Conkey criteria

The hunter-gatherer sites where visiting tribes collected and camped together are aggregation sites. Margaret Conkey (1980: 612) identified the following specific criteria for recognising aggregation sites in the archaeological record:

1. Large group size and its relationship to the spatial extent of the occupation
2. Seasonal occupation and its correlation with particular harvesting seasons
3. Site structuring – how and where different activities took place
4. Maintenance of relevant site features
5. Greater total range of activities that at any other (dispersion site)
6. Some activities different to those found in smaller sites
7. Ecological factors that might have prompted or contributed to the aggregation
8. The mixture of people from the region.

Of our lagoon sample only Barley Field Lagoon, Uralla was found to contain a site large enough to be considered as an aggregation site, but it is also possible that Big Llangothlin Lake and Little Llangothlin Lagoon might also have been aggregation sites but our sample size was too small to produce meaningful

results. Large sites away from lagoons are found at sites such as Baldersleigh, Sunnyside and Primose Hill (Table 6.2).

Aggregation sites in the New England Bioregion

While we do not have the range of potential qualifying factors/criteria outlined by Conkey for the Altamira cave site, in the open sites of the New England Bioregion, there are several that can be drawn upon to compare with her model.

1) Large group size and its relationship to the spatial extent of the occupation

The ethnographic information has established that groups of several hundred were seen in New England. Site size is a more easily identifiable factor of aggregation perhaps best illustrated by the Sunnyside site where the site extends for over 100 m from the creek and for several hundreds of metres along the creek banks (Table 6.2). Each of the larger sites often occur on broad, generally level river terraces and gently sloping valley floors adjacent to a reliable water source, with spaces capable of hosting 20 or more gunyahs (huts) at a time.

2) Seasonal occupation and its correlation with particular harvesting seasons

Evidence for seasonal occupation might include such remains as nuts, fruit stones, seeds but none are likely to have survived in the acidic soils of New England, especially in a surface context. However, the mullers at Baldersleigh and Barley Field Lagoon, and the seed-grinding dish at Big Llangothlin Lagoon (Table 6.5) are evidence of processing seeds or roots which would only be 'plentiful' at a particular time and season of the year.

Optimising seasonal resources for the timing of gatherings

Appleton was in discussion with the late Mr Eric Walker, a highly respected initiated Elder of the Bundjalung people, in the quiet banksia scrub on the east of Tenterfield, when we were interrupted by a sudden explosion of white moths from the surrounding banksias. Mr Walker immediately exclaimed mid-sentence that it was 'Bunyah time!'. He explained that the moths were a signal to all Aborigines 'everywhere' to head off to the Bunyah nut ceremony on the Darling Downs in south-eastern Queensland. The meetings regularly included some people who would have travelled from up to 250 km away (Low, 1988). The ceremony took place every three years when the nut was ready to harvest. A clear example of a resource seasonality triggering aggregation.

The major issue raised when there is any discussion of Aboriginal gatherings of up to 600 people on the tablelands is what did they eat? For much of the year the tablelands are dry, most rivers are devoid of water and many of the lagoons have dried up. In the absence of good eating grass even the kangaroos become scarce. So, the question, 'what did the people eat?', should be phrased, '...when were there sufficient resources to feed 600 mouths?'. As many of the ceremonies would have been organised during the previous meeting, which might have been two or three years previously how did everyone know when the time was the right time? The answer is we don't know. There are times when the locals expect rain, such as in November and February, but as in the 2019 drought expectations may not be met.

Planning for the gatherings had to be made in advance because of the amount of preparation that the hosting tribe had to do, and we can only speculate that advance communication was the only means of postponing or confirming when a pre-arranged meeting was to occur.

Regardless of how the meetings were organized, it is clear that to feed 600 people there had to be sufficient resources. Whatever the primary food source, the meetings could only take place when that resource was at the peak of its harvesting cycle.

While for most of the year the Northern Tablelands could not support 600 people for several weeks, there are times when after rain, there are natural increases in kangaroos, possums, koalas and 'sugarbag' (native bee honey), and when the flooded lagoons and swamps are flecked with black swan, ducks, pelicans, and succulent reed beds, and when the numbers of eels and fresh-water mussels increased then the tablelands could support gatherings of 600.

3) Site structuring- how and where different activities took place

Although Conkey was referring to the use of space within a cave context (Altamira), we believe that the principle is similar if not exactly the same as spatial planning in an open site. A cave might have three sides or more, defined by the rock face, and there will be a preferred spot within the cave for particular functions, whether it is to shelter from the wind or rain, keep the fire from the wind or rain, or for the sick or physically handicapped to be sheltered from the elements. In open sites the preferred campsite is the one on the flattest ground, nearest to the water, and with the best vantage point. However, the measure of the number of people using the site can be seen in the furthest distance that artefacts are away from the water-source. So, a site with great depth (distance from the water), a great width (parallel to the water) and a large density of artefacts, is likely to have had many people camped at the same place at the same time. If the site was only used by smaller residential groups, it could be expected that the artefact distribution would be in more discrete concentrations within a short distance of the preferred access to the water (Gamble 2002: 77).

If we apply these criteria to all of the sample sites in the New England, there are only four that qualify as large sites: Baldersleigh, Sunnyside, Saumarez Creek and Barley Field Lagoon (see Table 6.2). These sites as measured from the furthest surface artefact in one direction to the furthest artefact in the opposite direction and meet criterion three of Conkey's proposed criteria for identification of aggregation sites. Unfortunately, most of the Lagoon samples are too small to include here.

4) Maintenance of relevant site features

Maintaining site features such as carved trees, stone arrangements and bora grounds would be part of the aggregation site activities, Mathews describes some of these activities, but their archaeological traces are hard to discern.

5) Greater total range of activities that at any other sites: Tools

One of the criteria used to define aggregation sites by Conkey is the variation in site activities, where aggregation sites tend to contain evidence for a greater range of activities than large 'non-aggregation' sites.

We might assess the range of tools to be representative of the range of activities, both social and economic. So, a larger range of formal tools might represent a larger range of social and economic activities. In particular, formal retouched tools such as microliths have both economic and social functions, perhaps in risk reduction (Clarkson *et al.* 2017). Grindstones and ground edge axes may have more 'fixed' functions but the small tools are multipurpose (and reused) craft tools and weapons (Fullagar 2016, Hayes *et al.* 2020).

Table 6.7 The diversity of artefacts and site features related to aggregation sites

KEY P: Point; RET:Retouch; B BL: Backed blade; C: Core; SCR: Scraper; AXE:Ground edged axe; Mul: Muller; Art: Rock Painting; Scar tree: Scarred tree; GR: Grindstone; Knap floor: Knapping floor; AGGSITE: Aggregation site

SITE	P	RET	B BL	C	SCR	AXE	Mul	GR	ART	Scar tree	Knap Floor	Total	AGG SITE?
Baldersleigh	X	X	X	X	X		X	X				7	X
Big Llangothlin Lagoon	X	X	X			X		X		X		6	?
Gostwyck AGG	X	X	X		X	X					X	6	X
Barley Fields Lagoon	X	X	X		X		X				X	6	X
Sunnyside	X	X	X		X						X	5	X
Sandy/Duval Creeks	X	X	X		X		X					5	X
Yarrowyck Art Site	X	X	X	X					X			5	?
Saumarez Creek	X	X	X	X								4	X
Querra Creek	X	X	X		X							4	X
Little Llangothlin Lagoon						X				X		2	?
Chiswick	X	X										2	?
Thomas Lagoon	X	X										2	?

As Hayden (1977) observed, it is not always necessary to manufacture a formal tool to perform a particular function and indeed unretouched flakes seem to be used for all craft functions but not reused (Hayes *et al*. 2020). However, Odell (2003), and Hayden *et al.* (1996) argue that tool design analysis should be directed "to the prehistoric strategies facilitated by these tools rather than solely to the characteristics of the tools themselves" (Odell, 2003: 192). The vast majority of New England sites comprise of flakes, flaked pieces and occasionally cores. We have therefore selected only those sites in which there were at least 20 artefacts, in which there were more activities/tools than just the production of flakes, flaked pieces and cores (Table 6.7).

Table 6.7 shows the artefact types from 12 sites, where each item is counted as present or absent. The sites with the greatest diversity of artefacts have between five and seven items present (out of a total of 14 items). Not all sites with high scores are considered aggregation sites, due to the small number of artefacts and the lack of other relevant factors being present. Also, large sites can be frequently used by a residential group that perform different activities on different visits. Evidence for a wide range of activities at Baldersleigh includes the presence of mullers, ground-edged axes, very small thumbnail scrapers and to 50 mm long points. This site we interpret to be a potential aggregation site. Similarly, the site at Barley Field Lagoon, contained backed blades, points, and a muller. This site also covers a large area and contains numerous axe-grinding grooves. Other sites that extended over large areas are at Querra Creek and Saumarez Creek.

TABLE 6.8 POTENTIAL PLANT FOODS IN NEW ENGLAND (BECK ET AL 2015, BECK & BALME 2003, BECK 1985, GODWIN 1990).

PLANT	COMMON NAME	USE	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Boerhiva diffusa	tartar, towtar	creeper												
Brachychiton populneum	kurrajong	seeds, root												
Acacia sp.	wattle	gum												
Capparis mitchelli	native orange, native pomegranate	fruit												
Cissus hypoglauca	native grape	fruit												
Dioscorea transversa	yam	tuber												
Eustruphus augustifolius	wombat berry	seeds												
Exocarpus cupressiformis	native cherry	fruit												
Ficus sp.	fig	fruit												
Glycine tabacina	goonerang, glycine pea	root, fibre												
Eucalyptus viminalis	manna	sweet starchy extrusion												
Phaseolis truxilleusis	koomine bean	root, fibre												
Typha sp.	typha	swamp yam												
(the above data is compiled from Godwin 1990)														
WETLAND PLANTS														
*Eragrostis brownii**	Browns love grass	seed												
*Glyceria australis***	Australian sweet grass	seed												
*Juncus fockei**	slender joint-leaf rush	seed												
*Nymphoides geminata***	entire marsh wort	root (food)												
*Panicum laevifolium***	land grass (millet)	seed												
Poa sp.*	native grass	fibre												
*Potamogeton ochreatus***	blunt pondweed	root (food)												
*Potamogeton tricarinatus***	floating pondweed	root (food)												
*Carex gaudichaudiana***	tufted sedge	fibre												
*Eleocharis sphacelata***	spike rush	baskets, mats												

KEY to references * Beck & Balme 2003 **Beck 1985

KEY

AUTUMN WINTER SPRING SUMMER

Table 6.8 - Potential food resources and seasonality

6) Some activities different from those found in smaller sites: Multi-activity areas

In addition to a greater variety of tool types representing different activities, aggregation sites would also be in the vicinity of other ceremonial places such as carved trees, stone arrangements and art sites (Figure 6.3). Generally small sites might be less common in these areas.

7) Ecological factors that might have prompted or contributed to the aggregation

Collective resource gathering (criteria 1 and 2)

Gardner (1854: I: 18b) observed a large group of people performing a community kangaroo hunt using a net made from kurrajong fibre. Women and children herded kangaroos into the net that was strung across their path where they were killed by the men. Making a net sufficiently large for such hunts involves stripping the kurrajong bark, twisting the strips into cords with which to weave and knot and would have taken women over 250 hours to make 80 m of cord (Satterthwait 1987: 615), or many people working together over a shorter period. That indicates the net-making and the hunting group were connected to a large meeting of people, as well as a large number of kangaroos.

Important plant resources for the region are listed in Table 6.8. The starchy root foods especially could be used during aggregations and are available in winter and autumn. Australian wetlands such as lagoons could be important resources in Aboriginal aggregation and dispersal:

> Wetland ecosystems have always played an important role for the Aboriginal people in terms of subsistence, settlement patterns and mobility. Their seasonality (in both the north and south of the continent) did not make wetlands a reliable source of food or water. As a result, people occupied their margins but still remained linked to more permanent food resources. During periods of peak productivity, however, wetlands were able to support high populations of hunter-gatherers and also offered opportunities for gatherings of different groups. For how long the gatherings took place, and how large the population was depended on the size and location of the wetlands. The historical model of wetland use-whereby campsites were clustered along the wetland edges (to take advantage of wetland resources) has also been confirmed by archaeological evidence. (Menotti 2012: 80).

Our earlier research (Beck *et al.* 2015) is in agreement with Menotti's observations and indicates that in New England, the higher altitudes correspond with both lagoon locations and ceremonial sites. Lagoons here were temporary but most productive when the moist littoral zones are most extensive, which would not be in summer when rainfall is highest and the lagoons full. So Autumn, Winter and Spring could see optimum seasonal biomass productivity for aggregations of people.

8) Range of groups

A mixture of different people, tribes and cultures (Criterion 8)

The most obvious indication for aggregation sites is the historically observed flow of people on to the Tablelands referred to previously in this chapter. As Fife (1997) points out, people came to the tablelands for two reasons, to attend initiation ceremonies, or to attend trading and marriage corroborees. However, because the open sites contain little else other than stone artefacts, we have no easy way of identifying which of the two gatherings any aggregation site is associated with. One method could be the sourcing of stone raw materials on large sites, as foreign raw materials could indicate contact or trade. Binns and McBryde (1971) initiated work into this for stone axes, but further research is needed into the archaeology of ceremonial sites and raw material sources.

As a final observation of the practical argument for differentiating site types comes down to the suitability of the environment. A suitable camp site for a group of 150-200 or so people from four different tribes has to be a large enough for them all to camp on level ground and still be close to a reliable water supply. This rules out many of the sites as being 'ceremonial satellite camps' (Figure 6.3). Table 6.9 lists the other sites referred to in this chapter which are clearly in confined spaces and with limited water and totally unsuitable for a large camping area. Thus, further research into appropriate applications of Conkey's criteria for aggregation sites would help to understand better how the archaeological record of stone artefacts, bora, stone arrangements and carved trees might fit together.

Table 6.9 showing how Conkey's 8 criteria are used to determine aggregation sites (indicated in the column A/C site [aggregation or ceremony], yellow indicates ephemeral water resource)

Site	No of artefacts (Est = Estimate)	1	2	3	4	5	6	7	8	Total all criteria	A/ Csite	Nearest water	Dist m
Yarrowyck Art Site	Est >2,000						x		x	2	C	Rocky R	1,800
Church Gully	182											Rocky R	30-50
Reddestone Creek	Est >200					?	?			2		Flood	5-50
Big Llangothlin Lag	Est >3,000	?	?	?		x	x	x	x	7	A	Adjacent	10-40
Little Llangothlin Lag	Est 2,000		?			?	?	x	?	5	A	Adjacent	10-40
Apple Tree Quarry	Est >5,000						x			1		Yoogoonda Gully	300
Saumarez Creek	>5,000	x				x		x	x	4	A	Adjacent	10-30
Salisbury Waters	123							x	x	2		Adjacent	10-30
Dangars Lagoon	Est >200											Adjacent	10-30
Boorolong Creek	Est >200											Adjacent	30-75
Blue Holes	40							x		1		Vicinity	30-50
Black Mountain	117				x		x	x	x	5	C	Gully	250
Dangars Falls	72											Vicinity	20-50
Cluny Road	Est >200											Spring	20
Hillgrove	26							x		1		Pint Pot Creek	300
Blackfellows Gully	Est >2,000							x		1		Adjacent	30-50
Rockvale Road	42											Yoogoona Cr	10-40
Baldersleigh	Est >5,000	x	?	x		x	x	x	x	7	A	Adjacent	10-40
Querra Creek	Est >3,000	x	?	?		x		x	x	6	A	Adjacent	10-30
Sunnyside	Est >5,000	x	?	x		?		x		5		Vicinity	10-99
Chiswick AGG	Est >3,000						x	x	x	4	C	Gully	350
Thomas Lagoon AGG	Est >3,000						x	x	x	3		Vicinity	80

Site	No of artefacts (Est = Estimate)	1	2	3	4	5	6	7	8	Total all criteria	A/ Csite	Nearest water	Dist m
Alfoxton AGG	Est 100						x			1		Gully	600
Mount John AGG	0											Gully	1,100
Gostwyck AGG	Est >3,000	x		?			x	x	?	5	?	Gully	700
Barley Fields	Est <3,000	x	?	?		x	x	x	x	7	x	Adjacent	20-60
NETEC	14											Gully	30-50
Devils Pinch	11											Spring	5-20
Cressbrook AGG	>10							x		1		gully	40
Primrose Hill	Est >3,000	x						x		2	x	Adjacent	10-40
Sandy/Duval Creeks	Est >3,000	x		?		x	x	x		5	x	Adjacent	30-80
Laura Creek	Es t>500											Laura Cr	15-40
Racecourse Lagoon	7											Adjacent	15
Kings Plains Lagoon	Est >200											Adjacent	35
Laura Creek 2	6											Adjacent	15-50
Mt Yarrowyck carpark	Est >200											Rocky River	700

Conclusion

This chapter has been both an inventory of the surface archaeology of NEB (for comparison with the subsurface archaeology in Chapter 7), and the potential social and economic role of lagoons. The overall density of sites in New England is low: between 3 and 4 sites/km sq. and the site sizes are also low - on average less than 20 artefacts/site (Godwin 1990; Desic 2018). This is similar to the low densities at high altitudes in the southern uplands of NSW (Chapter 7). While the artefact sample sizes referred to in this chapter are small (with 2 to 1790 artefacts per site), they have served to illustrate the potential differences in site size and content between sites left by small residential groups, and sites left by large mobs of people attending ceremonies or corroborees. An important outcome of the analysis has been to show the potential of Conkey's criteria for identifying aggregation sites in Tablelands archaeology.

We have also provided evidence that refutes McBryde's and Bowdler's assertions that there was no seed-grinding on the tablelands and we suggest that, like Graman (McBryde 1974) on the western slopes, grass seeds were being ground. The predominant stone material used for artefacts is silcrete (41%) and the most frequently found formal tools manufactured from silcrete are backed blades, points and scrapers in small numbers. Quartz (14%) and metamorphic stone (13%) are the next most frequently used raw material. There is little difference between the lagoon assemblages and those away from lagoons, except that the lagoon assemblages are usually smaller in area and number of artefacts.

One suggestion which could account for the small site size at lagoons is that the major tools used for lagoon resource are nets and wooden tools, rather than stone tools (Godwin 1990). As the lagoons are only a metre or so deep when full, and with high evaporation rates, lagoons like Barley Fields, may dry out within weeks although the largest lagoons, such as Big Llangothlin, still retain subsurface water (Beck *et al.* 2015), When they are partly full the lagoons are rich in plant and animal resources (Beck *et al.* 2015), which are different from those in streams, but being so temporary cannot necessarily be relied

on when planning a gathering in twelve months time. There will be linkages expected between the lagoons, larger sites with other resources, and ceremonial sites (Menotti 2012).

This research project has significantly increased our knowledge of different site types existing in the New England Tableland Bioregion and provided further proof that the altitude of the site has little to do with its function. The New England Tableland Bioregion is an undulating plateau on which heights of 1,000 m are common. What appears to determine where there are large sites (over *c.*100 artefacts) is the location in relation to social resources and economic diversity.

Godwin's interpretation of the social networks in the late Holocene is that there are very separate Tablelands/Western Slopes versus Coastal networks, 'By manipulation of ritual information and social isolation they sought to establish exclusive rights to the tablelands, barring or severely restricting their coastal cousins.' Godwin (1990: 381). Thus, rituals with the Western Slopes people could have been most important. Small extended resident family groups can survive on minimal water resources but tenfold demand for a visiting group places a high demand for a reliable water supply. It makes sense that visiting groups travel to and from the Tablelands along the banks of west flowing rivers where they know there will be waterholes and tributary springs. And then on the high country use the resources at lagoons and the woodlands when in season.

As few major archaeological projects have been undertaken here, every new archaeological investigation undertaken in the New England Tableland Bioregion will produce new sites in new contexts and add to the data base. In New England, surface artefacts are assumed to be deposited within the last 1000 years, but there is still a lot to be learnt about the open sites, especially a more detailed location and raw material analysis of artefacts in the New England Bioregion, before we can positively link sites into a cohesive association or to any particular event such as a ceremonial gathering or corroboree. What is missing from our research are the regional landscape links-social and physical- defining landscapes of habit and social landscapes, not only places where people worked and lived, but also tracks and pathways and areas never or rarely visited (Gamble 2002: 97). Future research can uncover these.

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Chapter 7:
Lagoon Excavations:
New England Tableland Bioregion

John Appleton and Wendy Beck

Introduction

This chapter records the results of the archaeological excavations at seven lagoon locations on the New England Tableland Bioregion. These were selected because they represented environments, mostly lunette dunes, in which there is greatest potential for sub-surface artefacts to occur in dateable contexts. Due to the regional geology, there are very few caves with stratified deposits in which artefactual material might be found, and few sites with dateable organic material. In previous research a few excavations have been undertaken in granite 'shelters' that are no more than overhangs on the lee side of large boulders or in open sites where there is both surface artefacts and sufficient depth of deposits to suspect that there is also subsurface material.

Godwin (1990: 18) says of raw material for artefact manufacture:

> In terms of raw materials for stone artefact manufacture the tablelands offer a wide diversity and widespread but limited outcrops... of good quality. The Paleozoic rocks offer cherts, mudstones, jasper and greywacke...Volcanics and metamorphics provide the raw materials for high-quality ground-edge tools. ...there are outcrops of silcrete throughout the southern portions of the tablelands...

Beck *et al.* (2015) reviewed the paleoecological literature on Aboriginal resources of New England lagoons, including economic vegetation and fauna, in order to document the potential foods for the region over time. They found that resource productivity of lagoons can be high, especially in the early and very Late Holocene. Ecological productivity is highest, not at the lake-full stage, but when the moist littoral zones are at their most extensive. The reasons for the apparent sparseness of Aboriginal sites in the high country before the mid-Holocene are unresolved, but may be related to lagoon productivity, and the mid-Holocene appearance of new technologies may have enabled more efficient use of resources. In the later Holocene, Aboriginal occupation in upland areas becomes more visible in the archaeological record.

As described in the preceding chapter, there are now known to be numerous artefact scatters and isolated finds throughout the New England Tableland Bioregion. However, without a stratified dateable context there is no certainty that any two sites were contemporaneous or which sites are 'old' and which sites are 'young'. Land use and the impact on soils to extremes in weather have both exposed and disturbed artefacts which are now found in un-dateable, unstratified surface contexts.

The following section briefly summarises the results of all known excavations prior to 2012 to provide a backdrop for the results of the excavations undertaken for the Lagoons project.

Previous Subsurface Investigations

Prior to 2012 our knowledge of the sub-surface archaeology of the New England Tableland Bioregion was based on the results of the following excavations, which are divided into two categories - dated and undated deposits. All dates are late Holocene. Undated excavated deposits contain insufficient organic material for radiocarbon dating, but do contain artefacts for comparison.

Dated using radiocarbon:

- Bendemeer (McBryde 1974) (Note Bendemeer is not in the New England Tableland Bioregion (NETB) but in the adjoining Nandewar Bioregion); it is included for reasons explained below)
- Reddestone Creek (Horton and Connah 1981).

Excavations which are not dated by radiocarbon:

- Mount Yarrowyck (Williams 1980)
- Church Gully (Bowdler 1981)
- Saumarez Creek (Godwin 1990)
- Cluny Road, excavated by Appleton in 1990 (Davidson & Appleton 1990a & 1990b)
- New England Traffic Education Centre, excavation using heavy machinery (Appleton 1990a and 1990b)
- Devils Pinch, mechanically excavated (Appleton 2003)
- Sunnyside, mechanically excavated (Appleton 2005, 2007 & 2009).

McBryde – setting the benchmark

The first recorded archaeological excavation on the Northern Tablelands was performed by Isabel McBryde in the early 1960s long before the National Parks & Wildlife Act 1974 (as amended), was enacted. McBryde's objective was to identify and compare subsurface artefactual material in stratified occupation deposits in order to establish the age and sequence of various technological changes over time. She chose five sites in three different regions, one in the Clarence Valley, two on the Northern Tablelands (Bendemeer 1 and 2), and two on the western area (Graman GB1 and GB4) in order to compare assemblages from coast, Tablelands and Western Slopes. One of the sites she chose for the Northern Tablelands was Bendemeer, located between Uralla and Moonbi, 75 km southwest of Armidale, near the southern boundary of the New England Tableland Bioregion with the Nandewar bioregion (NSW Department of Planning Industry and Environment, NSW Bioregions 2021).

With no previous structured archaeological approach to the archaeology on the Tablelands, McBryde focused her general study on sites known for their association with past Indigenous activities. Such sites comprised predominantly of art sites, Bora rings, quarries, stone arrangements and places of ceremonial and/or religious significance. At a time when Indigenous sites were not protected the emphasis was on sites with a visual impact and so less visible sites were either ignored or not recorded or unknown.

McBryde (1974) wrote that most of the sites she surveyed were coastal middens or rock shelters, noting that open sites could also be valuable archaeologically. In the early 1960s Isabel McBryde pioneered the archaeological investigation and recording of Indigenous archaeological sites on the New England and provide the only large dated excavated locations similar to environments in the NETB that can provide comparative assemblages for our excavations.

Dated sites

Bendemeer 1 and 2

In 1964 McBryde selected a site at Halls Creek, west of Bendemeer and 75 km southwest of Armidale, where she excavated the occupation deposits beneath the overhangs of a number of massive granite boulders on which there are Aboriginal paintings (McBryde 1974). In addition to her intention to recover a sufficient number of stone artefacts to identify specific stone tool manufacturing techniques, she also hoped to recover material that would be dateable using radiocarbon dating. The site occurs at 750 m AHD.

Having determined which deposits she would excavate, McBryde began at Bendemeer 1 (McBryde 1974). The completed excavation was five feet wide and 17 feet nine inches long (approximately 1.5 m wide x 5.3 m long) aligned perpendicular to the body of art work. Although McBryde suspected that the upper levels had been disturbed, she was able to identify hearths from concentrations of charcoal and ash. As she went deeper the deposits became more easily identifiable as stratified units and in 1965, she found a number of 'finely-made' flake and blade tools including geometric microliths and points manufactured from a variety of siliceous rocks as well as in clear quartz.

McBryde (1974) observed that the industry represented by her finds was predominantly of blade tools, dominated by Bondi Points and geometric microliths, associated with fabricators, elouera, burins and scrapers, together with ground-edge tools. McBryde was surprised to find that in one level of Bendemeer 1 there were 204 formal implements comprising Bondi Points, microliths and elouera, out of an assemblage of only 291 artefacts, which at 70% was a significantly higher percentage of the assemblage than McCarthy had *found* in the Capertee Valley (42.2%). Only recently McCarthy (1964) had established clearly identifiable morphological attributes of artefact types and technologies which at the time, were used by archaeologists as a reference base with which to analyse assemblages elsewhere.

Perhaps not surprisingly, such a large excavation in Bendemeer 1 yielded a vast quantity of artefacts. McBryde (1974) recorded a total of 18,269 artefacts of which 17,327 were waste material. Of the 942 diagnostic items, 11 were complete or fragments of ground-edged axes, 128 were Bondi Points, 239 geometric microliths, 313 cores, 29 burins, 27 eloueras, and 47 scrapers. This assemblage was dated at the time to between 320 and 1340 BP (uncalibrated).

While the Bendemeer sites are technically outside the NB and in the Nandewar Bioregion, they are not far from the border between the two and represent a body of information to which any NEB subsurface archaeology can be compared given the almost complete absence of any other known such detailed analysis of subsurface material in the NEB.

McBryde (1974) made two observations particularly relevant to the current investigation. First, none of the dates she published in the 1960s from c14 dating were older than 1,340 BP (uncalibrated from Bendemeer 1). Secondly, she concluded that the Bondaian type assemblage, which included backed blades and in particular geometric microliths, continued in use in northern New South Wales until the recent past – c.1000-1700 BP and possibly until the historic present (McBryde 1977). Unfortunately, while McBryde clinically analysed the dimensions of the points, she did not relate the differences in dimensions to any differences in material. However, as she referred to the assemblage being predominantly of siliceous material and clear quartz, it is reasonable to speculate that the majority of the tools were manufactured from silcrete and crystal quartz.

As McBryde later stated (1974: 34): 'This particular study ... has perhaps concentrated too much on the problems of defining implement assemblages and the presentation of quantitative data on tool types' rather than considering past lifeways.

In 1965 McBryde dug a trial trench approximately 2.4 m long by 1.5 m wide (5 feet wide by 8 feet long) in an adjacent granite shelter, Bendemeer 2, against which she proposed to test the results from Bendemeer 1. She found the artefact assemblage to be similar to that of Bendemeer Site 1, dominated by geometric microliths and Bondi points, and including scrapers, burins and fabricators. In her quantitative analysis of the assemblage of 2,938 artefacts McBryde identified 43 (1.5%) Bondi points, 246 geometric microliths (1.6%), and 55 cores (a ratio to tools in the assemblage of 1: 53).

McBryde obtained radiocarbon dates in the 1960s from samples from the third of five levels in Bendemeer 1 of 1404-1058 cal BP (Gak 708) up to the recent past; and a date for a sample from the lowest level in Bendemeer 2 of 707- 1061 cal BP (Gak 711) (Kigoshi and Kobayashi 1966, Kiyoshi 1967).However, Bowdler and Coleman (1981), Godwin (1990) and McBryde (1977), later cited older basal dates for Bendemeer 1 and 2, suggesting that Bendemeer 1 has a date range of *c.* 3,000 to 300 BP, and Bendemeer 2 a range between *c.* 4,350 and 950 BP. Presumably these refer to samples dated after the initial excavations in the 1960s. We have not been able to trace details of these samples, but all suggest that the oldest occupation traces in the region, prior to our work, was mid-Holocene.

Reddestone Creek

In the 1980 David Horton and Graham Connah were called out to investigate the discovery of Aboriginal artefacts and Pleistocene megafauna bones in mechanically disturbed deposits at Reddestone Creek, northwest of Guyra, and about 100 k northwest of Armidale, where a dam was being excavated. Horton and Connah (1981) recorded that there were 45 stone artefacts in disturbed contexts, but significantly, the artefacts were from an open site at 1,040m above sea level (Horton and Connah 1981). Twenty-two stone artefacts were recovered during the archaeological excavation including a notched scraper of crystal quartz, and four retouched flakes, eight unmodified flakes, one core, one flaked piece, two 'spalls' and five fragments of debitage of various rock types. Seven other artefacts were recovered from the surface of the dam spoil heaps. In addition, another 18 artefacts had been recovered by someone else between 1977 and 1979. In total 47 artefacts were recovered from the site.

Horton and Connah (1981) concluded that, although 22 artefacts were recovered from stratified deposits, it was possible that the deposits had been disturbed, and that there was no evidence of direct association between the artefacts and the mega-fauna skeletal material. A date of 820 uncal BP was obtained below the artefacts, using radiocarbon dating of organic material, so it is thought that the artefacts were deposited in the late Holocene.

Undated sites

The following list is of sites that have not been dated using radiocarbon, however based on the regional stratigraphy and the artefact composition, all are believed to be late Holocene.

Church Gully

- In 1979 Sandra Bowdler conducted excavations at Church Gully 30 km southwest of Armidale within 30 m of an ephemeral stream. The stream is one of several tributaries of upper Kentucky Creek which rises near Kentucky Lagoon approximately 15 km to the southwest of Uralla, then flows north-westwards into the Gwydir River less than one kilometre to the west of Uralla, and

on into the Barwon River further westwards. Bowdler's excavations were at an elevation of 1,030 m AHD and located in the lee of boulders of a granite tor.

- Bowdler recovered 192 artefacts manufactured from a variety of stone materials, 52% of the assemblage is made from quartz and 36% is of silcrete. The assemblage includes only two tools, one being a backed blade. Bowdler interpreted the archaeological remains as indicating that it was a 'transit' site rather than a camp site, owing to the small numbers of artefacts (Bowdler 1981).

Mount Yarrowyck

In 1980 Williams, an honours student at the University of New England, excavated nine of a series of twenty-five granite rock overhangs at approximately 900 m AHD in the immediate vicinity of the Mount Yarrowyck art site (32 km west of Armidale). Bowdler and Coleman (1981) reported that the artefacts from these sites occurred in densities from 27 flakes per square metre to 300 flakes /m^3 at the art site.

Williams concluded that the art site was, '... occupied at a minimum of 400 years ago, and occupation could have occurred any time between this date and up to 5,000 years ago' (Williams 1980: 81), although this was not based on any absolute dating of material but estimated from the depth of sediment deposition. She also suggested that her findings showed that the adjacent shelters were not habitation sites but might have been sites for maintenance activities, and that, '... the presence of isolated surface finds, the absence of surface occupation sites, together with the paucity of remains from test excavations, suggest that Mount Yarrowyck was not a habitation area but was of ceremonial significance' (Williams 1980: 54). Williams concluded that because of the low densities of artefacts associated with the art site, and a previously recorded Bora ring nearby (Williams 1980).

More recently, Beck, Somerville, Duley and Kippen (2003) noted that within a 20 km radius of Mount Yarrowyck there are six shelters with art, five shelters with occupation deposits, two bora grounds, 16 open campsites, three isolated finds, three axe-grinding groove sites, two burials, two scarred trees and a stone quarry. Later anthropological research has proposed that Mt Yarrowyck was a male initiation site (Waters 2016: 8).

Saumarez Creek

- In 1990 Godwin excavated two small sections (2 m x 0.5 m) of an open site at Saumarez Creek, 10 km southwest of Armidale at an altitude of 1,010 m AHD. Godwin's objective was to locate artefacts in knapping floors and in direct association with organic or charcoal material that could be dated. The number of artefacts found was 135, all in the A horizon, less than 10 cm from the surface. Silcrete was the dominant raw material. No dateable material was found (Godwin 1990).

Cluny Road, Armidale

- In 1990 Appleton conducted hand-dug test-pitting excavations at Cluny Road in Armidale prior to the construction of an overpass for the New England Highway realignment. He had previously identified a number of artefacts eroding down the batter in the road easement to the eastern side of Cluny Road at an altitude of 1,010 m AHD. Sixteen artefacts were recovered from the batter and crest of the bank, and six additional artefacts were recovered from a series of randomly located test pits upslope of the batter (Davidson and Appleton 1990a and 1990b). No artefactual material was recovered from a dateable context.

New England Traffic Education Centre

In 1990 Appleton conducted an investigation of the site of the proposed New England Traffic Education Centre in Armidale, after several artefacts had been observed in patches of bare ground in the initial survey of the site. He recommended that, given the dense vegetation that covered most of the site, he should conduct a further investigation after the ground-cover had been stripped. Subsequently, 18 artefacts were recovered from the ground surface and an additional four artefacts were recovered from the mechanically altered surface. A woman's birthing site (a scarred tree), was also recorded and preserved and protected by a surrounding barrier of treated timber poles (Appleton 1990a,1990b). No dateable material was recorded.

Devils Pinch

In 2003 Appleton conducted a 'grader-scrape and spray' excavation at 1,270 m AHD at the top of the Devils Pinch section of the New England Highway 25 km north of Armidale. There was no surficial archaeological evidence to prompt the investigation but the owner of the property told him that she had seen artefacts dug up by her brother when planting fruit trees on the property 40 years previously. As the owner had been a student of McBryde's, Appleton did not question her ability to recognise Aboriginal stone artefacts.

The excavation method required a grader to remove the turf and then the underlying deposits in approximately 5-8 cm deep strips. Water was then applied in a spray from a water-truck between each layer being removed. The exposed surface and windrow was thoroughly inspected for artefacts prior to the next strip being removed. A total of 11 artefacts were recovered from the excavation (Appleton 2003). No dateable material was recorded.

Sunnyside Road

In 2005 Appleton undertook the investigation of the proposed route of the realignment of the New England Highway opposite its junction with Sunnyside Road, 20 km north of Armidale, at an altitude of approximately 1,010 m AHD. An open artefact scatter had previously been recorded in the area between two permanent waterholes in Tillbuster Ponds, but during the 2005 investigation he found that the site extended up to 100 m away onto the footslopes of the western valley slopes that bracket the site.

The additional artefacts were found on an undulating lower slope, part of which was concealed beneath a build up of slopewash. Subsequently a 'grader scrape and spray' excavation was used to ensure that there were no artefacts concealed beneath the accumulated deposits in the swales. The collection of surface items yielded 138 artefacts, and an additional 73 artefacts were recovered during the mechanical stripping of the swale deposits. The total of 211 artefacts (Appleton 2005, 2007, 2009) provided useful data in the analysis of the results in the current investigation. No artefacts were recovered from a dateable context.

Summary

There are two rockshelters in this sample of seven sites–Church Gully and Mt Yarrowyck–containing 192 and 300+ artefacts respectively, the largest assemblages of this group. One other site was stratigraphically excavated – Saumarez Creek open site (135 artefacts). The other four sites are open sites (extending over several tens of metres) where the artefacts were recovered for salvage by grader scraping. Grader scraping is a commonly used technique for establishing site presence and salvaging artefacts in development archaeology, but it was not very helpful for dating in this case. The number of artefacts

recovered at the open sites ranged from 211 to 11 artefacts. All sites are at high altitudes ranging from 900 m to 1270 m.

Notably, the only site in the NETB proper reviewed above that yielded absolute archaeological dates was at Reddestone Creek, which was dated to 820 BP. The oldest dates are from the Bendemeer sites are 4350 BP.

Selecting lagoons for this research project

The seven lagoons chosen were (from south to north):

1. Dangars Lagoon, Uralla
2. Barley Field Lagoon, Uralla
3. Thomas Lagoon, Arding
4. Big Llangothlin Lagoon, Guyra
5. Barley Field Lagoon, Glencoe (referred to as Glencoe here to avoid confusion)
6. Reddestone Creek, Glen Innes
7. Kings Plains Lagoon, Wellingrove.

More details about the selection process can be found in Chapter 3. The lagoon locations are mapped in Figure I.2 in the Introduction. The only sites where knappable silcrete stone outcrops occur are Barley Field Lagoon and Thomas Lagoon.

Having applied for and received Aboriginal Heritage Impact Permit (AHIP no C0002673) to conduct limited excavations in specific locations at each of the seven research sites, the team, including Aboriginal representatives for each of the LALC management areas relevant to the research location, began a series of excavations that were to take several weeks to complete.

The Lagoon Excavations

Dangars Lagoon, Uralla

Location

Dangars Lagoon is located 27 km southwest of Armidale adjacent to the Uralla to Walcha Road and 300 m to the east of the main northern railway line.
The geology and topography

Dangars Lagoon is an ephemeral lozenge-shaped lagoon in a shallow depression in granite/basalt/diorite derived sediments. The area of the lagoon when full is 55 ha (550,000 sqm), and occurs at an altitude of 1,022 m AHD. A remnant of a steep-faced lunette occurs at the north-eastern rim of the lagoon, and the Uralla/Walcha Road forms a barrier along its western margin. The south-eastern edge of the lagoon was the natural outflow but it was raised artificially to increase the depth of the lagoon and to increase the length of time that the lagoon held water - primarily to provide water to the gold workings at Rocky River for longer periods.

The lagoon is watered by run-off from the gentle slopes to the southwest but, because of the artificial banking to the south-eastern section, it is not clear how deep the lagoon was when full prior to the banking being constructed in the nineteenth and twentieth centuries (Uralla Visitor Centre nd).

History of Land Use

Prior to the gold rush at Rocky River the lagoon was used to water stock from nearby farms but, when gold was discovered at Rocky River in 1851, the eastern bank of the lagoon was raised and the water was diverted to the goldfield via a 2 km long race where it was used for sluicing. In 1925 the lagoon was declared a bird and animal sanctuary, and its name was changed from Salisbury Lagoon to Dangars Lagoon. In the early 1930s the lagoon became a popular venue for picnics and swimming carnivals and in 1940 the lagoon became a Travelling Stock Reserve (Uralla Visitor Centre nd). In 1972 the lagoon was declared a Wildlife Refuge and is now managed for nature conservation, complete with a bird-watching hide on its south-western corner.

The Archaeological Record

Artefacts have been observed exposed in an unsealed road that leaves the Uralla/Walcha Road adjacent to the north-western corner of the lagoon and follows the line of the eastern side of the lagoon carving a cutting through the lunette. Artefacts have been appearing in the track through the lunette for at least thirty years. Godwin (1990) reported finding 17 artefacts in the same area including two chert backed blades, and more than 15 artefacts have been recorded in the same area by Beck and Appleton over a period of ten years prior to the current investigation.

Excavations

Five pits were excavated in the remnant naturally formed section of the lunette in the north-eastern corner. Three pits were aligned west/east and measured from the crest of the lunette down to the water line at intervals of 0.5 m, 4 m, and 8.5 m. A parallel line of two pits 5 m to the north of the first line of pits were identified as 11m and 20 m. Each of the pits was dug to the top of the B Horizon which comprised a cemented layer of ferricrete. Pit 0.5 m was 1 m x 1 m, but the others were all 1 m x 50 cm in area. The area of excavations is shown in Figure 7.1. More detailed stratigraphic descriptions of the excavations are in Appendix D.

The stratigraphy is constant in each pit and comprises a shallow turf layer overlying a compacted pale sandy layer - the bottom few cms of which contained some loose angular gravel. This layer was immediately above ferricrete, at depths of approximately 90cm from the surface. Excavators recorded that in 'Pit 0.5' near the crest of the lunette there is little obvious layering in the deposit, but that the sediment is a loamy sand with Munsell of 7.5YR 6/3, Light Brown. The southern section of the Pit 0.5 is shown in Figure 7.2.

Artefacts had previously been observed in a vehicle track that slices through a lunette on the eastern side of the lagoon, and so the excavations were in the lunette between the lagoon and the road. Unfortunately, very few artefacts were recovered. We agreed that the most likely place where artefacts might be found is the back or lee of the lunette which is occupied by stock-yards on a private property. However, the very disturbed nature of the stockyards sediments made such an attempt unviable.

Results

Summary:

- 'Pit 0.5 m' was excavated to a depth of 95 cm. A single artefact was recovered from Spit 35-50 cm. An OSL date for a sample taken at 38 cm returned a central age of 1.88 ka.
- 'Pit 20 m' was excavated to a depth of 80 cm. Two artefacts were recovered from spit 43-46. Two samples were taken from the same spit and were OSL dated, the first returned a central age of 6.63 ka, and the second returned a central age of 6.23 ka.

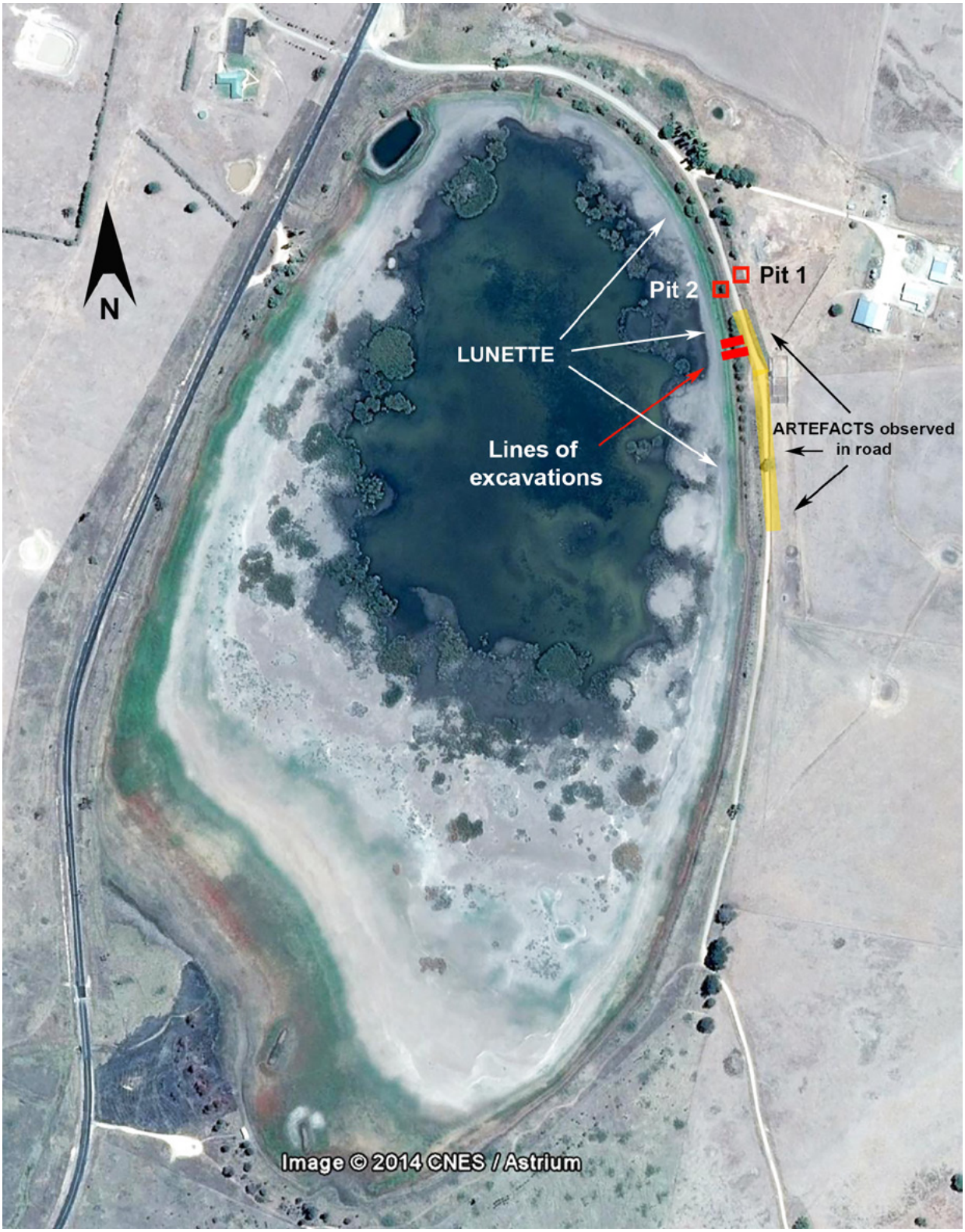


Figure 7.1 *Area of excavations (in red) and geomorphology pits 1& 2 at Dangars Lagoon*



Figure 7.2 *The Southern Face of Pit 0.05 Dangars Lagoon*

- The only other artefact, a backed thumb-nail scraper of crystal quartz, was recovered from Spit 9-11 cm in 'Pit 4 m'. No dates were recorded.
- No artefacts were recovered from 'Pit 8.5 m'.

It is interesting to note that on a return visit to the lagoon, when it was full after heavy rain, only 'Pit 0.5 m' and 'Pit 4 m' were above the waterline.

Conclusion

Only four artefacts in total were recovered, which was disappointing given that there is a history of many artefacts appearing in the track that slices through the top of the lunette. The artefacts were typical of late Holocene assemblages in southeast Australia. However, the results suggest that the artefacts derive from the rear section of the lunette which was not accessible because of the narrow steep embankment beside the road, and because it was occupied by substantial stockyards beyond the fence line.

Barley Field Lagoon, Uralla

Location

Barley Field Lagoon is located 20 km southwest of Armidale at the southern end of the study region. It occurs on the spine of the Tablelands, and the western side of the lagoon is bordered by the main northern railway line and the old Uralla to Armidale Road, now Barleyfields Road. A Travelling Stock Reserve, at the southern end of the lagoon, contains a dam that is used for sustaining stock during droughts.

The geology and topography

Barley Field Lagoon is a lozenge-shaped lagoon in a shallow depression on bedrock. The ephemeral lagoon is approximately 6 ha (60,000 sqm) when full, and occurs at an altitude of 1069 m AHD. A low lunette occurs at the eastern rim of the lagoon of clay pellets and coarse sands (See Chapter 5). The sediments in the eastern section are mostly covered in dense grass but a vehicle track along the crest of the bank has exposed sediments; and heavy stock and vehicle wear in the southern section has exposed clayey soils.

History of Land Use

The history of post-contact use of the lagoon begins with its use by farmers to water their stock, but in 1851 gold was discovered at Rocky River, four km north of Uralla. The only water available at Rocky River was an ephemeral creek from run-off which lasted only briefly after rain, and the lack of water was always a problem particularly as the gold extraction process required high-pressure sluicing. In order to meet the need for water a race was dug to channel lagoon water down from Barley Field Lagoon to Rocky River Goldfield four km away (Haworth 1997). This suggests the Lagoon was more permanent in the recent past.

Construction of the railway line between Uralla and Armidale in 1883, and the ongoing upgrading of the New England Highway have disturbed the local hydrology and water levels have been fluctuating during our project years. For most of the 20th Century the lagoon was part of a Travelling Stock Reserve, but since 2000 the lagoon has been fenced off and is now effectively a protected wildlife reserve.

The Archaeological Record

Prior to this study a previously unrecorded large artefact scatter was observed by Beck and Appleton in the vehicle tracks running east/west along the TSR at the southern end of the lagoon. Further field investigation resulted in finding several exposed silcrete boulders that appear to have been quarried downslope to the south, and additional low-density scatters on the southern slopes north of Uralla. A granite muller was found in the open woodland downslope and 200 m to the southeast of the lagoon.

Excavations

Two excavation areas were investigated: Excavation 1 (E1) near the centre of the eastern lunette, and Excavation 2 (E2) on the southern margin of the lagoon. These locations are shown in Figure 7.3.

At E1 an excavation square 1 m x 0.5 m was pegged out and at E2 two lines 50 cm apart were pegged out, aligned north/south and perpendicular to the southern end of the lagoon and bisecting the area of greatest artefact density in the surface scatter. Selected pits, each 1 m x 50 cm, were excavated between the lines from 59 m from the edge of the dry lagoon. The pits were named: Pits 32, 25, 17, 12 and 2. Each pit was excavated to the ferricrete concretion at the base which was only removable by firstly breaking it up with a mattock; this was assumed to be the base of the potentially archaeologically sensitive deposit. The ferricrete layer became shallower the further away the pit was from the lagoon. More detailed stratigraphic descriptions of the excavations are in Appendix D.

In E2 from the depth of 45 cm to 95 cm the pit was augured in order to identify any change of archaeological interest below 45 cm but no change was identified. It is unclear as to whether the cemented ferricrete is the base of the cultural deposits but either way it is impenetrable by trowel and only loosened by pick. A sondage 25 cm x 25 cm was removed in E1 to ensure that the ferricrete layer was only a shallow anomaly

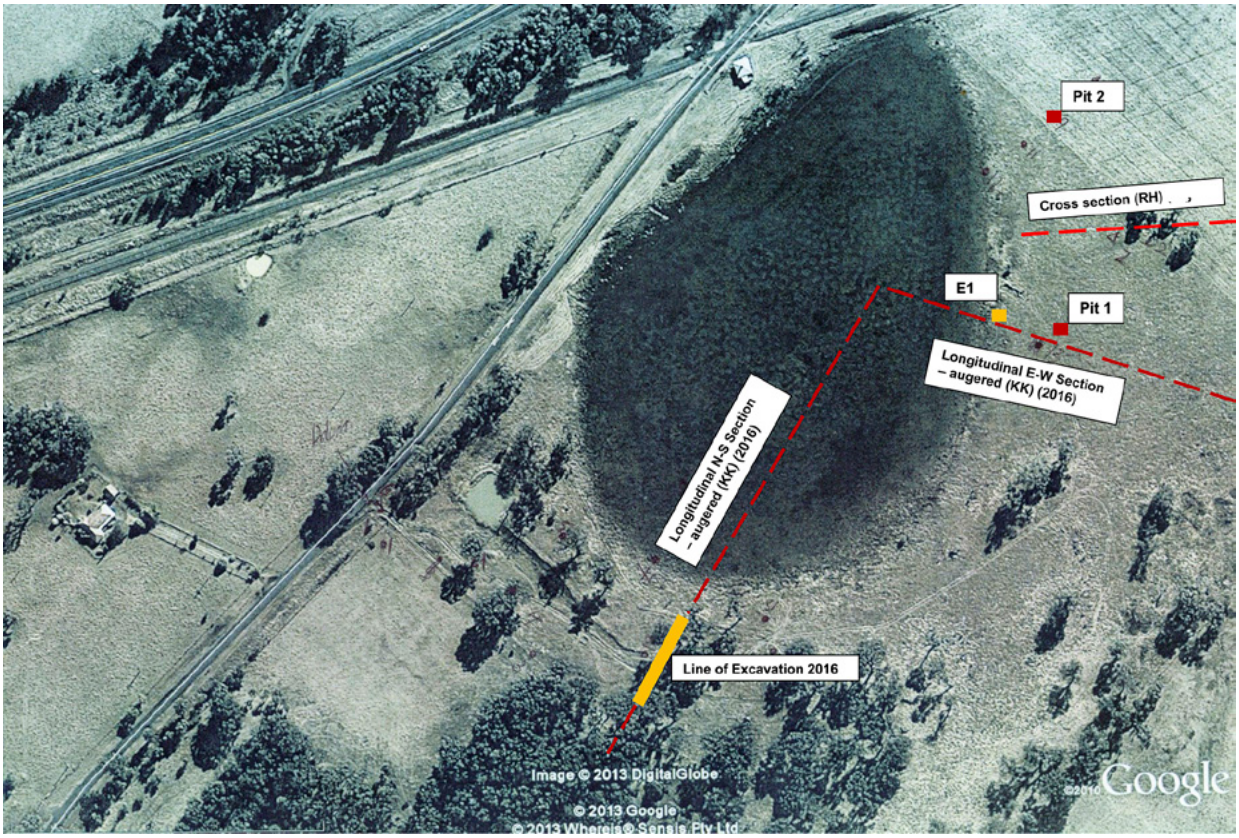


Figure 7.3 *Barley Field, Uralla, Lagoon showing excavation locations (yellow) and geomorphological investigations (red)*

but it was found to continue deeper. We decided that the feature was archaeologically sterile and that it did not warrant the effort necessary to excavate it. The eastern section of E1 is shown in Figure 7.4.

Results

Piit, 'E1'(1 m x 1 m) was excavated in the lower face of the lunette on the eastern side of the lagoon. Two artefacts were recovered, one from the 28-32 cm spit depth, and the other from below 32cm. These are shown in Table 7.1.

The first sample at 31 cm depth was OSL dated to a central age of 6.34 ka; a second sample at 40 cm depth was OSL dated to a central age of 7.75 ka; and the third sample from 42 cm depth was OSL dated to a central age of 6.75 ka. However, the 31 cm sample has 51.1% of the measured components at a most recent date of 6.80 ka; the 40 cm sample has 69.4% of the measured components at the most recent age of 8.34 ka; and the 42 cm sample has 64.7% of the measured components at the most recent age of 8.62 ka. The ages reflect the high dispersion (see Chapter 4, and Table 4.2). In summary, three OSL ages were obtained, the older ones dating from between 5000 and 9000 BP. These are currently the oldest dates for artefacts on the New England Tablelands.

Summary for E2: (each pit was 1 m x 50 cm):

- Pit 32 contained 14 artefacts, the lowest being at 33-35cm spit depth, five artefacts occurred in spit 11-16 cm from which a C14 date of 2290-2150 cal BP was obtained on charcoal. Three



Figure 7.4 *Eastern Face of Pit E1, Barley Field Lagoon, Uralla*

artefacts were recovered from spit 33-35 cm beneath an OSL date taken at 30cm with a central age of 3.14 ka. A lower date at 47 cm had a central age of 8.36 ka,

- Pit 25 contained five artefacts, the lowest being in the 31-35 cm spit depth, three of the artefacts occurred deeper than an OSL sample taken at 24 cm depth which had a central age of 3.53 ka. A sample at 47 cm depth and below the artefacts had a central age of 12.4 ka, and one below that, at 51 cm, had an age of 7.47 ka.
- Pit 17 contained three artefacts to a depth of 11-13 cm spit. No samples were dated.
- Pit 12 contained two artefacts in the 23-29cm spit depth, both being below the OSL date for a sample at 22 cm depth of 3.23 ka.
- No artefacts were recovered from Pit 2.

Conclusion

Clearly the site on the southern side of the lagoon potentially may contain many thousands of artefacts at different depths based on the several hundred surface finds and the excavated artefacts—the oldest of which, excavated from a depth of 51 cm OSL, dated to more than 4.7 ka and possibly as old as 8.6 ka (See Chapter 4). The artefacts are primarily silcrete (12/28) with quartz and chert making up the remainder, and one flake from igneous raw material (Table 7.1). A sample of quartz and silcrete artefacts is illustrated in Figure 7.5.

The two oldest artefacts (early Holocene) are flaked pieces made of yellow silcrete. The younger artefacts are mainly flakes and flaked pieces with one Bondi Point, which is consistent with the Holocene date of the Barley Field Lagoon site.

Table 7.1 Artefacts and dates of samples: Barley Field Lagoon, Uralla

Key as per Table 6.4 and 6.6'

Location	Site i.d.	Excav. Area (sq m)	Excavation depth cm	Artefacts Total N=28	Artefact types	Raw Material	c14 date calBP	Lab no.	OSL likely age range (ka)
Lunette	BA-E1	0.5	31	1	FP	SIL		UW3479	4.5-7.3
			32-40	1	FP	SIL			
			40					UW3483	5.0- 9.0
			42					UW3482	5.0- 9.0
TSR	BA-12	0.5	22					UW3484	0.6-5.0
			22-23	1	FP	M			
				1	FL	SIL			
	BA-17	0.5	8-11						
			8-11	1	FL	SIL			
				1	FP	SIL			
				1	FP	CS			
			13-16						
	BA-25	0.5	20-22	1	FL	Q			
			22-24	1	FL	Q			
			24					UW3481	1.4-4.6
			24-29	1	FP	IG			
			29-31	1	FP	Q			
			31-35	1	FP	CS			
			47					UW3480	>12.0
			51					UW3485	4.3-10.0
	BA-32	0.5	8-11	2	FP	SIL			
			11-16	4	FP	SIL			
				1	FP	CS			
				1	FL	CHERT			
				1	FL	CHA			
			16				2290-2150	Wk44209	
			16-20	2	FL	SIL			
				1	Bondi P frag	SIL			
			20-28	1	FP	Q			
				1	FP	SIL			
			30					UW3487	1.8-7.6
			33-35	1	FL	SIL			
				1	FP	SIL			
			47					UW3488	3.8-15.4

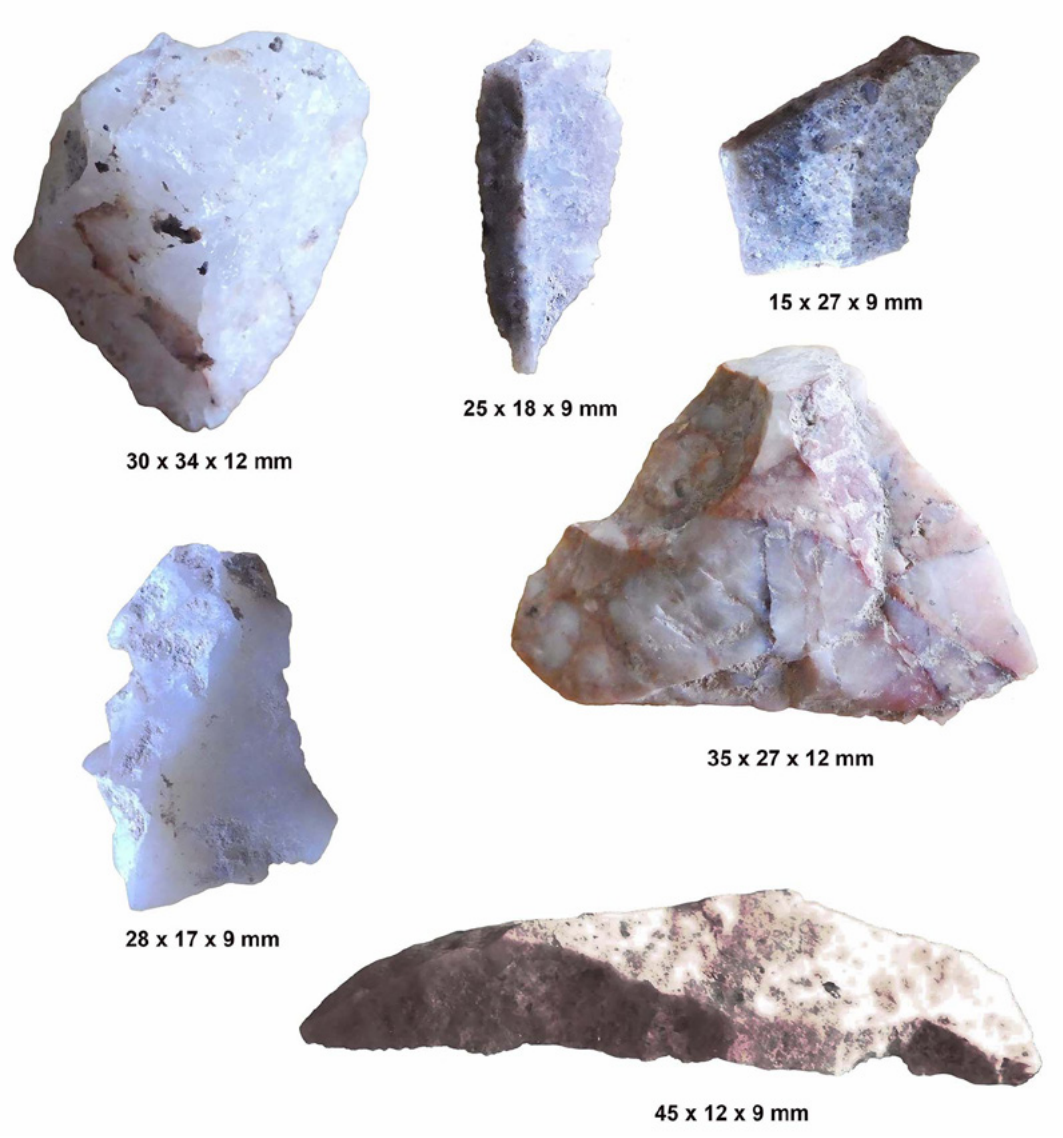


Figure 7.5 *Artefacts recovered from Barley Field Lagoon, Uralla E2 Pit 27*

Thomas Lagoon, Arding

Location

Thomas Lagoon is located 1,500 m north of Arding Road, Arding, and 8 km southwest of Armidale.

The geology and topography

Thomas Lagoon is an irregularly-shaped lagoon, in basalt/silcrete derived deposits overlying Armidale Beds sedimentary bedrock. The lagoon covers an area of 4ha (40,000 sqm) when full, and occurs at an altitude of 1,034 m AHD. The lagoon is approximately 500 m to the east of the 'spine' of the Great Divide and occurs in a broad shallow basin of the upper Saumarez Creek catchment. Contour lines on the Topographic Map (Armidale 9236-4N, 1:25,000) and the changes in colour in a Google image of the area show that the lagoon is a remnant of what was a much larger swamp that included Strahle Lagoon to the west before the area was drained and turned into pasture (Robert Haworth, pers. comm.)

The coarse silcrete bedrock on which the axe-grinding grooves occur are exposed, extends in an arc up to 80 m long in a strip approximately 20m wide to the west of the lagoon at a distance of approximately 100m from the present lagoon. There is no evidence that any of the silcrete has been quarried for knapping material. The lagoon has been dammed in the north-eastern corner, and the axe-grinding grooves where the excavations took place, occur on silcrete outcrops approximately 100m from the western shoreline of the present lagoon, but would have been adjacent to the lagoon or surrounding swamps pre-settlement when the lagoon was larger.

History of Land Use

The land on which the axe-grinding grooves occur was once owned by the late Mr Arnold Goode of Uralla. Mr Goode was consulted during this study and he stated that it had only ever been used for grazing. Within 100 m to the west of the grooves there are remains of stock yards, shed bases, and a well. Currently 'Goode's Paddock' is used for sheep grazing. Mr Goode recalled that the low-lying area between Thomas Lagoon and Saumarez Creek is reclaimed swamp.

The Archaeological Record

When recording the axe-grinding grooves at Thomas Lagoon, the investigators observed numerous surface stone artefacts with no apparent association with the axe-grinding. Not only are the tools manufactured from a variety of materials not readily available at that location, but they also appear to be associated with a wider range of activities other than those associated with axe-grinding.

Excavations

As many of the grooves disappeared under the flood-plain alluvium, it was decided to excavate in two locations, both immediately adjacent to the grooves. The two excavations were located at least 40 m apart, in order to establish any variation. The locations are shown in Figure 7.6. (IM and 27 A, B, C, T).

These pits were excavated in and around the silcrete exposure, in the flood-plain deposits around the axe-grinding grooves. The deposits were visually homogenous with no identifiable stratigraphy with each pit comprising flood-reworked soils aggregated between the silcrete floaters and bedrock. Both pits were dug to the ground level of the base of the floaters on which the grooves occurred. See Figure 7.7 for the stratigraphy.

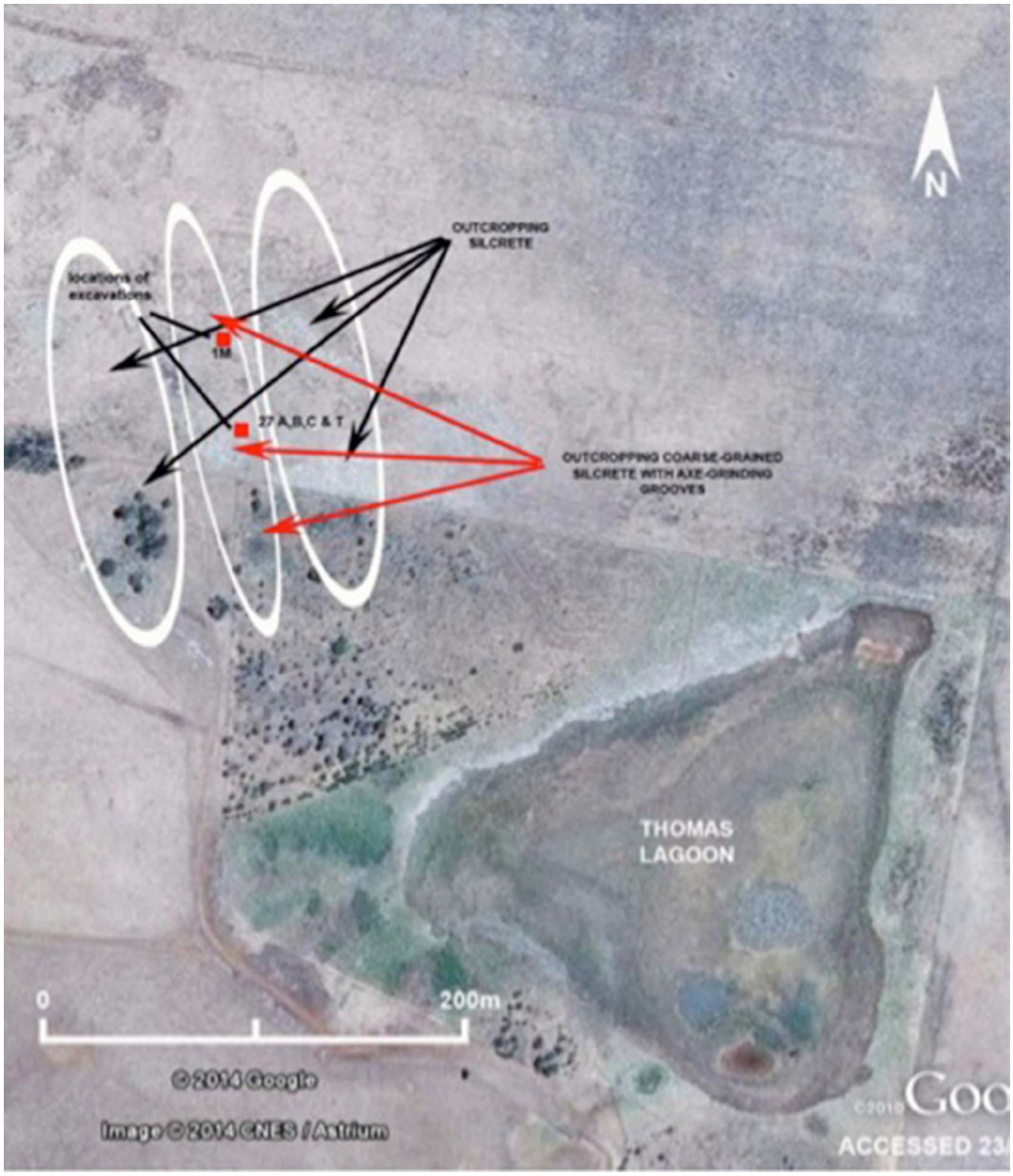


Figure 7.6 *Image of Thomas Lagoon showing location of excavations*

Among the grinding grooves there are a number of lozenge or ovoid shape depressions that are unlikely to have been used to shape the 'blade' of the axe. One explanation might be that these were polishing surfaces on which the body of the axe was ground for aesthetic reasons only, which might indicate that they were being polished to enhance the aesthetic values of axes that would be traded at corroborees. Similar circular ground depressions have been interpreted by archaeologists as seed-grinding bowls or areas reduced by the crushing of roots and tubers (Gorecki *et al.* 1997, Webb, 2007), however our belief is that, if they were seed grinding bowls, the bottoms would be visibly deeper than the sides, and similarly, if used for crushing roots and tubers, the area of impact would be visibly lower than the surrounding ground areas (Webb 2007). The bowl-shapes observed at Thomas Lagoon were uniformly shaped with no visible deeper impact areas.



Figure 7.7 *Overhead view of pit 1M Thomas Lagoon (scale 1 m). Note axe grinding grooves at top and left of image*

Two other test pits were excavated in the stock-degraded area about 30 m to the north of the silcrete exposure in order to test the depth of buried silcrete (not shown in Figure 7.7). No artefacts were found in these pits.

Results

In one 1 m x 1 m pit dug between the silcrete floaters and bedrock 67 artefacts were recovered, and in a second 2 m x 2 m pit, in which 75% of the volume comprised boulders and bedrock, 53 artefacts of different materials were recovered. Of the 121 artefacts from the two pits, 48 artefacts were identified as being trimming flakes from axe blanks. The remaining artefacts are made from a variety of different materials, none of which are directly available in the area, and some of which are retouched tools such as scrapers and points. Four heat-treated silcrete artefacts were recovered from different spits in Pit 27, in which artefacts occurred in every spit from the turf layer to the base at 35 cm below the surface.

Summary:

- 'Pit 1M', a 1 m x 1 m pit, was excavated to a depth of 35 cm which corresponded to the base of the bedrock floaters. Forty six artefacts were recovered from spits 2-5, representing a depth of 22cm. Nine artefacts were recovered from 'Spit 22-26 cm' from which a sample of charcoal produced a

radiocarbon date 600-530 cal. BP. A further 12 artefacts were recovered between 'Spit 26-30 cm' and 'Spit 30-35 cm' but no other samples could be dated.

- 'Pit 27- A, B, C and T', a 2 m x 2 m pit in which more than 75% of the area was occupied by silcrete bedrock and boulders, was excavated to a depth of 35cm. Three artefacts were recovered from 'Spit 5-10cm', which was radiocarbon dated using charcoal, with two dates of 250-140 cal. BP and 220-150 cal. BP. An additional 48 artefacts were recovered in disturbed deposits between 10 cm and 35 cm depth. No other samples could be dated.
- No artefacts were recovered from the two pits excavated on the flood plain more than 20 m away from the nearest silcrete exposure.

Conclusion

As the grinding grooves extend over a large area, there could be thousands of artefacts in subsurface deposits adjacent to the grinding grooves and surrounding area. What is surprising was that trimming flakes from the shaping of the axe blanks and artefacts of different material continued to the base of the excavations. The relatively high density of artefacts in such confined contexts indicates that the site was used frequently during the late Holocene. A recent excavation in 2020 at a group of 270 silcrete axe grinding grooves, about 15 km directly south of Thomas Lagoon, has produced over 2000 artefacts and axe trimming flakes and is radiocarbon dated to 2100-2310 cal. BP (Wk 51390) (Appleton 2021), thus supporting the richness and late Holocene date for this site type.

Big Llangothlin Lagoon

Location

Llangothlin Lake, or 'Big Llangothlin Lagoon' as it is known locally, is located 63 km north of Armidale (Figure 5.3).

The geology and topography

Big Llangothlin Lagoon occurs in an irregularly-shaped basin that conforms to the spurs and valleys of the surrounding catchment area. The bedrock is basalt and granite. The northern and western sides of the lagoon are more undulating than the eastern side and the southern sides and a lunette extends along the eastern rim.

The lagoon occurs at an altitude of 1,354 m AHD and, when full, has an area of 410 ha (4,100,000 sqm). Despite its huge area, it is only one or two metres deep when full and during dry periods most of the lagoon bottom is exposed as vast reed beds and granite boulders. The lagoon is fed by numerous drainage lines but the only apparent drainage line from the lagoon is to the west where a narrow stream discharges overflow into the Mann River.

History of Land Use

The Guyra area was first settled by Europeans in the early 1800s when several settlers took up land. The first written history associated with Big Llangothlin Lagoon describes the part that Bagot's Mill played in flour-milling on the Tablelands in the late 19th century (Connah 1994) Christopher Thomas Bagot began construction of his mill in 1874 employing Chinese workers to build a dam at the outflow of the lake into Mann River – but by 1879 Bagot was bankrupt. There is no evidence that the flourmill was ever completed or produced any flour but, whether it was because of the lack of a reliable water supply or over spending in constructing a saw mill and the flour mill, we do not know (Connah 1994; Pearson 1998).

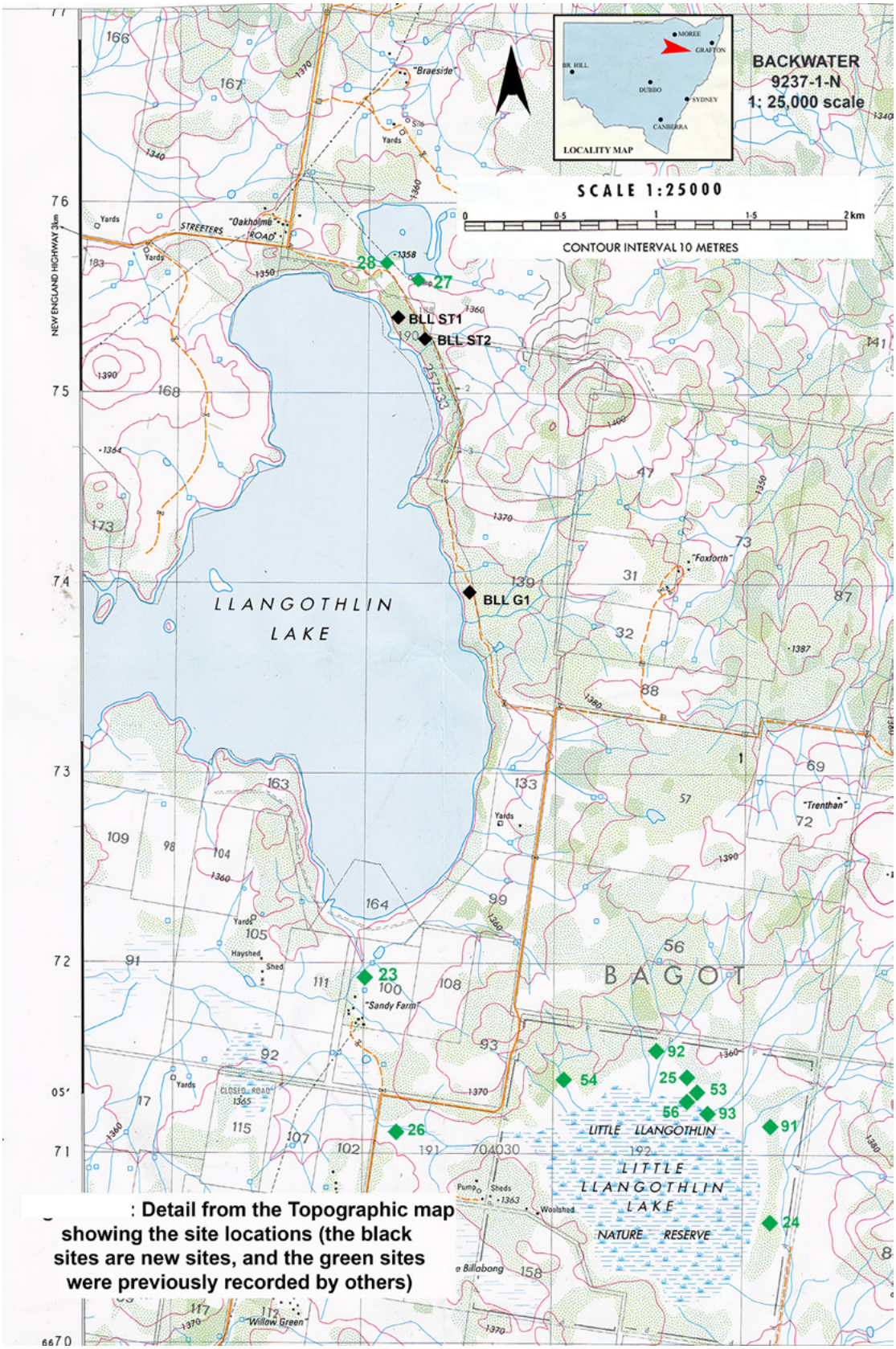


Figure 7.8 *Detail from the topographic map showing archaeological sites near Llangothlin Lake and Little Llangothlin Lagoon*



Figure 7.9 *Image of the eastern margin of Big Llangothlin Lagoon, showing the location of the excavations and newly recorded surface sites*

The Archaeological Record

In 1995 two scarred trees and an open site containing 30 artefacts were recorded on the southern end of the lunette in the south-eastern section of the rim of the lagoon (New South Wales Aboriginal Heritage Information Management Site database). In an attachment to the NSW Site Recording Form for this site, reference is made to several artefacts having been collected in the past including a number of ground edge axes and grinders or mullers – the top stone used in grinding seed.

Davidson (1982) previously reported finding artefacts on the lunette of Little Llangothlin immediately to the south, plus flakes from axe trimming on the lunette, scatters of artefacts to the northeast, on the lunette at the northern end of Big Llangothlin, and on the gentle sloping ground between Big Llangothlin and Little Llangothlin. Also, six ground-edged axes were found by the owner of an adjacent property (and deposited in the Glen Innes Museum) (Davidson 1982).

During the preliminary fieldwork for this research project two more scarred trees were recorded in the northeastern section, and a grindstone discovered midway down the eastern rim of the lake (See Chapter 6). The old and new sites are shown in Figure 7.8.

Excavations

Six pits (1 m x 50 cm) were excavated in the remnant naturally formed section of the lunette along the eastern side of the lagoon (see Figure 7.9). Three pits were aligned the crest of the lunette (Pits 1A-1C). The Pits 2A-2C were aligned the along the crest and lakeward slope of the lunette. The deposits in each of the three crest pits and 'Pit 2A' comprised featureless earthy organic sediments, but the lower pit (Pit 2B) comprised slumping earthy sediments with an admix of weathered granitic detritus.

The maximum depth was 48 cm. The area of excavations is shown in Figure 7.10.
Results

- 'Pit 1A' on the crest of the bank, a 1 m x 50 cm pit, was excavated to a depth of 39 cm. No artefacts were recovered.
- 'Pit 1B' on the crest of the bank, a 1 m x 50 cm pit, was excavated to a depth of 100 cm. An artefact was recovered from 'Spit 15-20c', and another from 'Spit 20-25cm'. A sample taken from 25 cm depth was OSL dated and had a central age of 1.83 ka, from 50 cm OSL central age was 6.45 ka and from 75 cm depth was 13.0 ka (for further discussion see Chapters 4 and 5). See Figure 7.10 for a photo of the excavation.
- 'Pit 1C' on the crest of the bank, a 1 m x 50 cm pit, was excavated to a depth of 75 cm, but no artefacts were recovered.
- 'Pit 2A' on the upper slope of the bank, a 1 m x 50 cm pit, was excavated to a depth of 48cm. A quartz flaked piece was recovered



Figure 7.10 *Lake Llangothlin section of Pit 1B*

from 'Spit 8-12cm', which was radiocarbon dated using charcoal to 240-70 cal. BP. A quartz flake was recovered from Spit 13-15 cm. A radiocarbon date of 320 cal. BP was recovered Spit 15-19. A quartz flaked piece was recovered from 'Spit 25-30 cm' which was also radiocarbon dated to 320 cal. BP. Four other quartz flaked pieces were recovered from 'Spit 30-48 cm' but no other samples were taken for dating (See Figure 7.10).

- 'Pit 2B' on the mid to lower slope of the bank, a 1 m x 50 cm pit, was excavated to bedrock at a depth of 15 cm. A single quartz flaked piece was recovered from 'Spit 5-10 cm'. No samples were dated.
- 'Pit 2C' on the crest of the bank, a 1m x 50 cm pit, was excavated to a depth of 43 cm. Three artefacts were recovered from 'Spit 9-14 cm'. No samples were dated.

Conclusion

The few artefacts recovered from the excavations were all from shallow depths and say very little about the early use of this lagoon. This is the largest lagoon in the district and would have had the greatest range of resources available for longer periods than the smaller lagoons that would dry out more regularly. This lagoon has much potential archaeology and it could be subjected to further research. The oldest archaeological material might still be unexplored by researchers (see Chapter 5).

Barley Field Lagoon, Glencoe

Location

Barley Field Lagoon, Glencoe is 80 km north of Armidale and 20 km south of Glen Innes. The lagoon is bracketed by the New England Highway immediately to the east, and by the defunct Northern railway line to the west.

The geology and topography

The elliptical-shaped lagoon is less than 300 m to the east of the Divide of the New England Tablelands at an altitude of 1,144 m AHD. It has an area of 10 ha (100,000 sqm) when full, and occurs on basalt derived deposits.

The New England Highway borders the eastern rim of the lagoon and appears to run through the remnants of a deflated or mechanically altered sandy lunette. The lagoon overflow drains southwards into a mechanically excavated channel that conveys it under the highway into an unnamed tributary of Marowan Creek, which flows to the north and the Mann River.

History of Land Use

The lagoon is part of the Glencoe Reserve which includes the Glencoe Cemetery, showground, sports oval and garbage tip. The reserve is contained within the southern half of a lenticular-shaped area defined by the defunct Main Northern Railway to the west and by the New England Highway to the east.

The Archaeological Record

There are no records of artefacts being found at this location but the presence of the remnant lunette and direct access to a gazetted road running west/east across the northern end of the lagoon, which appeared to be fallow and undisturbed, promised to be a likely context in which sub-surface artefacts might be recovered.

Excavations

The initial excavations were in the north-eastern corner of the lagoon surrounds where two pits (1 m x1 m) were excavated in the gazetted road corridor and a third pit was placed in the corner of the showground adjacent to the gazetted road. It was hoped that we could excavate in the lunette but it soon became apparent that we would have to dig under the New England highway, which was not a practical option! Three additional pits were then excavated on the southwestern margin of the lagoon, two on the slope and the third in the 'drainage area' between the lagoon and the overflow channel (Figure 7.11)

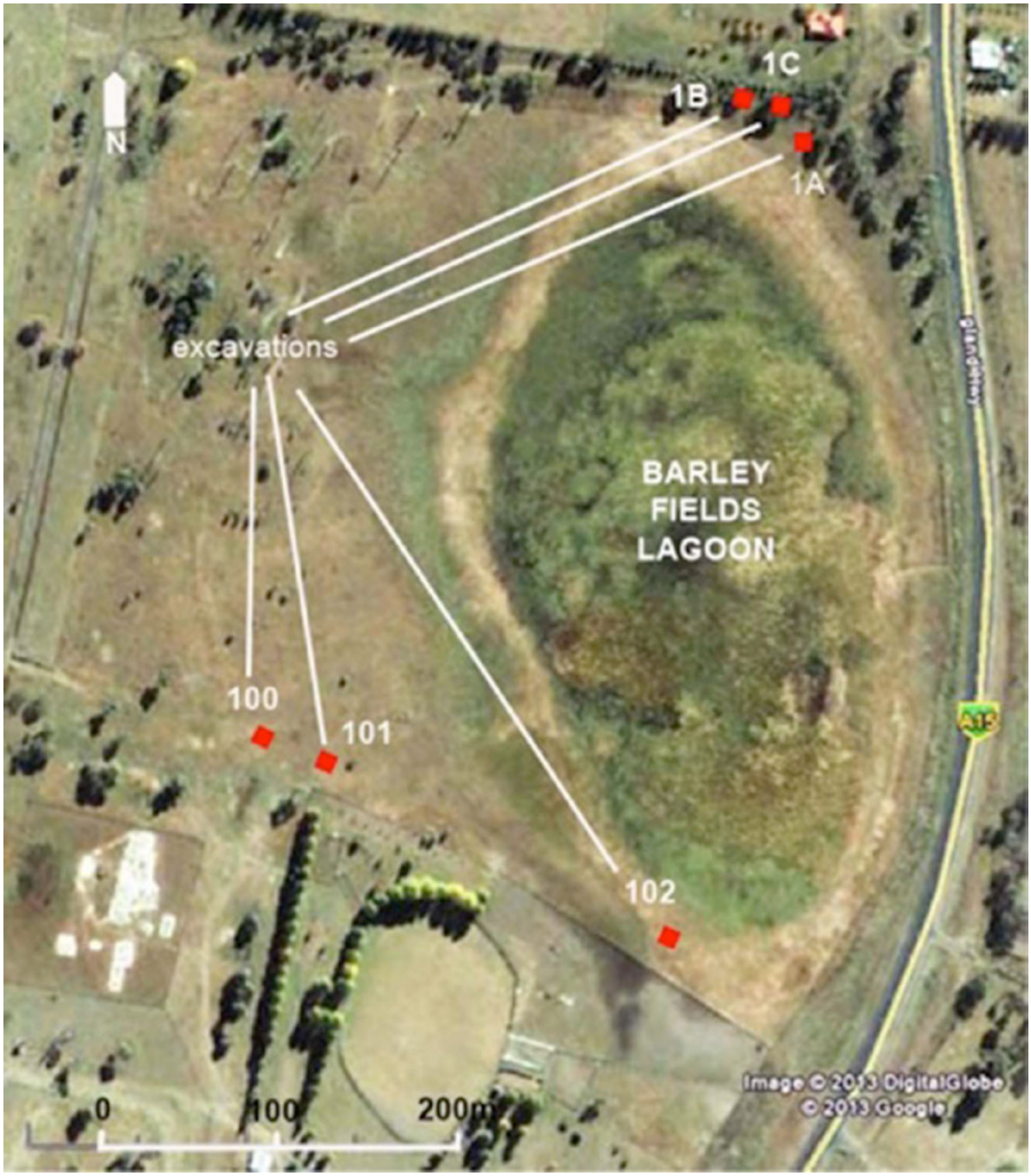


Figure 7.11 *Google Image of Barley Field Lagoon, Glencoe*

Results

- 'Pit 1A', a 1 m x 1 m pit in the gazetted road, was excavated to a depth of 18 cm where the decomposing bedrock was exposed. No artefacts were recovered.
- 'Pit 1B', a 1 m x 1 m pit, in the gazetted road, was excavated to a depth of 29 cm. A piece of clear glass with probable retouch was recovered from beneath the turf layer, No other artefacts were recovered.
- 'Pit 1C', a 1 m x 1 m pit in the adjacent paddock, was excavated to a depth of 43 cm. No artefacts were recovered.
- 'Pit 100', a 1 m x 50 cm pit on the slope to the southwest of the lagoon, was excavated to the rocky B Horizon at a depth of 30 cm. Three artefacts were recovered, one each from 'Spit 10-15 cm'; 'Spit 15-18 cm' and 'Spit 18-23 cm'. No samples were dated. (Figure 7.12).
- 'Pit 101', a 1 m x 50 cm pit on the lower slope in the south-western corner, was excavated to the bedrock at a depth of 21 cm. No artefacts were recovered. No samples were dated.
- 'Pit 102', a 1 m x 1 m pit on the lagoon overflow fan, was excavated to a depth of 20cm in dark, heavy clays. No artefacts were recovered.



Figure 7.12 *Southern Section of Pit 100 Barley Field Lagoon, Glencoe*

Conclusions

The results from this lagoon recovered four artefacts. Although it soon became apparent that we could not excavate in the lunette we thought that there would be some potential in the gazetted road easement which appeared to be undisturbed and fallow. We were surprised, having found that the upper levels were of sterile deposits, to find three artefacts in one of the pits on the southwest margin of the lagoon.

Reddestone Creek Lagoon

Location

Reddestone Creek was selected for investigation primarily because of the artefacts reported by Horton and Connah in 1981. However, that location was no longer accessible as it was being actively mined by the current owners. The fact that the artefacts had been found was an indication that the creek had seen Aboriginal activity in the past. We therefore looked for a location nearby that we thought would have the potential where relatively undisturbed archaeological contexts might still be intact.

The area chosen for the excavations was an overflow embayment of the dry lagoon comprising a broad flat-bottomed depression with a northeastern/southwestern axis, bracketed by banks less than 2 m in height (see Figure 7.13). The area is in a TSR 120 km to the north of Armidale at an altitude of 1,034 m AHD. It is in a triangular area defined on two sides by roads, the Strathbogie Road defines the western margin, and an unsealed road and an unsealed road (Hamel Lane) which veers to the northeast from its junction with the Glen Innes/Bonshaw road to the Emmaville Road, defines the eastern margin.



Figure 7.13 *Google image of the Reddestone Creek investigation location*

The geology and topography

This area is dominated by basalt but the embayment is bracketed by lateritic deposits on the eastern bank and by organic soils on the western bank, but these quickly give way to slopes of basalt boulders on the western slopes.

History of Land Use

There is no material evidence of any past use of the area other than as a TSR. The often found rusting billy-cans and beer bottles are the only evidence for stockmen using the TSR. There are no tree-stumps or tree-root depressions usually found where there has been tree-felling and the only visible unnatural features are fences and foot-tracks - the latter are likely to be well-worn animal tracks.

The study area occurs in a broad valley in gently sloping country that drains from the southwest to the northeast. Generally, the area is an unremarkable mosaic of remnant woodland and cleared paddocks in gently rolling to flat country.

The Archaeological Record

There are no records of any archaeological sites being found at this location but, in a walk-over during the preliminary field searches, Beck and Appleton recorded a scarred tree on the eastern side of the flat-bottomed over-flow area. The scar occurs at over 3 m above the ground in the skeletal outer remains of a dead eucalypt. From its fragile condition, it is unlikely that the tree will survive for more than a year or so. The fact that the tree is scarred might indicate that the scar is as much as two hundred years old or more. Reddestone Creek (but not the lagoon) is well known as a megafauna site and for its association with a relatively dense artefact scatter.

In 1980 Professor Graham Connah (UNE) was notified that some megafaunal skeletal material had been exposed by works for a sapphire venture. Horton and Connah excavated 8 sq. m in an undisturbed area and recorded:

> Fossil bones and teeth (of extinct fauna) were concentrated in the gravel layer, but many fossils were found in the grey clay and some in the base of the black soil. Some worked stone flakes (including ones of perfectly clear quartz) were found near the contact of the black soil and the grey clay (OEH Site Recording Form #12-4-4).

Connah recorded 22 stone artefacts at the site and another seven were recovered from dam excavation spoil heaps. Another 18 artefacts were collected by someone else, making a total of 47 artefacts of which 22 were recovered by excavation and 25 from un-stratified contexts. Connah was quick to point out that, while the artefacts were recovered from the same deposits as the skeletal material, there was no proven association between the two (Horton and Connah 1981). The results of our excavations are summarized below.

Excavations

Summary:

- 'Pit 2A', a 1 m x 50 cm pit on the eastern bank, was excavated to the ferricrete at a depth of 15 cm. No artefacts were recovered.
- 'Pit 2B', a 1 m x 50 cm pit on the eastern bank, was excavated to the concretion marking the surface of the B Horizon at a depth of 8 cm. No artefacts were recovered.



Figure 7.14 *'Pit 300', Reddestone Creek*

- 'Pit 2C', a 1 m x 50 cm pit on the eastern bank, was excavated to the concretion marking the surface of the B Horizon at a depth of 15 cm. No artefacts were recovered.
- 'Pit 200', a 1 m x 50 cm pit on the western bank, was excavated to the concretion marking the surface of the B Horizon at a depth of 14 cm. No artefacts were recovered.
- 'Pit 201', a 1 m x 50 cm pit on the western bank, was excavated to the concretion marking the surface of the B Horizon at a depth of 9 cm. No artefacts were recovered.
- Pit 300, a 1 m x 50 cm pit on the western bank, was excavated to a depth of 38 cm. A retouched clear-glass scraper was recovered from 'Spit 9-16 cm'. A charcoal sample from 14 cm depth was radiocarbon dated to 270-140 cal. BP. (see Figure 7.14).

An isolated artefact was found in a walking track a further 90m to the west in the TSR. Site Recording Forms for the scarred tree and the isolated artefact were lodged with OEH.

Conclusion

Initially, we had thought that the site that Connah had recorded further downstream was rare because no other sites had been recorded in the area but when we were ground-testing the site we observed the tree scar. We had also been told by an Aboriginal advisor that Aboriginal people had regularly travelled through this area, and so we decided that the site warranted test-pitting. Unfortunately, our investigation only yielded recent archaeology: a scarred tree, a piece of retouched glass, and an isolated artefact on the surface of a muddy woodland track.

Kings Plains Lagoon, Wellingrove

Location

Kings Plains Lagoon is located 52 km west of Glen Innes and 130 km north of Armidale. It lies to the north and adjacent to Kings Plains Road, and approximately 1,700 m to the west of the road junction with Western Feeder Road.

The geology and topography

Kings Plains Lagoon is a small kidney-shaped lagoon of only 2 ha (20,000 sq. m) with a north/south axis. The lagoon occurs at 930 m AHD on basalt derived deposits. The northern half of the lagoon occurs on private property that at the time of the excavations was under a grain crop. The southern half of the lagoon occurs in a TSR occupied by patchy open dry eucalypt woodland. There is no obvious drainage from the lagoon. A useful source of the analysis of the soils and country rock in the area is provided by a drilling report for Jingellic Minerals N.LO. (Coenraads 1988), who extensively described the deep stratigraphy.

History of Land Use

The recorded history of Kings Plains began in 1838 when John Vivers was led to the Kings Plains area by Joseph King, which then became Kings Plains Station. The station was soon stocked with sheep and cattle. In the same year shepherds were killed by Aborigines at Byron Plains and Kings Plains (Cameron 2002). The 1841 Census showed the station was home to five free males, one free female, and six male convicts, and by 1850 the station was stocked with 14 horses, 40 cattle and 17,000 sheep (Wiedemann 1981). The area has been used for grazing since then.

The Archaeological Record

Two isolated artefacts had been observed in table-drains beside the unsealed Kings Plains Road within 60m of the edge of the lagoon. A walk-over around the lagoon found two more isolated artefacts at the edge of the plough zone adjacent to the fence separating the TSR from the private property.

Excavations

With no clear indication of where sub-surface archaeological material might be concealed it was decided to use Appleton's predictive model to determine where to dig. The model states that open campsites are seldom found on ground with a greater slope than 3°. It also predicts that campsites will occur within the first strip of ground of less than 3° slope adjacent to creek banks, waterholes or lagoons. So, for example, regardless of how wide the area back from the waterline, if it is greater than 3°, no sites will occur in that area. However, the potentially archaeologically sensitive area will be in the first 20 m back from the break in the slope from more than 3° to 3° or less.

At this lagoon the slope of the first 22.8 m from the water edge was measured to be 8°. The slope for the next 24.3 m was measured as 6.5°. The ground beyond that was measured as having a slope of between 1° and 4° and so the first pit was excavated 9.3 m back from the break in slope between 6.5° and 1-4° (Figure 7.15). The first pit excavated was 'Pit Redig' which proved to be where the knapping floor of 25 artefacts was recovered. Additional test pits were excavated along two 50cm wide strips, the first was aligned adjacent to 'Pit Redig' and perpendicular to the edge of the lagoon. The second 50 cm wide strip was aligned at right angles to the first strip and abutted 'Pit Redig'. Randomly selected test pits were then marked along the two strips and the Test pits were then named with the number of 50 cm x 50 cm pits numbered from the break in the slope from 6.5° to 1-4° (Figure 7.15).

Results

Excavators described the excavated deposits in pit 'Redig' at Kings Plains Lagoon as very fine-grained silty sediment Munsell reading 7.5 YR 5.2- 4.6 Brown to Strong Brown and at the base of the excavation 5 YR3/4 Dark Reddish Brown (See the section in Figure 7.16).

- 'Pit Redig', a 1.75 m x 1 m pit, excavated to a depth of 36 cm. 25 artefacts of the same material were recovered from Spit 16-21cm. The knapping floor assemblage included a triangular-section point 51mm x 10mm x 7mm.
- A sample from 12 cm depth was OSL dated with a central age of 5.66 ka; and a sample from 16 cm depth was OSL dated with a central age of 4.28 ka.
- It was noted that the artefacts were in 'Spit 16-21 cm', and that the eleven-inch (27.5 cm) ploughs used in the early days of farming might have brought the isolated artefacts recorded on the edge of the plough zone to the surface.

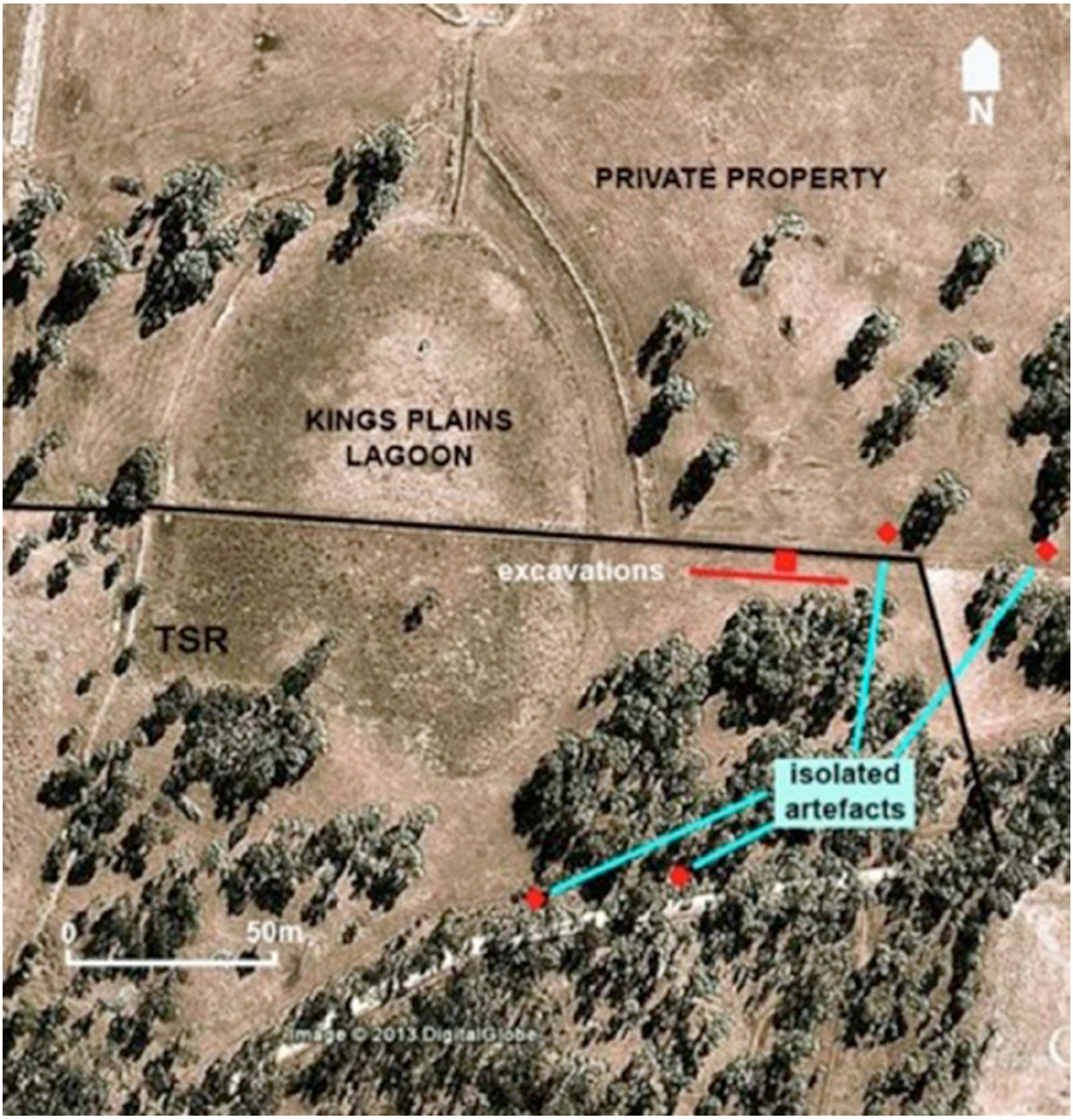


Figure 7.15 *Google image of Kings Plains Lagoon*

Additional test pit results:

- 'Pit KPN4', a 50 cm x 50 cm pit, was excavated to a depth of 21 cm. No artefacts were recovered.
- 'Pit KPN5', a 50 cm x 50 cm pit, was excavated to a depth of 19 cm. No artefacts were recovered
- 'Pit KPN7', a 50 cm x 50 cm pit, was excavated to a depth of 38 cm. No artefacts were recovered.
- 'Pit KPN118'. A 50 cm x 50 cm pit, was excavated to a depth of 23 cm. An artefact was recovered from Spit 12-23 cm. No samples were dated.
- 'Pit KPN11', a 50 cm x 50 cm pit, was excavated to a depth of 10 cm. No artefacts were recovered.
- 'Pit KPN41', a 50 cm x 50 cm pit, was excavated to a depth of 25 cm. No artefacts were recovered.



Figure 7.16 *View of Pit 'Redig', Kings Plains Lagoon*

Conclusion

To some extent finding artefacts at this site was a surprise. The four isolated finds and the 25 artefacts from the knapping floor are evidence that the lagoon had been used by the Aboriginal people of the region. It was in different 'country' to the other sites but the depth of the sub-surface artefacts and the presence of the two artefacts at the edge of a ploughed paddock suggests the sites are from the pre-settlement period.

This site was one of the first excavated and was instrumental in teaching the Aboriginal and other participants in excavation techniques, and so while the archaeological results are not noteworthy, the site was significant in providing an excellent classroom proving that there is archaeology in the least likely places

Analysing the overall results

Sampling

Before trying to analyse the results of the subsurface investigation it is important to briefly consider the small sample sizes at the various locations. Our initial excavations were small because we had no previous archaeological information about the site chronology or about whether artefacts were likely to be clustered or not (Way 2017) in the lunettes. We had hoped that we would be able to excavate up to 10 sqm at each location, however we had underestimated how much time it would take to instruct 18 inexperienced people in field techniques. As a consequence, we excavated only a third of the area we had proposed to excavate which also reduced the number of artefacts recovered. More sophisticated models now exist for sampling subsurface sites in similar sandy lakeside environments (e.g., Way 2017) which could be applied in future research. Larger excavated areas would provide larger assemblages in sediments with little visible stratigraphy (White 2021).

In Table 7.2 we have summarised the number of artefacts recovered and other features of the excavations overall. The excavated lagoon sites are small and shallow and Holocene in age. The areas excavated ranged from 3 to 4.5 sq m, and the number of artefacts from 1-28. All the excavations proceeded to a depth below the artefact finds, often to a ferricrete layer. Unsurprisingly, the specialised site at Thomas Lagoon axe grinding grooves had the highest number of artefacts (121) - made of metasediment and mostly axe trimming flakes.

There seems to be no clear correlation between the size of the lagoon and the size of the subsurface site, with the smaller lagoons having the larger assemblages (Table 7.2). The nature of the sediments seems fairly similar in all excavated contexts, and in both lunette and lake margins, with dispersion values in the OSL analyses indicating mixing of the grains, possibly due to wave and wind deposition and re-deposition (See Chapter 4, Table 4.2). However, at Kings Plains lagoons, 25 artefacts from a single knapping event were found in one 5 cm spit at 16-25 cm depth, suggesting that there has been little disturbance at this site.

Table 7.2 The relationship of the excavated sample to lagoon size and number of artefacts (* Thomas Lagoon is also an axe grinding site, so not directly comparable with the other lagoon sites)

LOCATION	Total area excavated sq m	Lagoon area sq m	Max depth of excavation cm	Approx. Depth of lowest artefact cm	Oldest dated artefact (see Chap 4)	No. of Artefacts recovered
Dangars Lagoon	4	550,000	95	45	5.9-17.7ka	3
Barley Fields Lagoon	4	60,000	35	35	5.0-9.0ka	28
Thomas Lagoon*	7	40,000	35	35	600-530BP	121
Big Llangothlin Lagoon	4.5	4,100,000	100	40	0.8-4.0ka	13
Barley Fields Lagoon Glencoe	3	100,000	43	20	Not dated	4
Kings Plains Lagoon	3.25	20,000	38	18	2.3-7.1ka	25
Reddestone Creek	3	300,000	15	12	270-150BP	1

Most of the previously excavated sites in the New England Tablelands have small assemblages of less than 200 artefacts (Appleton 1990a, 1990b, 2005; Bowdler 1981; Godwin 1990; Horton and Connah 1981). This assemblage size is similar to some other excavated high country rockshelter sites (over 1000 m) in southern NSW such as Boboyan (135 artefacts), Bulls Flat (79), and Nursery Swamp South (48) (Theden-Ringl 2017). These southern sites also date to the mid-late Holocene and are interpreted as sparse and short-term occupation of the high country, with a persistent presence of people 'in and along routes into the high country beginning in the Terminal Pleistocene' (Theden-Ringl and Langley 2018: 145). There could be a similar pattern in New England and the Bendemeer shelters could act as points of access to the high country.

The artefact raw materials

There are several materials that most frequently occur at the lagoons- silcrete (53%) and quartz (27%), Metasedimentary stone occurs at the Thomas Lagoon axe grinding grooves, and is used for axe manufacture. The frequencies are shown in Table 7.3. These materials reflect the local geology of the lagoons, and silcrete and quartz are the most common materials in surface assemblages. Godwin (1990) found that silcrete was the most common material in his sample of New England sites. Of the seven locations, the one with the broadest range of stone raw materials used in (seven materials in Table 7.3) was Thomas Lagoon, where the assemblage included artefacts of chert, and metasedimentary rock, these materials do occur locally. Flaked glass was found at two sites - Barley Field Uralla and Reddestone Creek, indicating a late Holocene use.

When divided into chronological phases based on palaeoenvironment (see Beck *et al.* 2015), the diversity of raw materials used increases over time (Table 7.4). Given that the late Holocene Thomas Lagoon site was primarily for working axes, it is not surprising that the raw materials are different from the other lunette sites. There is little change in quartz or silcrete proportions over time in the small lagoon samples (Table 7.4).

There were no surprises in the preferred materials as the landscape comprises granite (the source of the quartz) and silcrete which occurs throughout the New England Tableland Bioregion. Chert is available

TABLE 7.3 MATERIAL TYPES PRESENT IN THE EXCAVATED ARTEFACTS

	Arts	SIL	CHE	B	Q	CG	MET	CQ	CS	GW	IGN
DANGAR	3		1		2						
BARLEY FIELDS URALLA	28	13	2		3	1	2	3	3		1
BIG LLANGOTHLIN	13				11		1			1	
BARLEY FIELDS GLENCOE	4				4						
KINGS PLAINS	25	25									
REDDESTONE CREEK	1					1					
SUB TOTAL LAGOONS	74	39 (53%)	3		*20 (27%)*	*2*	*3*	*3*	*3*	*1*	*1*
THOMAS (AXE GRINDING GROOVE SITE)	121	18 (15%)	4	2	8		78 (64%)	2	9		
GRAND TOTAL	195	57	7	2	28	2	81	5	12	1	1

KEY					
	SIL	Silcrete		CQ	Crystal quartz
	CHE	Chert		CS	Coarse Silcrete
	B	Basalt		MU	Mudstone
	Q	Quartz		GW	Greywacke
	MET	Metasedimentary		IGN	Igneous
	CG	Clear glass		JAS	Jasper

in the valley floors. Silcrete is the only reliable and relatively abundant source of material suitable for knapping into small, sharp blades and artefacts. Quartz occurs both as pebbles within conglomerates, whereas on the tablelands frost and heat tends to cause fracturing in the quartz derived from seams, dykes and benches in the granite. Good quality quartz can be used for small, retouched tools, as at Bendemeer, and other places outside the region such as Lake George (Hawkins and Way 2020).

Several of the silcrete artefacts, including the oldest ones, show evidence of heat treatment, such as reddened colour and gloss on ventral flake surfaces (Maloney and Street 2020). This raises questions of when and how heat treatment was applied in New England.

Tools

Tool types, artefact size and incidence of retouch.

Table 7.5 shows some consistency in the data despite the sites being far apart. Of the 195 artefacts recovered from all seven excavations, there are 14 artefacts with retouch including six backed blades, five scrapers and three axes. Perhaps more surprising is that there are only three cores. The proportions of formal tool types in our excavations are very similar to those found in 'Bendemeer I' (McBryde 1974). Of 18,269 artefacts recovered from Bendemeer 1, 515 (2.8%) are formal tools (McBryde 1974). In all subsurface material recovered from the seven locations in our investigations, some as much as 80 km apart, formal tools comprise 3.1% of the assemblage. Similarly, McBryde found 313 cores (1.7%) and we

Table 7.4 Raw material by Holocene phase

	QUARTZ	COARSE SILCRETE	SILCRETE	OTHER	TOTAL
LATE HOLOCENE 150-1,000 BP	16	10	40*	91*	157
MID HOLOCENE 1,000-6,000 BP	7	2	13	6	28
EARLY HOLOCENE 6,000-9,000 BP	5	0	4	1	10
TOTAL	**28**	**12**	**57**	**98**	**195**

*includes knapping floor of 25 silcrete artefacts at Kings Plains & 78 metamorphic axe trimming flakes at Thomas Lagoon

found less than 1%. These proportions are very similar to those found in other eastern NSW sites, such as on the Cumberland Plain, where 3.3% of the overall mid Holocene assemblage were backed artefacts (McLaren *et al.* 2018).

Size of artefacts

Of the 195 artefacts recovered in our excavations only 10 have a maximum dimension greater than 40 mm, including the three axes and six scrapers. Most of the artefacts are small and have a maximum dimension of 10-20 mm (Table 7.5). The fact that there are so many small artefacts might be interpreted as indicating that the artefacts were produced from cores that had been significantly reduced since their initial knapping. However, there are 15 artefacts at two lagoons (Barley Field, Uralla and Big Llangothlin) that exhibit cortex which might indicate that the cores were small when first knapped and that the source of the core material is in the local area. Godwin (1990) found that silcrete sources in New England were usually more than 3 km from the sites, and that artefacts are highly reduced. The axe production site at Thomas Lagoon had 25 metamorphic artefacts with cortex which reflects its function as an axe production site.

Analysing the dates

Although relatively few dates were obtained for the lagoon excavations, the ones we do have are significant. In Table 7.6 we have plotted the Holocene phases and artefact distribution for each site. Basically, this shows that the frequency of artefacts in the early Holocene is much less than the Late Holocene with the total number of artefacts increasing from seven in the Early Holocene to 164 in the late Holocene, as well as the diversity of site types, activities and raw materials increasing.

The significance of the Barley Field excavation, however, is that it represents the earliest known dates of occupation on the New England Tablelands with an early Holocene OSL age (8.36±1.19 ka) for the silcrete artefacts in the lunette at this lagoon. It is also possible that the Dangars Lagoon lunette artefacts are of a similar age (7.30±0.875) ka. Further investigation, larger samples and more precise dating would enhance our understanding of this period of the New England Aboriginal history.

The New England Tableland archaeological sequence can be compared with the chronology of the southern uplands of NSW, due to its similar environment and geology. In the southern upland regions, backed artefacts continue use into the present (as they do in the NETB) which is unlike other parts of southeastern Australia (Hiscock 1994). As Theden-Ringl (2017:94) says

Table 7.5 Tool types, artefact sizes, incidence of retouch and presence of cortex

	Artefacts	F	FP	C	BB	Axe	Scr	Max dim. (mm) 10+	20+	30+	40-69	>70	Retouched	Cortex present
DANGAR	3	1	2					2	1					
BARLEY FIELDS URALLA	28	8	19		1			18	7	2	1		2	5
BIG LLANGOTHLIN	13	3	7		1		2	7	6				5	7
BARLEY FIELDS GLENCOE	4	1	3					2	1					
REDDESTONE CREEK	1	1							1				1	
KINGS PLAINS	25	19	4		2			12	10	2	1			3
SUBTOTAL	**74**	**33**	**35**		**4**		**2**	**41**	**26**	**4**	**2**		**8**	**15**
%		46%	45%		5%		3%	55%	34%	5%	3%		10%	20%
THOMAS	**121**	**64**	**48**	**1**	**2**	**3**	**3**	**56**	**40**	**16**	**6**	**3**	**6**	**25**
% total n is 121		53%	39%	<1%	1%	2%	2%	46%	33%	13%	5%	2%	5%	20%

KEY				
	F	Unretouched Flake	FP	Flaked piece
	C	Core	BB	Backed blade
	Ax	Axe	SCR	Scraper
	RET	Retouched	COR	Cortex

they could in fact comprise the continued risk-minimizing components of toolkits belonging to people reoccupying a relatively marginal landscape after a phase of reduced utilisation". "Indeed, the paucity of occupation deposits dating from 4500 to 2000 years BP and the appearance of backed artefacts mostly within the past millennium suggests a different situation in the [southern uplands], perhaps extending to other areas of the Australian high country, to that of surrounding regions (Theden-Ringl 2017: 95).

This hypothesis remains to be tested with larger artefact samples, in the uplands of the New England Tablelands.

Conclusion

Previous subsurface investigations in the NEB have been either opportunistic – as was Connah's excavations at Reddestone Creek, or driven by commercial development – as were Appleton's excavations at Devils Pinch, the New England Traffic Education Centre, Sunnyside and Cluny Road. A small number were a consequence of academic research between 1980 and 199, such as Williams' excavations at Mount Yarrowyck, Bowdler's excavations at Church Gully, and Godwin's excavations at Saumarez Creek. Each of these excavations provided another piece of information about site types, site distribution, subsistence

Table 7.6 Chronology of lagoon artefacts

LOCATION & PHASE	BARLEY FIELDS URALLA	DANGARS	THOMAS* (axe grinding site)	BARLEY FIELDS GLENCOE	BIG LLANGOTH-LIN	REDDE-STONE	KINGS PLAINS	TOTAL
LATE HOLOCENE 150-1,000 BP	4	1	121	4	8	1	25	164
MID HOLOCENE 1,000-6,000 BP	17	2	0	0	5	0	0	24
EARLY HOLOCENE 6,000-9,000 BP	7	0	0	0	0	0	0	7
TOTAL	**28**	**3**	**121**	**4**	**13**	**1**	**25**	**195**

strategies, or the implications of the impact and demand on resources associated with ceremony. However, a sustained program of excavation and synthesis has not been carried out until this project. We have obtained the oldest age (early Holocene) for artefacts on the New England Tablelands thus far.

The sub-surface investigations of this project have admittedly resulted in an exceedingly small sample of the potentially archaeologically sensitive landscape. They have concentrated on the role that lagoons potentially played in providing a concentration of resources sufficient to support large groups of visiting Aboriginal groups (Beck *et al.* 2015), especially in the late Holocene. Lagoons have been identified as an important resource base for both subsistence and ceremonial activity on the tablelands. Ceremonial activity has long been a focus of New England archaeology, including suggestions that the high country was not used except for ceremonial purposes (Bowdler 1981). This is a suggestion that may be worth revisiting in a more nuanced way with new information, including a comparison with the southern NSW uplands and a focus on the late Holocene.

Together with the information in Chapter 6 this project has provided a revised benchmark for subsistence activity and ceremonial infrastructure that could be related to lagoons and water sources for continuing occupation, however sporadic, from the early Holocene to the time of European settlement (Beck *et al.* 2015).

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Chapter 8:
Silcrete Grinding Grooves in New England, NSW

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Introduction: grinding patches and grinding grooves

Bedrock grinding patches vary widely in shape, cross-section, curvature, smoothing, polish and other attributes. Multiple functions have been documented ethnographically and archaeologically in Australia, including stone hatchet (axe) manufacture (e.g. Dickson 1980a); seed grinding/plant food processing (e.g. Atchison *et al.* 2005; Fullagar and Field 2011; Fullagar and Wallis 2012), maceration of animal material (Wright *et al.* 2014) and the processing of non-edible plant parts (e.g. leaves) for fibrecraft and medicinal purposes (e.g. De Graff 1967; Hayes 2015; Reynen and Morse 2016). A residue and use-wear study of bedrock grinding patches in the Pilbara region of WA indicates that grinding patches were used to process parts (seeds, stems and leaves) of several plant taxa, including *Triodia* sp. (spinifex) (Fullagar and Wallis 2012; Fullagar *et al.* 2016). In the Kimberley, Western Australia, and in Arnhem Land, Northern Territory, sandstone slabs, flat ledges and depressions (including small cupules, grooves and circular zones) on exposed quartzite and sandstone bedrock are still used as lower mortars and grinding slabs to pound edible fruits into a mash that can be fed to infants, old people, and others who cannot chew their food (e.g. Atchison *et al.* 2005). Wright *et al.* (2014) also documented collagen, among other residues, in stone cupules and suggest that these were used to pound animal tissue. Other grinding patches were used to grind green ant nests to create a paste that may be rubbed on the chest to alleviate flu symptoms (Hayes 2015). The function of grinding patches cannot be assumed on the basis of form.

Grinding patches include *grinding grooves*, usually oval shaped depressions. Small grinding grooves have been linked with grinding bone and wood (e.g. Spry *et al.* 2019). Grinding grooves are more commonly associated with grinding stone hatchet heads, often called axes. Bedrock grinding grooves are reported in many parts of Australia, usually on outcropping sandstone (Dickson 1980a), although they are known to occur on other rock formations including granite, aplite, diorite, and granodiorite—although these rock substrates may need added sand and water to be effective (e.g. Dickson 1980a).

In this chapter, we outline the distribution of grinding grooves in New South Wales and their potential association with hatchet manufacture, maintenance and use. We then report grinding patches, including grooves formed on silcrete outcrops in the New England study area, and the regional and local geology of silcrete formations. Finally, we present a case study, in which we apply use-wear and residue analysis to assess the function of selected grinding grooves at two sites: Chiswick and Thomas Lagoons. For comparison, we include a use-wear and residue analysis of a portable sandstone grinding stone from Big Llangothlin.

Background: distribution of grinding grooves in NSW

Grinding grooves are among the most common of the 20 standard site features of Aboriginal sites in New South Wales, and are described on the Guide to completing the AHIMS Site Recording Form:

'A groove in a rock surface resulting from manufacture of stone tools such as ground edge hatchets and spears, may also include rounded depressions resulting from grinding of seeds and grains.' <https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Aboriginal-cultural-heritage/guide-to-completing-ahims-site-recording-form-121008.pdf>

Grinding grooves are commonly associated with grinding and polishing stone hatchet heads made of tough fracture-resistant rocks (Corkill 2005; Dickson 1981; Domanski and Webb 2000; Kamminga 1982; McBryde 1978), and are usually found near water (e.g. pools, rivers and creeks), which is essential to remove swarf (Dickson 1980a). Grooves from the grinding of stone hatchet heads can sustain intensive wear, highly visible in the form of oval-shaped depressions, typically 25–50 cm long in plan-view and 2–3 cm deep (Dickson 1980a). A sandstone substrate that is well-suited for grinding hatchet heads (<15% clay bonding) can be equally useful for grinding seeds (according to Dickson 1980a) and other intermediate materials (e.g. plant, animal and mineral substances) between the bedrock and an active upper stone. In both situations, the bedrock acts as the passive lower stone to file, to abrade and/or grind an intermediate material with an upper (active) hand stone. Grinding grooves represent many hours of work, particularly for time-consuming tasks such as grinding hatchet heads or hard seeds. Depending on the abrasive quality of the file or bedrock, experimental studies indicate that it would take 1.5–5 hours to grind the edges of stone hatchets (Dickson 1980b; Hiscock *et al.* 2016).

Grinding grooves are linked with the manufacture and maintenance of edge-ground stone hatchet heads, which were hafted implements used for multiple purposes, although their design specifically allowed for heavy-duty tasks including woodworking, removing bark from trees, cutting toe holes to climb trees, and expanding existing holes to extract honey, possums and other resources. Although stone hatchet heads are rare archaeological finds, even in some areas where they were manufactured on a large scale (Corkill 2005), the distributions of volcanic/plutonic stone sources, grinding grooves and scared trees show a stepwise increase in the frequency of each site type, suggesting just how widely stone hatchets were circulated from production centres (McBryde and Watchman 1976).

The distribution of grinding grooves in Figure 8.1 is modelled on outcropping sandstone, but likely includes silcrete, which has been misidentified as sandstone in some areas such as the New England Tablelands. Sandstone and silcrete are common tool materials, widely used by Aboriginal people since initial settlement (Clarkson *et al.* 2017). Silcrete was used for core and flake tools whereas sandstone was mostly used for grinding technology. Outcropping sandstone is abundant in Australia but relatively restricted to broad zones in the Kimberley and eastern Australia (Hayes *et al.* 2018:99, Figure 8.1). In contrast, the distribution of outcropping silcrete is patchier and in smaller zones that are more evenly spread across the Australian continent (Taylor and Eggleton 2017: 989, Figure 8.1).

Study area

The lagoons investigated in the New England study area are commonly situated on basalt parent rock (Bell *et al.* 2008) that is sometimes associated with outcropping silcrete formations (see below). At least 670 grinding grooves have been recorded in the Armidale region (Table 8.1, 8.2,8.3). At Thomas Lagoon, we recorded 22 grinding grooves, distributed over 11 discrete clusters (Figure 8.2). The lengths of the grinding grooves are all at least three times their width, and all are between 1.5 and 3 cm deep. At Chiswick, we recorded 43 grinding grooves, distributed over 10 discrete clusters (Figure 8.3).

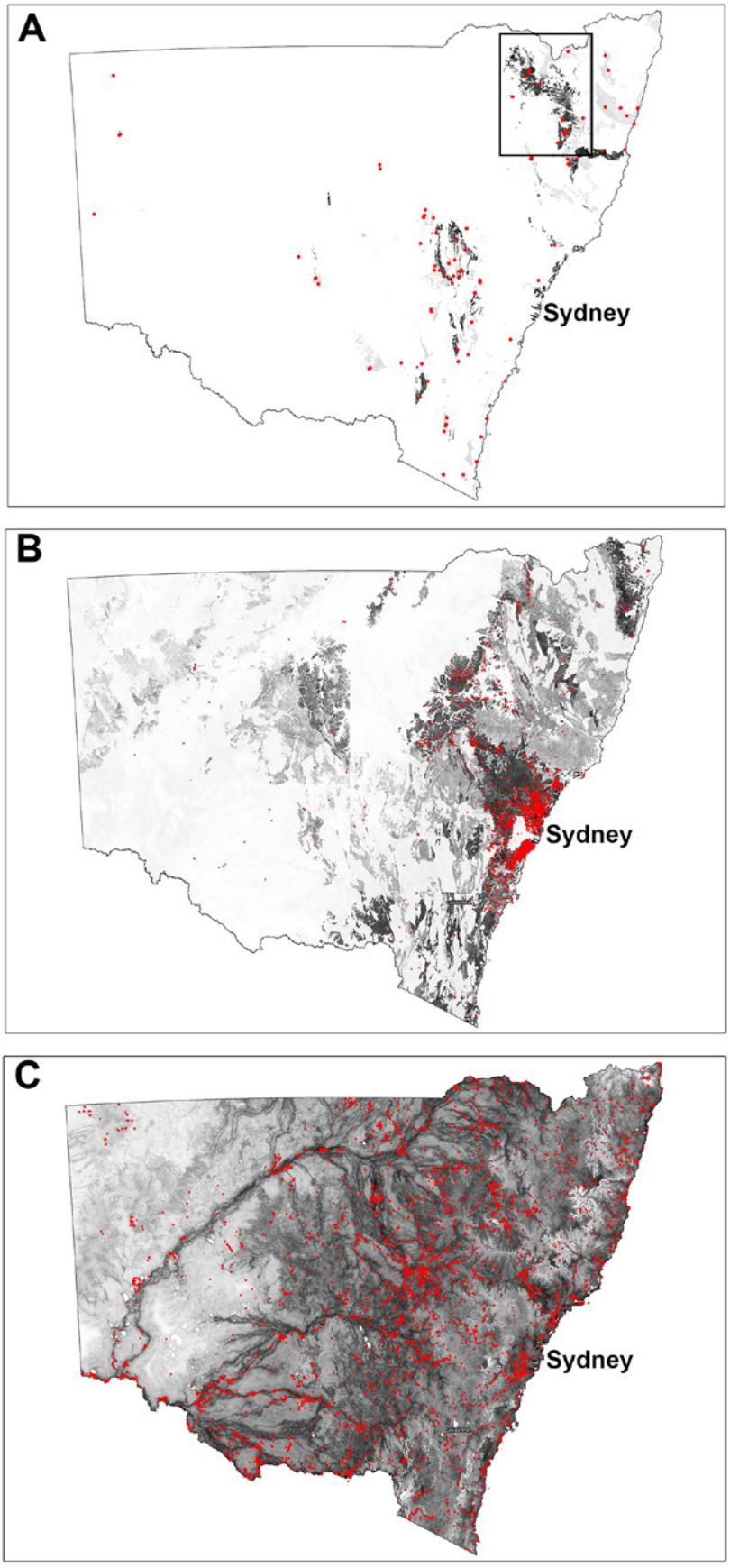


Figure 8.1 *Red dots show distribution models in NSW for (A) Hatchet stone sources (the black rectangle shows the New England Tablelands); (B) Grinding grooves; and(C) Scarred trees.*

Note: Data are based on the NSW Aboriginal sites decision support tool (ASDST) (https://www.environment.nsw.gov.au/licences/AboriginalSitesDecisionSupportTool.htm) and the Aboriginal Heritage Information Management System (AHIMS) (https://www.environment.nsw.gov.au/licences/AboriginalHeritageInformationManagementSystem.htm). As a surrogate for hatchet head sources, we refined the geological query to only include volcanic/plutonic geological units, and extracted those AHIMS stone quarries that intersect with those units.

Table 8.1 Grinding grooves in the Armidale region.

Site/Locality	Stone	Number of Grooves
Thomas Lagoon	Silcrete boulders bedrock	22
Chiswick	Silcrete boulders bedrock	43
Mount John	Silcrete boulders	8
Alfoxton	Silcrete boulders, bedrock	83
Cressbrook	Silcrete bedrock	64
Armidale Bypass	Silcrete boulder	2
Whans Cottage	Sandstone house block, late 1900s	2
Gostwyck	Silcrete bedrock	441
Tea-Tree Creek	Granite bedrock	5
Total Number of Grooves		670

Table 8.2 Thomas Lagoon grinding grooves locations and dimensions (See Figure 8.2).

Grinding Groove	Grinding Groove Size cm		
Location	Length	Width	Depth
GG1.1	33	9	3
GG1.2	24	8	2.5
GG2.1 (*TL2)	27	10	2
GG2.2 (*TL1)	50	7	7
GG2.3	50	8	7
GG3	27	8	2
GG4	35	9	2
GG5.1	30	8	2
GG5.2	30	8	2
GG6.1	45	11	3
GG6.2	29	7	1.5
GG7	28	9	2
GG8.1	24	7	3
GG8.2	29	7	3
GG9	32	9	2
GG10	33	9	3
GG11.1	27	9	2
GG11.2 (*TL3)	28	6	2
GG11.3 (*TL4)	27	8	3
GG11.4	29	9	?
GG11.5	24	8	2

* indicates use-wear/residue samples

TABLE 8.3 CHISWICK GRINDING GROOVES DIMENSIONS (SEE FIGURE 8.3).

Grinding Groove	Grinding Groove Size cm		
Location	Length	Width	Depth
GP1 GG1	26	11	3.5
GP1 GG2	27	11.5	3
GP1 GG3.1	29	9	3
GP1 GG3.2	32	8	2
GP1 GG4.1	32	11	2
GP1 GG4.2	32	11	4
GP1 GG4.3	30	11	3
GP2 GG1.1	23	8	1.5
GP2 GG1.2	29	8	2
GP2 GG1.3	22	7	1.5
GP2 GG1.4	25	6	1
GP2 GG1.5	32	6.5	3
GP2 GG1.6 (*CH1)	24	6	1
GP2 GG1.7	29	10	3
GP2 GG2.1	31	10	1
GP2 GG2.2	28	6	2
GP2 GG2.3	36	7	2.5
GP2 GG2.4	36	8	3
GP2 GG2.5	25	5	1
GP2 GG2.6	24	7	1
GP2 GG2.7	30	10	3
GP2 GG2.8 (*CH2)	40	22	3
GP2 Boulder.1	28	7	3
GP2 Boulder.2	28	10	2.5
GP2 Boulder.3	29	10	2
GP2 Boulder.4	29	10	2
GP2 Boulder.5	29	8	1.5
GP2 GG3.1	34	7.5	2
GP2 GG3.2	34	5	1
GP2 GG4.1	30	5.5	1
GP2 GG4.2	40	19	4
GP2 GG4.3 (*CH3)	50	29	7
GP2 GG4.4	25	9	1
GP2 GG4.5	33	9	3
GP2 GG5.1	32	17	5
GP2 GG5.2	31	10	3
GP2 GG5.3	28	6	2
GP2 GG5.4	28	6	1.5
GP2 GG5.5	34	6	2
GP2 GG5.6	25	5.5	3
GP2 GG6.1	62	19	8
GP2 GG6.2	23	14	<1
GP2 GG6.3	18	9	1
GP2 GG6.4	29	12	1.5

* indicates use-wear/residue samples

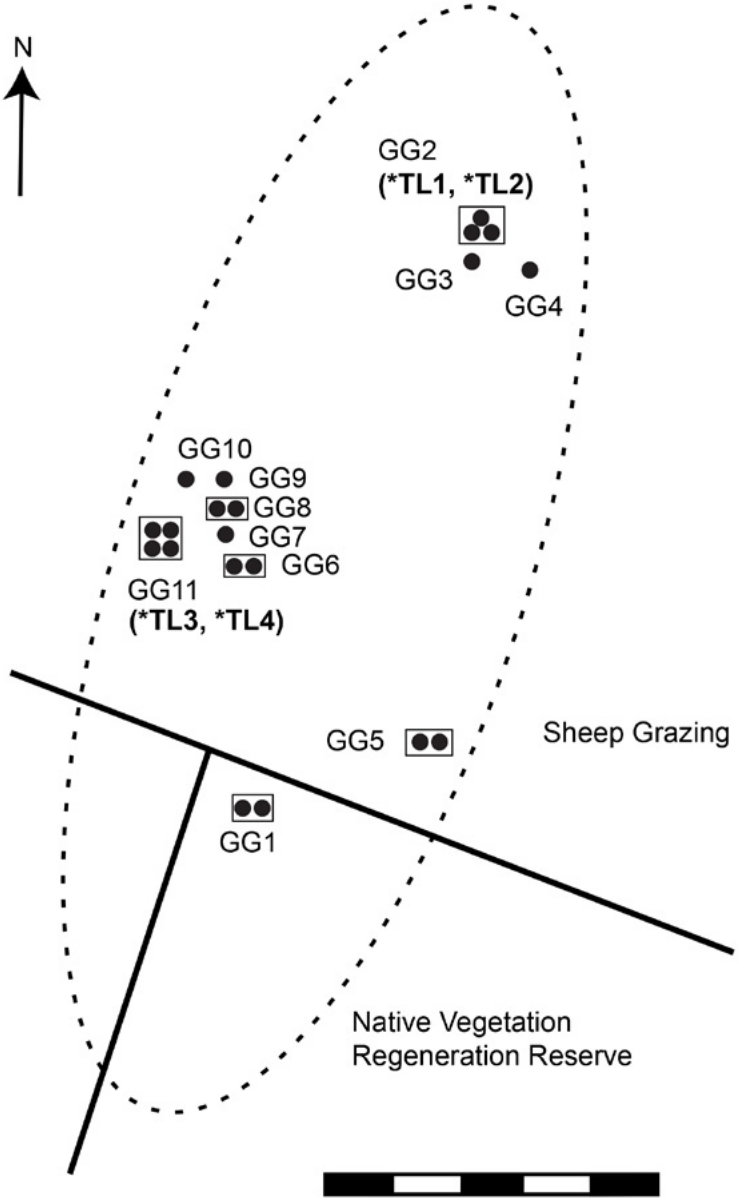


Figure 8.2 *Distribution of Thomas Lagoon grinding groove locations GG1–GG11. Asterisks show PVS and residue sample locations:* ***TL1**, ***TL2, *TL3** and ***TL4**. Black dots show the number of individual grooves (surrounded by a square if >1) at each location. Solid black lines are fences. The dotted line shows the approximate boundary of outcropping (mostly smooth) silcrete. The scale bar is 50m.*

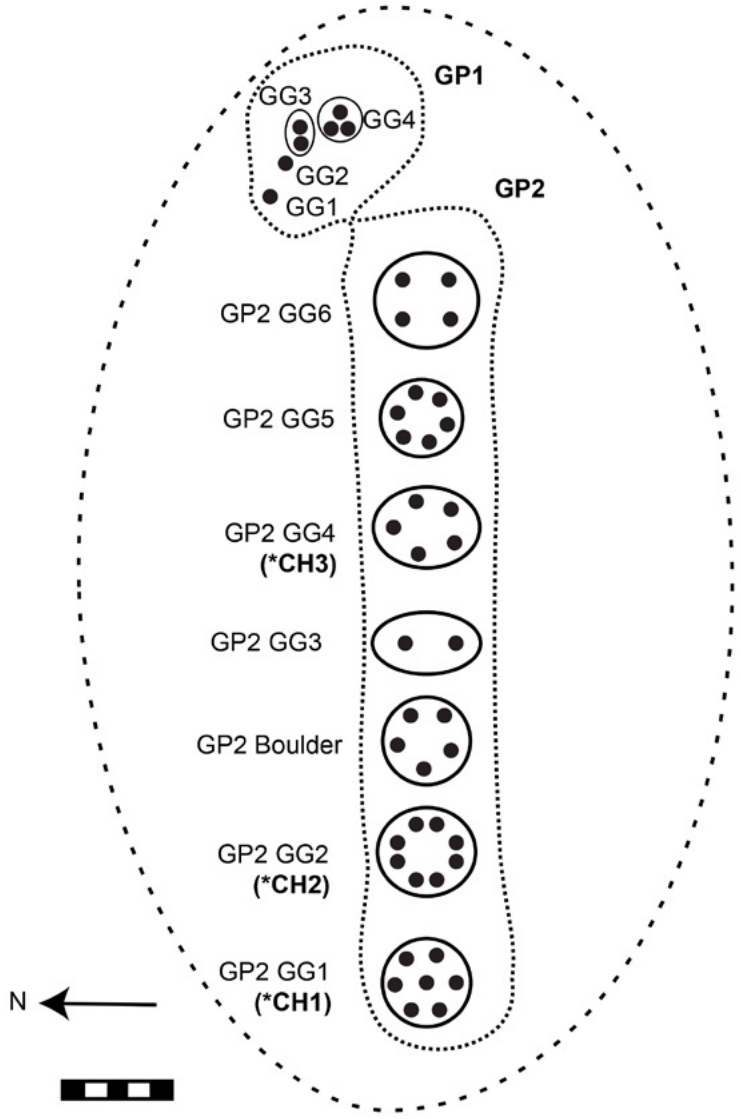


Figure 8.3 *Distribution of Chiswick grinding grooves, showing schematically two discrete patches: GP1 (with grinding locations GG1–GG4) and GP2 (with grinding groove locations GG1–GG6). Asterisks show PVS and residue sample locations:* ***CH1**, **CH2** and **CH3**. *Black dots show the number of individual grooves (surrounded by an ellipse if >1) at each location. The dashed line shows the approximate boundary of outcropping silcrete. The dotted line shows the boundary of gritty silcrete. The scale bar is 5m.*

Silcrete

Silcrete is a silica-rich rock formed by surficial processes involving the movement of groundwater. It is a type of duricrust, forming hard, indurated bodies that are highly resistive to weathering, and it has low porosity due to the microcrystalline to amorphous silica cement (see Appendix E). In New England, silcrete is formed by groundwater, preserving features of the underlying alluvial substrate formed by cement infill and partial replacement by quartz. Connelly (1985) divided silcrete into three variants, with moderately to well sorted clasts, unsorted clasts and silica-cemented brecciated chert. His classification gives a broad indicator of palaeochannels but is less useful for identifying features such as silcrete outcrop distribution and style.

Silcrete in the New England district is usually associated with basalts (Appendix E: Figure 1) and is formed by the preferential replacement of minerals such as clays by silica (as crystalline quartz or amorphous chalcedony), whilst the primary fabric and texture of the precursor rock is commonly preserved. Silcrete in the study area is nearly always massive and forms low ridges or isolated small flat outcrops in cleared grazing land. Original features (e.g. grain size, fabric and texture) of the clastic component are well preserved within the silcrete. Many variants, are spatially associated with nearby basaltic outcrops (Appendix E: Figure 1), and in some localities the basalt has probably been removed by erosion, leaving the silcrete exposed on surface. Four main types of silcrete were identified in the study region: (1) smooth silcrete, (2) gritty silcrete, (3) conglomeratic silcrete and (4) silcrete breccia.

Smooth silcrete (Smc)

Smc is pale grey, massive, and cement-supported fine grained silcrete. This variant forms low, rounded and smooth outcrop. It is the most abundant in the field area and recognised at Cressbrook Station and Thomas Lagoon (Appendix E: Figure E.5). In thin section, the finest-grained silcrete samples are up to 50% cement, dominantly chalcedonic to microcrystalline. Clasts are poorly sorted, range from 15 µm to 1.8 mm diameter and are sub-angular to sub-rounded in shape (Appendix E: Figure E.6). Fine-grained smooth silcrete, indurated by precipitation of siliceous cement, is more suited to flaking than grinding.

Gritty silcrete (GS)

GS is buff to red/brown, usually massive and homogenous (sometimes banded), and dominated by sand-sized grains. GS forms low, rounded outcrops which are generally less prominent than Smc variants (Appendix E: Figure E.7). In thin section, there is very little cement in these samples (generally less than 5%) and most grains are in physical contact with their neighbours. Clasts are reasonably well sorted, ranging from 20 µm to over 2 mm diameter and are sub-angular to sub-rounded in shape (Appendix E: Figure E.9). GS features silt to fine sand-sized particles (up to 0.5 mm in size), identified in the field by its relatively poor coherence and rough surface texture, with a high degree of porosity due to the even grain size of clasts and lack of cement. It is indurated by syntaxial overgrowth on quartz grains, rather than by silica cementation. Grinding grooves are developed in this variant at Cressbrook Station and Thomas Lagoon, where there is also an unusual GS variant that is banded with iron oxide-rich and iron oxide-poor bands. GS has similar mechanical properties to sandstone is potentially more useful for grinding than flaking.

Conglomeratic silcrete (CGS)

CGS is white-grey to red/brown cement, massive and homogenous, with pebble clasts. This silcrete is common in narrow outcrops where it forms low ridges, and more prominent than Smc and GS variants. CGS are dominantly pebble grade conglomerates that vary from cement (or matrix) to clast supported.

Clasts consist of quartz (white to grey) and chert/jasper (grey or red), typically ranging in size from 2 mm up to 5 cm and are angular to rounded in shape (Appendix E: Figure E.2). The conglomerates are generally poorly sorted (grain size is variable), and comprise angular clasts, indicating limited transport and abrasion of the original sediment. The cement ranges from very fine-grained (silt or finer) to sand-sized, and varies in colour from pale grey to red/brown. The poorly sorted pebble-sized clasts would make this variant an ineffective grinding stone.

Silcrete breccia (SB)

SB is pale grey, massive, with pebble clasts in very-fine grained buff cement. This variant is restricted to one location on Cressbrook Station, where it forms low, flat whale back-style outcrops on the top of a broad, elongate ridge. Clasts are poorly sorted and consist of rounded to angular chert, jasper and white vein quartz. They range in size from less than 1 mm to over 7 cm (Appendix E: Figure E.11). In hand specimen, these samples have a brecciated texture (the coarsest clasts are angular), although in thin section, the smaller clasts have a higher degree of rounding and the cement is dominated by a microcrystalline quartz cement. The samples contain approximately 40% matrix to 60% clasts and would make a poor grinding stone.

Case Study

Grinding grooves were sampled at Chiswick (n=3 grooves) and Thomas Lagoon (n=4 grooves) for use-wear and residues so that we could identify microscopic wear features and remnant particles of the ground material adhering to the stone surface. In addition, one portable sandstone grinding dish from Big Llangothlin (BLL), was also sampled (Table 8.4).

Experiments were undertaken to document the wear produced from grinding basalt on silcrete, using the locally found rocks at Thomas Lagoon (Figure 8.4). Other experiments document wear on sandstone, utilising a variety of materials including bone, stone, wood, haematite and a selection of native Australian seeds (Hayes *et al.* 2018).

Table 8.4 Residue and usewear samples collected.

Site Location	Grinding Groove Location (*Sample)		No. of Extractions	No. of PVS Peels
Big Llangothlin	BLL	(*GS1)	2	4
Chiswick	GP2 GG1.5	(*CH3)	2	2
Chiswick	GP2 GG2.1	(*CH2)	1	2
Chiswick	GP2 GG5.1	(*CH1)	1	2
Thomas Lagoon	GG2.1	(*TL2)	3	2
Thomas Lagoon	GG2.2	(*TL1)	1	2
Thomas Lagoon	GG5.1	(*TL3)	1	2
Thomas Lagoon	GG5.2	(*TL4)	1	2
Total number of samples			**12**	**18**

Methods

Use-wear

Wear on the grinding grooves was documented on impressions taken with Polyvinyl Siloxane (PVS) peels. The PVS compound creates a high-resolution negative impression for study under metallographic microscopes (x50, x100, x200 and x500 magnifications). At least one PVS peel was taken in each groove and on an adjacent unworn zone as a control (Table 8.4). PVS peels taken from within the grooves were sampled from zones of maximum smoothing and polish formation, visible macroscopically. Sampling areas were lightly brushed with a soft nylon paintbrush to remove any loosely adhering residues (e.g. dirt, leaves) and then gently swabbed with ethanol wipes to remove greasy films and other debris. The PVS compound was then applied to the sample area (approximately 1 x 1 cm) using a dispenser holding the PVS cartridge and a disposable mixing tip. The PVS was left to set on the surface for ~15–20 minutes to ensure adequate drying. Once removed, the PVS peel was placed in a small zip-lock bag and transported to the laboratory for microscopic analysis.

Residues

At least one residue sample was collected from each of the grinding grooves as well as the single ground surface of the BBL grinding dish (Table 8.4). Samples were taken by placing up to 50 µl of distilled water on a small area of the ground surface (~1 cm^2) using an adjustable pipette fitted with a disposable nylon pipette tip. Once the water was applied to the desired location, the surface was gently agitated to loosen any tightly affixed residues attached to the stone surface, while residues residing deep within the more porous zones of the rock were obtained by repeatedly expelling the water and withdrawing the resulting residue mixture. Extracted material was transferred to clean 30 µl vials and transported and transported to the laboratory at the for microscopic residue analysis.

Microscopy

The PVS peels were examined microscopically under reflected light using an Olympus metallographic microscope (model BX-50) with objective lenses of x50, x10, x20, and x50. This microscope has vertical incident light to enable a detailed view of use-polish, micro-fractures and micro-striations (including sleeks). Polish texture, which is considered to be a key feature for identifying worked material (see Hayes *et al.* 2018) was described and the frequency and orientation of micro-striations were recorded to indicate direction of movement.

Residue slides were prepared by placing approximately 5–15µl of extracted material on to a clean glass slide (wiped with acetone) and protected with a clean glass cover slip. Clear nail varnish was placed on each corner of the cover slip to set in place, the edges of which remained unvarnished so that additional solutions could be added if required. Slides were examined microscopically under transmitted light using an Olympus metallographic microscope (model BX-50) with objective lenses of x50, x10, x20, and x50, polarising filters and brightfield/darkfield illumination (see above). Micrographs were captured with an Olympus Infinity 2 camera permitting both colour and black and white digital images (recorded as TIFF files).

Residue staining

Following an initial examination under the transmitted light microscope, a water-soluble dye ('Methylene Blue') ($C_{16}H_{18}N_3SCI$) was added to all slides (n=12) to highlight non-lignified cell walls such as cellulose fibres within plant material (Cutler *et al.* 2008: 180; Wilson 1907: 647). The stain binds to the acidic

pectins on the cellulose cell wall that are stained various shades of blue (Lillie 1976: 425; Stadelmann and Kinzel 1972). Up to 10 µL of staining solution was applied to each slide until the residue sample was sufficiently covered and left for at least 10 minutes to enable the stain to develop. After this time, only a minimal amount of rinsing (if any) was carried out as to remove only the excess stain and not to wash out the colour from the target particle. The slides were then re-examined under transmitted light to document any organic material that had stained blue to indicate the presence of plant material.

Hemastix® test

All residue samples were evaluated for the presence of haem (in red blood cells and other compounds rich in iron) using a presumptive, haemoglobin specific chemical reagent test strip (Hb-CRTS) (Seimens 'Hemastix®' test strips). Hemastix® strips change colour in the presence of blood from yellow to various shades of green (Matheson and Veall 2014). The colour change is ranked on a scale from 0, indicating an absence of haem, to 6, indicating high abundance of haemolyzed (i.e. ruptured) red blood cells (>200 cells/µL): (1) slight trace/non-haemolyzed (i.e. intact, undamaged blood cells), >10 cells/µL, (2) trace/non-haemolyzed, >80 cells/µL, (3) trace/haemolyzed, >10 cells/µL, (4) small/haemolyzed, >25 cells/µL, and (5) moderate/haemolyzed, >80 cells/µL. Five micro-litres of extracted residue solution was placed on the Hemastix® test pad and left for 60 seconds and any colour change was ranked on the scale of 1–6. If no colour change had occurred after this time, the sample was deemed negative for haem and given a score of 0.

pXRF

Grooves were scanned with a (calibrated) portable XRF analyzer (Bruker Tracer III-V) to assess the feasibility of identifying residues from ground basalt hatchet heads that were forcefully ground into the outcropping silcrete.

Results

Use-wear

The use-wear on all grooves typically includes abrasive smoothing of the clasts and matrix, characterised by levelling of the surface microtopography and numerous fresh fractures on protruding quartz grains with rough bottomed, broad striations (Figures 8.4–8.7). The use-wear on silcrete from the experimental basalt grinding stone and both the Chiswick and Thomas Lagoon grinding grooves generally had low to very low polish development (Figures 8.4–8.6). Quartz grain microtopography shows abrasive smoothing and very low or no polish formation. This kind of wear is most similar to wear produced from stone-one-stone grinding, and lacks the more extensive and developed polish typical of grinding intermediary materials, such as seeds, or filing organic materials like wood and bone (Hayes *et al.* 2018). The largest more circular grinding groove GP2 GG2.8 (sample CH2) had slightly more developed polish than other grooves, suggesting processing of softer material. The use-wear on the sandstone BLL grinding stone had zones of more developed polish providing good evidence of processing plant and possible other tissue (Figures 8.7D, 8.7F).

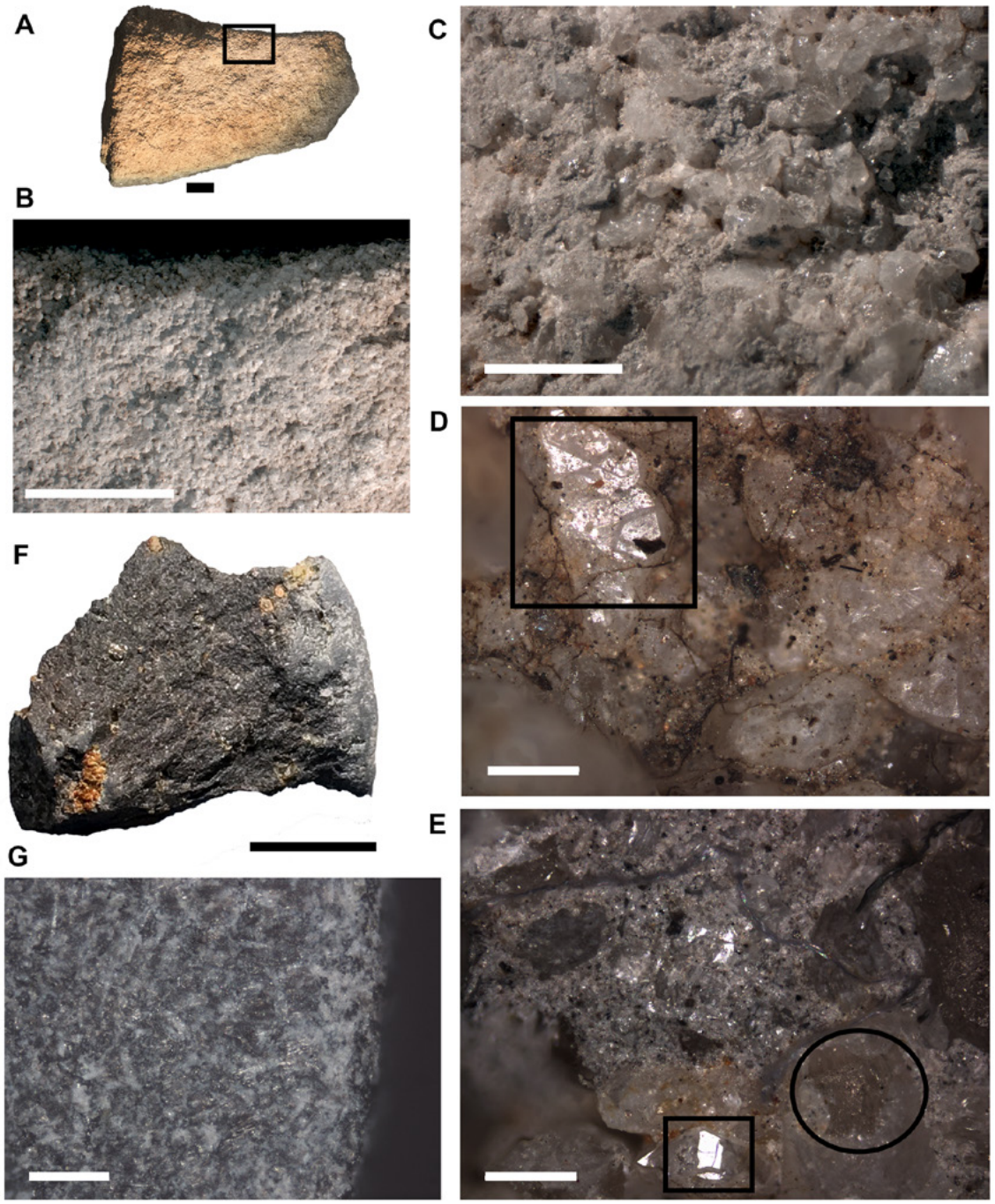


Figure 8.4 *Experimental grinding tools (used for ~60 min) made from local silcrete (A–E) and basalt (F–G) and their corresponding use-wear: (A) whetstone made of local silcrete, showing ground surface in black rectangle. Scale bar 1 cm. (B) Detail of the ground surface, showing surface levelling. Stereozoom microscope, oblique light. Scale bar 1 cm. (C) Detail of the levelled surface, showing rough microtopography of protruding sand grains, some of which are freshly fractured or abraded. Stereozoom microscope, oblique light. Scale bar 1 mm. (D) Detail of the microtopography of the silcrete surface* **before** *grinding, showing angular weathered fractures (black rectangle), and no surface levelling. Metallographic microscope, vertical incident light. Scale bar is 0.2 mm. (E) Detail of the microtopography of the silcrete surface* **after** *grinding, showing angular fresh fractures (black rectangle), levelling of the matrix, and weak polish development with striations across sand grains (black circle). Metallographic microscope, vertical incident light. Scale bar is 0.2 mm. (F) Experimental basalt flake with one ground edge (on the right the image). Scale bar 1 cm. (G) Detail of the ground edge on the basalt flake, showing surface smoothing and striations. Metallographic microscope, vertical incident light. Scale bar is 0.2 mm.*

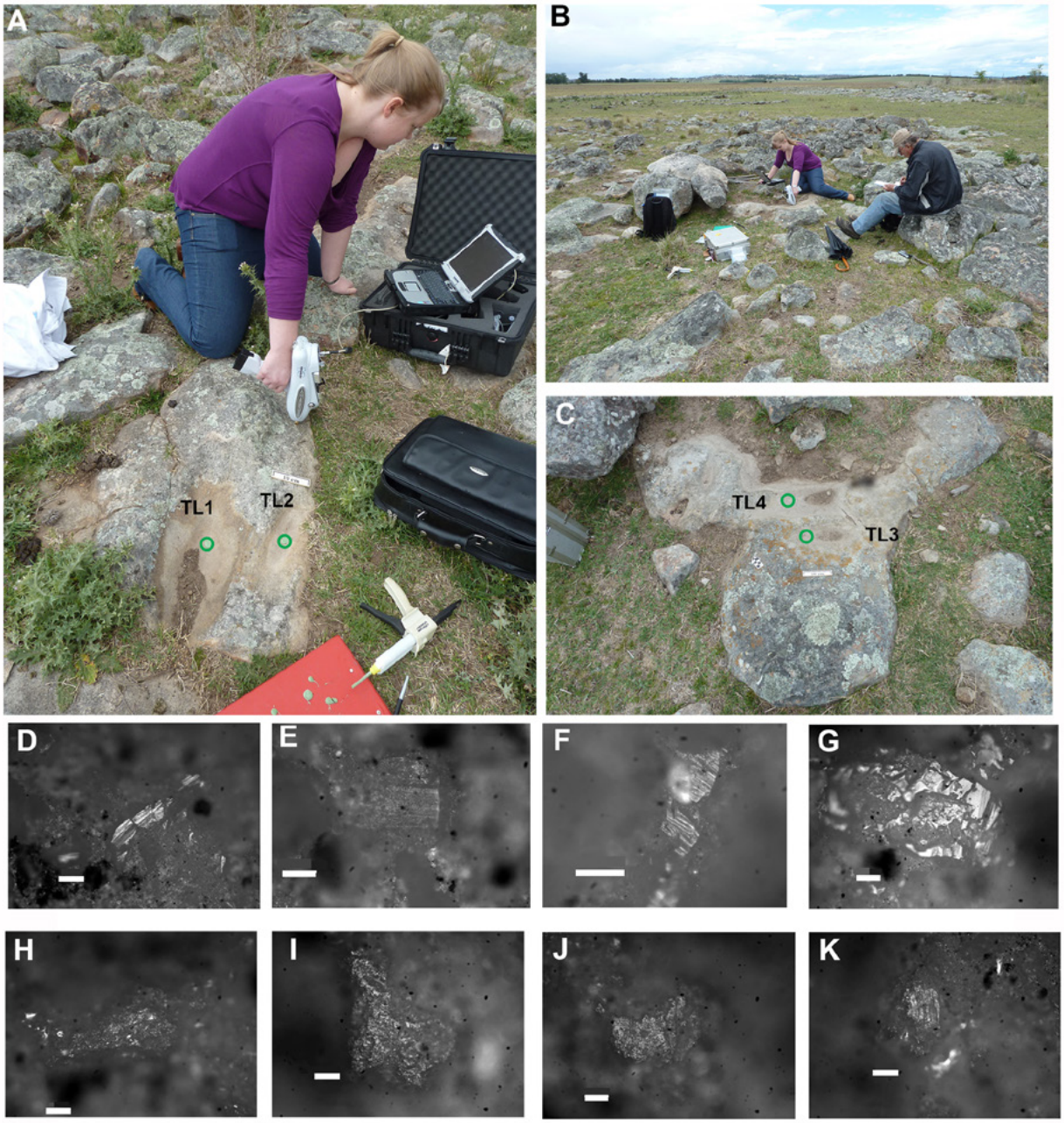


Figure 8.5 *Grinding grooves from Thomas Lagoon sampled for use-wear and residues (A–C) and use-wear documented on PVS peels (D–K). (A) Taking pXRF measurements and PVS peels (green circular material), labelled TL1 and TL2 on the grinding grooves at GG1. (B) Taking pXRF measurements on grinding grooves at GG2. View looking north towards the Thomas Lagoon, across the outcropping silcrete. (C) PVS peels (green circular material), labelled TL3 and TL4 on the grinding grooves at GG5. (D) TL1 fresh fractures with striations. (E) TL2 fresh fractures with striations. (F) TL3 fresh fractures with striations. (G) TL4 fresh fractures with striations. (H) TL1 abrasive smoothing/low polish. (I) TL1 abrasive smoothing/low polish. (J) TL2 abrasive smoothing/low polish. (K) TL4 abrasive smoothing/low polish. Scale bars are 0.05 mm.*

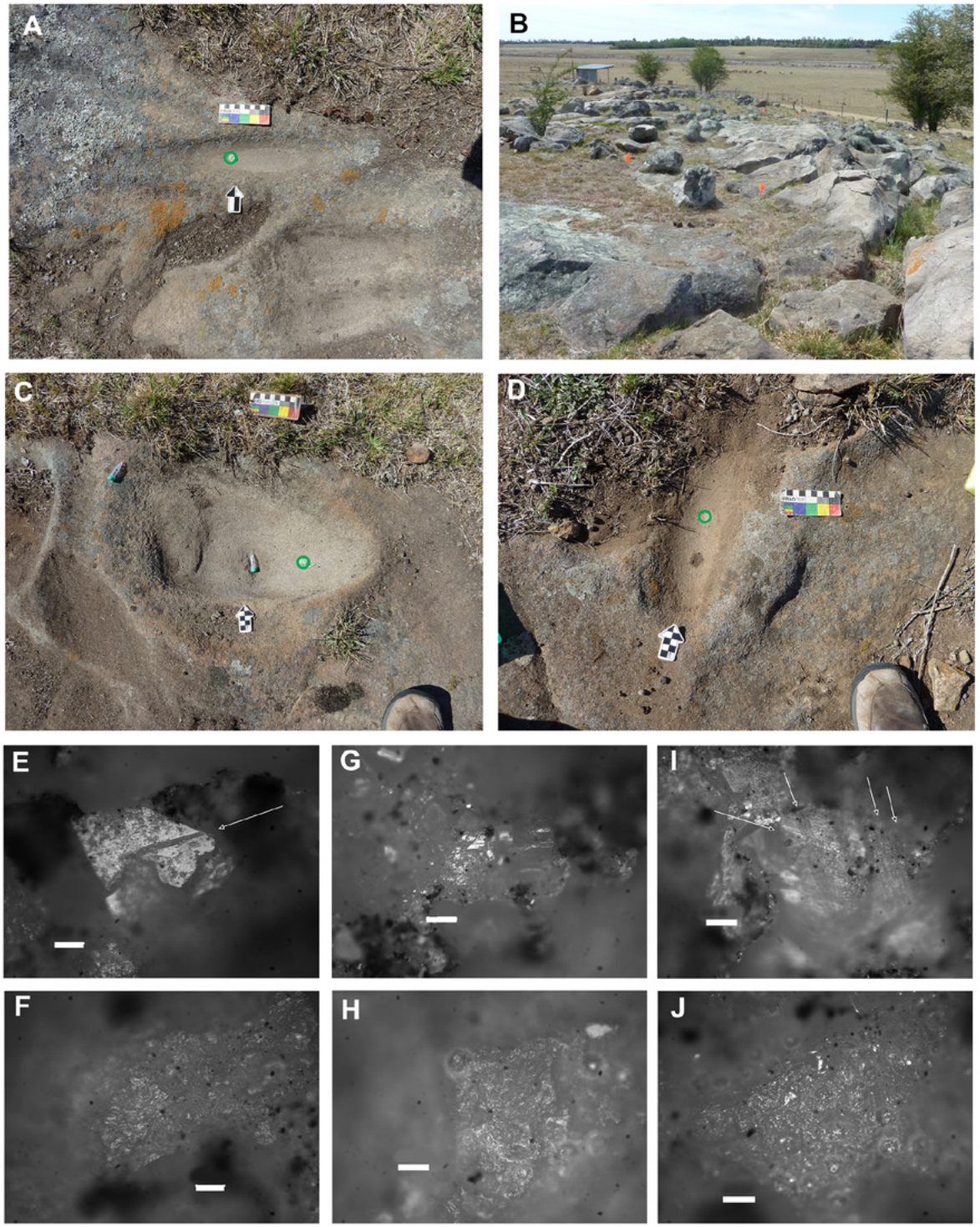


Figure 8.6 *Grinding grooves from Chiswick sampled for use-wear and residues (A–D) and usewear on PVS peels (E–J). (A) Grinding groove GP2 GG5, sample CH1. The green circular material in the centre of the groove is the PVS peel. (B) View looking north, across the outcropping silcrete. Red flags mark grinding groove locations. (C) Grinding groove GP2 GG2, sample CH2. The green circular material in the centre of the groove is the PVS peel. Green capped centrifuge tubes mark the location of residue samples. (D) Grinding groove GP2 GG1, sample CH3. The green circular material in the centre of the groove is the PVS peel. (E) CH1 fresh fractures with striations, scale bar is 0.05 mm. (F) CH1 abrasive smoothing/low polish, scale bar is 0.05 mm. (G,H) CH2 abrasive smoothing/low polish, scale bars are 0.1 mm and 0.05 mm, respectively. (I) CH3 fresh fractures with striations, scale bar is 0.05 mm. (J) CH3 abrasive smoothing/low polish, scale bar is 0.1 mm.*

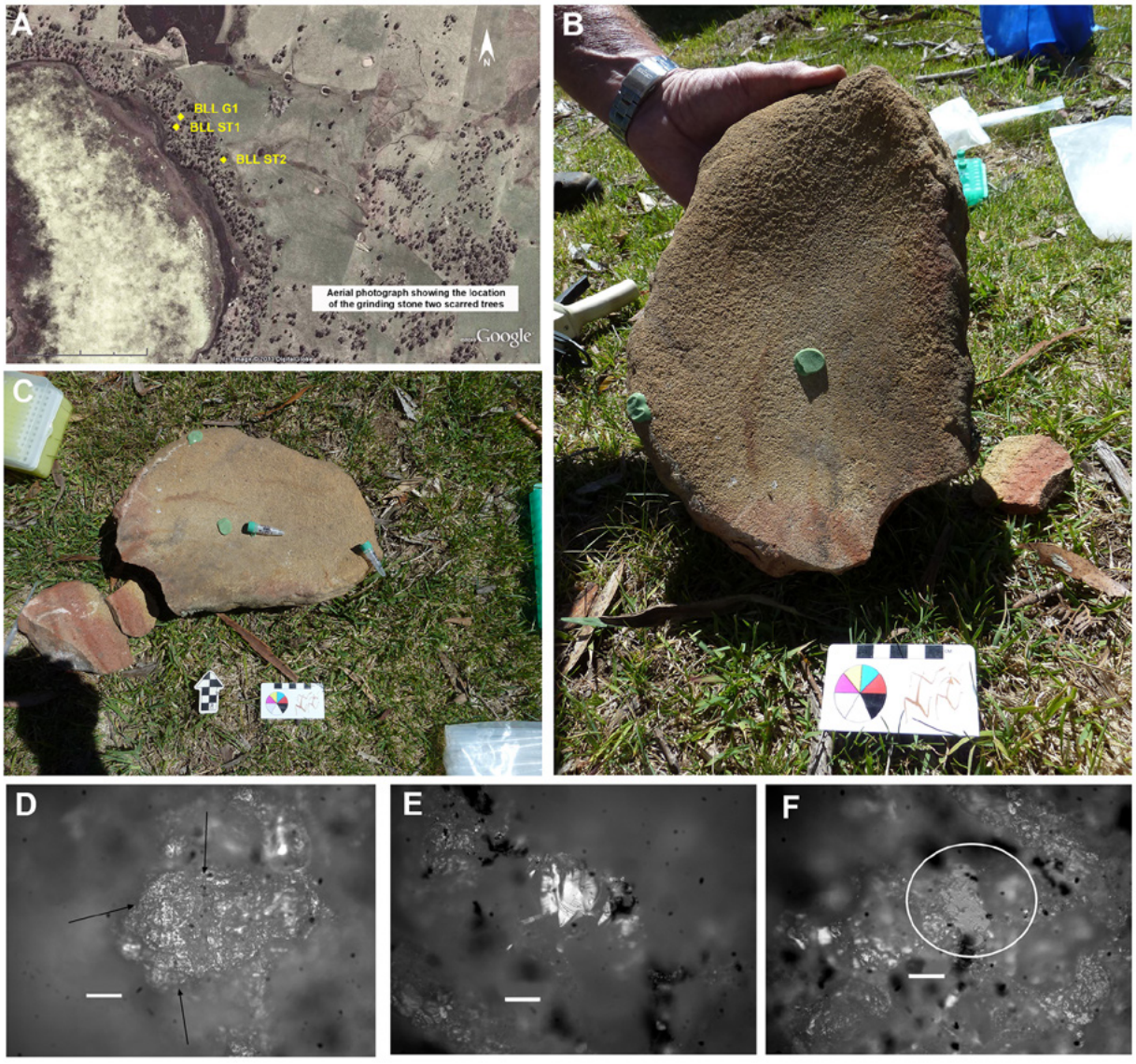


Figure 8.7 *Big Llangothlin grinding stone and use-wear. (A) Location of Big Llangothlin (BLL) grinding stone and nearby scarred trees on the northeast bank of the lagoon. (B-C) BLL grinding stone with green PVS peels indicating the location of use-wear samples in the groove (GS1) centre, and off the groove ((GS2) on the margin; and green capped centrifuge tubes marking the location of residue samples. (D) Abrasive smoothing/polish with striations (arrows) on PVS peel from central depression. (E) Fresh fractures on PVS peel from central depression. (F) Zone of developed polish (ellipse) with pitting and striations on PVS peel from central depression. Scale bars are 0.05 mm.*

Residues

Extracted residues from the Thomas Lagoon and Chiswick grinding grooves and the Big Llangothlin grinding stone comprise inorganic crystals (mostly quartz), freshwater pennate diatoms, freshwater algae, fungal hyphae, unidentified spores, a modern feather barbule, modern insect remains, generic rod-shaped phytoliths, modern cellulose fibres and highly fragmented plant tissue stained with Methylene Blue (Table 8.5, Figures 8.8, 8.9 and 8.10). Cellulose and amorphous plant tissue were rare (one or two fibres per extraction and occurring as fragments only) and absent on the portable grinding stone. The cellulose tissue was unaltered (i.e., non-degraded) and exhibited enhanced birefringence, suggesting modern environmental contamination. Plant cell structures and lignified epidermal tissue were also rare and have been attributed to modern contamination.

Table 8.5 Visible structures documented in residue extractions sampled from grinding grooves. BLL: , CH:, TL: , Plant: Ce=cellulose, L=lignin , St=starch, Ph=Phytoliths, Animal: Co=Collagen, B=bone, I=insect, F=feather Mineral: Pi=pigment, ITG=extraction from in the groove, OTG=extraction from just off the groove.

Site (Group)	Grinding Groove Location Number	Grinding Groove Extraction Sample	ORGANIC								INORGANIC			OTHER
			Plant				Animal				Mineral			
			Ce	L	S	P	Co	B	I	F	Pi	Round quartz	Angular quartz	
Big Llangothlin	BLL	GS1 (ITG)										+	+	Hyphae, algae
	BLL	GS1 (OTG)										+	+	
Chiswick (GP2)	GG1.6	CH1.1 (ITG)										+	+	Diatoms, hyphae
	GG1.6	CH1.2 (ITG)	+									+	+	Algae (common), hyphae
	GG2.8	CH2.1 (ITG)	+									+	+	Algae
	GG4.3	CH3.1 (ITG)		+		+			+	+		+	+	Algae, diatoms (common), unident. spore
Thomas Lagoon	GG2.2	TL1.1 (ITG)	+			+						+	+	Diatoms (common)
	GG2.2	TL1.2 (ITG)										+	+	Algae, bacterial spores, diatoms
	GG2.2	TL1.3 (OTG)										+	+	
	GG2.1	TL2.1 (ITG)										+	+	Diatoms
	GG11.2	TL3.1 (ITG)	+									+	+	Diatoms
	GG11.3	TL4.1 (ITG)				+						+	+	Diatoms, hyphae

Animal material was limited to one feather barbule and one insect particle from Chiswick Grinding Groove 3 (Table 8.5, Figure 8.10). However, in the absence of other animal tissues (e.g. collagen, bone, blood), these residues are not considered to be use-related. Other organic residues, such as freshwater pennate diatoms, freshwater algae and fungal hyphae were also recognised in all seven grinding grooves (Table 8.5). Diatoms are major group of algae and contain a cell wall made of silica (hydrated silicon dioxide) that vary widely in form; diatoms that are bilaterally symmetrical are referred to as 'pennate'. The diatoms recognised here may be further classified as those from freshwater communities. Green algal spores were also recognised in a number or residue extractions and may be further classified under the algae division Chlorophyta (i.e., green algae) (Maggs and Callow 2003). These are aquatic

photosynthetic eukaryotic organisms that appear as green chlorophyll sphere-shaped spores. The taxonomic origin of the freshwater diatoms and the algae spores has not been identified, but neither are suspected to be use-related. Other recognised spores (e.g. hyphae, bacterial) are also a form of environmental contamination.

Although the freshwater diatom and algal spores are not considered to be use-related, their presence in grinding grooves suggests that these are often filled with water following rainfall. Consequently, it may be expected that water soluble residues, or those that can be suspended in a liquid media (such as various plant and animal tissues and inorganic minerals such as stone and rock debris) may have been regularly washed away from the tool surface. This could explain the absence of abundant residue accumulations on these tools.

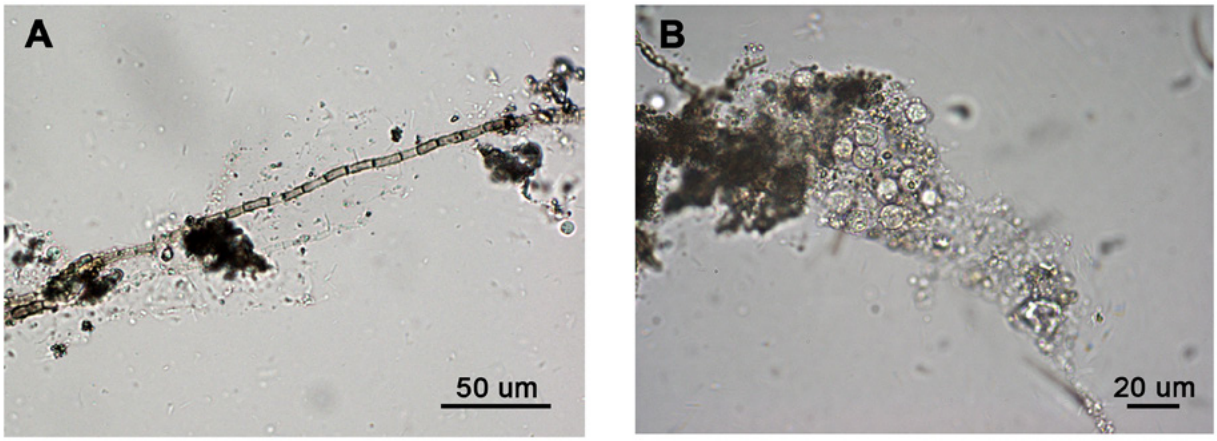


Figure 8.8 *Residues extracted from the BLL portable grinding. (A) Algae spores in Extraction BLL GS1 from within the central groove. (B) Fungal hyphae, Extraction BLL GS2, sampled from outside of the groove. Neither residue is considered use-related.*

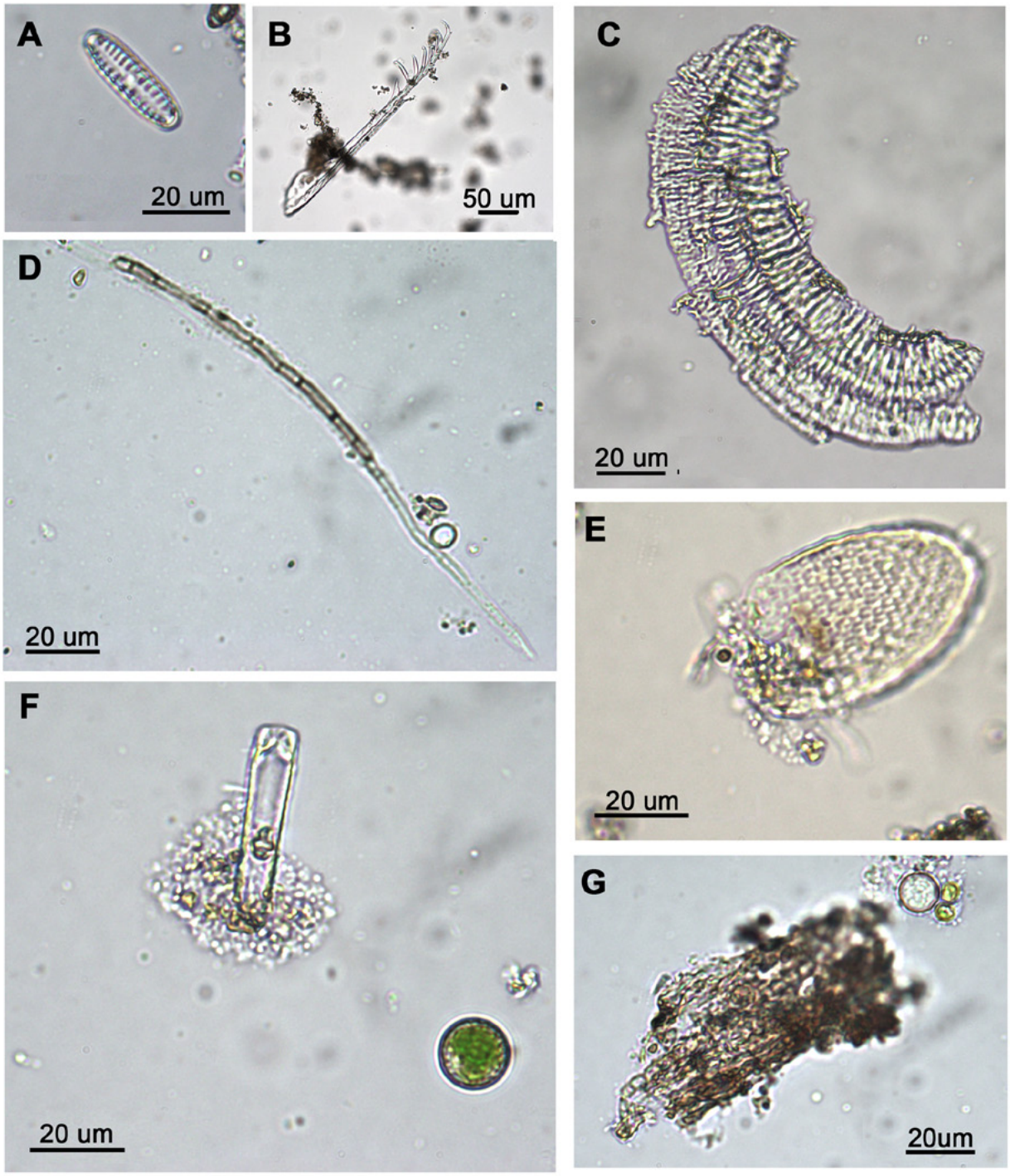


Figure 8.9 *Residues extracted from the Chiswick grinding grooves. (A) Freshwater pennate diatoms, Extraction 1.1. (B) Feather barbule, unidentified taxa, Extraction 3.1. (C) Unidentified plant cell structure, Extraction 1.2. (D) Fungal hyphae, Extraction 1.1. (E) Insect particle, distinguished by fine hairs and scale-like exoskeleton, unidentified taxa, Extraction 3.1. (F) Algal spores with chlorophyll (green sphere) and a diatom, Extraction 2.1. (G) Lignified tissue, fungal hyphae and spores, Extraction 2.1*

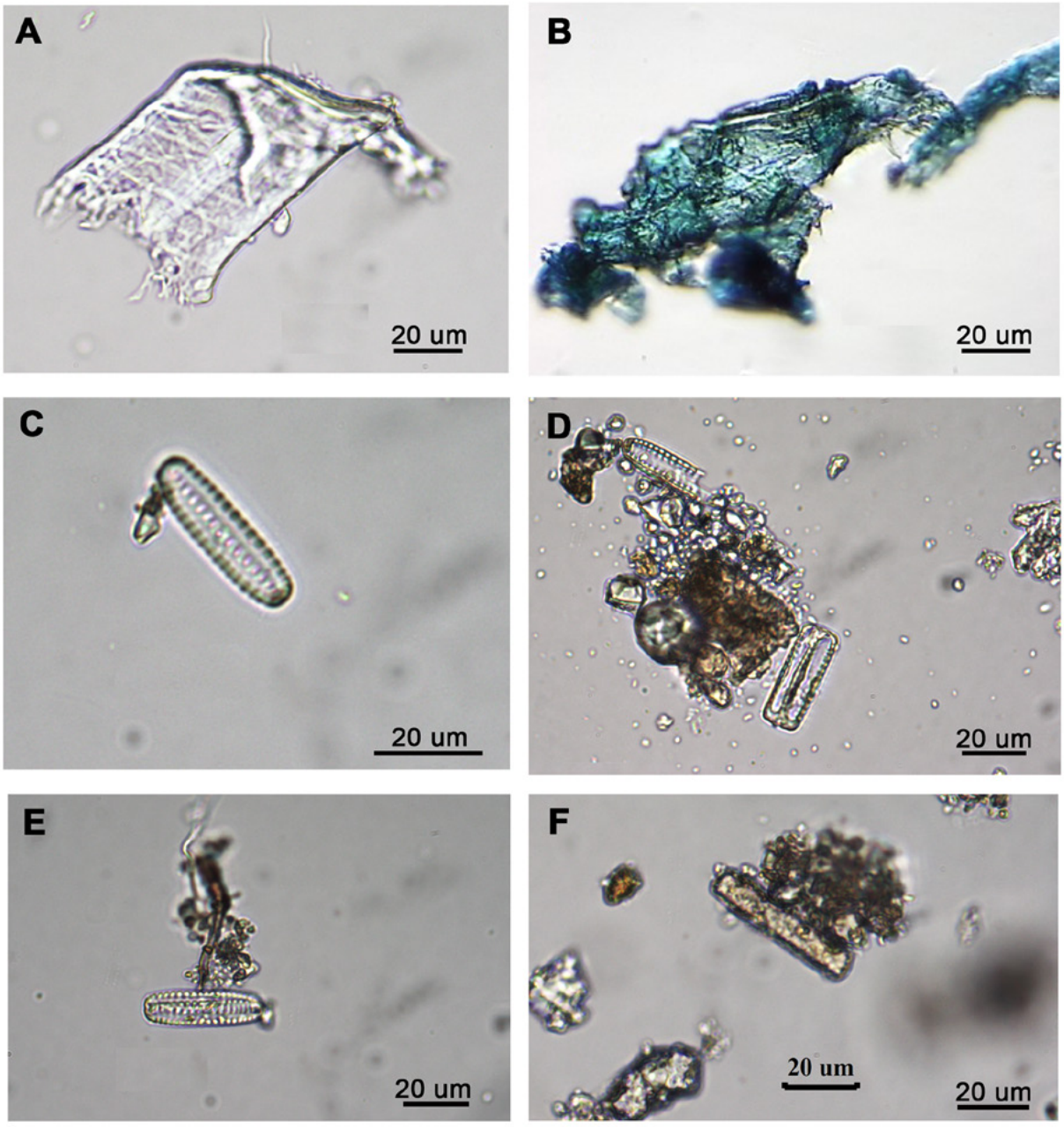


Figure 8.10 *Residues documented in extractions sampled from the Thomas Lagoon Grinding Groove 1 (A–D) and 2 (E) and 4 (F): (A) Fragmented cellulose fibre, Extraction 1.1, in groove. (B) Fragmented plant tissue stained with Methylene Blue, Extraction 1.1, in groove. (C) Freshwater pennate diatoms Extraction 1.1, in groove. (D) Mineral crystals and broken and complete freshwater pennate diatoms, Extraction 1.2; (E)Freshwater pennate diatom, Extraction 2.2, in groove; (F) Rod-shaped phytolith, Extraction 4.1, in groove.*

pXRF

The pXRF data indicate eight groups (Table 8.6, Figure 8.11). The two basalt artefact samples (a cobble with grinding: TL10, TL11; and edge-ground hatchet fragment: TL12 and TL13) separate from each other and all other groups, including the isolated dirt sample (TL24) and dirt from within the groove GG2 (TL3), which is also distinct from the three main groups(1, 2 and 3). It is uncertain whether these main

Table 8.6 pXRF data for Thomas Lagoon outcropping silcrete, grinding grooves and basalt artefacts

Location			pXRF data																	Principal components		
	Sample	Group	Ca K12	Co K12	Cu K12	Fe K12	Mn K12	Nb K12	Ni K12	Pb L1	Pb M1	Rb K12	Rh K12	Sc K12	Sr K12	Ti K12	Y K12	Zn K12	Zr K12	Prin1	Prin2	Prin3
GG1/2 next to grooves	TL1	1	454	48	130	7030	187	173	114	35	52	185	5350	1	428	648	0	227	1497	-1.049	-0.333	0.5055
GG1 in the groove	TL2	1	71	1	84	3838	109	111	99	33	81	74	3980	30	285	584	118	198	975	-1.988	-1.276	0.6867
GG2 in the groove	TL7	1	114	-2	119	4700	75	189	106	77	83	125	4880	20	251	809	0	208	1929	-1.345	-0.236	0.7269
GG2 in the groove, under dirt	TL4	2	80	1	137	3221	57	98	117	-19	30	38	4806	4	278	490	177	187	1347	-1.826	-0.29	-0.933
silcrete ~30m from GG1/2	TL6	2	65	37	143	2429	66	55	143	40	18	109	5266	1	191	319	150	186	3237	-2.15	0.2399	-0.821
GG2 in the groove	TL8	2	110	45	121	5507	68	175	96	80	32	289	4244	3	374	662	118	154	2252	-1.284	-0.218	-0.996
GG2 in the groove	TL9	2	118	183	134	18382	119	83	115	133	5	42	5606	13	160	875	9	184	1167	-1.715	0.6224	-1.34
GG4 in the groove	TL14	2	68	26	137	4679	123	109	101	-15	44	168	3194	1	82	747	137	258	3761	-0.798	0.5783	-0.534
GG4 in the groove	TL16	2	37	61	137	3559	63	7	114	40	33	163	3216	0	231	606	34	263	2618	-1.755	0.3556	-1.052
GG3 in the groove	TL18	2	30	30	117	2546	75	115	88	15	7	140	2648	15	177	291	108	240	2557	-1.809	-0.265	-1.297
on lichen ~30m from GG3/4	TL21	2	126	56	125	2841	76	143	110	48	33	215	2703	1	218	169	99	323	2122	-1.34	-0.683	-0.659
silcrete ~ 30m from GG3/4	TL22	2	46	0	115	1854	147	236	88	22	34	174	4896	16	193	222	0	191	3254	-1.563	-0.166	-0.402
GG4 in the groove	TL15	3	67	86	160	6424	134	127	110	107	27	123	4694	24	315	1226	67	236	5147	-0.595	1.9062	-0.034
GG3 in the groove	TL17	3	42	51	139	5244	248	0	113	63	22	109	4308	14	170	1072	2	286	5318	-1.176	1.883	-0.267
GG3 in the groove	TL19	3	26	0	100	6022	617	33	105	55	49	174	3732	36	158	1005	64	359	3366	-0.909	0.903	1.2553
GG3/4 next to grooves	TL20	3	72	0	118	6674	650	91	124	71	49	196	4383	20	245	993	12	283	5546	-0.637	1.7612	1.3999
on silcrete ~30m from GG3/4	TL23	3	36	100	126	8762	158	226	124	87	81	52	5858	5	64	805	176	210	6521	-0.177	0.951	0.9186
GG1/2 lichen	TL5	4	942	92	113	11220	126	186	153	29	105	136	5756	24	446	484	56	314	2143	-0.833	-1.568	3.8661
on dirt ~30m from GG3/4	TL24	5	476	309	202	18303	853	365	89	67	95	392	4838	2	989	1164	374	482	7033	4.6637	2.012	2.8429
GG2 in the groove on dirt	TL3	6	242	1260	159	86343	436	327	26	69	52	278	5300	1	639	1965	54	370	4282	5.4047	2.5694	-1.734
basalt cobble with grinding	TL10	7	84	638	150	45431	327	367	63	191	50	2949	5752	19	1647	785	133	574	3846	4.3073	-0.955	-0.66

Location			pXRF data																	Principal components		
	Sample	Group	Ca K12	Co K12	Cu K12	Fe K12	Mn K12	Nb K12	Ni K12	Pb L1	Pb M1	Rb K12	Rh K12	Sc K12	Sr K12	Ti K12	Y K12	Zn K12	Zr K12	Prin1	Prin2	Prin3
basalt cobble with grinding	TL11	7	82	702	145	53083	341	218	45	226	71	2083	5081	1	1474	1091	498	461	3747	4.742	-0.823	-1.234
basalt hatchet fragment	TL12	8	336	350	121	26319	161	218	90	81	72	2508	5923	1	5188	534	369	399	2829	2.967	-3.839	-0.095
basalt hatchet fragment	TL13	8	245	249	97	19930	159	144	76	106	62	1872	4267	18	3535	334	181	319	2372	0.8652	-3.13	-0.147

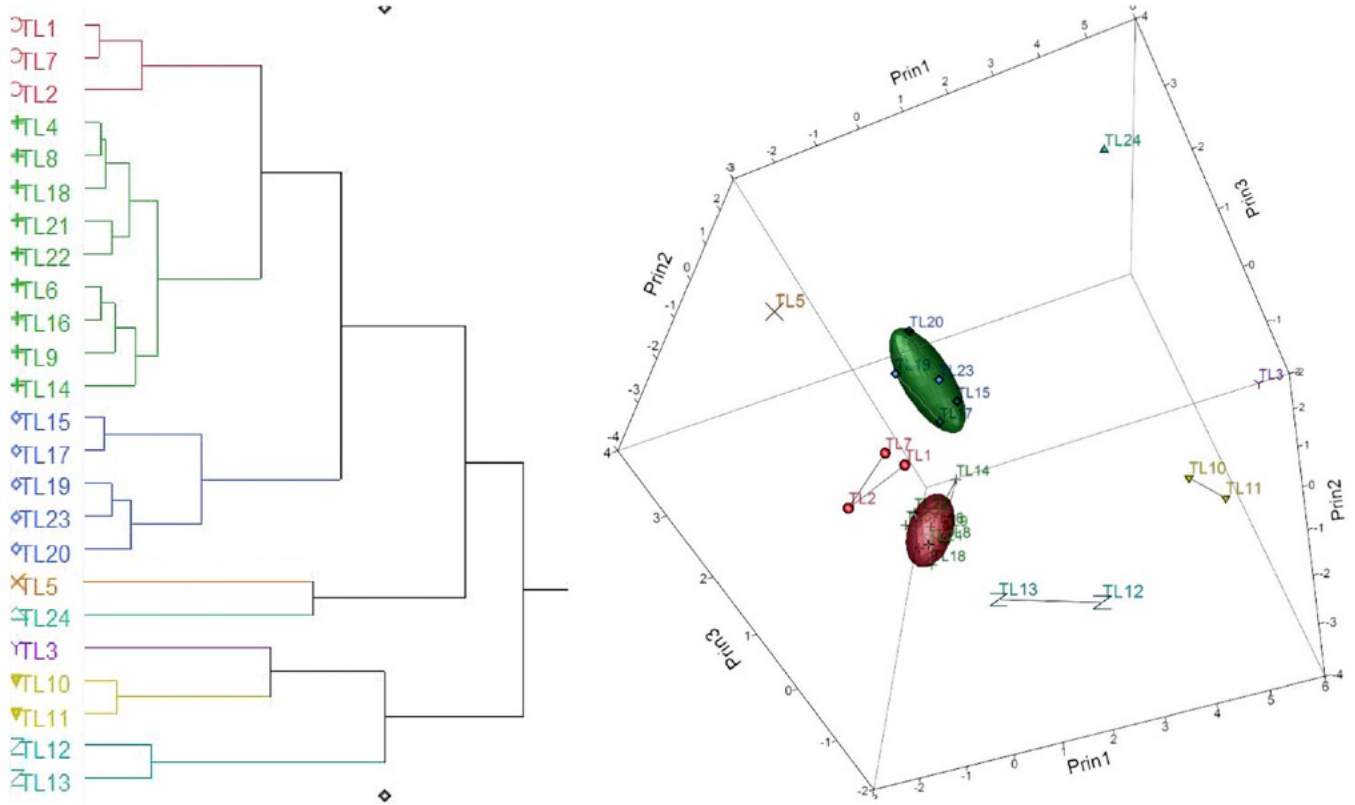


Figure 8.11 *Cluster analysis of pXRF data obtained for the outcropping silcrete, grinding grooves and basalt artefacts at Thomas Lagoon.*

groupings indicate variation in composition of the silcrete bedrock or variation in the composition of the stones that were held and ground into the grooves.

Discussion

Silcrete

The four variants of silcrete are characterised by relict primary rock features such as clast shape, rounding and sorting as well as petrographic features including grain size and distribution, relative cement and clast abundance and induration mechanism (syntaxial overgrowth or cementation). Outcrop style is closely related to the primary sedimentological features and overprinting textures of the silcrete. Gritty silcrete is similar to many types of sandstone used for grinding, and was used preferentially at Cressbrook Station and Thomas Lagoon. Abundant siliceous cement and the homogenous texture of Smc produces a smooth, non-porous silcrete more suitable for flaking, but lacking the uniform, rough surface qualities for grinding. The irregular, bumpy surfaces and large clasts of CGS and SB would also be ineffective for grinding intermediate materials or filing smooth the surfaces of stone hatchet heads.

Function

The microtopography of each grinding groove shows roughly smoothed surfaces typical of abrasive contact with hard stone. The larger more circular grinding patch at Chiswick (CH3) (Figure 8.6 has slightly more developed polish suggesting that other softer materials may have been ground or filed. The patches of wear on the sandstone grinding stone from Big Llangothlin has the most developed polish, indicating grinding of some intermediary material. The very low polish development on the silcrete grooves at Thomas Lagoon and Chiswick is consistent with use-wear from grinding stone hatchet heads. Extracted residues were low in abundance, with the exception of diatoms, hyphae and algal spores, all of which are derived from non-use agencies. The high frequency of these residues indicates that the grinding grooves have been immersed in rainwater (as observed on wet days). Exposure to extreme weathering episodes (drying, wetting, freezing and stock trampling) could have removed organic residues, but the use-wear indicates that an organic intermediary material is not likely, except for the larger circular groove in silcrete (CH2) and the sandstone grinding stone from Big Llangothlin.

The pXRF data appear to separate out three main groups of silcrete grinding grooves, the distant dirt sample and the basalt artefacts. However, we cannot infer support for grinding the particular basalt artefacts found at Thomas Lagoon, near the grinding grooves. It is likely that the grinding grooves have been exposed for long periods and extreme weathering has removed any impacted traces of basalt hatchet heads. Nevertheless, we recommend further study of this approach to identify impacted basalt residues within grinding grooves.

Conclusion

Silcrete bedrock and boulders may have been overlooked as potential focus of Aboriginal grinding activities, and perhaps it has been misidentified as sandstone, in some places. Our study identified four silcrete variants in the region and suggests that gritty silcrete was the preferred variant for grinding. Our sample size is small but our pilot use-wear/residue study indicates stone-on-stone wear, suggesting that the function of silcrete bedrock grinding grooves in the study area was predominantly for the manufacture and maintenance of stone hatchet heads, although one sample at Chiswick suggested processing softer material. We cannot exclude the possibility that grinding grooves were used for other purposes and traces have not survived the harsh weather conditions. The pXRF analysis did not identify

basalt traces in the grinding grooves, but we cannot exclude the possibility that locally available basalt or other particular tool stone was used.

Acknowledgements

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Chapter 9:
Contrasting Lake Formation and Late-Glacial Aeolian Activity Between the Tasmanian Central Plateau and Adjacent Midlands Graben

Kevin Kiernan, Anne McConnell, Robert Haworth, Richard Fullagar and Elspeth Hayes

Introduction

Variations in the character of lakes along a west-east transect across the Tasmanian Central Plateau and into the Midlands graben reflect a combination of forcing processes over time, including the effects of altitude, climate and tectonics working on the local lithology and landscape. The higher altitude and higher precipitation of the west allowed extensive glaciation in the colder phases of the Quaternary, producing distinctive small rock-basins that were eroded along bedrock lineaments and sometimes have a moraine-dammed threshold. In precipitation-shadowed areas further east, shallow depressions formed by weathering of susceptible rocks on back-tilted bedrock masses, sometimes coupled with damming by copious volumes of loose sediment that was produced under periglacial conditions, formed lakes that are commonly larger and less angular in plan than those in the west. At lower altitudes, east of the mountains in the Tasmanian Midlands, similar conditions formed shallow lakes and more ephemeral ponds and lagoons. While there are localised glacio-aeolian dunes associated with some of the glacial lakes in the west, the research reported in this chapter confirms that the source bordering aeolian deposits associated with the lakes further east are instead formed from sands and silts derived by primary weathering and erosion of local source rocks and reworking of earlier alluvial deposits. One sand unit in the drier periglacial environment of the Midlands was dated to as old as ~48 ka BP. Aeolian activity was particularly pronounced in the Midlands ~19-20 ka BP during the gLGM. The earliest lunette sands on the Central Plateau were dated at three sites to ~15-16 ka BP, suggesting desiccation associated with increased water uptake as a greater biomass developed immediately when the climate warmed or dried coincident with or immediately after deglaciation. One of the Central Plateau lunettes overlies a surface upon which numerous Aboriginal stone artefacts lie scattered. Elsewhere, artefacts observed during this study occurred only within the uppermost Holocene deposits, that is, dating to the last 5000 years. There is little evidence for any significant prehistoric human influence on landscape evolution apart from minimal soil surface disturbance.

The accessibility of water is obviously an important influence upon the potential for human use of any landscape, not only in terms of drinking water for humans and the animals upon which they may rely for food, but also as physical foci encouraging aggregation. Just as cultures vary in type and location, and transform through time, so do water bodies. These changes in the geography of water may be related to daily weather; seasonal changes that recur predictably within a single human lifetime; occur over decadal or longer timescales and hence be experienced but once or never by any one person or group; or involve changes that occur over millennial scales that go unnoticed by any one individual or group amid the noise of the everyday, but which profoundly influence human geography and culture in the longer term. The traditional views of indigenous Australians hold that they have simply always been present in the world, and science has confirmed their presence for at least 60 ka in northern Australia and 40 ka in Tasmania. Hence, humans have experienced changes in the geography of water

over all these time scales. Any organism has the potential to simply fall victim to such inevitable natural changes, but humans are among those species that also have the potential to adapt to environmental changes by changing their own geography or practices, or to themselves modify their environment and hence their opportunities, whether deliberately or inadvertently.

This chapter provides a geographical, geomorphological and hydrological backdrop to the archaeological investigations presented elsewhere in this volume. Its aim is to provide an environmental context for the human occupation of the studied archaeological sites, including the age and character of some water bodies relative to the known span of human occupation of Tasmania. It reviews likely modes of initial lagoon and lake inception, and how factors that influenced their subsequent evolution compare across a transect from the mountains of Tasmania's Central Highlands to the low altitude valleys that lie within the rain-shadow that those mountains cast, and some implications for these for the original Tasmanians. It addresses changes through time to the character of those occupied lagoons and lakes that may have influenced the geography, economy and culture of the people who were present around their shores. This includes the global climatic changes that caused their domain to fluctuate between being a southern peninsula of Sahul to the island we now know; some surface waters to be depleted due to reduced rainfall, enhanced evaporation or freezing as ice caps and glaciers gripped the mountains; and consequent changes to the plant geography and the game animals that it nourished. The evidence for human agency in further modifying the landscape, and how this may have varied from the Pleistocene to the present, is addressed in the subsequent archaeological chapter.

Background

An eastward transition in the morphology of the lakes in central Tasmania broadly parallels the precipitation gradient across the island, from over 1500 mm per annum in the west to 450 mm in parts of the central Midlands. The greatest density of lakes occurs in the windward western part of the ~ 5,000 km^2 Tasmanian Central Plateau, which slopes broadly eastwards from its north-western crest at ~ 1200 m altitude to ~ 1000 m in the south-east. Here the lakes lie within the former limits of small ice cap glaciers that developed at various times during the late Cainozoic, or the last few million years (Hannan 1989; Kiernan 1990, 1999; Jennings and Ahmad 1957). They are mostly glacially-eroded rock basins carved along bedrock lineaments, giving them strongly rectilinear outlines and sharp bedrock margins. In contrast, lakes on the drier, rain-shadowed eastern part of the plateau lie outside confirmed ice limits of late Cainozoic glaciers in terrain where loose surficial sediments are more abundant. These lakes are far less numerous than those in the formerly glaciated areas, are commonly much larger, and lack strongly angular bedrock shorelines. This eastward transition of lake forms continues onto the floor of the strongly rain-shadowed Midlands graben east of the Central Plateau, a 50 km-long tract at 200-300 m altitude caused by relative displacement of a block of land downwards with much higher country on either side. Here there are few permanent water bodies but many swampy or ephemeral basins that are locally termed lagoons.

Notwithstanding extensive glaciation of the higher parts of western and central Tasmania on several occasions during the last few million years, major loessic dust deposits of the kind commonly found world-wide downwind from glaciated areas are absent. However, small sand sheets and dunes occur around several lakes on the eastern part of the Central Plateau. Restricted source-bordering aeolian deposits up to a few metres thick also occur along the eastern side of some valleys draining the highlands (Nichols 1958; Sigleo and Colhoun 1975; Sigleo 1978). Some of these streams previously discharged glaciofluvial sediment, while the load of others was dominated by detritus produced by periglacial processes including rapid freeze-thaw activity. In addition, small lunettes formed around some lakes further east on the Central Plateau and also in the much lower Midlands (Sigleo 1978; Sigleo and Colhoun 1981).

Davies (1967) interpreted most of Tasmania's inland dunes as likely to date from a mid-Holocene semiarid phase around 5000 years before present (BP), but he also recognised that some might be of glacial age. An extensive sand body in far north-eastern Tasmania formed when glacially-lowered sea levels allowed an Australian continental desert dune complex to marginally overlap this part of Tasmania during the Last Glacial Maximum (LGM) (Duller and Augustinus 2006). The age and environmental implications of the inland sand bodies beyond the margins of the invasive desert dune complex are less clear. A post LGM age is implied for some small dunes in the west by their having been plastered against the up-valley sides of moraines of Marine Isotope Stage 2 (MIS 2) from 29-14 ka before present, including at Lake St Clair at the head of the Derwent River (Kiernan 1985). The age of the sands further east on the plateau has not previously been assessed. The few radiocarbon dates thus far obtained from around lagoons and lakes in the Midlands have all been of recent Holocene age, but radiocarbon dates and stratigraphic relationships led Sigleo and Colhoun (1975) to assign a glacial age to one sand sheet adjacent to a tidewater reach of the Derwent and to suggest a similar age for some other sands elsewhere in the Midlands.

While Davies (1967) envisaged dune formation as having been the product of mid Holocene aridity, subsequent palynological studies suggest a mid-Holocene arid phase across Tasmania can be discounted (Colhoun *et al.* 2010; Macphail and Jackson 1978; Macphail 1979). Nevertheless, drier and windier conditions appear to have been the main driver of the vegetation changes required to expose the ground surface sufficiently to allow entrainment of particles by the wind. However, human arrival in Tasmania dates from at least 34 ka BP (Allen 1996; Cosgrove 1995) and Sigleo and Colhoun (1975) recognised localised disturbance by Aboriginal Tasmanians of one sand surface in the lower Derwent probably as far back as the late Last Glacial (MIS 2). The ice cover during the glaciation of MIS 2 was relatively restricted compared to that present during some earlier glaciations, and the extent to which Aborigines may have utilised extraglacial parts of the Central Plateau even during glacial times, or how rapidly they may have done so as the climate ameliorated, has implications for their potential to have deflected vegetation trends, and hence influenced the evolution of aeolian landforms (Williams *et al.* 2015). Some more recent contributions have suggested that much larger scale sand mobilisation is attributable to Aboriginal activity. McIntosh *et al.* (2012) suggest that aeolian deposition was greater from 35-15 ka BP than at any previous time during the Last Glacial Cycle. They attribute this to either climatic effects such as windier conditions, or an increase in fire frequency involving an increased shrub-land biomass following extinction of the megafauna, coupled with the cold and dry glacial climate. However, it would seem to be drawing a very long bow to ascribe wholesale mobilisation of sand sheets to Aboriginal disturbance purely on the basis of overlapping time scales and in the absence of clearly demonstrated interaction, or from the mere presence of charcoal fragments in some deposits given that the Australian flora has evolved in the presence of naturally occurring fires over a much longer time frame than humans have been present on the continent.

Study area

The study area comprises the eastern edge of Tasmania's Central Plateau and the lower altitude Midlands area to its east. The Central Plateau is capped by Jurassic dolerite that originally intruded the essentially flat-lying sedimentary rocks of the Late Carboniferous-Late Triassic Parmeener supergroup. Erosion of the uppermost Parmeener rocks has left the relatively resistant dolerite capping the plateau. Those parts of the Parmeener sequence that remain beneath the dolerite comprise two broad divisions. The lowermost division comprises Palaeozoic (~300 million years old) glacial and glaciomarine beds, including tillite, siltstones, mudstones, sandstones, minor limestones and coal measures. The upper part comprises predominantly freshwater sediments including coal measures and mudstones that are overlain by abundant sandstones and gritstones. Basalts of Tertiary age are also present in some areas of both the Central Plateau and the Midlands.

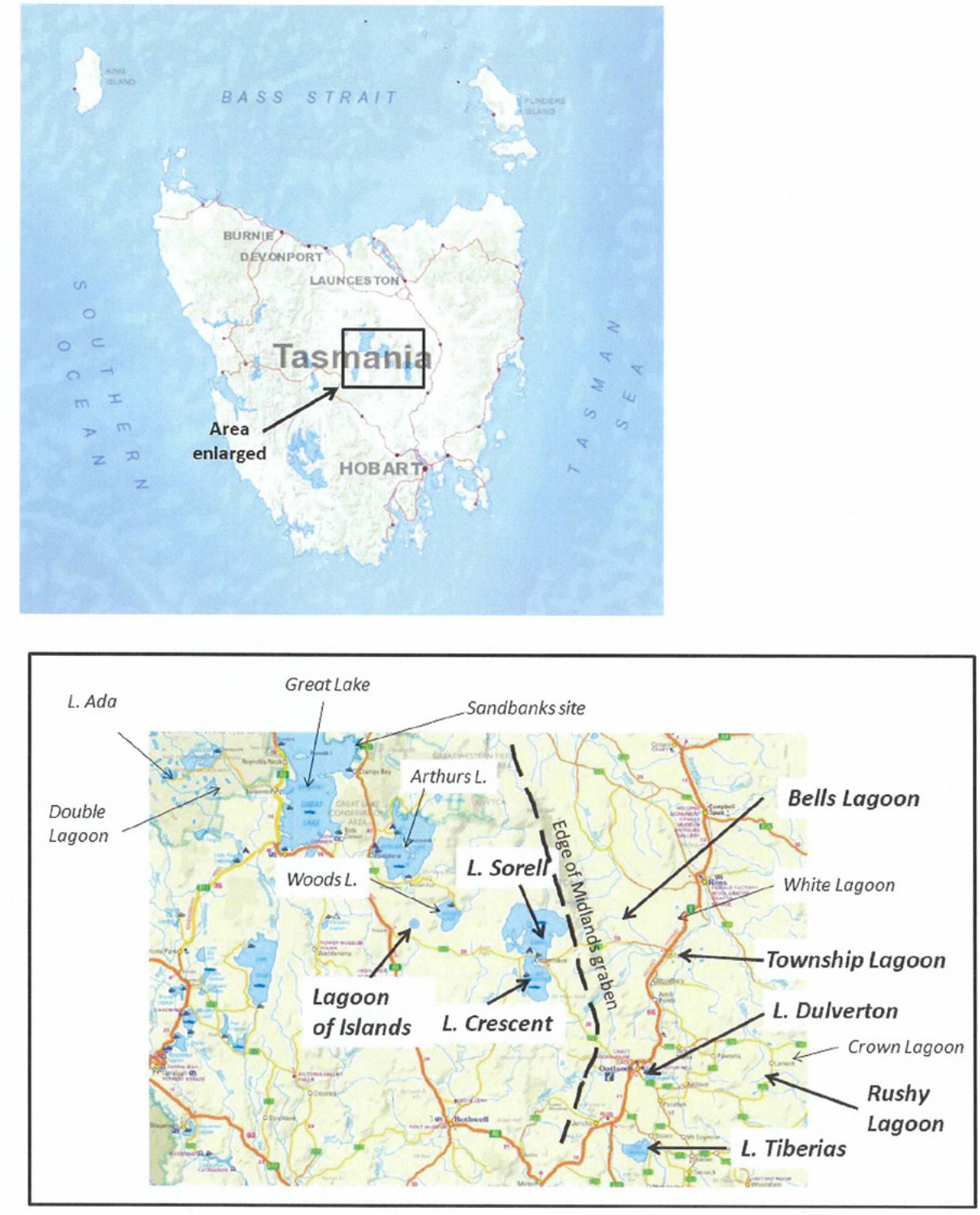


Figure 9.1 *Location of study area and sites examined during the fieldwork for this study. Principal study locations are indicated in larger bold type; other locations examined to obtain contextual or comparative information are indicated in smaller type.*

The broad form of the landscape is related to faulting that occurred during the late Mesozoic-early Tertiary as Gondwana fragmented, large volumes of the dolerite were intruded, and the Antarctic and East Australian plates separated. The tensional forces resulted in normal faults that are oriented predominantly NW-SE. The eastern margin of the Central Plateau is defined by the Tiers Fault in the north, and then a family of faults of broadly similar orientation further south (Forsyth *et al.* 2014). The faulting produced horst and graben systems, formed by normal faults of opposite dip. The grabens are represented by low lying areas such as rifts and river valleys while the horsts are represented by the ridges, escarpments or plateaus on either side of these valleys. The Tasmanian Midlands lie in a trough of subdued terrain that extends southwards from Bass Strait and which comprises the Tamar Graben in the north, then the Longford Basin, the Midlands Graben (Andrews 1910), and the Derwent Graben (Taylor 1918) in the south. A 400 m-thick sequence of non-marine sediments with basalt occurs within the Tamar graben, and a similar sequence up to 800 m thick occurs in the Longford basin. The Palaeocene-Eocene age of the sediments in the Tamar graben and Palaeocene age of those in the Derwent Graben, indicate that much of the faulting dates from the Early Tertiary. However, post Palaeocene plant fossils in deposits over 200 m thick that occur over 300 m above present sea level (Hill and Macphail 1985), imply some continuing tectonism in the Macquarie Harbour graben, west of the Central Plateau (Colhoun 1989). There was little faulting associated with later extrusion of lavas, including volcanic centres within the present study area (Banks 1958).

The Tasmanian landscape exhibits a somewhat 'stepped' form that Davies (1959) interpreted as sub-aerial erosion surfaces that formed following phases of uplift. This interpretation no longer enjoys significant support but the 'surface' names he established nonetheless still provide a useful framework for describing the conspicuously different levels in the landscape, namely the Lower Coastal Surface, 90-275 m; Higher Coastal Surface, 365-455 m; St. Clair Surface, 730-820 m; Lower Plateau Surface, 915-1065 m; Higher Plateau Surface, 1190- 1340 m; and High Monadnocks 1340-1614 m. The Central Plateau is a broad upland of ~ 4,600 km^2 that slopes broadly eastwards from its northern and western crest at ~ 1420 m altitude to ~ 600 m in the south and east. Within the study area the Higher Plateau Surface forms the uppermost tier of the Central Plateau, rising from 1200 m in the southeast to 1420 m in the northwest, with the Lower Plateau Surface prominent below this. The stepped form of the plateau margin in this area is dictated by geological structure. The Midlands are broadly equivalent to the Upper Coastal Surface.

Once consequence of the faulting has been the exposure along the horst flanks of the sedimentary rock units into which the dolerite was intruded. Breakdown of the Parmeener rocks has liberated particles of varying grain size ranging from clays and silts to coarse cobbles of siliceous rocks that originally occurred as erratics within the glacigenic rocks. Slope failure has left the horst slopes littered with fault-line-scarp breccias and more recent large boulders, while weathering of the dolerite has liberated considerable volumes of sediment from silty clay to cobble grade. The deposits contained within the grabens east of the central Plateau include both fluvial and lacustrine sediments that range from clay and silty clay through to coarse cobble beds. The finer fractions have been produced by weathering of dolerite, Parmeener sediments and granite in the adjacent uplands. The cobbles are predominantly of dolerite but there are also prominent siliceous cobble beds, the clasts presumably being erratics reworked out of the Permo-Carboniferous glacigenic sedimentary rocks. Some widespread surface cobbles may have resulted from the blocking of streams by lava flows. Lag deposits of pisolitic gravels occur in some areas. Thin veneers of Tertiary sediments that are overlain by basalt in the Lake Sorell area include probable subbasaltic silicastone and ferricrete (Forsyth 1989).

Climatic conditions on the plateau result from an interplay between simple altitude differences and the influence of topography on microclimates. Glacial erosion was intense along the western side of the plateau and little regolith remains to facilitate soil formation and provide material for dune formation,

but the intensity of glacial erosion diminishes eastwards in response to a rain-shadow effect. Hence, shrubs and herbfield and bog communities predominate due to scant soils, frosts and glazing winds, but with localised woodlands of *E. coccifera-E. subcrenulata* and alpine conifers. The eucalypt woodlands increase eastwards, with *E. gunnii* sometimes present around the margins of more open areas. Forests become more widespread on the Lower Plateau Surface, where grasslands are prominent in frost hollows and there are extensive shrubby areas and herbfield and bog communities. Eucalypt forest, typically *E. delegatensis-E. dalyrmpleanea*, predominates on the St Clair Surface but more open communities remain present in frost hollows and wetland communities are widespread in the most poorly drained areas. Forest density increases down the eastern margin of the plateau, partly in response to increased moisture availability where the cloud-base typically descends to ~1000 m around the plateau rim. Krumholz *Nothofagus cunninghamii* and other dense shrubs are locally common here, while *E. obliqua* progressively becomes a more prominent component of the eucalypt forests downslope, with *N. cunninghamii* and *Athersperma moschatum* present on some wetter slopes. Towards the foot of the escarpment, savanah woodlands with *E. pauciflora* and *E viminalis* over *Poa* sp. (pr spp.?) grasslands characterise the Midlands.

Atop the Central Plateau at Liawenee (1057 m altitude, 41.8997°S, 146.6694°E, 2001-2017) mean annual rainfall today is 953 mm, mean annual maximum and minimum temperatures are 12.1°C and 1.6°C respectively, with mean wind-speeds similar in all months but peaking at 26 km/h in September, predominantly westerlies but with north-westerlies and south-westerlies also exceeding 20%. The strongest winds are from the west and southwest. South-westerlies predominate and north-westerlies are reduced during the calmest month (June). A slightly longer record from a now-closed weather station at Shannon (altitude 939 m, 42.05°S, 146.75°E, 1957-1985) indicates a mean annual rainfall of 854.7 mm, peaking in August. Mean maximum and minimum temperatures are 11.4°C and 2.3°C respectively. Mean wind-speeds peak at 15.9 km/h in November with north-westerlies greatly predominating over south-westerlies and westerlies. All three can exceed 40 km/h but especially north-westerlies. North-westerlies are even more prominent in the calmest months (June and July).

In the northern Midlands, climate records for Campbell Town (altitude 200 m, 41.9333°S, 147.4833°E) from 1964-1988 indicate a mean annual rainfall of 578.8 mm, peaking in December, mean annual maximum and minimum temperatures of 17.8°C and 4.7°C respectively, and a peak mean monthly wind-speeds peaking at 16.9 km in November, mainly north-westerlies and northerlies but with southerlies approaching 20%. The same directions predominate in the calmest month (June) but with southerlies more prominent. In the southern Midlands, mean annual rainfall at Oatlands (406 m altitude, 42.3006°S 147.3711°E is 550 mm (1882-2017), distributed fairly evenly throughout the year but peaking in October-December. Mean maximum and minimum temperatures are 15.5°C and 5.0°C respectively. Mean monthly wind-speeds peak at 17.8 km/h in November and are primarily westerlies and south-westerlies, but with northerlies also significant. The westerlies and south-westerlies blow strongest. The same directions predominate in the calmest month (June) but north-easterlies also exceed 10%.

Methods

Three high altitude lakes located on the Lower Plateau Surface (Lagoon of Islands, Lake Sorell and Lake Crescent), and three lakes at lower attitude on the floor of the Midlands Graben (Bells Lagoon, Lake Tiberias and Rushy/Fonthill Lagoon), were selected for detailed study. Supplementary investigations were also undertaken around some additional water bodies for contextual purposes (Figure 9.1). The geomorphological research involved reconnaissance-level observations of bedrock exposures and Quaternary sediments around the perimeter of each selected lake. Record was obtained of slope deposits and alluvial sediments proximal to some lake shores; including the size of constituent clasts, clast angularity and weathering status, the latter being based mainly on the thickness of weathering rinds, assessing those formed on subsurface clasts separately from those on surface clasts. Investigation

of in-basin sediments included identification of cobble ridges and beach sands. The depth of organic-rich sediment on some basin floors was determined by hand auguring and examination of artificial drains. The spatial extent, morphology and stratigraphy of lunettes and sand sheets proximal to the lakes were recorded using aerial photography, ground based observations and hand auguring, and their stratigraphy recorded.

Particle size analysis was employed to identify changes in sediment size potentially indicative of changes in sediment provenance, and hence change in the depositing agent, such as wind, water or bioturbation (O'Connor 1990). It was also employed to assess the rate and continuity of sediment accumulation, and to identify any internal disturbance, taking account of the potential for confounding factors such as periods of soil formation with colloidal action producing fine clays, or of periods of deflation, or even anthropogenic disturbance, that might disperse sediment and cause a gap in the profile. Relative dating was achieved by examination of the morphostratigraphic relationships between these various elements, coupled with comparisons between the degrees of clast weathering in the slope deposits and the weathering status of dated glacial deposits elsewhere on and around the plateau, and variations in the degree of pedogenesis evident. Absolute age control was obtained by OSL dating of sand samples obtained from enhanced natural exposures or excavated pits. Multiple-aliquot age determinations were undertaken at the University of Wollongong, NSW, Australia.

Results

The Central Plateau lakes

1. Lagoon of Islands

Lagoon of Islands (altitude 758 m) is located on the south-eastern corner of the Central Plateau and occupies a shallow depression in hilly terrain that rises to *c.*850-900 m (Figure 9.2).



Figure 9.2 *Beach, lunette ridge and backswamp along the eastern margin of Lagoon of Islands*

It is fed by a small number of short creeks on its western margin and discharges from its the open southern end as Blackburn Creek, a tributary of the Shannon and then Ouse rivers, and ultimately the Derwent River. No Aboriginal name for this water body appears to have been recorded, but the name conferred by European colonists derived from the former presence of numerous floating islands. These islands were formed by the interlaced rhizomes of *Baumea arthrophylla* that covered virtually the entire surface of the lagoon, apparently having grown outwards from the shore to ultimately arch over the deeper water. Progressive colonisation of sections of the reed mat by sedges, shrubs and even small *Eucalyptus* sp. trees would eventually lead to their sinking under the accumulating biomass, resulting in demise of the vegetation and its decomposition (Tyler 1976). The mode of island formation was unique in the seral processes of floating islands reported from elsewhere around the world (Van Duzer 2004). This uniqueness was enhanced by the presence of several endemic plant species in the vegetation of the islands. Waterfowl are common.

The surrounding land has largely been cleared for pastoral use and the natural lagoon level artificially manipulated, triggering pronounced erosion of its sandy shores (Figure 9.3) and remobilisation of aeolian sand deposits.



Figure 9.3 *Large tree stumps in growth position attest to the extent of erosion along the eastern shoreline of Lagoon of Islands due to modern-day manipulation of its water level. Erosion of this magnitude is likely to have erased any evidence for previous Aboriginal use of the former shoreline area.*

The original area of the lagoon was just under 9 km^2 and its average depth 1.3 m, but it was artificially raised 2.5 m by a dam that was constructed for irrigation and fishery purposes in 1964. This led to shoreline erosion and destruction of the floating reed mat and the assemblage of islands, particularly severe erosion occurring in 1970-71 and 1974-75 (Cosgrove 1984a). However, the retained water proved inadequate for irrigation, so additional water was diverted into the lagoon in 1984 through excavation of a canal that diverted Ripple Creek into the basin, raising its level by an additional 2.2 m (Jackman 2012). Although this temporarily restored the impoundment to nearer its intended height, the water level subsequently declined again and this problem could not be resolved. In addition, decomposition of the plant material rendered the reservoir hyper-eutrophic and unsuitable for either agricultural use or as a fishery. The Ripple Creek canal was decommissioned in May 2010, four tributaries that had been artificially diverted into the lagoon were redirected back to their natural courses, and in April 2013 the dam was removed in the hope that restoration of the original ecology might be attainable. The fieldwork on which this paper is based was undertaken in late 2013 and in early 2014 immediately prior and subsequent to removal of the dam.

Published geological mapping by the Tasmanian Department of Mineral Resources depicts Lagoon of Islands as being entirely surrounded by Jurassic dolerite. However, some sedimentary rocks, principally sandstones, of the Carboniferous-Triassic Parmeener Supergroup are exposed in the lower reaches of the Ripple Creek canal on the northern side of the lagoon, where it contains numerous dropstones comprising a very wide range of lithologies. Pebbly sandstone crops out near the north-western corner of the lagoon, while a small localised patch of light sandy sediment on the south-western corner of the lake is also suggestive of decomposing Parmeener rocks at shallow depth. Debris lodged in the roots of wind-thrown trees behind the northern shoreline is dominated by Parmeener clasts.

The dolerite occasionally crops out as near-horizontal slabs that form the crests of some low spurs that project into the lagoon depression. Otherwise, virtually all dolerite surfaces have been shattered, with abundant angular fragments strewn downslope of them. On the northern side of the lagoon small block streams descend shallow valleys to within a few tens of metres above the lagoon surface. Shattered dolerite is particularly prominent where bedrock crops out along the lagoon margin. There are also localised small ridges of highly shattered dolerite that are oriented parallel to these shattered shorelines but lie at a slightly higher altitude. These ridges are absent from the steepest shores but otherwise remain at a consistent altitude irrespective of the severity of the shore slope (Figure 9.4).



Figure 9.4 *Low boulder ridge towards the western shore of Lagoon of Islands, interpreted as having been produced through bull-dozing by lake ice during the LGM.*

On all but the steepest slopes, where this material has spilled downslope, the vertical amplitude of these higher debris margins is less than 1.5 m. They are interpreted as reflecting earlier higher-level

shorelines. The surveyed height of the uppermost of the ridges coincides with the floor of one of a series of broad embayments into the bedrock-bounded south-western margin of the lagoon depression. This relationship hints that shoreline erosion may have been responsible for formation of the embayments, although it does not demand this origin. Coring through the peaty lagoon floor revealed an irregular surface of rock debris along the western shore, but further out the peat is underlain by light coloured sand. Aeolian sands occur along the eastern and south-eastern margins of the lagoon. The bulk of the sand along the southern shore is plastered across low-angled bedrock dolerite, forming a broad and apparently stable ridge.

Along the eastern shoreline there are 1-2 steep and narrow lunette ridges ~ 6-8 m high that are markedly less stable and are subject to considerable ongoing erosion (See Figure 9.2). In a few places the sand is very heavily iron-panned, and perching of moisture upon this has permitted formation of some pools and swamps leeward of the lunette. Piping of the sand from immediately beneath the hard pans reflects localised discharge of water from these wet areas onto the upper edge of the beach. Two very low beach ridges occur forward of the lunette system, the upper one 40-60 cm above the lower. These have not been erased by the wind erosion that has formed scours through the lunettes, which suggests that these beach ridges are very recent and that they are probably related to the artificially high water levels associated with dam construction. Dark-coloured organic material appears to carpet almost the entire lagoon floor. At the western shore of the lagoon this organic sediment overlies frost shattered detritus. Within 10 m of the edge of this material its depth exceeds 1 m, and coring along a transect extending right across the lagoon floor confirmed that it remained at least this thick; it is probably much thicker. Light coloured sand was encountered beneath this organic material wherever its base was reached by this coring. Approaching the eastern perimeter of the lagoon this material still overlies the lagoon floor and extends onto the lowermost beach sediments. Sections and coring towards the thalweg of the valley that was dammed to raise the lagoon water level reveal that ~ 1 m of the organic sediment is underlain, at least locally, by > 1 m of blue-grey gleyed lacustrine or palludal clays.

Morphostratigraphic relationships and post-depositional modification of the sediments permit erection of a broad relative dating framework. The slope deposits that overlie the bedrock surfaces indicate that the key bedrock landforms all predate the phase of intense rock shattering and mobility of the clasts that this shattering produced. Angular fragments in various stages of detachment from their parent outcrops are uniformly weathered on their outer surfaces which, together with lichen and moss over-growth across many fractures, suggests that rock fragmentation is no longer occurring. The mechanical weathering responsible for producing the angular clasts is likely to have involved frost shattering under previously colder conditions that also facilitated mobility of the block stream.

The pronounced rock shattering has involved dolerite surfaces at the lagoon margin, consistent with repeated freezing of moisture at the shoreline. The narrow ridges of rock rubble along parts of the shoreline are interpreted as having been produced by frost shattered debris having been pushed against the shore by ice on the lagoon surface. Subsurface clasts in the matrix-supported slope deposits exhibit weathering rinds up to 2 mm thick, which is only slightly greater than the average 1.3 mm rinds that have formed on dolerite clasts in tills in comparable climatic and pedogenic settings elsewhere in Tasmania that were deposited during MIS 2 (Kiernan 1989). This suggests that the uppermost of these slope deposits accumulated during the Last Glacial cycle, probably during MIS 2. The lake-bed sands and aeolian sands overlie some of the angular rock rubble and hence must post-date it, allowing the possibility of their being either late-Glacial or Holocene in age. Shoreline erosion has exposed iron pans and a remnant B horizon at depth in the lunette sands. These pans are the product of seepage through the sand by organic-rich back-dune waters, and they indicate that pan formation is rapid under present day conditions. Hence, despite localised intense panning of the lower sand, this alone does not demand that it is of particularly great age.

Exposures along the western face of the main lunette complex have revealed the deeper sand to be yellowish-brown in colour. It is locally capped by remnants of a B horizon that formed prior to deposition of the upper and lighter coloured sand unit that forms the bulk of the present lunette. Grain size analysis of sand samples obtained from along the dune face revealed all to be unimodal fine sand, sometimes with subdued finer secondary silt/dust peaks (Table 9.1).

TABLE 9.1 GRAIN SIZE ANALYSIS OF SANDS FROM LAGOON OF ISLANDS

Depth (cm)	Volume weighted mean (microns)	Character
Sand from eastern lunette LOI BOW (BLOW OUT WALL)		
LOI BOW (BLOW OUT WALL)		
2	261	unimodal: fine to medium sand; small tail of silts
50	248	unimodal: fine sand; zero silts.
100	276	unimodal: fine to medium sand; extremely small silt tail
LOI S1		
0-2	230	unimodal: fine sand; zero fines (silt, clays, colloidals)
LOI-S2		
60	240	unimodal: fine sand; faint tail of silts etc.
LOI S4		
12-15	249	weakly bi-modal: dominant fine sand; subdued fines peak; ?colloidal tail
15-20	240	weakly bimodal: dom. fine sand; smaller peak of silt
38-40	199	weakly bimodal: dominant fine sand; smaller silt peak
65	227	weakly bimodal: dom. fine sand; smaller silt peak; long silt tail
LOI S5		
0-1	222	weakly bimodal: fine sands dominant; smaller silt peak; long silt (or dust) tail
20	197	weakly bimodal: fine sand main peak; small silt peak; silt tail
45	245	weakly bimodal: dominant fine sand peak; subdued silt peak; silt tail
55	209	weakly bimodal: dominant fine sand peak; subdued sit peak; silt tail
Beach sand LOI—S3		
26-27	231	weakly bimodal: dominant fine sand peak; smaller silt peak
40	248	unimodal: fine sands; weak silt tail

The bulk of the sand is likely to have come from a nearby source. The subdued secondary silt peak could reflect either a small long-distance source, or more likely some limited lacustrine or flood deposition, or possibly some in-situ colloidal development to explain the fine tails. Given the geomorphic location of the sampled dunes in a fairly sheltered basin, the profiles suggest a local wind-blown origin for most of the sample with a small very fine fraction which may have been either wind delivered fine dust,

or silt deposited by fluvial or flood water input. The most likely source of the sand is by breakdown of the sedimentary rocks that occur in some locations around the lagoon margins, in the catchment of streams that drain into it, and probably from the floor of the lagoon. The persistently uniform pattern suggests little internal disturbance from bioturbation or other processes.

Samples for OSL dating were obtained from 50-85 cm depth at four locations along the eastern end of Lagoon of Islands (Figure 9.5). These samples (LOI S1, S2, S4, and S5), gave ages ranging from 15.6±1.0 to 16.6±0.7 ka BP (Table 9.2).



Figure 9.5 *Typical section through the lunette face at Lagoon of Islands, showing iron-panned darker sand overlain by looser-textured and unconsolidated paler sands.*

Table 9.2 OSL dating of sediments at Lagoon of Islands

Sample	Location	Depth (cm)	Stratigraphic position	Date (ka)
Sand from eastern lunette				
LOI S1	Southernmost scarp	50	pale upper loose sand	15.8±0.9
LOI S2	Blow-out floor	60	lower indurated sand	15.6±1.0
LOI S4	Central scarp	60	30 cm beneath indurated zone	16.6±0.7
LOI S5	Northern scarp	85	25 cm beneath heavy iron pan	16.4±0.7
Beach sand				
LOI S3	120 m windward of blow-out	50 cm	20 cm depth in sand beneath blow-out beneath 28 cm lake-bed organics	13.6±0.8

The uniformity of grain size and ages suggests that the dunes were all formed at a similar time and maintained from the same source and agent, with little disturbance. Cosgrove (1984a) had previously interpreted the lunette as being of Holocene age, but conceivably as old as 10 ka BP. A further sample (LOI S3) obtained from 50 cm depth in beach sand beneath peaty organic sediment that carpets the basin floor 120 m forward of the lunette gave a slightly younger age of 13.6±0.8 ka (Figure 9.6).



Figure 9.6 *Thin organic sediment overlying beach sands dated to 13.6±0.8 ka (LOI S3), eastern end of Lagoon of Islands.*

The latter is stratigraphically consistent with a radiocarbon age of 7,430±150 previously obtained by the late W. D. Jackson from the base of the peat overlying the sand that floors Lagoon of Islands, but no specific site information is now available for that sample (Colhoun 1979).

Stone artefacts found towards the north-eastern corner of Lagoon of Islands occur in three principal situations: (1) close to the lagoon shore between a small tributary stream and the northern end of the lunette system; (2) along the sand flats immediately west of the lunette in positions where there is evidence for very pronounced recession of the lunette face; and (3) in a wide blow-out that cuts through the lunette. Very few artefacts were located on the sheltered eastern side of the lunette where there has been relatively recent deposition of sand blown from the lunette crest. No artefacts were found on the eastern lunette itself, despite relatively clear ground surface visibility along much of its length and the likelihood that aeolian erosion of the sand would have left a lag of any stone tools formerly present on or with the upper sands of the lunette. In addition, inspection of sand brought to the surface from deeper in the lunette at 11 wombat burrows and by the roots of 23 large-wind-thrown trees also failed to reveal any stone tools or other rock fragments. This suggests that the lunette ridge in this area is largely sterile with respect to Aboriginal artefacts.

While it remains possible that the artefacts on the lower sand unit have been lowered onto it by deflation from the upper sand, the failure to find any concentrations of stone tools on or in the lunette

is suggestive that occupation occurred prior to its formation. Given the 15.8 ±0.9 ka age of the lunette mass, this indicates human presence along the eastern shoreline of Lagoon of Islands prior to that date. The most likely scenario is that campsites on the leeward eastern side of the lunette were subsequently buried as the sand mass was blown eastwards, stone tools being revealed on the windward side of the migrating sand. No significant broad-scale charcoal concentrations suggestive of wildfires of potential Aboriginal origin were detected.

Towards the western end of the lagoon basin stone tools occur on dolerite ridges and on the floor of some embayments where they are scattered upon dolerite bedrock and on the detritus derived from it. Given the evidence for this shattering having occurred during MIS 2 these artefacts imply an Aboriginal presence subsequent to climatic amelioration. Some stone tools also occur on the sand that mantles bedrock slopes well above the lagoon floor along the southern edge of the lagoon basin. Here the underlying sand is yellowish in colour, unlike the upper sand unit in the lunette, but there are no ready means of determining the age of the artefacts. The Lagoon of Islands area is known to have been used historically. Although there is no information on the use of the lagoon itself, various resources (*e.g*, cider gums, another edible gum, native bread) occur in its vicinity.

Aboriginal stone artefacts around the lagoon margins comprise rock types that occur locally, including as ice-rafted erratics in the Parmeener rocks. The artefacts on the beach at the eastern end of the lagoon occur almost entirely on the yellow iron-panned sand and appear absent from the upper sand. This is suggestive of Aboriginal presence dating back to the Pleistocene. A steep and active scarp face along the main lunette attests to severe erosion by waves when the dam was full. The lunette has also been breached by some wind scours, in one case leaving remnants of old fence-lines up to 60-70 m windward of the inner end of the sand blows. Sand blown from the scours and dune crests has locally spilled into small back-dune ponds and swamps lee-ward of the lunettes. Trees windward of the retreating lunette scarp appear to have grown in the indurated lower sand. About 50-100 m windward of the eastern lunette remnants of beach ridges and small dunes rise no more than 1-2 m above the bed of the lagoon. Large cut tree stumps that occur in growth position on the eroded surface of some of these dune remnants suggest some erosion occurred prior to artificial manipulation of the lake level, possibly due to over-grazing by livestock. No evidence was detected for any larger scale landscape disturbance in this area having been caused by its previous Aboriginal inhabitants, despite their apparently very long-term presence.

2. Lake Sorell

Lake Sorell (altitude 804.36 m) is located 13 km east Lagoon of Islands. It has a surface area of 51.6 m but a maximum depth of only 4.3 m, its mean depth being 3.07 m. Its catchment area is 98.4 km^2. Lake Sorell is partly divided by bedrock spur that forms a projecting peninsula, and the small St Georges Island offshore. This lake lies along the uppermost tributary of the Clyde River, which joins the middle reaches of the Derwent River. The Clyde River provides the water supply for the historic towns of Bothwell and Hamilton, and the lake level has been slightly manipulated for this purpose since the 1830s. It is historically noteworthy as the site at which the Young Irelander Thomas Meagher, a political prisoner exiled to Tasmania by the British government, built a cottage in which he lived with his wife Catherine beyond the Dogs Head promontory at the head of picturesque Powells Bay. Rendezvous with the other Young Irelanders occurred in the nearby cottage of a shepherd named Cooper, located where the police districts to which they were officially confined theoretically overlapped. Lake Sorell is surrounded mainly by woodlands but with some areas of pasture, and part of its southern shoreline is included in the Interlaken Lakeside Reserve, which is listed under the Convention on Wetlands (Ramsar, Iran, 1971) (Ramsar Convention) as an internationally significant wetland. Hence, both the lake and surrounding bushland are likely to have provided plentiful food resources for Aborigines. The freshwater golden

galaxias fish (*Galaxias auratus*), endemic to Lake Sorell and to adjacent Lake Crescent, and their tributaries, and is listed as Rare under Tasmanian legislation and endangered under Commonwealth legislation. Lake Sorell now has a reputation as a recreational fishery based on introduced exotic trout.

Lake Sorell is surrounded by hills of Jurassic dolerite. Very small outcrops of lithic rich quartz sandstone and pebble layers of Permian age occur immediately inland of the western shoreline and in the hills south-east of the lake. There are also rare outcrops of Permian sedimentary rocks at the northern end of the lake. Tertiary basalt crops out locally in the west near Kemps Bay and Kermodes Bay. Basalt also forms the small Dogs Head peninsula on the eastern shore; and a small hill at the southernmost extremity of Lake Sorell. Angular clasts of dolerite form slope deposits on the flanks of some hills and basalt slope deposits are also present locally. Weathering rinds formed on subsurface clasts in the dolerite slope deposits are up to a few centimetres thick in some areas but thicknesses of 1-3 mm are more common, consistent with them being most recently mobile during the LGM (Kiernan 1989). Along the lower reaches of some tributary streams, such as in the Silver Plains area, these slope deposits have been buried by alluvial silts, while close to the lakes they are mantled by palludal and lagoonal sediments. Aeolian dune and sand deposits and palludal and lagoonal deposits with higher level shoreline deposits occur along the shoreline of Powells Bay at the eastern extremity of Lake Sorell.



Figure 9.7 *Extensive beach and dune sands on the north-eastern shoreline of Lake Sorell.*

Four short sandy beaches occur along the western side of Lake Sorell with a much larger sandy beach 800 m long and often 50-100 m wide is present in the north-eastern corner of the lake at Powells Bay (Figure 9.7).

Sand dunes 4-5 m high occur behind the beach with sand still up to 1 m thick occurring about 100 m inland, beyond which only a thin film of sand appears to exist. The lake-face of the dunes is actively eroding due to wind-driven waves when the lake level is high, and wind erosion of the exposed face. Sand blows penetrate up to 100 m back from the dune face, over-running and killing shrubs and trees (Figure 9.8), probably due to past fires, clearing and other disturbance since European settlement.

Samples obtained from 100 cm and 200 cm depth were both strongly unimodal fine sand (Table 9.3).



Figure 9.8 *Actively mobile sand behind the north eastern shoreline of Lake Sorell.*

Table 9.3 Grain size characteristics of dune sands at Powells Bay, Lake Sorell

Depth (cm)	Volume weighted mean (microns)	Character
LS-02		
100	184	strongly unimodal: fine sand
200	226	strongly unimodal: fine sand

Apart from the sand around Lagoon of Islands, 13 km further west, there is no apparent sand source upwind. There are outcrops of sandy siltstone and mudstone of Permian age within the Lake Sorell catchment south-east of the lake, and also in the headwaters of Scrubby Den Rivulet, which drains into its northern end. The only potential source rocks at or close to the lake edge are very minor occurrences of the Permian rocks and a tiny outcrop of Triassic sandstone. Twelvetrees (1902) suggested that the sand probably came from the bed of the lake and, although the lakeshore exposures of potential source rocks are very restricted, they are nevertheless suggestive that the contact between the dolerite and sedimentary rocks beneath it may indeed be very close to the surface, and that further occurrences of these rocks may form parts of the lake bed.

Two samples for OSL dating were obtained from the base of the eroded western face of sand dune located near the apex of Powells Bay, adjacent to the Young Irelanders' site immediately north of the Dogs Head peninsula (Figure 9.9).



Figure 9.9 *Sampling site used for dating of the north-eastern lunette at Lake Sorell. The lower sample (LS-01) gave an age of 0.6±0.1 ka and the upper sample (LS-02) gave a result of 0.1±0.01 ka*

Sample LS-01 was obtained from 315 cm depth, ~15 cm beneath a 5 cm thick darker-coloured zone, conceivably a very incipient palaeosol. It gave an age of 0.6±0.1 ka. Sample LS-02, from 265 cm depth, gave an age of only 0.1±0.01 ka, consistent with the current mobility of this sand mass having been in progress for some time.

No Aboriginal artefacts were found associated with the aeolian sediments. Given their presence elsewhere around the lake shores, and also in the Silver Plains area a short distance to the west, their apparent absence from the Powells Bay dunes may have resulted from sites located on the leeward side of the dunes having been buried by the sand. Instability of the dunes at Powells Bay clearly predates colonial settlement by some centuries, but no evidence for fires having triggered it was detected. The very considerable volumes of sand mobilised over the last century or so are consistent with post-colonial disturbance of the vegetation but the lakeshore erosion has also coincided with the period over which the level of Lake Sorell has been artificially manipulated.

3. Lake Crescent

Lake Crescent (altitude 804 m) is located 200-300 m south of Lake Sorell from which it is separated by a few hundred metres of topographically subdued, sometimes swampy land that is mantled by alluvium that fills narrow gaps between low bedrock hills. Lakes Sorell and Crescent may once have formed a single water body. Lake Crescent extends over an area of 23.1 km^2 and has a maximum depth of 3.8 m, averaging only 2.3 m deep. Its local catchment is 32.8 km^2 but it also receives discharge from Lake Sorell (Uytendaal 2006). It is the source of the Clyde River, a tributary of the Derwent River. Lake Sorell is surrounded by grassy woodlands, marshes and some farmland, and its level has been artificially manipulated since the 1830s for water supply purposes. Despite the close proximity of lakes Crescent and Sorell, and their physical and chemical similarity, Lake Crescent has ten times the standing crop biomass of phytoplankton than Lake Sorell. However, its greater turbidity limits light penetration and restricts production per unit of surface area to only 2.6 times greater than Lake Sorell. Historically, Lake Crescent has been the more turbid of the two lakes, and been dominated by phytoplankton, in contrast to the clear, macrophyte-dominated water of Lake Sorell. Turbidity is greatest when the lake level declines nearer to the natural level that prevailed prior to manipulation of the water level. Drought and competition for water by various users has seen persistent low lake levels and declining water quality and ecological values. Evaporative losses from the wide, shallow lakes greatly exceed water lost to irrigation and town water supply for Bothwell and Hamilton. The Interlaken Lakeside Reserve (173.5 ha) in the north-western corner of Lake Crescent has been listed as an internationally significant Ramsar wetland since 1982. Hence, Lake Crescent is likely to have provided plentiful aquatic food resources in addition to the marsupials and other wildlife of the surrounding plains and hills.

Like Lake Sorell, Lake Crescent is largely bounded by Jurassic dolerite hills that rise around 100 m to 880-920 m west and east of the lake, and almost 300 m to 1097 m atop Table Mountain, 4 km to the south-west. At its southern end the depression that contains the lake is floored by sandstones, commonly quartzitic and cross bedded. Two low ridges of Tertiary basalt occur to the south and south-west. Dolerite slope deposits are less widespread around the Lake Crescent shoreline than they are around Lake Sorell. Where present, these deposits, and also other small occurrences of basalt slope deposits, appear to be at least partly overlaid by the palludal and lagoonal sediments that predominate around the lake margins. Quaternary dune and sand deposits are pronounced along the eastern shoreline south of Trifitt Point, and also at the south-eastern extremity of the lake, where they overlie the dolerite slope deposits.

Given Lake Crescent's close proximity to Lake Sorell, similar influences on lake basin formation are likely to apply. Eruption of Tertiary basalt that forms a low hill at the northern extremity of Lake Crescent may have separated into two a once-continuous water body. If Lake Crescent formed independently of Lake Sorell then tectonic tilting that ponded water, coupled with decomposition of the sandstone that forms at least part of the lake bed, probably accounts for initiation of the basin. Given the impeded fluvial discharge, deflation under dry conditions is likely to have removed some of the weathering products, assisting in the attainment of its limited depth. Basin widening is likely to have involved chemical weathering of the dolerite and stripping of the weathering products by lakeshore erosion.

A sandy beach about 1.2 km long but seldom more than 10 m wide occurs at the south-eastern corner of Lake Crescent, towards the western end of its Table Mountain Shore. Another sandy beach about 1.7 km long occurs along the Sandbank Shore on the eastern margin of the lake (Figure 9.10).



Figure 9.10 *Angular dolerite clasts overlain by thin beach sands along the Sandbank Shore of Lake Crescent.*

At least two series of dunes occur along the eastern shoreline (McConnell 2009). This dune system is at least 200 m wide, and localised active blow-outs penetrate into the vegetation for up to 100 m. The dune system also continues for several hundred metres northwards from the beach behind a steeper shore. Here it crosses the mouth of a wide opening in the dolerite hills east of the lake. This opening is floored by sand at least as far inland as Agnews Marsh (814 m altitude), a small former lake 1.5 km distant that is aligned NW-SE and which appears to have its own small lunette at its south-eastern end. The dunes along the Sandbank Shore have been eroded by wave action, presumably during times when the manipulated lake level has been high (Figure 9.11). The undercut and collapsing sand-dunes are being actively eroded by the wind. Burial by the wind-blown sand is progressively killing shrubs and trees immediately behind the dunes.

In the absence of sand sources upwind from Lake Crescent, the sand accumulations along its southern and eastern shorelines seem most likely to have been derived from the sandstone outcrops that form the lake bed at its southern end. Sand of similar origin may have been introduced by small tributary streams and the discharge from Lake Sorell. Sand samples were obtained from the varying depths in a profile exposed along Sandbank shore. Here light grey sand 2-10 cm deep graded into very light coloured unimodal fine sand with a transition to medium sand at 50 cm depth (Table 9.4).



Figure 9.11 *The dune along the Sandbank Shore of Lake Crescent continues to be actively eroded when an artificially high water level is maintained in the lake.*

Table 9.4 Grain size analysis, Lake Crescent.

Depth (cm)	Volume weighted mean (microns)	Character
TLC 01		
0-2	242	unimodal: fine sand with incipient v.fine sand peak
50	250	unimodal: fine/medium sand boundary
200	264	unimodal: medium sand
290	265	unimodal: medium sand with incipient v fine sand peak
300-340	243	unimodal: fine sand peak; incipient v.fine sand peak
350	245	unimodal: fine sand peak; incipient v.fine sand & silt peaks (colloidal?)
TLC 02		
100	243	unimodal: fine sand peak
TLC 03		
10-20	276	unimodal: medium sand peak; incipient v.fine sand peak

At 1.9 m depth there is a sharp demarcation between this light coloured upper sand and more indurated sand of yellowish brown colour, very similar in appearance to the sand observed in some profiles at Lagoon of Islands. It comprises unimodal medium sand but fine sand, with incipient very fine sand and silt, peaks then persist from 290-340 cm the base of the visible section. Single samples from two other sections along the Sandbank Shore also proved to be unimodal fine or medium sand. The volume weighted mean for all samples was restricted to the range of 242-276 microns. This uniformity suggests a similar sand source for all these samples, and the grain sizes are consistent with wind having been the transporting agent.

Sample TLC 1A from 204 cm depth in the indurated yellowish-brown sand returned an OSL age of 16.9±1.2 ka (Figure 9.12). Sample TLC 1b from 120 cm depth in the loose upper sands gave an age of 0.1±0.01. The first date again confirms a late glacial phase of lunette construction on the Central Plateau, while the latter is consistent with the visible present day sand movement around the site.



Figure 9.12 *Sampling site for OSL dating, eastern side of Lake Crescent. The lower sample from the indurated yellow sand gave an age of 16.9±1.2 ka (TLC-1a) while the loose upper sample was dated 0.1±0.01 (TLC-1b), comparable to the result obtained from Lake Sorell.*

Of those Aboriginal sites thus far identified around Lake Crescent only one, an artefact scatter at the southern end of the Sandbanks Shore, is associated with aeolian deposits (Thomas and Associates 1986, Chilcott 1986, McConnell 2009). The absence of more sites from the sandy shores may reflect more recent shoreline erosion and shifting of the sand mass rather than the absence of prior Aboriginal activity there. The date of 0.1±0.01 ka obtained from 120 cm depth in the dunes along Sandbanks Shore is consistent with the current phase of dune instability post-dating colonial settlement and the artificial manipulation of the water level in Lake Crescent.

Unnaturally high lake levels have the potential to permit further erosion of the dunes around Lake Crescent. The rocky substrate essential to spawning of the endangered golden galaxias, while abundant in Lake Sorell, is not available below 802.2 m AHD in Lake Crescent, and hence at least shallowly covering this during the spawning season, which occurs over the windy winter months, is an important management consideration (Inland Fisheries Service 2008), as is the need for occasional flooding of the Ramsar wetlands at the northern end of the Lake Crescent (Heffer 2003). Current water level management also aims to maintain the level sufficiently high that the recreational exotic trout fishery is not degraded by turbidity resulting from bottom scour (DPIWE 2005, Uytendaal 2006). Hence, balances need to be struck and careful management employed if the aeolian geoheritage of Lake Crescent is not to be further degraded by lakeshore erosion.

The Midlands lagoons

4. Bells Lagoon

Bells Lagoon (257 m altitude) is located 9.5 km east of Lake Sorell but nearly 600 m lower, on the floor of the Midlands graben. It is aligned NNW-SSE, with a length of 1.46 km and maximum width of a little under 500 m, and is kidney-shaped due to a bedrock hill that intrudes into its western margin. Bells Lagoon is the southernmost of a complex of lagoons that extends for 5 km northwards across the Ellinthorp Plains area, located within a wind-gap between two dolerite ridges, Kitchener Ridge (~305 m) to the east and Gavins Sugarloaf (>600 m) to the west, the latter being a spur from the Great Western Tiers. The hill on the western shore of Bells Lagoon reaches 257 m altitude and it is bounded to the south by a ridge that attains just over 250 m altitude. Its waters drain northwards into Ferndale Creek and then via the Isis, Macquarie, and South Esk rivers before ultimately joining the Tamar River. The terrain surrounding Bells Lagoon has been converted to farmland, the lagoon outlet has been partly canalised and an historic World War II bunker at its southern end adds to the historical human impacts.

Minor outcrops of Triassic lithic and quartz-rich sandstones occur on the lowermost slopes of both margins of the wind gap. Bells Lagoon has been impounded at its northern end by sediment that accumulated against the northern slope of one of several low remnant dolerite hills on the floor of the wind gap. Its western margin abuts a ridge of bedrock dolerite, to the west and north of which are Tertiary sediments with ferricrete that comprises altered Tertiary sediments including pisolithic conglomerate and some massive ochre. Much of the western ridge is mantled by lag deposits of Tertiary siliceous rocks, ferruginous fragments and pisoliths that also occur on the low land north of the lagoon. Localised marshy deposits at the northern end of the lagoon may represent a fossil shoreline. Aeolian sands mantle the terrain east of the lake where they are plastered against the foot of Steeles Bluff at the southern end of Kitchener Ridge. These sands may have infilled a former embayment, thereby imparting the presently elongate form of Bells Lagoon, which is now oriented NNW-SSE in the thalweg or topographically lowest part of the wind gap. Aeolian sand has been deposited across and accumulated above and beyond the rock bar that forms the southern shoreline, imparting the appearance of a massive lunette (Figure 9.13) although in some places the sand is only a relatively thin veneer.



Figure 9.13 *Bells Lagoon, viewed from the sand-veneered bedrock ridge that bounds its southern end.*

Breakdown of infrequent exposures of bedrock dolerite has produced angular clasts generally less than 30 cm in size. That fragment production is not occurring under present-day conditions is indicated by the fact that surfaces of both the clasts and the outcrops from which they have been derived bear weathering rinds at least 1 mm thick and sometimes up to a few centimetres thick. Their angular form is similar to the rubbles atop the Central Plateau and this again suggests production by frost shattering under colder climatic conditions in the past, but their advanced weathering status suggesting much of this material predates the LGM. Along the western margin of the lagoon brown fine sand and silty sand overlies this rubble. Lacustrine/palludal organic-rich silts occur around the western and south-eastern shoreline, while alluvial silts overlie the sand where the small Devils Leg Gully discharges into the northern sector of the lake, and also along the channel that exits from the western margin of Bells Lagoon. These relationships suggest that fragmentation of the bedrock by physical weathering had ceased by the time the most recent sands were deposited, but that there has been limited sand movement more recently, when wetter conditions have prevailed.

The lake depression has formed adjacent to a bedrock barrier that encircles its southern end. The topography of the plains to the north comprises remnants of various Tertiary sediments. Aeolian redistribution of fine sands from this source appears to have deranged the drainage pattern originally present, one consequence of which has been to impede discharge from the Bells Lagoon area. Moisture retention at the proto Bells Lagoon site would have favoured rock weathering, with deflation of the weathering products under dry condition, while wind-driven waves during wetter times have contributed to the erosional morphology of its southern sector.

An excavation to 2.3 m depth on the upper eastern limb of the lunette, ~10 m above the lagoon, failed to reach the base of the sand (Figure 9.14).



Figure 9.14 *Medium to fine sand was revealed in the uppermost part of the 2.3 m-deep trench excavated beside Bells Lagoon, but at 152 cm depth there was a dramatic transition to predominantly very fine dust that largely persisted to the base of the excavation.*

The uppermost 1 m comprised medium to fine sand, but below 1 m depth there was an increasing proportion of fine sand. There was very little fine dust at ~145 cm depth but then at ~152 cm there was a very dramatic transition to predominantly very fine dust (Table 9.5).

TABLE 9.5 GRAIN SIZE ANALYSIS OF SEDIMENTS FROM BELLS LAGOON LUNETTE

Depth (cm)	Volume weighted mean (microns)	Character
0-50	221	asymmetric bimodal: fine sand dominant; v. fine sand secondary peak; long tail of silts
100	205	bimodal: fine sand dominant; but increasing v. fine sand; large silt tail
104-106	287	unimodal: medium sand; v. fine sand incipient swell & silt tail
106-140	265	weakly bimodal: medium sand dominant; v. fine sand secondary peak; silt tail
145	263	bimodal: med. sand dominant; v. fine sand second peak; silt tail;
160	200	bimodal: fine sand dominant; increasing silt peak; & incipient ?dust peak
170-180	87	bimodal: dominant very fine sand; silt/dust?
200	111	bimodal, dominant v. fine sand, fine sand secondary, silt tail;
230	157	bimodal: fine sand dominant; large v. fine sand secondary; thick silt/dust tail

The sample at 1.8 m depth is especially extreme, with a volume weighted mean of only 87 microns. This half metre of deposition could have been the result of either one extreme event, or a number of extreme events over a relatively short period of time (~ 1000 years?). It is likely to have been several events, considering the disparity in grain size of the unit in the middle at 1.8 m, which is only 87 microns compared to 200 microns for the unit at 160 m, but 111 micron for the unit at 2.0 m. These last two are close enough in size to perhaps represent one event fining upwards, or at least to have been derived from the same source. Given the location of the excavation near the hill top, the very fine material could not be flood deposit, and is almost certainly wind-blown dust. The sequence is interpreted as recording an extreme environmental event associated with drought and strong winds, with deflation of the lake bottom sediments. However, the volume of sand present suggests most was derived from elsewhere, the most likely sources being reworking from Tertiary sediments immediately to the north, including alluvial and lacustrine deposits, together with Quaternary alluvial deposits that include alluvial fans from the Great Western Tiers. These sediments contain an abundant supply of fine material transportable by winds funnelled through the wind gap in which Bells Lagoon is located.

Samples for OSL dating were obtained from three positions in the profile. A transition from medium sand to fine sand was encountered at ~152 cm depth. One sample from just above the base of the medium sand at 150 cm (BSLE 02) gave an age of 20.17±1.5 ka, while a second sample from just below the transition at 154 cm depth (BSLE 03) gave a date of 18.7±1.2 ka. A sample from the base of the excavation at 180 cm depth (BSLE 01) dated to 20.25±1.1 ka. Notwithstanding the appearance of inversion implied by BSLE 03 all three dates are statistically identical. They indicate that the enormous (at least 0.5 m thick) dump of very fine sand and dust was concurrent with the LGM.

Aboriginal artefacts are scattered right around the margins of Bells Lagoon. Two sites have previously been excavated (Kee 1990) and provided some insight into the subsurface sediments there. At site BLW on the south-western corner of the lagoon an excavation to 1.5 m depth revealed 30 cm of brown fine sand overlying greyish brown sand that contained a cultural layer, charcoal from which was radiocarbon dated to 4,540±410 BP (Beta 29264). The sediments beneath this comprised basaltic gravels in a sandy matrix, then grey sand, and finally yellowish brown silty clayey sand. A second excavation to 1 m depth (site BLE) on the windward face of the lunette near the south-eastern corner of the lagoon revealed 30 cm of brown sand overlying dark brown silty sands with a cultural layer beneath it, dated to 1,030±60 BP (Beta 29262) and 3,010±60 BP (Beta 29263). Beneath this was 20 cm of archaeologically sterile dark grey silty sand that rested in turn upon light yellowish brown silty clayey sand.

Many deflated artefacts were found on the surface but none were encountered in the geomorphological excavation undertaken as part of the present study. No charcoal suggestive of fire events was revealed at any point in this deep pit. Thus, there appears to be no evidence for pre-industrial anthropogenic influences on the landscape beyond minor surface disturbance around Aboriginal campfires in the late Holocene. Kee (1990) noted that artefact deposition at site BLW coincided with destabilisation of the sands ~4.5 ka and suggested that it was a temporary camp. Palaeotemperature reconstruction based on speleothem isotropic evidence obtained from elsewhere in Tasmania (Goede and Hitchman 1983, Goede *et al.* 1990) suggests temperatures were 1°-2°C colder than at present during the mid-Holocene, implying diminished evaporation rates at that time. The evidence of aeolian activity thus seems readily explicable by climatic events at that time. There is nothing to suggest more than minimal localised superficial disturbance of the landscape as a result of Aboriginal activities.

5. Township Lagoon

Township Lagoon (199 m altitude) is located 8.6 km south-east of Bells Lagoon on the southern outskirts of the small town of Tunbridge. The lagoon measures 170 m north-south and 150 m east - west but it is commonly dry (Figure 9.15).



Figure 9.15 *View north-eastwards across Township Lagoon.*

Any water present is generally confined to this shallow depression, but if it were to spill it would drain into Tin Dish Rivulet, a tributary of the Blackman River, the waters of which then join the Macquarie River, South Esk River, and ultimately discharging via the Tamar River into Bass Strait. The lagoon is hypersaline, with a TDS of 86,334 ppm, and it has occasionally been used for salt production in the past (Williams 1974). It is surrounded by grassland and lies within the 17 ha Township Lagoon Nature Reserve, focused around the salt pan lagoon. This reserve hosts the highest concentration of threatened plant species in Tasmania, and is a listed grassland community under the Commonwealth EPBC Act. Its flora includes 22 threatened species, six of which are listed as Endangered Tasmania, four listed as Vulnerable and 12 listed as Rare. Threatened fauna present includes one species listed as endangered and one as Vulnerable, (Zacharek *et al.* 1997, Southern Midlands Council 2017), but neither are sufficiently large as to have provided a significant food source for Aborigines in the absence of other resources.

The lagoon is bordered to the east by a low (20 m high) ridge of Jurassic dolerite and this appears to also underlie the terrain to its south. Triassic sandstones form the northern and eastern rims of the lagoon basin and the terrain to its east. The bedrock imposes a linear form to the western shoreline of Township Lagoon, but its eastern and southern shorelines are concave. Dolerite detritus occurs right along the western shoreline with localised outcrops of dolerite bedrock. The upper part of the weathering profile on the dolerite comprises clayey sand but the density of the clay rapidly increases with depth. The floor of the lagoon depression is mantled by black cracking clays that have been washed into the depression

from the north. Along the eastern shore of the lagoon these clays are typically no more than 40-60 cm deep, beneath which heavily decomposed dolerite bedrock is present.

There is a striking contrast between the very large volumes of sand deposited to the north-east at Bells Lagoon and a paucity of aeolian sediments at Township Lagoon. This paucity is probably due to the partial shelter provided by the bedrock ridge north of Township Lagoon, and limited funneling of wind by surrounding higher ground. No evidence of any lunette was detected, although a minor aeolian component may contribute to the looser texture of the clays at the southern end of the lake compared to the other shores. The western slope of the lagoon basin is steeper than the eastern side of the lagoon, and the upper part of the soil profile here is sandier, however this is attributable to the presence of a duplex soil profile on this slope rather than to aeolian sedimentation. A thin salty crust surrounds the actual water body in the lagoon depression, with small sandy beaches. While these rise up to ~1 m above present water level on the southern end of the lagoon it is a moot point whether this relief is entirely a beach or there may be some aeolian contribution to it. Likely sources for the limited volumes of sand present include the sandstone that forms the eastern flank and probably also the base of the depression, and the numerous other outcrops of this rock, and alluvial sediments containing its breakdown products, immediately upwind.

The Township Lagoon depression is shallow but better developed than might be anticipated given the degree to which it appears imbedded in the surrounding bedrock. Salt weathering and deflation of the loosened weathering products provides one possible explanation for evolution of the basin. Salinity affects not only the lagoon basin but also the wider area, the lagoon lying 3 km to the west of a locality known as Saltpan Plains. Notwithstanding the hypersaline conditions and the heavy clays currently evident on the lagoon floor bed, no evidence for any clay dune is apparent.

There are numerous small fragments of siliceous and other rock around the shore of Township Lagoon. Some are scattered on top of the black cracking clays suggesting that these clasts are of very recent age. There are also some areas of crushed bluestone on a vehicular track that runs around the perimeter of the lagoon, further suggesting that much of the siliceous material may be very recent. A few Aboriginal stone tools formed from siliceous material were also recognised, all scattered on the light coloured surface clays that floor the lagoon depression. The limited topographic shelter and saline conditions are likely to have impeded development of vegetation cover sufficient to provide much shelter for Aborigines, while the hypersaline condition of the lagoon water and paucity of alternative water sources in close proximity, probably further rendered Township Lagoon unattractive as a campsite. Hence the absence of apparent ancient anthropogenic landscape modification is to be expected.

6. Lake Dulverton

Lake Dulverton (altitude 401 m) is located just over 2 km to the west of Tin Dish Creek, about 18 km upstream from Township Lagoon, and 19.7 km southeast of Lake Crescent. It has a maximum depth of 3 m, and measures 2.4 km WSW-ENE, giving it an area of 233 ha. It is of irregular shape due to bedrock protrusions, and comprises two principal basins, the northernmost being 0.78 km wide and the southern basin 1.4 km wide. A series of smaller lagoons occur within a few hundred metres of its shores, namely the two Weedings Lagoons to its north, Longs Lagoon to its east and Round Lagoon to the south-east. Lake Dulverton drains into the Jordan River, which joins the Derwent River estuary at tidewater. The town of Oatlands, originally planned to be the Tasmanian capital, was developed on a bedrock ridge that forms the western margin of Lake Dulverton. A railway formation for a former branch line from the main north-south railway extends along part of the shore. The other shores and hinterland of Lake Dulverton have been entirely cleared for farming.

The average annual rainfall is 570 mm while annual evaporation rate is around 700 mm, and this has led to periodic drying of the lake since white settlement, to the extent that the lake bed has at times served as an airstrip. This periodic drying has prompted various attempts to maintain the lake level by artificial means, commencing with an earthen and stone dam that was constructed using convict labour in 1827, and which raised the potential lake level by ~ 1-1.5 m. A concrete dam replaced this in 1928 and a slightly higher dam was built in 1977. Much more recently, three bunds have been constructed across the lake floor in a bid to retain deeper water basins and reduce evaporation, the most recent in 1997. The lake has also been supplemented from a bore or with water from the Blackman River, 17 km distant. Since 2014 water from Arthurs Lake in the Central Highlands has been delivered into Lake Dulverton as part of the Midlands Water Scheme. Lake Dulverton supports nationally threatened species and communities and 200 ha of its surface is now a Conservation Area. The presence of eels, and the fact that at least 77 bird species have been recorded when the lake level has been sufficiently high, suggest the likely significance of Lake Dulverton as a food source for Aboriginal people in the past.

Triassic sandstone forms the bedrock throughout the lake area. The Jurassic dolerite typically present around the other lakes investigated during this study is here confined to over 1 km distant, and the nearest basalt is over 1 km to the south-east. Sand mantles rock benches along the western side of the lake, and occurs behind some west-facing bays. Alluvial silts occur along the lower reaches of Netting Creek, which drains into the southern end of Lake Dulverton, and also along its tributary Parattah Creek.

In a very few localities there are exposures of slope deposits in which clasts of sandstone, generally less than 40 cm long, occur in a sandy matrix. This material appears to generally be overlain by slope-wash sands and also wind-blown sands towards the southern end of the lake. Hence, it predates both, contrary to the impression that might be drawn from a few sites where slope deposits have slumped and spilled onto younger sand. The clasts are generally weathered but given the very short distance across which they are likely to have been transported any pre-existing weathered surfaces are unlikely to have been knocked off them, rendering the weathering rinds they bear of no assistance for relative dating of the most recent broad-scale slope instability. Weathering and erosional features on bedrock sandstone surfaces more usefully assist age discrimination. Solution pans in excess of 1 metre diameter and up to 30 cm deep occur on sandstone benches along parts of the eastern shore, but towards the northernmost corner of the lake they are much less well developed, suggesting rock surface exposure may be more recent there. The most conspicuous weathering features in the sandstone are rock shelters that have formed at various heights above the lake (Figure 9.16).



Figure 9.16 *Rock shelter a few metres above water level at Lake Dulverton.*

These are most pronounced within 1-2 m of the present lake level, where the cliffs are notched at a similar level for hundreds of metres along some sections of the north-eastern shoreline. This relatively uniform notching contrasts with a more irregular profile of the higher-level rock-shelters. In both cases sandy breakdown occurs on floors and ledges, but organic-rich lacustrine and palludal sands also floor some of the lakeshore shelters. No convincing stratigraphic relationship could be discerned between the presently-exposed palludal/lacustrine sediments and the alluvial sediments deposited by Netting Creek and Parattah Creek. Localised blow-outs through parts of the dunes along the south-eastern sector of the lakeshore have occurred predominantly where breaks in the sandstone cliff lines have funnelled north-westerly winds. Some of this sand has spilled downwind into smaller palludal basins such as Longs Lagoon, and blanketed alluvium.

Both basins of Lake Dulverton have formed up-valley of the sandstone bars. These bars probably sufficiently inhibited drainage towards the Jordan River as to retain moisture on their up-valley sides. This would have facilitated more pronounced decomposition of the bedrock in these two positions than beneath other, better drained parts of the stream channel. Deflation of the basin floors under dry conditions has evacuated the weathering products and facilitated deepening of the initial basins. The rock shelters close to the lake shore are well-developed in comparison to the more randomly distributed upper level shelters, and they imply protracted periods of water levels slightly higher than at present. The south-eastern shoreline of Lake Dulverton is broadly convex westwards for its entire length of 1.4 km. This suggests lake broadening by wave action that was driven by winds from the westerly quadrant.

Towards the southern end of the lake sandstone benches over 3-5 m above lake level are mantled by fine-medium quartz sands that exceed 4-5 m in thickness. Sand examined on ledges inside east-facing rock-shelters, where it is unlikely to be windblown material, is generally medium quartz sand, slightly browner than the aeolian sand that has been incipiently modified by pedogenic processes. Hence, the aeolian sediments are interpreted as having been derived from the products of sandstone breakdown and to have been deflated from the lake bottom and other areas by the north-westerly winds that produced the dunes towards the south-eastern end of the lake. The wetter conditions indicated by the extensive notching of lakeshore bedrock probably predated the deflation responsible for the dunes. The clast weathering and weathering pans similarly attest to wetter conditions than at present, but would not have taken as long to form as the lakeshore-rock-shelters, and may even have developed subsequent to the land-surface stripping that facilitated dune formation.

While post-European activity has impacted significantly on the landscape of Lake Dulverton, no evidence was discerned for significant earlier anthropogenic impacts. At least 34 Aboriginal sites have been recorded from around the margins of Lake Dulverton (Kee 1990), mostly on the sloping lake shore but also two in sandstone rock shelters that border the lake (Figure 9.17).



Figure 9.17 *Rock shelter containing artefacts, eastern side of Lake Dulverton.*

The northern end of the lake has revealed the most sites, except in the areas disturbed by residential and railway development (Kee 1990). Fewer sites have been recorded further east, which would be consistent with vegetation on the upwind side of the lake having offered more attractive conditions than the exposed eastern shoreline which is swept by wind blowing across open water. However, a lesser number of Aboriginal sites in the east may equally be explicable by the burial of any sites there by sand blown from the dry lake bed. Little morphological evidence of major remobilisation of the dunes is discernible from air photos or satellite images apart from in locations where wind has been funneled through breaks in the bedrock benches around the lake. Negligible charcoal that might be suggestive of Aboriginal fires having contributed to sand movement was found during the present fieldwork. Kee (1990) observed that the area of Round Lagoon, set back from the edge of Lake Dulverton and possibly offering shelter trees, appears to have been particularly favoured by Aborigines. This implies that the morphology of the sand masses in that area had already become established prior to at least the most recent phase of its use by Aborigines.

7. Lake Tiberias

Lake Tiberias (altitude 437 m) lies 26.4 km southeast of Lake Crescent, 9.5 km south of Lake Dulverton, and 6 km southwest from the headwaters of Tin Dish Rivulet. Its maximum dimensions are 4.16 km east-west and 3.5 km north-south. Its total catchment is only about twice the size of the lake, the surrounding hills rising ~100 m higher than the lake surface. Lake Tiberias drains southwards into the Jordan River, which joins the Derwent estuary near its tidewater limit. Its maximum depth is unknown but it is generally no deeper than 2m, most of its surface being covered by aquatic plants. Only a few hundred metres east of Lake Tiberias, is a 100 m-deep gorge formed by the Coal River. Springs that discharge into this gorge drain part of the groundwater storage that supports Lake Tiberias (Leaman 1968). The surrounding area has been cleared for pasture, and there were early aspirations to drain the lake itself (Jones 1887), but a channel excavated at its outlet carries water only seasonally, and more recent studies have highlighted the adverse consequences of draining for those reliant upon water bores in the surrounding areas. Other proposals to raise the lake level entailed probable destabilising of some structures including the main north-south railway line which runs along the lake's eastern shoreline. The small catchment, shallow basin, high evaporation rates, and evapotranspiration by the aquatic vegetation (Leaman 1968), all inhibit its use as a water storage site. The potential to artificially deepen the lake is also restricted to less than 3 m by low ground south and east of the lake, and it would represent a miniscule addition of water compared to the discharge of other upper Jordan River tributaries. However, these difficulties do not appear to have in any way extinguished ambitions to do so (Tasmanian Irrigation 2016). The aquatic vegetation is a listed community under the Tasmanian Nature Conservation Act 2002. The lake is classified as a Game Reserve, emphasising its likely earlier importance to Aborigines when environmental conditions were conducive to its support of waterfowl.

Lake Tiberias is bounded to the west by a major ridge formed of Jurassic dolerite. At the easternmost extremity of the lake there is one localised outcrop of Permian freshwater sedimentary rocks of the Parmeener Supergroup, predominantly felspathic sandstone but varying from siltstone to conglomerate and with occasional carbonaceous beds. Elsewhere, the foot of the dolerite hills comprises younger Parmeener rocks, mainly Triassic-age, thickly bedded, medium to coarse-grained quartz sandstone with minor black shaley strata. This latter material also forms the floors of the valleys south and east of the lake. Minor micaceous mudstone crops out along the northernmost shoreline. These bedrock units dip westwards at 5°-10° (Leaman 1968). Angular rock fragments up to 1 m or more in size occur on some dolerite hill crests and down their flanks, and similar angular fragments occur on some of the sandstone hills. There is extensive alluvium, including terrace deposits, along the axis of the valley north of the lake, on the lowermost hill-slopes, and along some tributary valley axes. Lacustrine and palludal sands occur around parts of the lake shoreline. Wind-blown sands form a mantle along much

of the eastern margin of the lake, and drilling by the Tasmanian Department of Mines indicates these reach a maximum thickness of 20-40 m.

Morphostratigraphic criteria and post-depositional characteristics of the sediments enable elements of a broad relative sequence to be discerned. Clasts in the dolerite slope deposits are generally weathered on all surfaces, with weathering rinds commonly 2-5 mm thick but occasionally several centimetres thick. The angularity of these clasts indicates their production by mechanical weathering, but the weathering rinds on the dolerite and solution sculpting on sandstone clasts both indicate subsequent chemical weathering. Alluvial sands and silts along some tributary valley axes are intermixed with similar rocky material, but also overlie the slope deposits adjacent to the western side of the lake. A clear stratigraphic relationship between the alluvial and aeolian sediments was not determined.

The Jordan River exits Lake Tiberias via a gorge cut through the major dolerite barrier to its west. Given the very limited catchment of the lake, and its infrequent overflow, cutting of the gorge requires an earlier phase of landscape development when the topography to the east of the dolerite ridge was markedly different to present. The lake itself rests upon sedimentary rocks that dip westwards towards the dolerite barrier at 5°-10°. No similar barrier exists between the lake and the deep gorge of the Coal River only a few hundred metres to its east. Hence, the most probable explanation for the existence of Lake Tiberias is that its waters were ponded where progressive lowering of this westward sloping surface became intersected by exposure of the present-day dolerite barrier. Water is now naturally evacuated from the lake mainly by evapotranspiration and by seepage towards the springs in the Coal River gorge. Embayments along the southern shoreline of Lake Tiberias that are concave towards the north-west are permissive of waves that were driven by winds from that direction having played a role in shaping the lake. However, the eastern shoreline is concave to the west, and sections of shoreline that are smoothly concave towards the south-west occur along the lake's northern margin. These features are all consistent with the lake shore having been shaped by waves generated by winds from the west that passed through a wind gap formed at the Jordan River outlet, between Bowsden Hill and Pikes Hill (696 m) to the north of the lake, and Hilly Goon which forms the northern end of Flat Top Tier that extends along the western side of the lake.

Leaman (1968) attributed cutting of the Jordan gorge through the dolerite ridge west of Lake Tiberias to erosion during the Tertiary and particularly during the Pleistocene when he suggested rainfall was 'much greater'. He similarly attributed the Coal River gorge to incision under similar conditions that exploited weaknesses produced by faulting. However, given the very low barrier between Lake Tiberias and the Coal River gorge immediately to its east, it is difficult to envisage a sufficient volume of water being retained in the lake basin to permit sufficiently vigorous discharge for the Jordan River to cut its outlet gorge. Given the very small catchment of the lake, precipitation rates would have needed to very greatly exceed those at present, and evaporation been very much less. No evidence of such changes of sufficient magnitude have been forthcoming thus far, at least during the most recent Glacial-Interglacial cycle. The most probable explanation for the gorge through which the Jordan River exits Lake Tiberias is that it is a drainage line that has been superimposed from a much older landscape.

Sands varying in degree of compactness, clay content and colour were observed at various locations along the railway cutting (Figure 9.18) on the eastern side of the lake (altitude 450-453 m), but no exposure could be located or established in which the full sequence of the variation recognised laterally could be observed in a single vertical section.



Figure 9.18 *Lunette along the eastern side of Lake Tiberias.*



Figure 9.19 *Colour variation of sands in upper part of the Lake Tiberias lunette.*

The best partial sequence was obtained by hand auguring at one location (site 2) but was limited to 1m depth by the equipment available and bedrock at shallow depth. Analysis of samples from this site revealed a transition in grain size from predominantly fine sand near the surface to predominantly silt at greater depth, with small fractions of very coarse sand mid core (Figure 9.19).

This suggests that the material was derived from a volatile environment. The extremely fine nature of the grains most probably partly reflects some aspect of the local lithology, but the shift below 60 cm, and extreme shift below 80 cm to very fine sand and silt suggests some extreme environmental event where wind-blown material dominated (Table 9.6).

Table 9.6 Grain size characteristics of sand at Lake Tiberias (site 2).

Depth (cm)	Volume weighted mean (microns)	Character
5-10	141	bimodal: fine sand and silt peaks, dust (-3.9 μm) tail
10-20	105	bimodal: fine sand and silt peaks, thick dust tail
20-25	147	bimodal: fine sand & silt peaks; small large grain tail as well as thick fine dust tail.
30	191	trimodal: fine sand & silt peaks; small v. coarse sand peak
40	191	trimodal: dominant fine sand; secondary silt peak; & a very coarse sand peak
50	84	bimodal: fine sand & silt; long dust tail; no coarse sand
60	108	trimodal: dominant fine sand; large secondary silt peak; v. small coarse sand peak
74	108	bimodal: dominant fine sand; large secondary silt peak. No coarse sand.
84	80	bimodal: dominant silt; secondary fine sand; small v. coarse sand tail
88	83	bimodal: dominant silt peak; secondary fine sand

Trimodal peaks at 40 cm depth, including a small peak of very coarse sand which also occurs episodically to the base, suggests some possible flood event or very high lake level (or alternatively extreme aeolian saltation), that allowed water-borne deposition of large grains. Given the similarity of the material at 60 and 74 cm depth, it could be they represent the same sedimentation event. However, the 84 and 88 cm samples, which are also similar to each other, are quite different to the upper pair, having extreme dominant silt/dust peaks. This suggests an extreme environmental event. The huge fraction of fine dust/silt at 84 and 88 cm is particularly striking. The most likely source of all the sand is from breakdown of the local Triassic sandstone, and hence these variations demand only very local environmental changes.

Samples for OSL dating were obtained from two artificial exposures along the railway cutting. The first section reveals 30-40 cm of loose sand in which charcoal is abundant, but which appears to be spoil from excavation for the railway. A sample of more compact and apparently undisturbed light brown sand from 60 cm depth in this first exposure gave an age of 7.1±0.7 ka. About 250 m to the north loose sand forms the top of the embankment and appears to be largely *in situ*, but the only section that could be cleared was slightly lower down the slope. A sample of more clayey sand at 60 cm depth in this exposure (site 2) gave an age of 17.5±1.6 ka. Another 350 m north is an exposure in which loose, light coloured sand is underlain by an apparently considerable depth of compact, light orange coloured sand, from which a date of 50.5± 4.3ka was obtained. The date of 7.1±0.7 ka from the first section bears comparison with the radiocarbon age of 9, 550±200 Gak 2239 obtained from the base of a 2 m-deep organic peat deposit beneath the lake by Macphail and Jackson (1978) This suggests either the reworking of beach or aeolian sands when lake levels were low, or perhaps anthropogenic disturbance. The OSL age of 17.5±1.6 from 60 cm depth at site 1 suggests that the dominance of silt/dust peaking at 74 cm was associated with the Last Glacial Maximum. The recurrence of small quantities of coarse sand from just above the LGM date and occasionally below it is less easily explained. It conceivably reflects high lake levels in between high dust events or perhaps winds sufficiently strong to saltate large grains up the hill from beach deposits. Given that the only apparent source for the sand is the lake bed itself, this date also makes untenable the suggestion by Leaman (1968) that Lake Tiberias is post-Pleistocene in age, which he based on his belief that the Jordan River outlet was incised by major flows during the Pleistocene. The older OSL date of 50.5± 4.3 ka and the widespread presence of this sand indicates a very major geomorphological event.

A few Aboriginal stone tools were found scattered along the lunette and on its lee-ward eastern side. One artefact was encountered at less than 30 cm depth when coring, but no others were detected at depth either in the natural sections exposed or in material obtained by coring. In the absence of any evidence thus far for Aboriginal occupation of Tasmania prior to 40 ka, the major phase of landscape instability dated to 50.5± 4.3 cannot be attributed to any anthropogenic cause. Subsequent phases of instability were of lesser magnitude, and there is both geomorphological and palynological evidence for climatic changes having coincided with such events (Macphail 1979). Hence, any pre-industrial landscape disturbance by humans around Lake Tiberias was relatively minor compared to that caused by natural events.

8. Rushy Lagoon ('Fonthill Lagoon')

Rushy Lagoon (altitude 383 m) is located 17 km ESE of Lake Dulverton and 18.6 km NE from Lake Tiberias. It measures 680 m from east-west and 580 m north-south, and drains northwards into the catchment of Cullins Creek, a tributary of the Little Swanport River which discharges into the sea from Tasmania's east coast. Hills rise to above 400 m to its north and northwest, and also to its south, but no similar barrier exists eastwards where the broad expanse of the Eastern Marshes (altitude 200-260 m) borders Rushy Lagoon. In its natural condition Rushy Lagoon retained water through the summer, and was the habitat of ducks and other waterfowl. However, the lagoon was reclaimed by Mr W. Wm. Burbury, apparently revealing a floor mantled by a thin layer of peat overlying 30-60 cm of black loam, resting in turn upon clay. During the course of clearing work the peat caught fire and burnt down to the underlying clay, plaguing those working on the project with severe dust problems that caused skin irritation. The reclaimed lagoon floor initially proved highly productive for root vegetables, but the dust and skin irritation problem led to the abandonment of cropping. Thereafter it was used instead for grazing, but the quality of the pasture progressively declined (Chestnut Blue 2017; Jones 1887). The floor of Rushy Lagoon is still artificially drained by canals. Nearby Stoney Lagoon was drained subsequent to the Rushy Lagoon project, but this was curtailed after a layer of hard flinty sandstone was encountered.

Current published mapping by the Department of Minerals and Energy depicts the entire area as comprising sedimentary rocks of Triassic age, principally sandstones. However, fieldwork during the present study revealed that a ridge of basalt, presumably Tertiary in age, forms the eastern edge of the lagoon. Angular rock rubble derived from the sandstone and basalt appears to be overlain by the dense lacustrine and palludal sediments that occur on the lagoon floor. If these fragments are assumed to be the result of mechanical weathering under periglacial conditions, then the most recent of them are likely to be no younger than MIS 2, which would imply that deposition into the lagoon has been occurring only since deglacial times. However, bedrock fragmentation might conceivably have occurred if sufficiently arid conditions obtained at any time in the early-mid Holocene. Sandy alluvium that occurs along the lower reaches of drainage lines that lead into Rushy Lagoon is still being deposited today. The most recent alluvium overlies the sediments on the lagoon floor, but no older alluvial sediments were recognised and hence no relationship between lagoon sediments and earlier alluvial deposition could be established.

The catchment of Rushy Lagoon is only ~115 ha, which seems disproportionately small for a basin of such size to have developed in bedrock. However, based on reconstruction of possible former drainage patterns, it seems likely that its catchment was somewhat larger prior to widespread excavation of canals in the general area. Eruption of the basalt that forms the ridge along the eastern side of Rushy Lagoon probably impeded earlier drainage eastwards, with development of the present outlet requiring some time, during which ponded water and seasonal drying allowed weathering of the underlying sandstone, coupled with deflation of the weathering products, facilitated deepening of the basin. The eastern shoreline which is smoothly concave towards the wind-gap, the northernmost third of which has

been eroded into bedrock is smoothly concave towards the wind gap west of Rushy Lagoon. This allows the likelihood of wave action having contributed to shaping of the eastern shoreline.

Clays derived from breakdown of the basalt partly floor of the former lagoon and dominate the sediments along its outlet channel. Only a limited volume of sand is present, primarily on the lee-side eastern flank of the rock ridge along the eastern margin of the former lagoon. The sand is fine, light brown, and generally < 50 cm thick, although a depth of >150 cm was recorded during exploratory coring in one depression on the leeward footslope of the ridge (Figure 9.20).



Figure 9.20 *Localised thicker lee-side sand accumulation on lower foot-slope of the bedrock ridge bounding the eastern side of Rushy (Fonthill) Lagoon. The 1 m length corer is resting on apparent bedrock.*

The most likely source of the sand is from breakdown of the Triassic sandstone that is present to the east, but there is relatively little of this rock in the catchment, hence little sand at the lagoon. Observation of large volumes of sand being mobilised by the wind from freshly-ploughed fields on sandstone on other properties in the general area also highlights the likelihood that, after well over a century of intensive grazing at Rushy Lagoon, the ground surface exposure is likely to have caused similar re-mobilisation, further reducing the volume of sand now present. While human activities since European settlement have significantly deranged the natural drainage and modified the local landscape in other ways, evidence of earlier Aboriginal presence at Rushy (Fonthill) Lagoon is limited to scattered stone artefacts that were found along the ridge on the eastern side of the lagoon.

Discussion and conclusions

The lakes and lagoons in the study area have been formed by a variety of mechanisms that have required varying amounts of time, some critical changes occurring very rapidly while other have been of much longer duration. Some of these water bodies, and the shorelines, sand-sheets and lunettes formed around them, are likely to have been available for use by any humans who may have been present in the area since well before the apparent advent of people in Tasmania ~40 ka ago. Others may be very much more recent, having not formed until well after Aborigines arrived, and even then, having provided a water resource only intermittently. The paragraphs that follow synthesise, in turn, (1) the origin of the lake basins; (2) the generation of their aeolian landforms and associated sediments; (3) palynological

evidence for vegetation changes coincident with lake and sandsheet evolution; and (4) the climatic implications of their form and age.

1. Origin of the lake basins

The Central Plateau lakes

An ice cap more than 5000 km^2 in extent developed over the Tasmanian Central Highlands during the most extensive late Cainozoic glaciation, and glaciers developed there on at least six subsequent occasions (Kiernan 1990). The western part of the Central Plateau formed part of the ice-covered area, and is noted for its myriad of lakes (Banks 1973; Jennings and Ahmad 1957). The vast majority of these lakes lie within the former limits of the smaller ice caps that developed at various times during the later Cainozoic, and most have been attributed convincingly to glacial erosion (Jennings and Ahmad 1957, Hannan 1989, Kiernan 1990, 1999). However, there are few moraines, with such till as does occur mostly forming hummocky drift.

Abundant moraines further west in Tasmania attest to a considerable solid precipitation input, rapid throughput and ablation. This is consistent with cryogenesis involving heavy precipitation, but with temperature fluctuations of only limited amplitude and relatively warm winters. These conditions have permitted only relatively slight freezing of rain and meltwater infiltrating the ice mass, thereby allowing liquid water to penetrate glaciers and basal meltwater to facilitate glacier sliding and hence erosion and sediment generation. In contrast, moraines are only minimally developed further east where precipitation shadow effects inhibited glacier build-up. Here glacier persistence was more reliant on colder temperatures with the cold reserve of the ice mass being sufficient to freeze infiltrating liquid water (Peterson 1968; Shumsky 1964). This rendered the inland glaciological regimen somewhat sluggish. Given the much smaller scale of the most recent Tasmanian glaciations it seems unlikely that these affected the intense erosion responsible for the lakes of the western plateau. They are more likely attributable to erosion during earlier glaciations. The apparent freshness of their form is probably due to their reoccupation and re-touching, or in some cases perhaps even exhumation from beneath glacial drift, during the later, much smaller glaciations.

In contrast to the strongly rectilinear outlines, sharp bedrock margins and relatively small size of most of the western lakes, the lakes on the eastern part of the plateau are far less numerous, generally larger, and lack strongly angular bedrock shorelines. Drift depths of up to 80 ft (24.4 m) reported during drilling for hydro-electric construction at Lake Augusta led Jennings and Ahmad (1957) to conclude that originally both lakes Augusta and Ada were probably moraine-dammed, but just how far eastwards ice once extended remains unresolved. Diamictites on the eastern Central Plateau have not generally been regarded as being glacigenic, however Hannan (1993) interpreted some deposits 5 km east of the plateau margin on the graben floor at Poatina as being weathered till. Although some parts of the plateau margin north-east of Great Lake appear to be glacially eroded this relatively small potential source area seems insufficient to have nourished a sufficiently extensive glacier to have deposited till at Poatina. A diamictite that Hannan also interpreted as till at the head of Palmers Rivulet, only 1.6 km east of Great Lake, led him to suggest that the main ice source was an ice cap on the Central Plateau, but more work is required.

If the Central Highlands ice cap did indeed once extend far enough north-eastwards to overflow the margins of the Midlands graben, then it would seem likely that it would also have discharged towards the Lagoon of Islands and lakes Sorell and Crescent, with glaciofluvial sediments being discharged into the Midlands thus providing a potential source of fine material for reworking by the wind. While some apparently mammalated bedrock surfaces around the Lagoon of Islands shoreline are potentially

suggestive of past areal scouring by laterally unconstrained glaciers (Sugden and John 1976), similar forms are also known to occur on dolerite well beyond any likely past glacier limits in Tasmania's Eastern Tiers and elsewhere. This implies that other processes besides glaciation may also give rise to terrain with a similar general form, and that it does not provide compelling evidence for past glaciation (Kiernan *et al.* 1993). Lagoon of Islands lies many kilometres distant from the nearest confirmed glacier margin at any time during the late Cainozoic (Banks 1973, Kiernan 1990). Hence, a glacial origin for the depression that contains this water body seems very unlikely.

No detailed geomorphological analysis to establish the likely genesis of the larger lakes on the eastern side of the Central Plateau has hitherto been reported. Davies (1965) suggested that they reflect slight downward tilting to the north of the surfaces on which they occur (Davies 1965). Banks (1973) has observed that apparent emerged shorelines at the western end of Arthurs Lake, and more marked deposition on the western sides of Lagoon of Islands, Woods Lake, Lake Sorell and Lake Crescent, are theoretically consistent with the possibility of glacioisostatic rebound in response to deglaciation of the Central Plateau. However, both Davies and Banks preferred a tectonic explanation for this tilting. Some of the larger lakes occur on the lowermost of the three principal topographic surfaces that are prominent in the Central Highlands, the St Clair Surface (750-825 m), close to its junction with the intermediate Lower Plateau Surface (900-1050 m). Other larger lakes have formed towards the inner edge of the Lower Plateau Surface close to the rise onto the Higher Plateau Surface (1200-1420 m) (Banks 1973). The faulting responsible for this stepped topography seems predominantly of Cretaceous-Tertiary age, but the area is not altogether tectonically quiescent today. Twelvetrees (1902) drew attention to "mysterious noises heard from time to time resembling the distant booming of cannon". Similar but still unexplained phenomena have been recorded from various seismically active parts of the world. Twelvetrees preferred a geological rather than atmospheric explanation for the sounds at Lake Sorell, despite the absence of perceived ground vibration. Verbal accounts of similar large detonation-like sounds were given to one of us (KK) by residents of the Marion Bay area in south-eastern Tasmania during a minor earthquake swarm of up to magnitude 2.1 that occurred there in 1986-87. The largest historical earthquake recorded in the present study area occurred on 15 June 2002 and was of magnitude 4.3, its epicentre (147.31 E, 42.15 S, depth 8±5 km) located only 9.45 km east of Lake Crescent, 9.4 km ESE of Lake Sorell, 7.2 km SW of Bells Lagoon, and 9.7 km west of Tunbridge Lagoon.

While tilting would provide a mechanism for ponding of water along the interfaces between these surfaces, other factors are likely to have determined the precise locations at which specific lake basins evolved. The positions at which the outcrops of Parmeener rocks occur around the margin of Lagoon of Islands suggest that its floor is broadly coincident with the base of the dolerite sill. This raises the likelihood that the horizontally-bedded Parmeener rocks have intercepted seepage down the vertical joint systems in the overlying dolerite and have perched water such as to predispose formation of a topographic hollow by weathering of the dolerite. Lateral expansion of the resulting water body, still perched upon the Parmeener rocks, is thus the most likely origin for the basin in which Lagoon of Islands now occurs. In contrast to the relatively angular bedrock shoreline along the western side of the lagoon, its eastern shoreline is a broad embayment that is concave to the east and clearly attributable to erosion and deposition by wind-driven lagoon waters. Progressive eastward expansion of the lagoon combined with the close proximity of the Parmeener rock strata is likely to have precluded the lagoon achieving any great depth. The presence of Parmeener strata at lakes Sorell and Crescent suggests that a similar influence is likely to have also operated there.

While Lagoon of Islands, Lake Sorell and Lake Crescent all lie downwind of the former Central Plateau ice cap, the area subject to glaciation is almost entirely on dolerite or locally on basalt, and hence glacio-aeolian processes cannot account for the very considerable volumes of siliceous sands that occur on their beds, beaches and dunes. The most probable source of this material is the Parmeener strata.

Subaerial exposure of sand liberated by weathering of this substrate, and its redistribution by the wind, would require lowering of the water level in these basins. The volumes of sand present at all three sites, and their shallow depths, suggest a similar origin for all three of these Central Plateau lakes.

The Midlands lagoons

A very large number of water bodies and palaeo-waterbodies of various kinds occur in the Midlands, and the five active examples examined during this study do not encompass the full range of variation present. Nevertheless, our limited sample does permit some general observations that are likely to be more widely applicable. The two largest, lakes Tiberias and Dulverton, have both formed on Parmeener Supergroup sedimentary rocks. Both show evidence of having formed where low gradient streams encountered localised areas of more resistant bedrock that caused a retardation of flow and resultant ponding of water upstream from the obstruction. In the case of Lake Dulverton, a second obstruction led to two basins forming. The situation at Lake Tiberius is more complex, with slight westward tilting of the strata towards the present lake outlet rather than back into the hill as at Lagoon of Islands and lakes Sorell and Crescent. The tilting at Lake Tiberius directed discharge away from the deeply entrenched Coal River only a few hundred metres to the east of the lake, while the outlet of Lake Tiberias is into what appears to be a superimposed channel that very greatly predates the present lake. The shallowness of both lakes suggests that, once again, the relatively horizontal rock beds encouraged lateral expansion of the basins rather than their deepening.

In contrast, Bells Lagoon has formed against the margin of Tertiary basalt hills adjacent to the principal northward-flowing river that drains the Midlands. The reasons for inception of the basin are open to question. Among the possibilities are that the basin originated from an ancient incised river meander; that runoff from the basalt was impounded in a depression between the foot of the hill and back-sloping sediment deposited by the river; or that the local topography emphasised deflation at that point. Irrespective of what caused the original ponding, the low valley gradient and the presence of sub-horizontal Parmeener Supergroup rocks would have again favoured lateral expansion rather than deepening of the basin, including by dissolution of the basalt, with periodic drying allowing deflation of the weathering products that would otherwise have insulated the bedrock and impeded its further weathering.

The influence of underlying bedrock structure also appears to have been the key determinant of the forms of Township Lagoon and Rushy (Fonthill) Lagoon. At the former, the Parmeener rocks again appear to have formed a relatively resistant surface that restricted basin deepening. The ephemeral nature of the lagoon, which may well have remained dry throughout periods of cold glacial-type climate, and the saline conditions, are likely to have minimised vegetation and hence biogenic acid production, although salt weathering was potentially enhanced, perhaps especially so if there was also potential for saline groundwater to seep from the basin margins. At Rushy (Fonthill) Lagoon runoff from the surrounding basalt and sandstone hills was probably impeded by the restricted outlet through which the area currently discharges. Limited moisture availability during glacial times would have reduced the rate and efficacy of channel down-cutting and resultant accumulation on the lagoon margins and floor of an insulating blanket of clays produced by weathering of the basalt.

Many of the Midlands lagoons thus bear comparison with water bodies on the southern tableland of NSW where weak landscape dissection and numerous small lakes on the early Tertiary Monaro basalt suggest prolonged stability. As in the Tasmanian Midlands, the Monaro lake basins seem most likely to have been initiated by dissolution of the bedrock, with drier periods allowing the basins to be deepened by deflation, and leaving only poorly developed soils and weathered zones with Holocene sediments that are seemingly at variance with the size of some lake basins (Pillans and Walker 1987). Evidence from

the lakes and lagoons of the New England Tableland, NSW, is consistent with a similar great antiquity of the basins, and also a similar origin, albeit with some pre-Holocene sediments inferring a greater level of stability during late Glacial times, and recognition that there are also waterborne sediments incorporated in some dunes (Bell et al 2008, Woodward *et al.* 2014a).

2. Aeolian sediments and landforms

Central Plateau

Despite a history of recurrent glaciations, the loess deposits typical of many glaciated landscapes elsewhere are lacking from the study area, several factors probably having contributed to this. The earliest and most extensive late Cainozoic glaciation hitherto recognised in Tasmania appears to considerably predate the Pleistocene, thus allowing ample time for any resulting aeolian sediments to have been weathered to the clay and silty clay characteristic of dolerite decomposition, and reworked into non-glacial deposits. Being of lesser extent, the glaciers that formed on subsequent occasions, and their melt-water streams, discharged into narrow valleys where there was only very limited opportunity for the formation of expansive outwash plains from which particles could be entrained by the westerly wind. On the Central Plateau, the glaciological factors that contributed to the sluggish glacier regimen, coupled with the low gradient of the plateau surface, inhibited glacial erosion and hence the generation of glacigenic sediment from which loess could be derived. Aeolian sediments are thus less common on the plateau than might otherwise be supposed. The most conspicuous dunes occur along the eastern margin of Lake Ada (Figure 9.21), 44 km north-east from Lagoon of Islands, with other lunettes present a few hundred metres further north at Sandy Lake, and 2 km east of Lake Ada at Lake Botsford.



Figure 9.21 *Dunes a short distance outside the confirmed ice cap margin at Lake Ada on the Central Plateau.*

Prominent dunes also formed along the eastern perimeter of a formerly discrete lake that now forms the western basin of the artificially raised Lake Augusta, and the nearby Carter Lakes. Further lunettes occur a little over 3 km to the south-east at Double Lagoon, and 8 km further south at Lake Fergus (Figure 9.22).



Figure 9.22 *Heavily iron-panned sands at Double Lagoon, Central Plateau, overlain by lighter coloured younger sands.*

All are formed from doleritic sand with the exception of one location near Carter Lakes where the sand is siliceous (Bradbury 1994).

Further east, there are also sand accumulations along some parts of the eastern shoreline of Great Lake, most notably at The Sandbanks (Figure 9.23), in the mouth of a wind gap between Sandbanks Tier and Cathcart Bluff.



Figure 9.23 *The eroding sands on the eastern shoreline of Great Lake are locally littered with lag artefacts.*

This site is drained eastwards by Palmers Rivulet, a tributary of the Macquarie River and hence a potential contributor to its extensive sand sheets, and it also lies within 2 km of one of the diamictite exposures interpreted by Hannan (1993) as till deposited by a Central Plateau ice cap of larger size than has hitherto been recognised. About 14 km south-east of The Sandbanks two dune systems formed from fine sand occur on the north-eastern corner of Little Lake, while at its southern end rounded dolerite cobbles are overlain by dark coloured sand that contains abundant charcoal, overlain by 1 m of lighter coloured fine sand (Cosgrove 1984). Arthurs Lake, 3 km south of Little Lake and 7 km north of Lagoon of Islands, is an artificial impoundment 20 m deep that drowned the former Blue Lake and Sandy Lake, both of which had sandy southern shores. Both discharged into Woods Lake, another artificial reservoir, from which the Lake River descends the Great Western Tiers to join the Macquarie River. These sands on the eastern side of the Central Plateau are lighter in colour than those further west, form larger dune systems, and contain a much higher proportion of quartz. These characteristics

suggest that they have been derived from breakdown of the local sedimentary rocks, rather than their being of glacio-aeolian origin from the glaciated dolerite landscapes further upwind. Their grain size is also somewhat coarser than is typical for loess, which characteristically contains ~40-50% silt, up to 30% clay, and up to 10% fine sand (Easterbrook 1993).

Midlands

Nichols (1958) drew attention to the presence of aeolian deposits up to a few metres thick along the eastern side of some valleys in Tasmania, typically overlying terraces cut in the graben sediments and more recent deposits. He reported most particles as being in the 0.11-0.35 mm range, with most around 0.2 mm, but also elevated volumes of clay in some cases, which he attributed to their movement as aggregates in the manner previously outlined by Butler (1956). A variety of fine sediment deposits is present in the Midlands, all of them quartz-rich. Extensive sand-sheets occur down the Macquarie River system from Ross to Cressy, with numerous other sandy lunettes, such as that on the eastern side of Clarks Lagoon, 3.5 km north of Bells Lagoon (Kee 1990). Weathering and erosion of widespread sandstones within the Parmeener Supergroup sedimentary sequence has released considerable volumes of sand. Hence, soil profiles are often rich in sand, and sand is prominent in some surficial sediments. The Tertiary sediments that were deposited within the graben system contain abundant sand, some of which has been reworked into Quaternary fluvial and aeolian deposits. These sources allow ample local availability of fine sediment to nourish the Pleistocene aeolian landforms and sediments recognised in the Midlands during this study. While the massive influx of fine sand at Bells Lagoon stands out as somewhat unusual, the very limited research in the northern Midlands thus far does not allow any assessment of whether it might be locally anomalous.

Few of the northern Midlands lagoons, the largest of which is at Grimes Lagoon near Ross, have been subject to detailed investigation. However, Sigleo (1978) has provided some data from a little further south at White Lagoon, a 10 ha water body located 4 km north of Tunbridge and 8 km east of the Western Tiers. A low-lying lunette about 4 m above its south-eastern margin comprises three aeolian units that overlie a basal gravel unit that occurs well above the modern alluvial sediments of the adjacent river and which rests upon weathered dolerite. The basal aeolian unit is 120 cm thick. Its weak pelletal structure suggests the presence of clay aggregates. The sand fraction ranges from 56.03-73.18 % at the base, silt from 3.84-4.59% and clay from 22.26% towards the base to 41.42% at the top. Granules of ironstone suggest strong winds from the northwest. The overlying aeolian unit is considerably coarser but the unit which then comprises most of the 80 m-wide lunette surface comprises 20-120 cm of massively bedded aeolian clay that has a very distinct granular structure and which post-dates the last major phase of lacustrine sedimentation. A gradational soil profile occurs in the uppermost unit, while the underlying sand lens appears unweathered. However, the basal sand shows some podzolic soil profile development with soil carbonate and ped cutans, while the gravels are well weathered, some clasts bearing weathering rinds 10 cm thick (Sigleo 1978), suggesting that they are ancient.

At Crown Lagoon, southeast of Lake Dulverton near Lemont (42°17'S, 147°38'E, altitude 375 m), a small lunette rises *c.* 7 m above a dry lake basin of *c.* 200 ha extent. Black carbonaceous clays up to 85 cm thick at the base of the lagoonal deposits include some ironstone granules indicative of runoff into the basin. A middle unit comprises alluvial sands and gravels, lacustrine clays and beach deposits. Bordering sandy aeolian clays up to 3 m thick again suggest periodic drying of the basin. The upper unit is similar, comprising up to 2 m of alluvial sediment with ironstone pebbles and granules that interdigitates with lacustrine sediments and beach sediments of fine quartz sand with ironstone granules. This transitions into the upper alluvial sediments which unconformably overlie those sediments at the base of the lunette that were deposited by north-west to westerly winds. Their texture is comparable to that of the sand sheets in the lower Derwent Valley. Multiple thin cover sands overlie the upper aeolian unit

(Sigleo 1978). A 200 cm deep core revealed 45 cm of dark coloured organic-rich silty clay overlies 150 cm of olive coloured silty clay, with 5-10% very fine quartz sand overlying nearly 13 m of deeply weathered basalt. The clay fraction is markedly less than at White Lagoon. Further south, Sigleo (1971) recognised three main aeolian units in the Glenfield and Old Beach source-bordering sand sheets in the lower Jordan River Valley and adjacent to its tidewater entry into the Derwent River estuary. Here a strongly weathered sand sheet, truncated by later intense wind scour, is overlain by two less altered sand units. The sequence rests on estuarine sediments of probable Last Interglacial age.

The provenance of the sand and silt deposits in the Midlands thus appears generally explicable by local sources. If the volume and caliber of the material at Bells Lagoon is indeed anomalous compared to the other studied sites further south as it presently appears, then one further possibility may warrant consideration. The largest aeolian complexes in Tasmania occur in the far north-east of the state, where these include the 21 km-long Ainslie Dune. The earliest of the dunes in this area appear to have formed on the southern margin of an extended Australian desert system when Bass Strait was dry during glacial times, and the Australian High Pressure System reached further south. OSL dating indicates dune formation in this area from 23.8±1.6 to 16.8±0.9 ka BP (Duller and Augustinus 2006), thus encompassing the period during which the massive influx of very fine sand occurred at Bells Lagoon. It is possible that this southward shift of the Australian High allowed some desert sands to creep into the northern Midlands.

Lunette generation

Two broad categories of sediment appear to accumulate in closed lake basins, a coarse component (> 200 microns) produced by saltation during storm events, and a finer one (0.2-0.4 microns) comprising two closely-overlapping silt components with a smaller amount of other fine-grained material that is likely to be suspended load carried under less turbulent conditions, and to potentially be of pedogenic or biochemical origin (Sun *et al.* 2002).

In shallow (1-2 m deep) lakes, waves generated by strong unidirectional winds can entrain sediment from the lake bed resulting in migratory sub-aqueous bed-forms from which shoals and ultimately an emergent barrier form. Because the shallow depth results in horizontal rather than vertical return circulation, development of a complete barrier is hindered, but a partial barrier can sufficiently impede exchange between the two lake segments to enable formation of a complete barrier and its upward development of a fore-dune and lunette (Lees and Cook 1991). Although the initial sediment is sourced from the lake bed, as the water body deepens fines are able to accumulate at depth under calmer conditions, providing clays that may later be deflated onto the lunette. This model of lunette formation appears applicable to those at all the water bodies examined during this project. The northern Midlands in particular is replete with the 'ghosts' of former lagoon basins, often with low ridges on their downwind margin that appear to be the remnants of former lunettes that have long since been erased. In the Monaro district of NSW, similar low depositional landforms, which are locally termed 'lake shadows', occur on the eastern perimeters of most lakes. There they comprise clay pellets blown from basin floors under dry conditions that occurred predominantly during Quaternary glacial periods, when pre-existing soils and weathered zones were also stripped from the surrounding landscape, the present soils being the product of the modern climate (Pillans and Walker 1987).

The evidence from Lake Tiberias indicates multiple phases of aeolian sediment accumulation, commencing well prior to MIS 2. The massive influx of very fine sand at Bells Lagoon occurred during the peak of the LGM. In contrast, the dates obtained from Lagoon of Islands, Lake Sorell and Lake Crescent are all consistent with lunette formation during the latter part of the LGM, subsequent to peak glacial conditions. These results are similarly consistent with ages obtained from other Tasmanian sites. Ages

as great as 87.5 ka have been suggested for sand deposits of claimed aeolian origin in southern Tasmania (McIntosh *et al.* 2012). The crescentic Dunlin dune in north-eastern Tasmania formed in two phases, the earlier lasting from prior to 29 ka until 21 ka cal kyr BP after which a podsolised palaeosol formed. Dune formation recommenced from 16-14.5 cal kyr BP (McIntosh *et al.* 2009). Charcoal from another aeolian sand sheet at Malcoms Hut road, 15 km northeast of Hobart, has been dated to 15,740±700 BP by Colhoun (1975).

Lunette formation also occurred in Tasmania at various times during the Holocene. A lunette at Rushy Lagoon formed after 9.1-9.7 cal yr BP (Bowden 1983, Cosgrove 1985). Kee (1990: 11) suggested that 'at Lake Tiberias a period of clay dune formation during low lake levels is dated to 9,550 years ago' but does not cite any further details or reference. At Double Lagoon on the Central Plateau a dark-coloured organic palaeosol occurs within the dunes. Similar palaeosols occur in some other locations atop the plateau, including at Lake Fergus from where a radiocarbon age of ~3,700 yrs has been obtained (Cullen 1995). This implies remobilisation of the sand at some unknown time after that date. Although invoking a climatic or anthropogenic cause is instinctive, it ought be remembered that saline conditions alone can impede vegetation and maintain the ground exposure necessary to allow aeolian processes to be effective. Clay dune formation seems to require saline conditions and seasonal drying that facilitates the salt efflorescence that allows production of clay aggregates that can be entrained by the wind (Bowler 1970).

3. Climatic conditions during human presence

Geomorphological evidence

The study area spans a tension zone between both the upland and lowland regimens, with the Midlands also lying in a precipitation shadow from both directions and also being exposed to driving north-westerly winds that are funnelled by the surrounding topography.

The coarse gravels recorded from White and Crown Lagoons infer previously much wetter conditions in the Midlands than is presently the case. The advanced chemical weathering of the basal fluvial gravels at White Lagoon suggests that they vary considerably pre-date the 50.5± 4.3 ka age of the earliest aeolian sands recorded during the present study.

Inland aeolian activity throughout Tasmania has generally been presumed to be associated mainly with a reduced vegetation cover caused by colder, drier and windier glacial climates.

Studies from eastern and central Tasmania have suggested that arid conditions prevailed in the Tasmanian midlands during the LGM (Macphail 1975, 1979, Macphail and Jackson 1978) with concomitant aeolian activity producing source-bordering dunes and lunettes (Bowden 1983; Nicolls 1958, Sigleo and Colhoun 1975, Sigleo 1978). The dates of 20.17±1.5 ka, 18.7±1.2 ka and 20.25±1.1 ka obtained from Bells Lagoon, and 17.5±1.6 ka from Lake Tiberias, are consistent with aeolian activity in the Midlands during the LGM.

However, the dates of 16.9±1.2 ka from Lake Crescent, and 15.8±0.9, 15.6±1.0, 16.6±0.7 and 16.4±0.7 from Lagoon of Islands, are broadly coincident with the most recent deglaciation dates obtained from Tasmania (Kiernan *et al.* 2014) and with the cessation of periglacial frost shattering at low altitudes in the Franklin River valley in western Tasmania (Kiernan *et al.* 1983; Kiernan 2009). Although there is clear evidence for a reduction in precipitation in western Tasmania having persisted into the Deglacial until ~14 ka (Colhoun *et al.* 1999, Hopf *et al.* 2000) this reduction was not so great as to preclude survival of most elements of the flora there (Kirkpatrick 1982, Pyrke and Kirkpatrick 1984). Hence, both deglaciation and

the cessation of frost shattering are likely to have been driven by temperature changes rather than by changes in atmospheric moisture.

Sigleo (1978) identified at least two major phases of aeolian activity that he interpreted as having occurred under relatively cold and seasonally arid conditions, either during or immediately after periods of periglacial slope instability. The presence of alluvial and lacustrine sediments derived from the unstable slopes that underlie the earliest aeolian sediments infers that any reduction of precipitation was more than counter-balanced by reduced evaporation. Truncated palaeosols on the older sand reflect climatic amelioration prior to another phase of sand deposition coincident with another period of alluvial fan deposition. Sigleo (1978) concluded that the late Glacial deflation and aeolian sand deposition dated to 15,740 BP at Malcoms Hut Road was broadly synchronous with the second phase of fan deposition and higher lake levels in the Midlands. As summer temperatures increased towards the end of the Last Glacial increased evaporation allowed intermittent or seasonal drying of lakes and facilitated clay dune formation and a second phase of sand-sheet deposition. This seems consistent with the timing of lunette formation on the Central Plateau. Weathering and pedogenesis occurred with the onset of climatic amelioration at the beginning of the Holocene.

The ice-pushed ridges at Lagoon of Islands also require that water was present in the basin when conditions were sufficiently cold to induce frost shattering and freezing of the lagoon surface. Our beach sand sample from Lagoon of Islands returned an age of 13.6±0.8. The Central Plateau is sufficiently far west, and sufficiently high, as to have probably still received at least some precipitation from the west during glacial times.

Botanical changes in western Tasmania and south-west Victoria following deglaciation have been attributed to the advent of either warmer or wetter conditions (Harle 1997; Hopf *et al.* 2000; Macphail 1979; Williams *et al.* 2006; Petherick *et al.* 2013). However, neither temperature nor precipitation per se may provide sufficient explanation for the volumes of water in lakes and lagoons. Changes that climatic variables caused to the vegetation cover may also need to be factored into the equation. The persistence of water bodies is dependent upon there being sufficient vegetation to prevent erosion of the soil cover in the catchment that might otherwise fill the basin with sediment, but not so much vegetation that evapotranspiration absorbs all the available water. Research from the Mt Kosciusko area of mainland south-eastern Australia found that 10,000 kg/ha (dry weight) of herbaceous vegetation or 20-25,000 kg/ha of shrubs or sclerophyll litter (less if stoney) was sufficient to maintain the soil cover. There was a rapid reduction in runoff as the vegetation biomass increased to 10 kg/ha, but beyond that relatively little change was evident (Costin 1967b, 1973). If the forest biomass surrounding Lagoon of Islands and Lakes Sorell and Crescent was reduced under the colder LGM climate, then runoff into these basins may have diminished little or even increased during glacial times, precluding exposure of the sands on its bed to wind action. Such may have allowed the ice-pushed ridges along parts of the western shoreline of Lagoon of Islands to have formed during the LGM. The lake bed may have become exposed only as the vegetation began to redevelop, coincident with the demise of the last glaciers further west. If so, then Lagoon of Islands may have provided useful resources for Aboriginal Tasmanians during the LGM rather than being a dry and sandy basin, a proposition consistent with the glacial age of some of the artefacts there.

Deforestation has been shown to generally increase water yields, with evapotranspiration from grasslands being about one third less than from forests, and this can reasonably be assumed to increase discharge into adjacent wetlands (Brown *et al.* 2005; Silberstein *et al.* 2003, Woodward *et al.* 2014b; Zhang *et al.* 2001). The strong rain-shadow affect in the Midlands, coupled with reduced vegetation under the colder, drier and windier glacial climates, saw diminished transpiration during these times. This would have allowed small lagoons to form on the floor of the Midland graben in response to locally

raised water tables. The small lunettes that formed around some of these presumably reflected greater exposure of surrounding land surfaces, where fine-grained sediments in the widely exposed Tertiary fluvial and lacustrine sediments were readily transported into lagoons and lakes. Most of the Midlands lagoons are now dry in summer, hence wetter conditions seem to be required for the higher levels apparent during the earlier Holocene, involving either lower temperatures or lower evaporation rates. Warmer summers would increase evaporation. Crown Lagoon lacks fossil shorelines or other evidence suggestive of any earlier higher water levels (Sigleo 1978).

Both Crown Lagoon and White Lagoon probably dried before 9 ka BP, by analogy with a radiocarbon date of 9,500±200 BP (GaK-2239) from the base of a 2 m thick peat deposit on the floor of Lake Tiberias (Goede, in Sigleo 1978). A clay dune subsequently formed at White Lagoon where the catchment provided large quantities of salts, but not at Crown Lagoon where the catchment offered less salt and conditions may have been insufficiently alkaline to inhibit vegetation growth (Sigleo 1978). A basalt barrier exists between Crown Lagoon and the sandstone-bearing alluvial sediments in the Birralee Valley to its west, hence relatively strong west to north-westerly winds would have been required to transport the quartz sand from this source into the Crown Lagoon basin (Sigleo 1978).

Palynological evidence: a brief review

Colhoun and Shimeld (2011) suggest that Last Glacial-Holocene vegetation changes in Tasmania were driven by temperature changes in the west, and a combination of temperature and precipitation changes in the east. The pollen record from Brown Marsh, located at 750 m altitude on the Central Plateau, 28 km WSW from Lagoon of Islands, indicates that at 9ka BP Eucalyptus and Pomaderris were increasing while Poaceae and alpine shrubs and herbs were decreasing (Macphail 1984). Over the last 7,500 years continuously treeless conditions and infrequent fires have prevailed at Camerons Lagoon (1100 m), a lagoon near the limit of the tree line on the Central Plateau 25 km NW of Lagoon of Islands (Thomas and Hope 1994).

The pollen record obtained from some Midlands' lakes confirms that conditions were substantially colder than at present during the late Glacial (Sigleo 1978). A 2 m-long core from Crown Lagoon (42.28876 S, 147.63872 E), located 7 km NNW from Rushy (Fonthill) Lagoon, is thought to have extended from prior to 25 ka BP until historical draining of the swamp. The pollen record indicates that the vegetation varied from grassy woodland through grassland to grassy woodland and grassy open-forest during the latest Pleistocene and the Holocene. This was presumably in response to a transition from moister to colder and drier conditions during the LGM, after which there was a reversion to moister conditions during the Holocene (Sigleo and Colhoun 1981). This pollen record suggests a transition from savannah or open woodland with *Eucalyptus* spp. and *Allocasuarina* spp., prior to MIS 2, to grassland or steppe under peak glacial conditions, with Poaceae, Asteraceae, Chenopodiaceae and less than 5% *Eucalyptus* spp. By late glacial times steppe grassland persisted with still less than 10% *Eucalyptus* spp, but by 12.0 ka BP the record from Stoney Lagoon, 1.8 km SSE of Rushy (Fonthill) Lagoon, indicates dry sclerophyll forest with 81% Eucalyptus pollen, plus mainly Poaceae and Asteraceae (Sigleo and Colhoun 1981). A more recent vegetation and fire history from Stoney Lagoon, based on pollen and charcoal analysis, indicates that a relatively moist early deglacial was followed by a later dry deglacial (ca. 14,000–12,000 cal. BP), when sclerophyll forests became well established and burning increased (Jones *et al.* 2017).

By early Holocene time c. 9.0 ka BP the pollen deposited into Stoney Lagoon indicates dry sclerophyll forest with 66% Eucalyptus, 12% Poaceae and 4% Asteraceae, with 9% *Pomaderris* and 5% *Phyllocladus* transported from the west. Dry sclerophyll forest was also present at Lake Tiberius with 75% Eucalyptus, 5% *Allocasuarina* and 10% Poaceae, with 5-15% *Pomaderris* blown inform the west, along with 5% *Nothofagus cunninghamii*. Conditions were similar at c. 6.0 ka BP at both Lake Tiberias and Stoney Lagoon.

However, increased Eucalyptus and *Allocasuarina* at Stoney Lagoon *c.* 1.0 ka BP suggests drier conditions (Sigleo and Colhoun 1981). Jones *et al.* (2017) concluded that dry sclerophyll forest persisted at Stoney Lagoon throughout the Holocene; with a pronounced transition from more to less grassy understoreys between ca. 9000 and 7000 cal. BP, and then relative stability of the sclerophyll community from the mid Holocene. However, they interpreted increased fire activity and trends in moisture-sensitive taxa as being suggestive of generally drier conditions coupled with greater hydroclimatic variability under the strengthening influence of the El Niño–Southern Oscillation (ENSO).

Frost frequency and aridity are the principal factors limiting tree growth and favouring grass cover in the Midlands (Jackson 1973). While Jones *et al.* (2017) acknowledged the role of macro-scale climatic shifts in shaping vegetation development in Tasmania's inland east, they suggest that their evidence from Stoney Lagoon hints at the concurrent importance of local ecological drivers. Jones *et al.* (2017) suggested that the Midlands' vegetation responded to climatic signals that were dissimilar to trends in western Tasmania and instead more characteristic of Australia's south-eastern coastal regions.

Interpretation

Previous archaeological researchers in eastern Tasmania have generally accepted and thereby to some extent reinforced the assumption that conditions remained dry during the LGM (Brown 1986; 1991; Cosgrove 1995) but without advancing the evidence for its veracity. Palaeosols dated from 26.4-16 ka BP that are present on some aeolian deposits in eastern Tasmania require periods of stability and relatively humid conditions in order to form. There is some evidence that suggests a positive water balance in parts of eastern Tasmania at around this time (Colhoun 1977; Jones 2008; McIntosh *et al.* 2009, 2012). McKenzie and Moss (2014) found Hazards Lagoon on Tasmania's central east coast to have retained permanent water throughout the LGM until 16 cal yr BP, suggesting either increased precipitation or decreased evaporation. However, other evidence from eastern Tasmania and some other eastern Australian sites suggests drying conditions from 15-12 ka cal BP. This contrast has been suggested to imply an increasing influence by a south-westerly airstream and that a north-easterly airflow became dominant in eastern Tasmania after 21 ka, thereby enhancing precipitation there (Fletcher and Moreno 2012; McIntosh *et al.* 2012).

Derbyshire (1967) recognised a broad similarity between those parts of Tasmania that were formerly glaciated and those that presently receive >250 mm/pa (water equivalent) of snow. Because this was inconsistent with the Central Plateau being the heart of the ice cap, as was generally assumed at that time, he argued that during glacial times a greater proportion of the solid precipitation budget must have been derived from north of west. However, more recent research has shown that during the most extensive glaciation, which likely first shaped the erosional landforms, the thickest ice lay west of the Central Plateau rather than upon it, hence this altered wind direction is no longer required to explain the glacial landforms (Kiernan 1985, 1990). Recent research from the Frankland Range in southwest Tasmania has highlighted how the location and form of glaciers that developed there during the smaller scale MIS 2 glaciation were largely dictated by the older glacial landforms they inherited (Kiernan *et al.* 2017). Similarly, during the more recent glaciations in the Central Highlands pre-existing erosional landforms are likely to have been reoccupied and elaborated upon by the ice masses largely irrespective of any subtle differences in the trajectories of precipitation input.

Shulmeister *et al.* (2010) argued that strong winter cooling of the Australian mainland during the LGM enhanced the winter High Pressure System over south-eastern Australia, which the disappearance of Bass Strait allowed to move further south. This may have reduced winter rains over westerly dominated areas but still ventilated Tasmania, while onshore easterlies passing over the East Australia Current on the northern limb of the high maintained humid and warm conditions on the eastern lowlands

of mainland Australia and a cool humid belt along its highlands. No major change in circulation was envisaged but there is likely to have been greater baroclinicity as the westerlies and the westerly jet diverted around the enhanced southern Australian High pressure cell. Anti-phasing of moisture regimes between western and eastern Tasmania since 14 ka cal BP have been attributed to fluctuations in the intensity of the SSW airstream (Fletcher and Moreno 2012). Any such change in the predominant airflow direction may also have contributed to the retention of moisture in basins on the Central Plateau.

The question arises as to how these various changes in Tasmanian climate, and hence landscape morphogenesis, relate to regional climatic trends in the wider southern mid-latitudes. Our OSL age of 50.5± 4.3 ka obtained from Lake Tiberias significantly post-dates the phase of regional drying suggested by the most extensive glacier advance of the Last Glacial Cycle in New Zealand, which occurred from 67-62 ka rather than during the global LGM (gLGM). It is also older than the greatest of the glacier advances that occurred in New Zealand during the gLGM, which were most extensive 32-26 ka BP, about 12 ka before the northern hemisphere maximum. The glaciers had almost disappeared from New Zealand's lower valleys by the time of the gLGM in the northern hemisphere (Williams 2017). Hence, the timing of Tasmanian aeolian activity generally seems somewhat out of phase with conditions in New Zealand.

A changing stage for Aboriginal occupation

Variations in the character of lakes along a west-east transect across the Tasmanian Central Plateau and into the Midlands graben reflect a combination of forcing processes over time with the effects of altitude, climate and tectonics working on the local lithology and landscape. The higher altitude and high rainfall of the west supported extensive glaciation during the colder phases of the Quaternary, that produced distinctive small rock-basins by erosion along bedrock lineaments, these sometimes having a moraine-dammed threshold. In precipitation-shadowed areas further east, broader shallow depressions formed by weathering of susceptible rocks on back-tilted bedrock masses, coupled with damming by copious volumes of loose sediment that was produced under periglacial conditions. At lower altitudes east of the mountains in the Tasmanian Midlands, similar climatic factors caused shallow lakes and more ephemeral ponds and lagoons to form. While there are localised glacio-aeolian dunes associated with a few of the glacial lakes in the west, aeolian deposits that border the lakes in the Midlands are instead formed from sands and silts derived by primary weathering and erosion of local source rocks, and reworking of earlier alluvial deposits.

It is probable that all of the lakes and lagoons investigated during this study had their genesis long before the earliest date thus far reported for the arrival of humans in Tasmania. Nevertheless, people were present on the Central Plateau sufficiently early to have witnessed the most recent glaciation of the highlands, and to have experienced periglacial climatic conditions on the plateau. An initial occupation date of 30,840±480 BP has previously been reported from a large sandstone rock shelter, ORS 7, located 21.6 km SSW of Lagoon of Islands at 440 m altitude in the Shannon River Valley. Initial occupation of Parmerpar Meethaner, a quartzite rock-shelter located 80 km north-west from Lagoon of Islands at 350 m altitude in the Forth River Valley, which drains northwards from the Central Plateau, has been dated to 33,850 ± 450 and 33,260 ± 420 B.P. Later phases of its occupation occurred *c.* 19,000-17,500 BP, at *c.*10,400 BP, and at *c.*2,400 BP (Cosgrove 1989, Cosgrove *et al.* 1990).

Both ORS 7 and Parmerpar Meethaner lie well below the glacial equilibrium line (ELA) during the LGM, which in the Forth Valley lay at ~800 m altitude (Kiernan and Hannan 1991). However, although Cosgrove (1995a) reported that no ice was present in the Forth River Valley during their presence, people were in fact living within only a few kilometres of the glacier that flowed ~13 km down the Forth Valley at this time. The inferred Glacial age of some of the stone tools at Lagoon of Islands now indicates that they may also have ventured to much higher altitudes during the LGM than the relatively sheltered Shannon

and Forth valleys, Lagoon of Islands lies virtually at the ELA where thermal conditions would have allowed glaciers to form during the LGM had available precipitation allowed it, hence an Aboriginal presence at this time would seem very noteworthy. The only apparent alternative is that the artefacts that were buried beneath the Lagoon of Islands lunettes must predate the LGM. This would beg the question as to the earliest age of some of the undated artefacts among scatters at other high altitude sites on the plateau, including those around Great Lake, Arthurs Lake and elsewhere.

The Pleistocene presence of people on and around the Central Plateau stands in striking contrast to ages no greater than mid Holocene which our landform and sediment dating implies for the artefacts observed at our Midlands sites. The earliest evidence for any human presence in the Tamar graben is a bone artefact from a limestone cave at only 140 m altitude at Flowery Gully that has been dated to 7,080 years BP (Gill 1968). The only glacial age sites reported thus far from the lowland valleys east of the Central Plateau have come from near sea level in the Jordan River Valley close to its outflow into the Derwent estuary (Sigleo and Colhoun 1975; Paton 2010).

Just why this contrast should exist remains unresolved. Because Lagoon of Islands was sufficiently cold to itself have been glaciated during the LGM, but for the precipitation shadow in which it lay, it might seem likely to have offered a much harsher environment in which to live than the lowland lagoon margins of the Midlands. Greater aridity in the shadow of the mountains, cold air drainage from their heights, and diminished vegetation to provide shelter from the colder and stronger LGM winds may go at least some way towards explaining the contrast in occupation dates between the Central Plateau and the Midlands. Despite the lower altitude of the Midlands, perhaps conditions there were more volatile and unpleasant, the environment offering less reliably available food, water and other resources than on the slopes higher up towards the Central Plateau. More varied topography along the mountain slopes may have provided better sheltered and watered sites that served as refugia for elements of the vegetation, and hence the game animals on which people also depended, while also offering greater shelter for those people who dwelt in this part of Tasmania during the Pleistocene.

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Chapter 10:
The Archaeology of Lagoons of the Tasmanian Midlands and Eastern Central Plateau and Its Role in Re-Interpreting Past Tasmanian Aboriginal Landscape Use and Meaning

Anne McConnell, Andry Sculthorpe and Kevin Kiernan

Introduction

This chapter documents new archaeological investigation of select inland lagoons on the Central Plateau and in the central Midlands of *lutruwita*/Tasmania (refer Figure 10.1), the two lagoon-rich regions of the island. The chapter examines these and earlier archaeological findings, as well as available Tasmanian Aboriginal historical information, in relation to inland Tasmanian lagoons. It uses this information to review and reframe our understanding of the historical Tasmanian Aboriginal connections to inland lagoons, including at a landscape level.

The current knowledge of Aboriginal archaeology in Tasmania has evolved from a small number of major archaeological research projects undertaken in the 1960s to mid-1980s (e.g., Bowdler 1979; Gaughwin 1985; Jones 1971; Lourandos 1970; Stockton 1982; Vanderwal and Horton 1984), and an even smaller number of later research projects (Allen *et al.* 1988;[1] Cosgrove 1989; Cosgrove 1995; Sim 1991; Thomas 1991). It is grounded however in a set of regional archaeological studies undertaken from the early 1980s to 1994 and which cover the full State (i.e., Brown 1986, 1991; Cosgrove 1984a; Dunnett 1994; Kee 1990, 1991; Macfarlane 1993; Sim and West 1993). These studies are regional analyses which provide information on the nature of the Aboriginal archaeology of the regions investigated, landscape based site patterning, and in a number of cases chronological information derived from site excavation and dating. They also provide strategic level advice for the management of this cultural heritage. These regional studies provide an archaeological framework for Tasmania which is used to the present day. This framework is augmented by the considerable body of cultural heritage management research that has been undertaken in the state, and the non-management oriented research noted above.

Interpreting the archaeology is hampered by the great loss of knowledge about traditional Aboriginal lifeways, a direct result of the appalling treatment of Tasmanian Aboriginal people as a result of the British colonisation of *lutruwita*/Tasmania, a treatment very similar to that of most other indigenous peoples in places colonised by the British in the 1700s and 1800s. However, in Tasmania today there is a growing reclamation of traditional knowledge, practices and language, and also a desire to have a stronger connection to the land ('country') through access and through land and cultural heritage management, which also helps realise traditional custodial obligations to country. This however does not augment the information about pre-colonial Aboriginal life in *lutruwita*/Tasmania.

The present day Tasmanian Aboriginal focus also demands greater recognition of broader Aboriginal values when considering Aboriginal cultural heritage. As a result, Tasmanian Aboriginal people have

[1] This is just one of a number of pieces of work that, collectively, comprised a major research focus between c.1983 and 1990 on the Aboriginal archaeology of the limestone areas of southwest Tasmania (primarily the Aboriginal use of limestone caves). This research however was undertaken as a number of small discrete archaeological projects which were mostly were reported separately.

been spearheading a move away from a narrowly focussed discourse on archaeological sites only, the traditional key focus of academic research and the only heritage protected under legislation. This has led to a small number of broader Aboriginal heritage identification projects being undertaken (McConnell and Hamilton 2001; Maynard and Smith 1996; Smith *et al.* 1996); an increased use of traditional Aboriginal place names, and increased Aboriginal participation in Aboriginal heritage research and management in Tasmania, including Aboriginal-led research and management. Much of this new work and thinking has been led by the Tasmanian Aboriginal Centre (TAC), with the broadening of scope of Aboriginal heritage interests also being driven by the Tasmanian Aboriginal Land and Sea Council from the mid-1990s to mid-2000s.

This new focus and Aboriginal involvement allow for richer understandings of historic Aboriginal land use and connections, and of contemporary Aboriginal meanings of the land and sites that occur within the landscape. The understanding of Tasmanian Aboriginal history and traditional culture is also enriched by the detailed observations on Aboriginal life post-European arrival in Tasmania of a small number of observers, albeit non-Aboriginal observers, that are a legacy from the late-1700s to mid-1800s. In spite of all this information, our knowledge of Tasmanian Aboriginal history is still very sketchy, with vast quantities of information missing and large areas of Tasmania archaeologically uninvestigated.

Included in this, and in spite of some important and seminal studies of Tasmanian lagoons and Tasmania's lagoon rich landscapes (i.e., Cosgrove 1984a; Cosgrove 1985; Kee 1990; Sigleo 1978; Smith *et al.* 1996; Thomas 1991), there is a still limited understanding of the role and importance of lagoons for Tasmanian Aboriginal people, both historically and today. At the same time, historical observations (e.g., as documented in Plomley (2008) and Ryan (1996)) provide indications that lagoons may have been of critical importance historically; and a small number of synthetic reviews (e.g., Brown 1991; McConnell 2010) hint at historically regionally widespread, targetted use of Tasmanian lagoons, and for lagoons perhaps being an important influence on the location of historical travel routes, at least in the central eastern part of Tasmania in the more recent past.

The present lagoons study was seen as an opportunity to examine the historical Aboriginal use of lagoons in greater detail – to fill in gaps in the archaeological knowledge of lagoons, to marry this with the historical accounts, and to undertake a landscape level analysis with the aim of not only providing greater understanding of the historical role and importance of lagoons in Aboriginal Tasmania, but also a greater understanding of the Aboriginal history of Tasmania more generally, at least in the regions investigated. The eastern Central Plateau–Midlands region of Tasmania (refer Figure 10.1) was selected as the study region as this area contains the majority of lagoons, has had some previous research that provides a framework for the project, and has some of the most detailed historical information away from the Tasmanian coast. Collectively, the available information points strongly to considerable traditional movement in this region (and beyond to the east and west) and provides a tantalising glimpse into possible earlier lifeways with patterns of land use incorporating lagoons, which demands further exploration.

The project was also seen as an opportunity for collaborative research between Tasmanian Aboriginal people and the project (led by non-Aboriginal researchers). Aboriginal involvement in the project was highly desired given that the project related to Aboriginal heritage and was also essential to meeting the broader project Work Integrated Learning (WIL) aims (refer Chapter 1). Aboriginal involvement was sought through initial letters to Tasmanian Aboriginal cultural organisations with a state-wide scope



Figure 10.1 *Tasmanian study region, key lagoons and other key archaeological sites referred to in Chapter 10. [Map of Tasmania reproduced with permission from Alexander, A. (ed) 2005, Companion to Tasmanian History].*

Key: **Lagoons – study region (red)**

1. Laughing Jack Lagoon
2. Bradys Lake
3. Lake Echo
4. Lake Fergus
5. Lakes Ada & Augusta
6. Lake MacKenzie
7. Great Lake
8. Arthurs Lake
9. Lagoon of Islands
10. Lake Sorell
11. Lake Crescent
12. Cleveland Lagoon
13. Diprose Lagoon
14. York Lagoon
15. Bells Lagoon
16. Township Lagoon (Tunbridge)
17. Lake Dulverton (Oatlands)
18. Lake Tiberias
19. Crown Lagoon
20. Rushy Lagoon (Fonthill)
21. Eastern Marshes
22. Hobbs Lagoons

Lagoons and Key Sites – outside study region (blue)

1. Rushy Lagoon
2. Wet Marsh
3. Coal River sites
4. Kutalina
5. ORS 7
6. Navarre Plains
7. Warragarra
8. Parmerpar Meethaner

and to Tasmanian Aboriginal educational organisations. A partnership approach was subsequently developed with the Tasmanian Aboriginal Centre (TAC)[2]. This led to:

- developing and signing a project Memorandum of Understanding between the TAC and University of New England;
- exchange visits of a small number of TAC sponsored Aboriginal people to New England for field work, and a return exchange visit by NSW Aboriginal project participants for the Tasmanian field season;
- co-hosting of the Tasmanian field season in March 2014;
- training in archaeological method and field techniques for Tasmanian TAC sponsored volunteers;
- sharing of local knowledge and of traditional skills, including stone knapping;
- sharing of personal stories, meanings and associations attached to lagoons by Tasmanian TAC sponsored volunteers as part of the project; and
- collaborative project reporting.

Aboriginal participation in the project is discussed in more detail in Chapter 1 – 'Indigenous Participation and Aboriginal education'.

Given the aims and scope of the UNE Lagoons Project 'Working Ancient Wetlands for Social Benefit and Cultural Understanding' (refer 'Introduction', this publication), the aim of the Tasmanian part of the project was to provide a parallel study, essentially for comparative purposes with the New England Tablelands to help assess the importance of lagoons in an Eastern Australian context (see Chapter 11). A secondary aim was to extend Aboriginal involvement and promote cultural exchange within the scope of the project.

Context – Prior understandings of traditional Aboriginal life in the Central Plateau and Midlands, and of the role of lagoons

Observations from the recent past

Based on contemporary observations from 1804, when the British took possession of *lutruwita*/Tasmania, until the 1830s[3], and their later synthesis (e.g., Ryan 1996), the eastern Central Plateau–Midlands region of Tasmania sits at the junction of the historical territories of three Tasmanian Aboriginal tribes (i.e., language speaking groups). These were the North Midlands, Big River and Oyster Bay tribes or nations, which were estimated to have as many as 400, 500 and 800 people, respectively, at least at the time of colonisation (Ryan 1996). The Central Plateau is known to have been used extensively historically by the Big River people, with limited use, possibly not on a regular annual basis, by the surrounding 'lowland' tribes, including the Oyster Bay and North Midlands people. That part of the Midlands in the study area appears not to have been a core area, except around Campbell Town. It appears rather to have been a resource rich travel zone for all three tribes, supplying important and reliably available resources to travellers, as well as highly valued special seasonal resources at certain locations such as the Eastern Marshes on the southeast edge of the Midlands, as the three tribes moved, largely seasonally, between the Central Plateau and the East Coast. The Ben Lomond people, whose territory was to the north of the North Midlands people, also appear to have joined in much of this largely seasonal large scale travel,

[2] The Tasmanian Aboriginal Centre (TAC) was the only organisation that expressed a clear interest in being involved in all aspects of the project.

[3] This historical information needs to be used with care, as by the 1820s and 1830s, when most of the observations were made, the Tasmanian Aboriginal people had been significantly impacted by British colonisation – they were no longer able to access much of their land, particularly in the Midlands; large numbers of Aboriginal people had died, and they were in the midst of fighting to defend their country, often involving quite different relationships with other Aboriginal tribes than had been traditional.

frequently travelling through the Midlands with the North Midlands people to the East Coast and Central Plateau (Ryan 1996).

The historical documentation indicates that the northern Oyster Bay people moved from the East Coast up through the Midlands to the Central Plateau area for summer, stopping in the Midlands in spring; then returning to the Midlands in autumn, then to the coast in June; although in some years they appear not to have moved away from the coast. The Big River and Midlands people had a similar round of annual travel (Ryan 1996), but it is assumed that each group spent more time in their own territory than in other territories, and used their own territory more extensively. The different tribes are understood to have had arrangements with other tribes that allowed travel in other territories. In spite of these arrangements involving the shared use of land and resources, relationships appear not to have been always amicable between the different tribes (although much of this conflict may have been a result of the impact of colonial settlement and the accompanying Aboriginal loss of life, land and cultural dispossession by the time the conflict was observed in the 1820s-1830s).

Specific routes appear to have been used for long distance travel (refer Figure 10.2). Within the Central Plateau area there were major north-south routes which connected to the major inland north coast east-west route that ran from the northern Midlands to the Surrey Hills area in North West Tasmania. The north-south routes included a route that ran through the Central Highlands via Cradle Mountain and Lake St Clair and a more easterly route that ascended the Western Tiers near Quamby Bluff then ran via *yingina*/Great Lake and Lagoon of Islands to the Shannon River area. A second road in this area ran from near Lagoon of Islands southeast to Lake Sorell and Lake Crescent (Plomley 2008; Ryan 1996). There also appears to have been a well used road between Lake Echo and Lake Fergus, which possibly continued south past Bradys Lake and Father of Marshes on Black Bobs Rivulet where there was a marked road; and another road appears to have run east from this via Dee Lagoon (Jorgenson, cited in Cosgrove 1984a: 45; Plomley 2008: 549, 553). On the Central Plateau the major 'roads' were indicated by notched trees and were named (Plomley 2008).

In the Midlands area there appears to have been three main east-west routes connecting the East Coast and the Central Plateau, as well as a major north-south route which ran down the eastern side of the Midlands. The north-south route on the eastern side of the Midlands, appears to have run from east of Campbell Town on the northernmost east-west road south via a chain of marshes in the foothills of the Eastern Tiers, including (north-south) the Windfall Marshes, Stockers Bottom/Sandstone Marsh, Punches Marsh, then across the Macquarie River near Blanket Bottom, to Black Johnnys Marsh, then to the marshes on the headwaters of Stonehouse Creek. The route then appears to have run southwest to the northern end of the Eastern Marshes (the Faddens Lagoon - Crown Lagoon area), then southeast across Marshalls Tier to the eastern edge of the Eastern Marshes (in the Little Swanport River - Eastern Marshes Rivulet area), then southwest to the southern part of the Eastern Marshes (Little Swanport River - Hobbs Lagoons area) (Plomley 2008).

The northernmost east-west connecting route in the Midlands appears to have run from the East Coast in the Oyster Bay area via the Meredith River across the Eastern Tiers, then via the Elizabeth River to Campbell Town, then northwest to connect to the major north coast inland route that ran west to the Surrey Hills, or west onto the Central Plateau via Lake River to Arthurs Lake and *yingina*/Great Lake (by an unspecified route). The central east-west route ran from Lake Crescent down the Western Tiers to the Blackman River, then east along the Blackman River and across the Salt Pan Plains, then south on the route on eastern side of the Midlands to the Eastern Marshes area, then via the Little Swanport River to the East Coast, or to the southeast via the Prosser River (Plomley 2008; Ryan 1996). The third east-west route ran from the Clyde River somewhere north of Bothwell, down off the Western Tier crossing the Jordan River near Jericho, then east across the Midlands via the Blue Hills (near Mt Seymour) to the

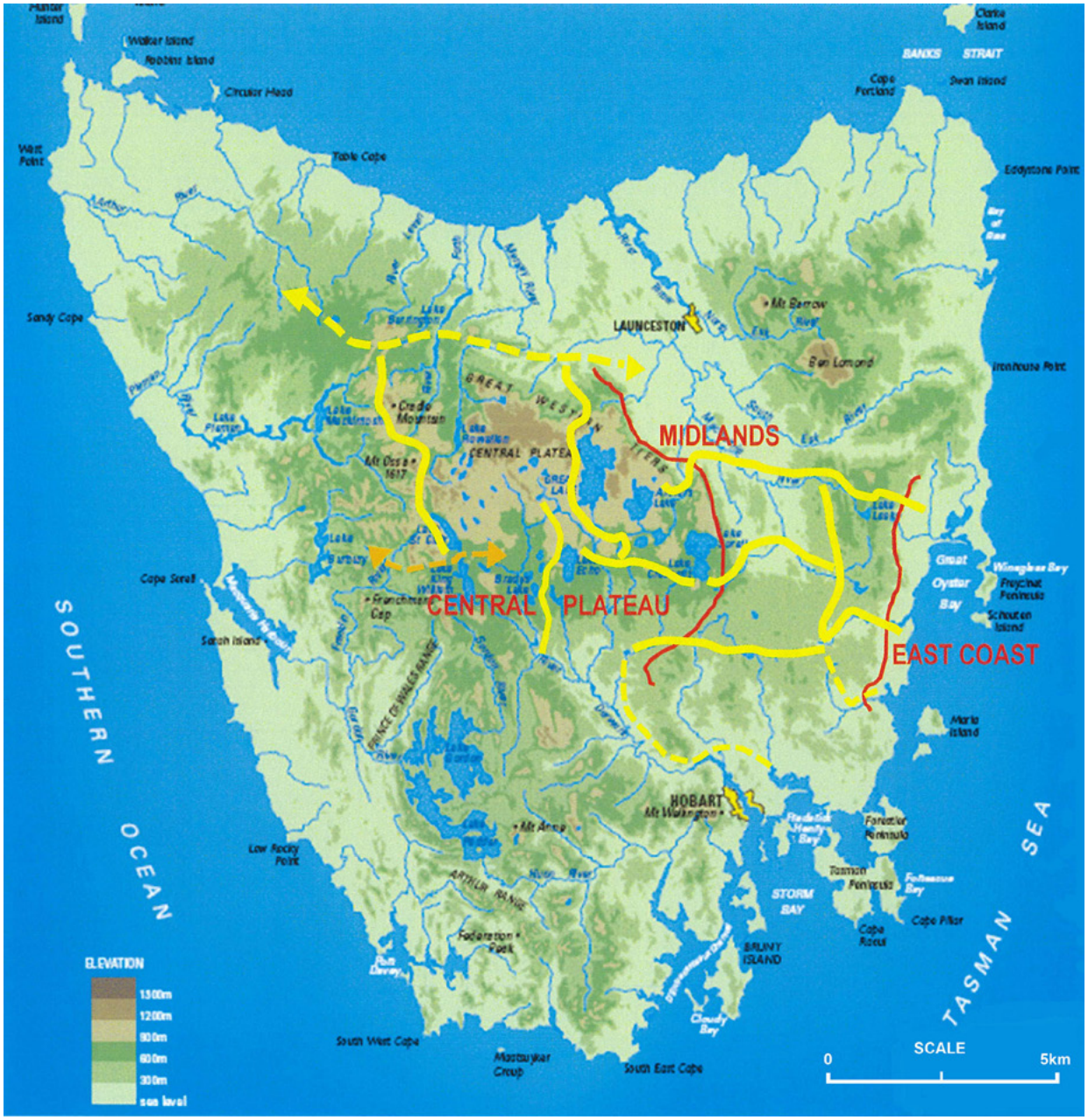


Figure 10.2 Lines of connection from the Central Plateau to the East Coast. *Heavy lines are major routes/roads, and lighter lines are considered to be less major routes/roads. The solid lines are the known routes wholly or largely in the study area. Yellow routes are known routes based on data in Plomley (2008) and Ryan (1996); the orange route is a reconstructed route (McConnell and Hamilton 2001); the map of Tasmania is reproduced with permission from Alexander, A. (ed) 2005, Companion to Tasmanian History.*

Eastern Marshes area (Robertson, cited in Kee 1990, Appendix 2: 6). One historical account (Jorgenson, cited in Kee 1990, Appendix 2: 6) notes that the Salt Pan Plains were accessed via Antill Ponds and Oatlands, suggesting that there were other routes, possibly more minor routes, across the Midlands. There was also another major eastern route from the Central Plateau to the coast outside the study area. This ran southeast from the Clyde River into the Lower Derwent valley then to Pittwater.

There is no evidence that the major routes in the Midlands were marked or named, but it is probable that the routes were kept open by regular burning, as was the case for the north coastal route in northeast Tasmania, where the 'road'[4] appears to have been made and maintained by regular burning of land along the route (Plomley 2008: 412-419). This is suggested by G.A. Robinson's observation (Plomley 2008: 21/10/1831) while on the north-south Midlands road that 'On approaching the Macquarie River saw burnt ground, which had been recently done. My natives assured me it had been done by the natives and the road we was [sic] travelling was the native road'.

The historical information also notes areas that were important Aboriginal stopping places, either because large numbers of people, huts or hut remains, or artefact concentrations were observed at these locations, or because of information to this effect from Aboriginal people. The observers give inhabitant numbers for some of these places as up to 200 or 300-400 people. These places tend to be areas (e.g., 'the country between the Windfalls and Maloneys Sugarloaf') rather than specific locations, and are usually areas of grassy plains, generally in association with a river or marshes. Areas on the Central Plateau noted as major Aboriginal gathering places include St Patricks Plains on the Shannon River, Lake Fergus, Lake Echo (east side), Four Mile Marsh (now London Lakes) west of Lake Echo, Father of Marshes south of Lake Echo, and the Navarre Plains (Plomley 2008). Identified such locations in the Midlands are Campbell Town, Keaneys Bogs on the Elizabeth River, the Windfall Marshes - Maloneys Sugarloaf area, York Plains, Oatlands, in the forests southeast of Lake Tiberias, Shotts Lagoon, the greater Eastern Marshes, and the Lower Marshes on the Jordan River (Kee 1990; Plomley 2008). Open areas on rivers or marshes, and lagoons, also appear to be important regular camping places, although not necessarily for large groups.

Although the Eastern Marshes appear to have been a particular focus, being located at a major 'cross road' and with seasonally important resources, most of these major gathering places appear to have been important for abundant or important seasonal resources. The majority are noted as being areas that were important kangaroo (wallaby) hunting grounds, but the lagoons, and particularly in the Eastern Marshes area, were known to be important for waterfowl (ducks and swans) and their eggs (Brown 1987; Cosgrove 1984a). The lagoons of the greater Eastern Marshes are also known to have had an 'abundance of eels' (G.A. Robinson, cited in Kee 1990, Appendix 2: 8). Other resources also appear to have been specific to, or particularly abundant at, particular lakes/lagoons, for example abundant possums are noted at Lake Dulverton (Plomley 2008: 533) and to the southeast of Arthurs Lake was a stand of tea tree noted as being preferred for spear making as the wood had a special hard quality (Plomley 2008: 578). *Eucalyptus gunnii* (cider gum), which is endemic to the high country and generally found only over 800m asl, is common on the Central Plateau, occurring most commonly around the edge of marshes and lagoons. It produces a gum which could be eaten raw and was made into an alcoholic drink and was a popular resource (Cosgrove 1984a). Obtaining and drinking the alcoholic gum is noted as occurring at Arthurs Lake, Lagoon of Islands and Lake Echo (Ross *et al.* 1993).

Only one contemporary account of Aboriginal people camping by a lagoon without European direction or intervention has been identified. This is the following description by Ross (1830: 99-100) who at a 'large rushy lagoon' in the centre of an 'extensive plain' south of Lake Echo (probably Nine Mile Marsh) encountered 'several small parties of blacks, some strolling about, while others sat in little families, as it were, round small fires'. Ross also notes 'We found they were a tribe of about sixty or seventy, whom I had occasionally met with before, and who had sometimes visited Hobart-town ...'. Ross stayed at the lagoon overnight and observed a man return to the lagoon with seven possums that were cooked in the fires and then eaten; people with 'red pigment mixed with grease' in their hair; one man who had

[4] In this case the 'road', unlike in southern Tasmania, was a c.25 km wide belt extending inland from the coast where people wandered and did not 'keep to one road' (Plomley 200: 419).

decorated himself with two white cockatoo feathers; and people drinking water from the lagoon by lying face down and drinking the water directly by mouth.

The archaeological evidence

Existing archaeological information helps augment the understanding of the past Aboriginal lifeways of the Central Plateau and in the Midlands derived from the historical data. This archaeological information, which is essentially derived from regional studies that have identified the archaeology through site surveys of sample areas, and from a relatively small number of small area environmental impact assessments, only provide limited additional information. These studies however demonstrate that on the Central Plateau and in the Midlands, the archaeological sites, hence evidence of past Aboriginal use, are extensive.

The key Central Plateau regional studies (Cosgrove 1984a; Smith *et al.* 1996) and main Central Highlands study (McConnell and Hamilton 2001) demonstrate a spread of sites across the Central Plateau-Central Highlands in a range of landscapes and at all altitudes, including over 1,100 m asl, with a similar site patterning and no significant discernible differences in the extant material culture throughout. The initial and largest regional study (Cosgrove 1984a) demonstrated that the Central Plateau was archaeologically rich, with sites spread across the Plateau in a variety of environments. Cosgrove's study and the later regional studies indicated that the archaeological evidence is predominantly (95%) in the form of open sites (surface artefact occurrences) plus a small number of sandstone rockshelters and tool stone quarries. They also found that open sites typically have only stone artefacts which are predominantly debitage, but include formal tools (predominantly scrapers) and utilised pieces, and more rarely cores. Most artefacts are made on hornfels,[5] suggesting local material is being used predominantly, with other stone (quartzite, chert, quartz) being relatively rare, and silcrete being extremely rare (Cosgrove1984a; McConnell and Hamilton 2001). Most open sites are small (i.e., ranging from single artefacts to scatters of only 10-15 pieces). Cosgrove's (1984a) survey indicates it is the larger sites that tend to have a diversity of artefacts and stone types, and also tend to have a greater diversity of cultural material, including for example ochre, faunal remains and hearths, and in one case evidence for stratified cultural deposits.[6] To date only a small number of large open sites (i.e., >250 artefacts) have been identified on the Central Plateau. With one exception, these are all associated with lakes/lagoons or the region's larger rivers (Cosgrove 1984a; Smith *et al.* 1996).

The Central Plateau archaeological studies have consistently shown that lakes and lagoons will generally have associated archaeological sites and, in most cases, relatively high site densities, and have amongst the largest identified sites (McConnell 2009b). For example surveys of Lake Echo and Crescent Lake (McConnell 2009a) resulted in the location of 29 and 15 surface artefact scatters and site densities of 4.5 and 2 sites/linear km, respectively; while surveys of *yingina*/Great Lake[7] identified over 250 sites and a site density of 4.1 sites/linear km (Cosgrove 1984a; Thomas 1983); and survey of Arthurs Lake (Cosgrove 1984a) identified 38 sites and a site density of 5 sites/linear km. The site distribution on lakes/lagoon edges is however not uniform, with some lakes/lagoons having site clusters, in some cases in particular areas, most commonly the west, the north/northeast, and the south sides (Cosgrove 1984a; McConnell 2009a; Smith *et al.* 1996; Thomas 1983). The overall density of lake, lagoon and river areas is however still high compared to areas away from lakes and lagoons. Translating the sites/linear km measure to

[5] The particular hornfels used in Tasmanian for artefacts is a fine grained, quartzose meta-sediment, usually of Permian or Triassic age which has been contact metamorphosed by the emplacement of Jurassic dolerite (Jurassic dolerite underlain by Permo-Triassic rocks is the geology of the Central Plateau).

[6] At Laughing Jack Lagoon (Cosgrove 1984).

[7] Great Lake sits at just over 1,000 m asl and is c.24 km by 8 km. Prior to damming it was Australia's largest natural freshwater body (Thomas 1983).

sites/km^2 indicates lake/lagoon/riverine site densities in the order of 40–90 sites/km^2 [8] compared to a site density in the order of *c.* 5 sites/km^2 away from lakes, lagoons and rivers.[9] This site patterning and densities are also supported by the results of Smith *et al.* (1996).

Although most lake/lagoon sites were small (with *c.*30-50% of sites being isolated artefacts), some lakes/lagoons were found to have large sites, for example at *yingina*/Great Lake, Arthurs Lake, Lagoon of Islands, Laughing Jack Lagoon, Lake Augusta, Talinah Lagoon (west of Lake Ada) and Lake Mackenzie (Cosgrove 1984a, 1984b; Smith *et al.* 1996; Thomas 1983). Other lakes/lagoons on the Central Plateau known to have more occupation evidence than a few small open sites are Lake Sorell, Crescent Lake, Little Lake (*c.*3 km north of Arthurs Lake), Bradys Lake, Lake Echo and Lake Fergus (Cosgrove 1984a; McConnell 2009a; Stanton 2002).[10] McConnell (2009a) interpreted the larger lagoon edge sites as campsites and the small artefact scatters and isolated artefacts as miscellaneous activity sites (e.g., meal time camps, food procurement sites, or short stops while travelling). Thomas (1983) also interpreted the larger lake margin sites as campsites, but places that represent protracted occupation, rather than ephemeral visits.

The distribution of the sites in the vicinity of the Central Plateau lakes and lagoons has been found to broadly conform to the generalised site patterning identified for the broader region, and Tasmania more generally (Cosgrove 1984a; McConnell 1995a; Smith *et al.* 1996), with sites being located generally close to water, on gently sloping ground (particularly near creeks), on low well drained rises (including aeolian source bordering deposits), in sheltered locations, on spurs and ridges, at forest-heath interfaces and at breaks in slope (generally between flats and hillslopes).

The different lakes/lagoons however appear to have different archaeological signatures in relation to where sites are situated, with different lakes/lagoons having sites differently located with respect to the microtopography and vegetation zones. For example, at Lake Echo the largest known sites occur on banks along the edges of broad wetland valleys at the north end, while at Lake Crescent what is interpreted as the historical lake margin appears to be the most sensitive environment for Aboriginal sites (McConnell 2009a). McConnell (2009a) also observed that for these two lakes, some sites will be in rocky terrain on moderate-gentle to moderate slopes, often on small benches or in small saddles and not necessarily close to water, an environment that is generally considered to be of low sensitivity in most other parts of Tasmania (McConnell 1995a). Other examples are the limited occurrence at Arthurs Lake of sites located on flat promontories (Stanton 2000), a situation found to be a common site location at Crescent Lake (McConnell 2009a), while at Lake Echo the only promontories that sites were found on were those defining major embayments (McConnell 2009a), and at *yingina*/Great Lake it appears that sites occur in the lee of ridges, promontories and headlands rather than on them (Thomas 1983).

Cosgrove's (1984a) study highlighted the preferential location of open sites at forest and plain (heathland or grassland) boundaries both for lakes/lagoons and in other environments, and he viewed this environment as the most advantageous positions for climatic protection and for maximising access to food resources, and consequently as a 'decisive sub-alpine adaptation' (Cosgrove 1984a: 87). Although this same patterning has been found in other studies (e.g., McConnell 2009a; Parham 1992; Smith *et al.* 1996; Thomas 1983), this particular patterning may not be ubiquitous as it is not the only site patterning

[8] This assumes that a linear km survey zone is 50 m wide.

[9] This is based on the survey of a c.83 ha area of very high ground visibility area on the Central Plateau, but away from lakes, lagoons and major rivers (Parham 1993). (It should be noted that Cosgrove (1984) calculated an average site density of 4.9 sites/km2for the lacustrine and riverine areas he surveyed on the Central Plateau, but it is argued here that this is a major underestimate given the approximately equivalent number of sites/linear km located in later surveys; and is considered to largely reflect much poorer ground visibility).

[10] Four of these lakes/lagoons are at over 1,000 m asl.

noted in these other studies and a survey at Arthurs Lake, which has considerable associated grassland, found only a small number of sites in this environment or on gently sloping land near freshwater (Stanton 2000).[11]

Sites have been identified on aeolian source bordering deposits, either lunettes or small to extensive sand sheets associated with lagoons and rivers (Cosgrove 1984a, 1984b; du Cros 1992; McConnell 2009a; Ross *et al.* 1993) and it is the larger open sites (*c.*>1000 m^2 in area and/or with >250 artefacts) that tend to be located in this context (at Lagoon of Islands, Little Lake and the Clyde River) although small sites also occur in this context. The large sites on lunettes or extensive sand sheets are a substantial proportion (at least 25%) of the large sites in the region.[12]

River margins have been found to be another Central Plateau environment with relatively abundant sites, possibly for similar reasons as the lakes and lagoons, and echoing the role played by the lakes and lagoons (see above). The sites are generally open sites on or near river banks, although in the case of the Derwent River in the Navarre Plains area, sites appear to be also preferentially located on the forest and plains boundary (McConnell 2009a). Site densities in river edge contexts appears to be similar to, or greater than, those found on lake/lagoon margins in the same areas. River edge sites appear to occur primarily on the more major rivers in the region and then in the upper-middle reaches where there are associated plains (Cosgrove 1984a; McConnell 2009a). Central Plateau rivers that have been found to have large numbers of sites are the Derwent River, Little River, Little Pine River, and Clyde River.

Only a small number of rockshelters with occupation evidence have been located on the Central Plateau. These are all Triassic sandstone rockshelters in the southern half of the Plateau. The known examples are at Crescent Lake and on the Clyde River (Cosgrove 1984a; McConnell 2009a).

There are also few known unequivocal quarries on the Central Plateau, and these are all hornfels quarries. Three of these – the Dennistoun quarry near Bothwell, Micks Creek quarry on the headwaters of Lake River, and the Mt Rufus quarry (which contains secondary hornfels within a large high altitude moraine)[13] - are extremely large sites (McConnell and Hamilton 2001; Painter 2001; Parham1992). The other known quarries include five quarries on the edge of *yingina*/Great Lake (Thomas 1983), one quarry at Split Rock to the west of *yingina*/Great Lake (Cosgrove 2015), two quarries in the vicinity of Lake Ball-Mt Moriah (Smith *et al.* 1996) and one quarry near Ironstone Mountain (Smith *et al.* 1996), a probable large hornfels procurement site at Arthurs Lake (Cosgrove 1984a; Ross *et al.* 1993), and a quarry at Gibraltar Marsh on the lower Ouse River (Cosgrove 2015).

The key Central Plateau-Central Highlands regional studies (Cosgrove 1984a; McConnell and Hamilton 2001; Smith *et al.* 1996) have generated similar conclusions about the past Aboriginal history of the Central Plateau-Central Highlands. Cosgrove's (1984a) foundational study established that there is a spread of sites across the Central Plateau, including at altitudes over 900 m, and in a variety of environments, but particularly near lakes, lagoons and rivers and on the boundaries of forests and plains. Later work reinforces this, but also suggests that the large open sites have a differently patterned distribution that is in contrast to the heterogeneous, primarily environmentally based patterning of the small-medium sites. This was indicated indirectly by Thomas (1983) who noted that larger sites were approximately a day's travel away from each other. Smith *et al.* (1996) and McConnell and Hamilton (2001) interpreted this dual level pattern as being due to a complex regional land use pattern strongly influenced by trade, travel and resource availability, with Smith *et al.* (1996) seeing resource abundance and shelter from the

[11] Poor ground surface visibility however may have been a factor with Stanton's (2000) survey.

[12] With all large open sites identified in the region to date being associated with a lake/lagoon or major river.

[13] The Mt Rufus quarry is a c.2 km long procurement site that sits at c.1,100-1,390 m asl in the main range of the Tasmanian Central Highlands (McConnell and Hamilton 2001).

elements, primarily prevailing winds, as the key determinants of the location of these larger sites at the local environmental level.

This larger-site distribution pattern was described as a 'nodal' pattern by McConnell and Hamilton (2001), with the nodes being at the meeting points of important, heavily used routes. McConnell (2009b) suggested that there might be at least another smaller scale of patterning relating to micro-environmental factors and the overlap of resources/resource rich areas, something that is also hinted at by Smith *et al.* (1996). Smith *et al.* (1996) and McConnell and Hamilton (2001) however urge caution in interpreting the site patterning given issues with limited survey, survey effectiveness, the need to also factor in non-environmental determinants of site location (i.e., social and cultural factors), and the probability of the present patterning being a palimpsest of different patterns of historic usage, in particular resulting from the significant environmental changes with changes to and from the glacial and interglacial conditions that occurred on the Central Plateau.

Cosgrove (1984a: 3) concluded that the Central Plateau archaeological evidence 'suggests a rich and varied Aboriginal exploitation of the highlands coupled with adaptive strategies for protracted upland living' including in sub-alpine parts of the Plateau. Smith *et al.* (1996: 60) regard the archaeology as evidence that 'everyday life on the Central Plateau was as varied as everyday life anywhere else in Tasmania'. Cosgrove (1984a: 3) suggests that Aboriginal use of the Central Plateau was primarily seasonal, with the 'prolonged occupation' in the less environmentally extreme areas around the large lakes and lagoons in the slightly lower, eastern part of the Plateau. Smith *et al.* (1996) however argue for prolonged occupation also in the higher altitude areas of the Central Plateau given the existence of a number of large open sites (base camps) above 1,000 m asl in these areas. Smith *et al.* (1996) argue this particularly on the basis that, based on Gott (1992), there is year round availability of food resources in the higher parts of the region.[14] McConnell and Hamilton (2001) also suggest that winter occupation of the higher Central Plateau was feasible, and indeed likely.

In the Midlands there is also widespread archaeological evidence; also primarily in the form of open sites (surface artefact scatters). Similarly to the Central Plateau these open sites occur in a variety of environments and topographical situations, commonly near permanent water bodies such as rivers, lakes and lagoons, but were found by Kee (1990) to be relatively rare in the steeper hilly terrain. These open sites are generally small stone artefact scatters ranging from single artefacts to scatters of only a few square metres, with isolated stone artefact sites comprising *c.*40% of surface scatters in the region (Kee 1990).

The larger open sites (i.e., those covering one to several hectares and which contain upwards of a thousand artefacts) are located near permanent water. Such sites occur at Bells Lagoon and Clarkes Lagoon on the Ellinthorp Plains; at Lake Dulverton and Round Lagoon, both near Oatlands; and on the Blackman River at the base of the Western Tiers (Kee 1990; McConnell 2010). Kee (1990) estimated these lake and lagoon sites to have between 2,000 and 150,000 artefacts each. Areas of permanent water also have amongst the highest concentrations of open sites in the Midlands. At Lake Dulverton, for example, at least 34 sites have been located around the margin of the lake (Kee 1990); while there is a *c.*18 ha artefact scatter on the Blackman River, the largest site identified to date in the Midlands region and one of the larger sites known in Tasmania. This Blackman River site occurs in association with several other site clusters and large continuous sites, also in the headwater section of the Blackman River (McConnell 2010).

[14] This view refutes an early view (Jones 1971) that the western high altitude part of the Central Plateau was not used at all; and the view of Bowdler (1981) that these areas were only used in the warmer months due to a lack of a low key dependable resources such as that found on the coast.

For the Midlands region Kee (1990) estimates site densities to be in the order of 8-8.5 sites/km^2 in areas of source bordering dunes – marsh complexes; densities of around 3.3 sites/km^2 elsewhere on the Midlands plains; and densities of *c.*1-3 sites/km^2 in the uplands.[15] Overall, Kee (1990) found that in the Midlands open sites comprised c.87% of identified archaeological sites (the other sites being quarries and rockshelters). This same general pattern has been corroborated in more recent small scale impact assessment studies (McConnell *et al.* 2001; McConnell 2010).

Within the Midlands, the artefacts in the open sites are mainly made of hornfels, the most ubiquitous tool stone in sites in southeastern Tasmania; although other regularly used materials are silcrete, cherts (including petrified wood), quartzite and quartz (Kee 1990; McConnell 2010). With the possible exception of the quartz and some quartzite, these materials are locally available and are likely to have been locally provenanced (see below). At two sites in the Midlands, artefacts of bottle glass have been found (Brown 1986; Kee 1990), indicating a clear continuance of traditional culture post-colonial invasion. The artefacts are mainly debitage, with only a small number of formal tools (generally scrapers) and retouched/utilised pieces and cores, although formal tools occur in small scatters and as isolated artefacts. In contrast, the larger sites tend to have much higher proportions of formal tools and a greater variety of tools (e.g., a greater variety of scrapers, and also grindstones and hammerstones) (Kee 1990; McConnell 2010).

There has been little interpretation of these surface sites. Kee (1990: 57) concluded from her regional study that the extensive spread of surface sites, which she refers to as 'the sparse background scatter of artefacts dispersed throughout the region', has accumulated over the long term Aboriginal occupation of Tasmania with the sites resulting from 'predominantly mobile and transient occupation generally as part of local resource acquisition'. The relatively rare, large and stratified sites, such as Bells Lagoon, she regards as base camps, i.e., places that had longer term or more regular occupation; and, given the dates from some of these sites, as providing key evidence for commencement of 'extensive and permanent occupation' of the Midlands from the Mid-Holocene (Kee 1990: vii). These large, stratified sites are all associated with lunettes or other source bordering sand deposits. Known sites of this type are Bells Lagoon and Crown Lagoon, both of which have been excavated and dated (Lourandos 1970; Kee 1990), Clarke's Lagoon on the Ellinthorp Plains and Round Lagoon near Lake Dulverton (Kee 1990).

Kee (1990) recognised the Midlands lagoons and lakes, together with areas of aeolian source bordering deposits which occur frequently as associated lunettes and sand sheets, as environments of particular archaeological importance because of their known and potential high site density. She regarded lake and lagoon environments in the Midlands as having been focal points of Aboriginal life due largely to the presence of permanent water, but also because of the presence of 'a wealth' of resources (Kee 1990: 62). Lourandos (1968), who undertook the first work on large Midlands sites, interpreted the lagoon sites as campsites associated with the utilisation of marsh/lake resources and occasional hunting forays into the hinterland based on the diverse artefact assemblages at these sites and the historical accounts of the resources available at or near the Midlands lakes/lagoons (see above). Kee (1990) however saw the lake and lagoon sites as being evidence of longer-term occupation and more complex use,[16] although still associated essentially with lake/lagoon and hinterland resource use. Kee (1990) cites the presence of ochre at Bells Lagoon as evidence for possible social and ceremonial activities also occurring, at least at Bells Lagoon.

[15] These densities are likely to be lower than the actual site densities given the poor surface visibility in much of the survey areas due to issues such as dense vegetation cover, ploughing, wind erosion and burial. (The densities provided here also include quarries as well as surface artefact sites).

[16] Kee (1990) also interprets stratification of sites as evidence of repeated use over long periods.

The other key types of Midlands archaeological sites are rockshelters and tool stone quarries (procurement sites). Over thirty individual stone quarries have been identified in the Midlands (Kee 1990; Painter 2001).[17] These represent *c.* 9% of the identified sites in the region (Kee 1990; McConnell 2010). The quarries range from small procurement sites (including on exposed isolated boulders), to extensive working floors in areas of bedrock, up to large quarries of *c.*10,000 m^2 (Kee 1990; Painter 2001).

On the basis of archaeological signature, Painter (2001) recognised two types of quarry in the region – 1. small procurement sites which have no associated living areas (campsites) or stone working areas (reduction sites); and 2. large quarries with a very high number of artefacts which have associated campsites and stone working areas. Painter (2001: ii) interpreted the large quarries as 'well-known places people visited regularly, staying for a long period of time, collecting stone and breaking it into smaller pieces for travelling, or making tools for trade'. The majority of known quarries are hornfels quarries, but silcrete, chert and a quartzite formed from contact metamorphism of sandstone have also been quarried. Quarries in the Midlands can also be recognised as being of two types on the basis of lithology – 1. those at the margins of fine grained siliceous Permo-Triassic sedimentary rock and the intrusive Jurassic dolerite which exploit hornfels and, to a lesser extent, quartzite; and 2. those in Tertiary ferricrete, sands, silts, clays and conglomerates where long term weathering may have produced various types of silcretes and chert, including petrified wood; or in a sub-basaltic context where silcrete will occur (McConnell 1995a; McConnell 2010).

The larger known quarries are located on the margins of the Midlands. The known larger hornfels quarries are mostly located in the Eastern Tiers, one near Lake Leake in the north (Badger Hill quarry) and several on the southern edge near the Eastern Marshes, including on the headwaters of the Little Swanport River and Bluff River (Marshalls Creek and Tin Pot Creek quarries); with one other larger hornfels quarry known north of Antill Ponds, one on the edge of the Ellinthorp Plains (Verwood quarry) and one at York Lagoon, this latter being a dense scatter with many thousands of artefacts (Brown 1991; Kee 1990; Painter 2001). An extensive chert quarry (Annandale quarry) and a silcrete quarry are also known on the western edge of the Midlands in the area of the Ellinthorp Plains (Kee 1990). Two linear sets of hornfels procurement and associated sites, in one case running for 2-3 km, have also been identified – one along the eastern side of the York Plains and one running down the headwater reaches of Tin Dish Rivulet south of Andover (McConnell 2010).

The Midlands also has evidence for the past use of rockshelters as camp sites, with occupied rockshelters making up *c.*1.5% of Midlands archaeological sites (rock shelters in the Midlands occur in the resistant units of Triassic sandstone). The most common location for rockshelters in the Midlands is on the margins of the region on the slopes of the Western and Eastern Tiers (Cosgrove 1990; Ross 1990). A small number of occupied rockshelters however have also been located in the low lying central Midlands area in the headwaters of Tin Dish Rivulet and on the margin of Lake Dulverton, this latter rockshelter containing stone artefacts and bone points (Kee 1990; McConnell 2010), and in the Jordan River valley (Cosgrove 1984a).

Occupation chronology

Although the archaeology of the study area is relatively well known, there are few dated archaeological sites in the study region with which to establish a chronology for occupation. Up to the time of the present study, no sites on the Central Plateau had been dated and only two sites in the Midlands, both in lagoon edge aeolian sediments, had been dated. Dates from occupation sites in various parts of Tasmania

[17] Recent research by Theys *et al.* (2019) identified 11 hornfels quarries in the Midlands, a small number of which appear to be newly located quarries.

however confirm an Aboriginal presence in Tasmania from at least *c.* 34,000 years ago and possibly *c.* 40,000 years ago (Cosgrove 1995; Paton 2010), with evidence for continuous or at least semi-continuous occupation in a number of regions (although not on the Central Plateau[18] or in the Midlands) through the late Pleistocene and the Holocene to the recent past (e.g., Cosgrove 1989, 1995; Kee *et al.* 1993; Paton 2010).

Archaeological dates from the Midlands indicate occupation of the region in the period *c.* 5,000 years ago to present (Kee 1990; Lourandos 1970). Excavation at Bells Lagoon provided an upper and lower date for occupation of 1,030+/-60BP and 3,010+/-60BP at one site, and a date of 4,540+/-410 BP at a second site (Kee 1990). Excavation at Crown Lagoon provided dates of 4,860+/-96 BP and 4,170+/-80 BP (Lourandos 1970). As the dates come from only two sites, both on the lagoon edge of an eroding lunette, they are not seen as being adequate to reliably date Aboriginal occupation of the Midlands.

The investigation of lunette sites in the Midlands has also given rise to questions about the role humans have played as agents of landscape change, in particular whether all Holocene source-bordering dune formation was climatic, or whether it was due to human agency, in particular Aboriginal burning practices (Kee 1990).

Most Central Plateau studies argue for occupation of the Central Plateau from at least the start of the Holocene. Cosgrove (1984a) for example was of the view that the existing evidence from other areas such as the Mersey valley (Lourandos 1983) and the Franklin valley (Kiernan *et al.* 1983) indicated that Aboriginal Tasmanians 'had already adapted to sub-alpine living by 20,000 years BP and initial exploitation of the Tasmanian Central Plateau had probably taken place by 9,000 years BP', the time by which the Central Plateau and Central Highlands are thought to have been deglaciated (Kiernan 1990). Although there is no direct evidence for such Aboriginal occupation on the Central Plateau, some studies have argued that it is probable that there was successful human occupation of the Central Plateau and in the Central Highlands by the late Pleistocene which continued to the present (McConnell and Hamilton 2001; Smith *et al.* 1996). Based on the evidence from Parmerpar Meethaner in the upper Forth River on the edge of the Central Plateau - Central Highlands for continuous occupation in the valley from *c.* 34,000 years ago, but with upland resource exploitation (Cosgrove 1995), and from studies elsewhere (Benedict 1981), McConnell and Hamilton (2001) argued that widespread Aboriginal use of the region, including close to glacier edges, is likely since the last interglacial (i.e., since at least *c.* 34,000 years ago).

The understanding of lagoons

The studies that have been undertaken within the Central Plateau and Midlands study region (see above), as well as the limited studies of freshwater lagoons outside the study region (i.e., at Rushy Lagoon in northeast Tasmania (Cosgrove 1985) and Wet Marsh on the east coast (McConnell and Stanton 1997)), demonstrate that lakes and lagoons in inland areas of Tasmania routinely have relatively high site densities and often the larger open sites in a region, hence were important locations in the historical Aboriginal landscape. In relation to the actual lakes and lagoons, they present a picture of past Aboriginal occupation at these waterbodies as being focussed primarily on source bordering sand deposits (i.e., lunettes and sand sheets) in the case of the Midlands (Kee 1990; Lourandos 1970); or as scattered occupation loci around waterbody margins in the case of the Central Plateau, most commonly on source bordering deposits, in the lee of knolls, on low bedrock benches, or at forest–grassland interfaces (e.g., Cosgrove 1984a; McConnell 2009a; Smith *et al.* 1996; Thomas 1983). The patterning of sites on lake and

[18] Excavation of ORS7 on the southern edge of the Central Plateau (Cosgrove 1989) and excavation at Parmerpar Meethaner on the northern edge of Central Plateau (Cosgrove 1995) have however provided basal dates of 30,840+/-480 BP and 33,850+/-450 BP respectively.

lagoon edges is not entirely predictable and, at least on the Central Plateau where more survey of lakes/lagoon has been undertaken, there appears to be different patterning at different lakes/lagoons.

Although some of the earliest work (e.g., Lourandos 1968) interpreted the lake/lagoon sites as short term base camps associated with the use of local lake/lagoon resources supported by hinterland hunting, the more recent interpretation (e.g., Cosgrove 1984a; McConnell 2009a; Thomas 1993) regards the larger lake/lagoon edge sites as longer term base camps (sites of 'prolonged' occupation) and the small artefact scatters and isolated artefacts as miscellaneous activity sites, although still associated primarily with lake/lagoon and hinterland resource use. Kee (1990) was very much of the view that the larger sites, such as the stratified sites at Bells Lagoon and Crown Lagoon in the Midlands, represented short term and seasonal, but repeated, occupation with more complex use (this latter based on the range of artefact types and the presence of ochre).

The base camps on the lakes and lagoons of the Central Plateau and the other large camp sites on the Plateau are regarded as having a different distribution pattern to the smaller Central Plateau sites, with the location of these large sites being seen as being strongly influenced by travel and resource availability, with shelter also being a consideration (McConnell and Hamilton 2001, Smith *et al.* 1996). This is evident in the spread of these sites across the Central Plateau forming a network of sites located approximately one to two days travel apart (Thomas 1983), often on major known Aboriginal 'roads', in what McConnell and Hamilton (2001) have termed a 'nodal' pattern, in contrast to the more heterogeneous spread of smaller open site across the Central Plateau. The patterning of the larger sites in the Midlands has not been explored, although some studies have noted the location of some of the larger sites on major historical routes of Aboriginal travel (e.g., McConnell 2010).

This picture of lagoons within the historical Aboriginal landscape is however based on limited archaeological survey. The Central Plateau lakes and lagoons have had the best survey coverage, with most of the larger lakes and lagoons having been partially surveyed (but only a small number - *yingina*/Great Lake, Crescent Lake and Lake Echo - having been fully surveyed). No Central Plateau lake/lagoon sites have been excavated and all site data is from surface archaeological evidence, often in conditions of limited ground visibility. By contrast the Midlands lakes/lagoons have had very limited research, with the only known such research being the Ellinthorp Plains and Lake Dulverton block surveys by Kee (1990), which included a full survey of Bells Lagoon; and archaeological excavation at Bells Lagoon (Kee 1990) and Crown Lagoon (Lourandos 1970), both of which were limited in extent, but provide the only dates for Aboriginal occupation of the Midlands.

The only other freshwater lagoons which have had focussed research are Rushy Lagoon at *tebrakunna*/Cape Portland in northeast Tasmania (Cosgrove1985) and Wet Marsh on the East Coast north of Swansea (McConnell and Stanton 1997).

Study design and approach

Geographic scope

The scope and approach of the archaeological component of the Tasmanian part of the UNE Lagoons Project 'Working Ancient Wetlands for Social Benefit and Cultural Understanding' strongly reflects the aims of the broader project, and the project time frame and funding.

Key factors in the selection of the eastern Central Plateau and Midlands region as the Tasmanian study area were:

- the large number of lagoons in this region;
- the variety of types and sizes of lagoons in the region; and
- the known presence of lunettes on many of the lagoons in the region as these can provide critical information for understanding the evolution and dynamics of the lagoons (through for example landscape and stratigraphic analysis and through dating) (refer Chapter 9).

This region (refer Figure 10.1) was also selected as it is considered to provide the best Tasmanian comparative region to the New England Tablelands. This is primarily because this region, like the New England Tablelands, contains a number of lagoons in one macro environment (or in this case in two macro environments). Although the project could have restricted itself to the high altitude eastern Central Plateau area as a strictly comparative region, the Midlands was included because this lower altitude environment with its numerous lagoons provides an intra-Tasmanian comparison, enabling a more robust Tasmanian - New England Tablelands comparison.

The larger eastern Central Plateau and Midlands area was also selected as, although there had been previous investigation of lagoons in the region, these were limited in number and extent, leaving a large number of still unstudied or poorly studied lagoons in this broader region. The existing information for the broader region however provided a rudimentary framework that the project could usefully test. In addition, some of the archaeological studies provide chronological information for Aboriginal occupation of lagoon environments, as well as localised resource utilisation; while for the broader region the historical literature provides some of the limited, but more detailed information in Tasmania on historical Aboriginal movement and land use away from the coast.

Geographically, the eastern Central Plateau and Midlands area was also suitable for the project because the lagoons are relatively easily accessed, and easily accessible from Hobart or Launceston, and were able to provide nearby accommodation facilities for the field work.

General approach

The study of the lagoons in Tasmania involved preliminary field reconnaissance to get a feel for the lagoons in the eastern Central Plateau and Midlands and their landscape context; background archaeological and historical research; a single 2014 field season; and, ultimately, project reporting. Each of these components is described briefly below.

Background Review

The background review included both historical observations and the archaeological literature. Historical background was mainly sourced from secondary sources, in particular Brown (1991), Cosgrove (1984a), Kee (1990) and Ryan (1996), as these provide comprehensive synthetic, yet highly detailed, historical information. The key primary source for this region, G.A. Robinson's 1828-1834 observations (Plomley 2008), was also reviewed.

All Aboriginal archaeological publications and reports relating to lagoons or site patterning for the study region and nearby were reviewed. Key archaeological resources were the regional archaeological studies (Brown 1991; Cosgrove 1984a; Kee 1990) and other landscape scale archaeological studies or major lagoon (or lake) focussed studies within or adjacent to the region (i.e., Cosgrove 1995; du Cros 1992; Lourandos 1970; McConnell 2009a, 2009b; McConnell 2010; McConnell and Hamilton 2001; McConnell and Stanton 1997; Smith *et al.* 1996; Thomas 1983).

Geomorphological studies related to lunette occurrence and the dating of these (i.e., Dixon 1997; Sigleo 1978; Sigleo & Colhoun 1975) were also reviewed.

Field Reconnaissance

Preliminary reconnaissance of the study region to locate, inspect and assess suitable lagoons for the project, and to develop a better understanding of archaeological and landscape context was undertaken by the Tasmanian project team (AM and KK) in early-mid 2012.

From this and the background review (see above), 24 lagoons were identified for further consideration as field sites. Seven of these were on the Central Plateau and 16 were in the Midlands. One lagoon on the east coast was also identified as this was seen as being able to expand the consideration of the lagoons in Tasmania across all major environmental regions (refer Figure 10.1 for lagoon locations and a list).

In September 2012, a two-day full project team field reconnaissance of the study region was undertaken. The aim of this reconnaissance was for the non-Tasmanian team members to gain some familiarity with the region and the 24 lagoons identified as possible study sites through the earlier reconnaissance. A brief report (McConnell and Kiernan 2012) containing maps, air photos and summary existing archaeological, geomorphological and dating information for the 24 potential lagoon study sites in the region was prepared to support this field reconnaissance trip and as a Tasmanian project reference document more generally.

Selection of Lagoons for Detailed Field Research

Based on the background review, field reconnaissance and logistic considerations six lagoons were selected for field study from the 24 possible study sites. The key criteria for selection were:

- ability collectively (including with previously well studied lagoons) to represent a cross section of lagoon types and setting, and provide an east-west regional transect and a north-south transect for both the eastern Central Plateau and the Midlands;
- limited prior archaeological research;
- the presence of a lunette or other geomorphic features of interest that could potentially be used to better understand the geomorphic evolution of the lagoon and/or for dating; and
- accessibility.

Ultimately, *Lagoon of Islands*, which is centrally located, was selected as the main Central Plateau site. (*Lake Crescent*, to the east, which had been comprehensively archaeologically surveyed, was also selected for geomorphic research). In the Midlands area *Bells Lagoon* on the western margin, *Tunbridge Township Lagoon* in the central part of the Midlands, the south east corner of *Lake Tiberias* on the south central margin and *Rushy Lagoon* on the eastern edge were selected as the key lagoons for research (refer Figure 10.1).

It had also been hoped to include Cleveland Lagoon at the north end of the central Midlands (refer Figure 10.1), but it was not possible to gain access to this private property area. Obtaining permission to work on private property was an issue for the project and significantly restricted the lagoons the project was able to investigate in Tasmania. The project greatly appreciates the generosity of the private landowners in the Midlands who did allow the project access to their property.[19]

[19] This includes the Gardners at Annandale and Dowlings at 'Verwood' (Bells Lagoon), the Whites at 'Fonthill' (Rushy Lagoon) and the Rowlands (Lake Tiberias).

Archaeological Field Study

The Tasmanian field research was undertaken over 10 days in March 2014, with the two days prior being used for a Hobart-based orientation and introduction to Tasmanian Aboriginal heritage and geomorphology for all participants.[20] Some field time was spent providing participants with an appreciation of the Central Plateau and Midlands landscape and archaeological context. This included visiting other archaeological sites, other lagoons, sites of geomorphic significance and *trawtha makuminay*, the Aboriginal land at Gowan Brae.

Six full days were spent undertaking field investigation. The field work comprised archaeological survey and site recording and geomorphological investigation (refer Chapter 9) at the study lagoons.

The lagoons investigated during this field study phase were:

Central Plateau

Lagoon of Islands - 2 days *(geomorphological research also undertaken)*

Midlands

Bells Lagoon – 1.5 days *(geomorphological research also undertaken)*

Tunbridge Township Lagoon – 0.5 days

Lake Tiberias – 0.5 days *(geomorphological research also undertaken)*

Rushy Lagoon – 0.5 days *(geomorphological research also undertaken)*

The archaeological field study phase was also used as an opportunity to interview the Tasmanian Aboriginal participants about their views on the Aboriginal importance of lagoons historically and today, and about their connection to lagoons and stories connected with lagoons. As in the New England Tablelands, the participants were also asked about their views on being part of the project, in particular as a Work Integrated Learning exercise. (Findings in this area are reported in Chapter 1).

The field team, some 22 people, included nine Tasmanian Aboriginal Centre volunteers[21], nine New England Tablelands Local Aboriginal Land Council volunteers and about half the project team (4 people). A full list of participants is provided in Chapter 1.

Excavation

Although for the New England Tablelands there was a final fieldwork phase that involved archaeological excavation at a small number of lagoons (refer Chapter 7), no archaeological excavation was undertaken in Tasmania as part of the project. Site destruction, including for research purposes, is looked on unfavourably by the Tasmanian Aboriginal community although the Tasmanian Aboriginal Centre was prepared to consider archaeological excavation as part of the project, but only where it was answering important questions and would provide a benefit to the Tasmanian Aboriginal community (Heather Sculthorpe, pers comm). After review, it was decided not to undertake archaeological excavation in

[20] This involved presentations on the Aboriginal Land at piyura kitina/Risdon Cove (the venue being made available courtesy of the Tasmanian Aboriginal Centre) and field visits to other significant Aboriginal heritage sites in the Derwent and Channel areas.

[21] Two of the TAC personnel participated in a paid supervisory capacity and as part of the field staff.

Tasmania given the research that had already been undertaken on lagoons, including an archaeological excavation at Bells Lagoon, and given that the geomorphological research being undertaken was designed to provide chronological information on occupation as well as on the evolution of the lagoons.

Reporting

This chapter documents the project's Tasmanian archaeological research. As per the Memorandum of Understanding, the Tasmanian Aboriginal Centre has reviewed and approved the Tasmanian heritage material presented here; and the contribution of the Tasmanian Aboriginal Centre is acknowledged, including through co-authorship.

Site Recording Forms were also completed and submitted to Aboriginal Heritage Tasmania (July 2016) for all Aboriginal sites newly identified by the project or where substantial new site information was generated for previously recorded sites.[22]

Archaeological field methods

Standard field methods were employed during the Tasmanian field study. This included landscape familiarisation (and where relevant site familiarisation), transect based site survey, and in-field recording of archaeological sites.

At each lagoon the field school was split into groups of 3-5 people, with each party surveying a different area and recording all archaeological finds in their survey area. Each party included one experienced site surveyor. Responsibility for determining the survey approach at each lagoon, recording landscape attributes, mapping the lagoon archaeology and collating the archaeological data rested with one of the authors (AM).

Different approaches to transect surveys were taken at different lagoons depending on the local landscape, ground visibility and existing site knowledge. In all cases the transect survey aimed at being systematic, although transects were modified to ensure all areas of high ground visibility were included. At Lagoon of Islands, Bells Lagoon and the Tunbridge Township Lagoon the full lagoon margin (low lying area and banks within *c.* 50 m of the lagoon edge) was surveyed. At both Rushy Lagoon and Lake Tiberias the survey was focussed in the south east quadrant as this is typically where source bordering aeolian deposits occur, hence is the lake area with the greatest archaeological and geomorphic research potential. In the case of Lake Tiberias the restricted study area was due to issues of access to the other parts of the lake margin and to the large size of the lake.

Site recording involved written descriptions of individual artefacts (dimensions, modification, artefact type, material), photographing individual artefacts (generally ventral and dorsal surfaces and key features (e.g., worked edges)), and mapping locations. A hand-held GPS was used to establish the location of individual artefacts where scatters were small or extensive and dispersed. Where scatters were dense, the artefacts were mapped using a tape measure and tape measured offsets. Landscape context was also documented. Most documentation was on a project paper proforma, but some of the documentation was done digitally using a Tasmanian Aboriginal Centre hand-held tablet and a program called trackr (which also recorded a GPS location).

As there were generally up to four parties surveying concurrently and the number of experienced surveyors was limited, on occasions not all areas were surveyed systematically, there were some gaps in

[22] Provision of information about new sites to government is a legal requirement in Tasmania.

the full lagoon surveys, and site data was incomplete. This was the case mainly at Bells Lagoon, and to a lesser extent at Lagoon of Islands.

Archaeological research results – towards a better understanding of the past use of Central Plateau and Midlands lagoons

Lagoon of Islands (Central Plateau)

Summary Description of Lagoon

Lagoon of Islands is situated at *c.*760 m asl in undulating to hilly dolerite terrain (rising to just over 1,000 m asl) on the southern margin of the Central Plateau lakes and towards the eastern extent of these lakes. Although the terrain is predominantly Jurassic dolerite, some Carboniferous-Triassic sediments are known to occur near the lagoon edge. The lagoon sits in a sub-angular to rounded shallow basin c.4 km east-west by *c.*3.5 km north south (refer Figure 10.3). The original area of the lagoon was just under 9 km^2 and its average depth 1.3 m, but the level was artificially raised by 2.5 m when the lagoon was dammed in 1964. This led to shoreline erosion and destruction of the floating vegetation rafts which gave the lagoon its name and which are an extremely rare phenomenon (Tyler 1976) (refer Chapter 9 for more detail). The dam was recently decommissioned, and by the time of the field survey (March 2014) the lagoon had been drained, the dam wall removed and the local terrain rehabilitated.

The lagoon is circled by hills on the west, north and east sides, with small inflow valleys in the northeast corner and on the western edge, and a wide, low outflow plain (of the Blackman River) to the southeast. The lake margin has a gently sloping bank with lagoon edge muds and sandy deposits on the western side, rocky outcrop with a low level bench behind on the north and south edges, and high rocky outcrop in the south eastern corner. As noted in Chapter 9, aeolian sands occur along the eastern margin of the lagoon and to a lesser extent on the southeastern margin (below the higher rocky slopes) (refer Figure 10.3).

The aeolian sand deposit is a *c.*2.5 km long source bordering deposit comprising 1 to 2 steep narrow lunette ridges. This deposit is draped over a moderately steep bedrock bank and has been partly eroded. Investigations in 1984 (Cosgrove 1984b) and for this project (refer Chapter 9) indicate that the source bordering dune was formed in two different periods; and dating undertaken by this project indicates that lake-bed sands and aeolian sands are of either late-Glacial or early Holocene age.[23] The sand on the eastern margin is heavily iron-panned, and in the northeast corner behind the dune there is an area of swamp resulting from water perched on the hardpan layer (refer Chapter 9).

The surrounding vegetation is dry forest and woodland with a grassy and heathy understorey, with the dominant species being *Eucalyptus delegatensis*, but with areas of dominant *Eucalyptus pauciflora* (DPIPWE 2019). There has been substantial clearing of the lagoon basin edges since European establishment in the area, however there are remnant eucalypts and some regrowth forest today in this area today.

Historical Background

The Lagoon of Islands is likely to have been within the territory of the *luggermairrerner-pairrer* of the Big River people whose focus was *yingina*/Great Lake (Ryan 1996). The traditional name for Lagoon of Islands is not known, with *noreruckeer mennanyer* (Shannon River) and *torerbuner* (Table Mountain) being the only Aboriginal place names known for the broader eastern Central Plateau region (Plomley 2008).

[23] A date of 4,700 +/- 150 BP from the base of the organic muds in the lagoon (Cosgrove 1984: 11) suggests a minimum age of c.5,000 years BP.

The only historical account known for Lagoon of Islands and Aboriginal use is from G.A. Robinson who travelled past Lagoon of Islands twice in December 1831 (Plomley 2008). It is clear from his account that by this time the lagoon was subject to European grazing and had a government hut and an access track from the south, and had been given an English name. However, it is also clear that at this time the general area had a network of established and marked Aboriginal travel routes (*markomenya*), abundant food resources (some specialised), and had locations of regular enough use to warrant the construction of Aboriginal huts.

On 17th December 1831, en route from the north of *yingina*/Great Lake, down the west side and south to St Patricks Plains, Robinson and the party of Aboriginal people he was travelling with passed by the west side of Lagoon of Islands, and –

> ... came to a large lagoon and which from its appearance I recognised to be the Lagoon of Islands. It had a singular appearance: the whole face of the lagoon was studded with small islands covered with bush. It looked like a graveyard with the gravestones banked up. On the north side of this lagoon was some tolerable good pasture, and a flock of sheep was feeding upon it (G.A. Robinson in Plomley 2008: 589).[24]

Robinson's diary also notes on the previous day that he had camped on the south side of a marsh a short distance to the north of Lagoon of Islands (presumably Jacks Marsh) where the 'mellifluous cider tree' (*Eucalyptus gunnii,* or cider gum) was 'growing most luxuriantly, some of them twelve feet in circumference, and the liquid was oozing out in tolerable quantities'. He notes that the Aboriginal people he was travelling with ran 'from tree to tree to suck this juice, of which they are very fond'. He also noted that at the camp site the people he was travelling with also collected 'gum from a tree in appearance like a prickly mimosa, having a yellow flower and pods like a chestnut' and this gum is eaten. On the same day (travelling south from *yingina*/Great Lake) Robinson also notes he came across trees at different places along his route which had their bark notched. On asking the Aboriginal people he was travelling with about these he was advised that they indicated the Aboriginal *markomenya* or 'road' they were travelling (Plomley 2008: 589).

On the 18th December 1831 Robinson travelled east from St Patricks Plains towards Lake Sorell, crossing a small river which he notes as draining from Lagoon of Islands and at this point encounters the 'cart road which went to the Lagoon of Islands and the government hut'. He then continues southeast towards Lake Sorell (Plomley 2008: 590). On the 19th December he notes that the route he has been following is 'apparent from the barked trees' (Plomley 2008: 591), suggesting he is following another east-west Aboriginal road towards Lake Sorell.

On the 22nd December, Robinson sets off from Lake Sorell back to Lagoon of Islands, arriving on the 24th December. En route they encounter 'some old native huts and trees that had been barked by the natives in every direction' and Robinson notes that their route from Lake Sorell has been an Aboriginal travel route known by the Big River people as *luke.et.ter markomemenyer* (Plomley 2008: 595).

By the late 1820s, there was stock grazing on the Central Plateau, in particular the eastern and southern margins which were closest to the colonial settlements of this time. This incursion by the colonists resulted in major disruption to Aboriginal life and in conflict between the two groups. By 1832, there was no Aboriginal presence on the Central Plateau, the culmination of the violent program by the colonists to take control of the 'settled districts' of Tasmania (Ryan 1996).

[24] Ross (1830: 118) also provides the following contemporary description of Lagoon of Islands – 'a large piece of wet marshy ground, covered with rushes, and interspersed with patches of low shrubs and trees'.

Previous Research

Lagoon of Islands has been subject to partial archaeological survey prior to this study and, prior to that, had been subject to some limited investigation. The first reported observation is that by W.J. Jackson (pers comm) (cited in Sutherland 1972, locality 54 [AH233]) of a 'worked pavement of cherty hornfels [hornfels] between dunes, N. end of lunette'. The second is a 1974 inspection by Peter Murray who noted there was a large site 'appearing to be a thin scatter over an extensive area' and 'large and typical of lunette sites' on the lunette on the eastern side of the lagoon (cited in Stockton 1975: 1). Murray also noted that 'the area is well known to amateurs [collectors] and has been thoroughly picked over in the past' (cited in Stockton 1975: 1).[25] Two additional sites [AH595 & 596], both isolated artefacts, are also recorded along the northern margin of the lagoon, but there is no information about who located the sites and the nature of the sites.

Two years later, Jim Stockton undertook a salvage excavation (a 1 m x 1 m pit) in the north end of the lunette in a highly eroding area, as well as a survey of a nearby 10 m x 10 m area of deflated dune [both within AH2395]. The excavation was shallow (*c.* 35-40 cm) and located 20 artefacts, all of which were waste material except for one tool (a possible steep edge scraper); and made of quartzite (5%), an unnamed material later identified as cherty hornfels (90%) and another unidentified stone material (5%). Stockton also encountered a lens of darker soil with charcoal, but without artefacts, a feature interpreted as a hearth (but possibly only a palaeosol). The survey (and collection) located 39 stone artefacts, of which only 2 were formal tools. Three pieces with pebble cortex and thought to potentially represent two hammerstones were also collected. These artefacts were of quartzite (61%), quartz (18%), chert (3%), a dark red material (10%), and other unidentified stone types (8%) (Stockton 1975).

In 1984, as part of an environmental impact survey of Ripple Creek – Jacks Marsh and based on Murray's and Stockton's reports of Aboriginal sites on the eastern shore of Lagoon of Islands, a team of three people systematically surveyed the eastern shore of Lagoon of Islands,[26] locating several scatters of artefacts in the sandy deposits of the eastern margin of the lagoon (Cosgrove 1984b). At the time of Cosgrove's survey, the sand lunette that comprises most of the eastern shoreline was heavily eroded and ground visibility in the deflated areas was high. Although the artefacts located by Cosgrove on the eastern margin of Lagoon of Islands occurred in discrete clusters along the 2.5 km lagoon margin, they were recorded as a single site - site 10, areas a, b and c (Cosgrove (1984b) [subsequently registered as 3 separate sites – AH2393, 2394 and 2395 respectively]. The clusters, which were located on the shoreline in areas of dune deflation as well as on the crest of the dune, varied in size and individually included from five to ten stone artefacts up to more than 250 artefacts, with artefact densities of up to 5 artefacts/ m^2 being noted. Artefacts were made of hornfels (termed by Cosgrove 'chert') which is local, but also of silcrete, quartzite and quartz, all materials that do not naturally occur locally. The artefacts were predominantly waste flakes, but steep edge and straight edge scrapers were also present.

Cosgrove (1984b) also undertook some hand augering in the lunette. This established that the source bordering sand deposit comprised two different sand bodies – a recent, upper pale yellow sand deposit with an organic rich surface horizon (with charcoal), and an underlying darker yellow sand with evidence of charcoal between the two sands, presumably the remains of an A horizon in the older deposit. Cosgrove suggests on the basis of this evidence and Lourandos' (1983) evidence from Warragarra rockshelter on the northern edge of the Central Plateau that Aboriginal occupation at Lagoon of Islands could be as old as *c.* 10,000 years BP.

[25] This was based on the author knowing of several collections holding implements from the Lagoon of Islands (Stockton 1976: 5).

[26] This forms approximately a quarter of the margin and is the only part of the lagoon edge with substantial sand deposits.

A further survey, a heritage impact assessment for the proposed removal of the Lagoon of Islands dam wall, was undertaken in 2012 (Jackman 2012). This survey focussed on the area to be potentially impacted (i.e., adjacent to the dam wall near the eastern end of the southern shoreline). Jackman's (2012) survey located a scatter of over 35 Aboriginal stone artefacts on a sandy beach deposit[27] at the base of the dam wall [AH11701] which he considered to be contemporaneous with the deposits on the eastern margin; and three sites (1 isolated stone artefact site and 2 stone artefact scatters (of four pieces each) [AH11702, 11703 & 117111] near the dam wall which he considered had been introduced or redeposited during dam building. AH11701 comprises 31+ waste flakes, an area of fine debitage, 1 retouched/utilised flake, 1 core and 5 formal tools; of which 63% are hornfels, 13% chert, 13% quartzite and two pieces each are of brecciated chert and a 'white meta-siltstone (probably a silcrete). The formal tools are predominantly of hornfels. AH11702 was a single stone artefact (details not provided) thought to be introduced; and AH11703 is described as a low density scatter of mudstone flakes and flaked pieces, which Jackman suggests may be introduced and possibly 'dozer-facts'. AH11711 comprises 3 waste flakes and 1 formal tool, all of chert.

The ten registered Aboriginal archaeological sites on the margin of the lagoon were the only known sites within 10 kms of Lagoon of Islands at the time of the project field work.[28]

Archaeological Project Findings

Given the previous survey and existing archaeological knowledge for the eastern side of the lagoon, the project undertook a continuous systematic survey of the remaining area (i.e., the western two thirds of the lagoon edge - from the Blackman River outflow in the southeast to the Swampy Bay inflow creek in the northeast corner). The focus of the survey was the lagoon margin, with intensive survey undertaken within *c.* 20 m of the recent water's edge (marked by the outer edge of surface organic deposits or ridges of broken rock), however low gentle slopes and benches within *c.* 50 m of the lagoon edge were also surveyed. The already surveyed eastern margin was resurveyed, but the archaeological evidence was not re-recorded.

Seven new artefact rich zones were identified in the previously unsurveyed western two thirds of the lagoon margin[29] (refer Figure 10.3, zones 1 to 7) and one new artefact rich zone was located on the central eastern margin (zone 9), bringing the total number of identified surface scatter zones on the full lake margin to twelve. Generally, the artefacts were located from just within the dried lake bed (up to *c.* 10 m inside) to *c.* 10 m beyond the lake bed. In two zones artefacts were located as much as *c.* 25 m and *c.*60 m beyond the lake edge. A possible Aboriginal scarred tree (a small-medium vertical oval scar on mature eucalypt (*E. coccifera*?)) was located near the south edge of zone 2 and *c.* 50 m back from the lagoon edge (refer Figure 10.3). No other archaeological features were located.

The project survey failed to relocate AH595 and AH233 (the 'pavement of cherty hornfels'), and also failed to locate any hearths. This suggests that the evidence interpreted as hearths by Murray (cited in Stockton 1975) were in fact *in situ* palaeosol remnants, for which there is abundant evidence in the lunette (refer Chapter 9). The survey and subsurface investigations also failed to find any evidence of significant charcoal deposits that might provide evidence of broad scale Aboriginal burning.

[27] This has been reinterpreted as an aeolian deposit by the present project (refer Chapter 9).

[28] When Lagoon of Islands was selected as a study site in early 2012, the project was unaware of the work that had been undertaken by Jackman.

[29] One of these zones included AH11703 and was in the area of AH596.

Site Analysis

The eight new surface artefact zones were of variable dimensions, ranging from small scatters of 2-4 artefacts and of *c.* 3 m x 1 m, up to large, variable density scatters of over 60 pieces and up to *c.* 1.25 km long and up to *c.* 50-60 m wide (refer Figure 10.3).[30] The lithic content of the different zones is summarised in Table 10.1, which includes comparative data from the other known sites at Lagoon of Islands. In all, over 174 new stone artefacts were recorded.[31]

Artefact types included waste flakes and flaked pieces (debitage), cores, utilised pieces and formal tools, primarily scrapers (including steep edge, discoidal and round edged) and two probable hammerstones, one with distinct hammer pecking. The lithics are of a variety of stone types including hornfels, other Permo-Triassic metasediments, silcrete, quartz, quartzite, chert and minor amounts (1% to 4.5%) of other materials, but with hornfels being the most common (82% of all newly recorded lithics). The formal tools also were predominantly of hornfels, with all the cores and scrapers being of hornfels except for one scraper each of quartz, silcrete and an unidentified stone, and one quartzite core. One of the hammerstones was a modified river pebble of a red quartzite.

The survey results indicate that there is also a relatively high percentage of formal tools to waste material compared to most sites (other than very large sites) in Tasmania (McConnell 2010). Except for three smaller artefact concentrations, the project recorded formal tool percentages of between 11% and 50% for individual zones. The mean percentage however is *c.* 15%, which is considered a more reliable indication of the overall percentage of formal tools. Cosgrove (1984b) also noted the high percentage of tools to waste in the artefact concentrations he recorded on the eastern margin of Lagoon of Islands (but does not give any figures). The figure of 15% may be artificially lowered due to the amateur artefact collecting (usually of formal tools) known to have occurred in the past at Lagoon of Islands (Murray, cited in Stockton 1975).

The nature and distribution of the lithics within each zone was heterogeneous and there was no apparent intra-site or lagoon-wide patterning of lithic material type. The project survey did not identify any artefact working locations, although Jackman (2012) records two clusters of 'reduction flakes' suggestive of working areas at AH11701, and the presence of cores and hammerstones, material with cortex and large quantities of debitage indicate that raw material reduction and tool manufacture were occurring at Lagoon of Islands. It is probable however that if there had been any intra-site patterning, evidence of this has been erased by wave and wind erosion. The project survey also did not identify particular artefacts or material type use in particular zones or parts of the lagoon margin, although the formal tools and utilised pieces were found to only occur in the larger artefact zones. This however is statistically likely given the ratio of formal tools and utilised pieces to debitage, and may not reflect a differentiation of function between zones with large and small quantities of lithics, particularly given that zone sizes are likely to reflect artefact visibility conditions rather than be a true representation of the on-ground lithics.

The large size and presence of formal tools and cores, and the variety of lithologies identified by the project in zone 1 clearly indicate that AH11703 is an *in situ* artefact scatter and not 'dozer-facts' as Jackman (2012) suggests, although the zone may include some dozer-facts near the dam wall. It is not possible from the project survey to comment on the nature and validity of AH233 and AH595, particularly without more information on the nature and location of these sites. Although zone 7 has been interpreted as AH596, it is possible that both AH595 and AH596 are situated on the low rock formed

[30] Across the full lagoon artefact scatters range from small scatters of 2 artefacts up to extremely large scatters of over 250 pieces and up to c.75-80 m wide.

[31] Not all the artefacts for the three larger artefact zones (i.e., zones 1, 3 & 5) were recorded.

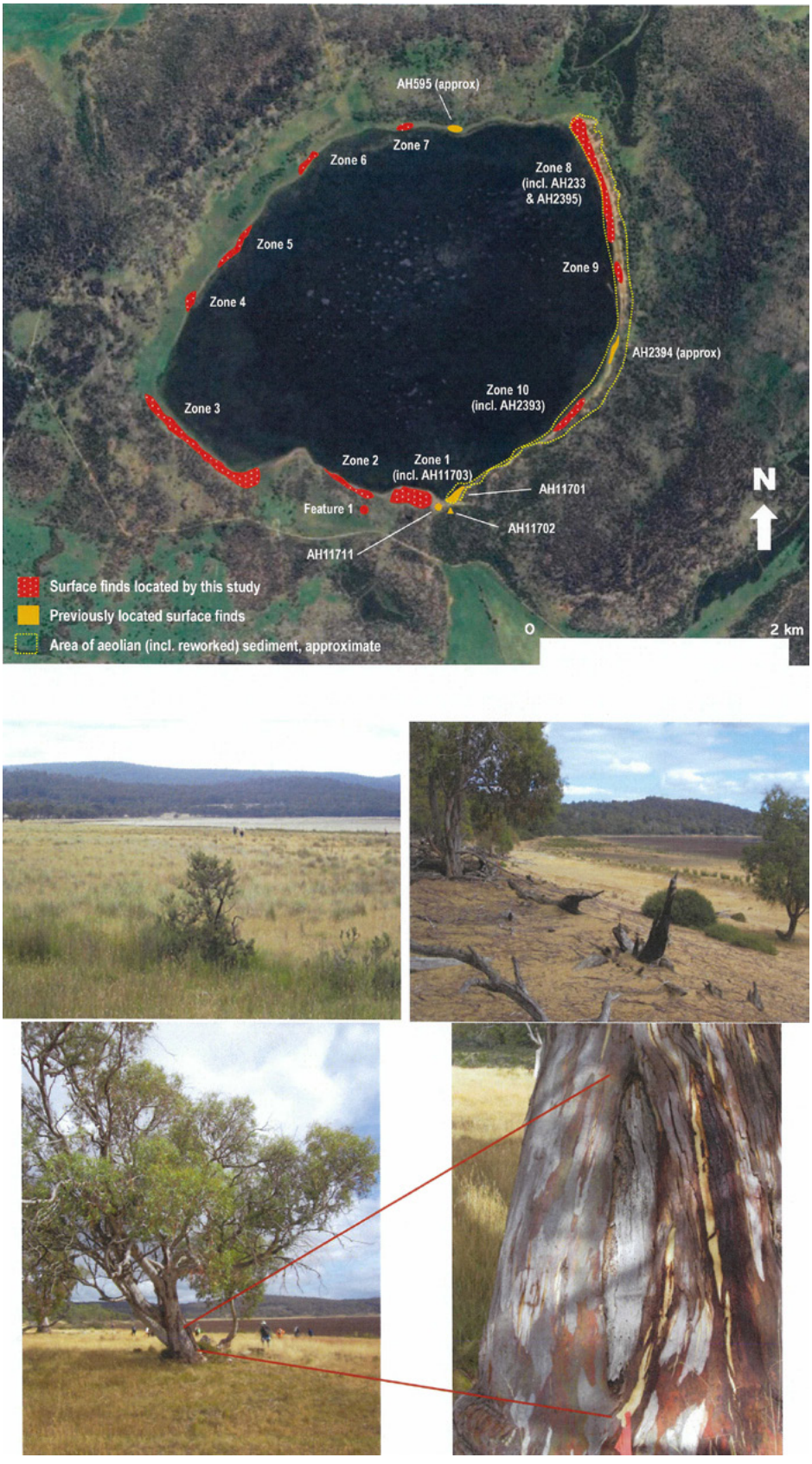


Figure 10.3 Lagoon of Islands and identified archaeology. *The landscape views are across the western half of the lagoon with grassland and forested dolerite hills behind, view north (LHS); and down the eastern edge of the lagoon along the sandy shoreline, view south (RHS). The bottom images are of a scarred tree (and scar detail) at the southern end of the lagoon (Feature 1) which may be of historical Aboriginal origin and, if so, could potentially be a markomenya/road marking scar. (Satellite image, 2019, from Google Earth, August 2019; images – A. McConnell, 2014).*

Table 10.1 The Archaeology of Lagoon of Islands, a Summary

[Note – the artefact zones and other archaeological features are located in order clockwise around the lagoon margin starting on the west side of Blackburn Creek. See also Figure 10.2]

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debitage	core	utilised	tool [1]	horn-fels	othermetased	quartzite	silcrete	chert	quartz	other	
1	53+	70	13	5.5	11	87	9	-	2	-	2	-	Includes AH11703 recorded by Jackman (2012). Area 300m x 50-60m. On a low dolerite rocky bench behind the shoreline. Native forest-woodland vegetation.
Feature 1	-	-	-	-	-	-	-	-	-	-	-	-	Possible scarred tree. Location similar to zone 1 but c.50m back from shoreline.
2	7	86	0	14	0	86	0	0	0	0	14	0	Area 500m x 5m. On rocky and sandy shoreline below a low dolerite rocky slope with flat area behind. Some grass.
3	68+	85	0	0	15	96	0	0	0	3	1.5	0	Area 1,250m x 5-25m. On gently sloping sandy beach of variable width. Some grass.
4	2	50	0	0	50	100	0	0	0	0	0	0	Area 100m x 3-10m. On gently sloping backshore. Patchily grassed
5	34+	79	3	0	18	77	9	12	3	0	0	0	Area 500m x 5-10m. On gently sloping backshore. Patchily grassed
6	4	100	0	0	0	50	0	0	50	0	0	0	Area 230m x 6-9m. On gently sloping backshore. Patchily grassed
7	3	100	0	0	0	33	0	0	66	0	0	0	Possibly AH596. Area 3m x 1m. On shoreline below a low dolerite rocky bench, slightly rocky. Some grass.
AH 595	-	-	-	-	-	-	-	-	-	-	-	-	Not relocated / no data
8	250+	✓			✓	✓	0	✓	✓	0	✓	0	AH2395 recorded by Cosgrove (1984b). Area 50m^2. On gently sloping, sandy lagoon shore (dune deflation zone). No vegetation.
AH 233	-	-	-	-	-	100	0	0	0	0	0	0	Not relocated. Described as a pavement of hornfels.
9	3	-	-	-	-	-	-	-	-	-	-	-	Area 10m x 5m. On gently sloping, sandy lagoon shore (probable dune deflation zone). No vegetation
AH 2394	7	100	0	0	0	0	0	✓	✓	0	✓	0	Recorded by Cosgrove (1984b). Area 100m^2. Deflated road cutting on dune. No vegetation.
10	20	100	0	0	0	100	0	0	0	0	0	0	AH2393 recorded by Cosgrove (1984b). Area 100m^2. On gently sloping, sandy lagoon shore (probable dune deflation zone). No vegetation.
AH 11701	38+ (>50)	82+	2.5	2.5	13	63+	0	13+	5	18+	0	0	Recorded by Jackman (2012). Area 140m x 40m. On gently sloping, sandy lagoon shore (probable dune deflation zone). No vegetation.

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debit age	core	utilised	tool [1]	horn-fels	othermetased	quartzite	silcrete	chert	quartz	other	
AH 11702	1	-	-	-	-	-	-	-	-	-	-	-	Recorded by Jackman (2012). On gently sloping stony (dolerite) ground immediately behind the shoreline and 60m from the Blackman River. Some grass.
AH 11711	4	75	0	0	25	0	0	0	0	100	0		Recorded by Jackman (2012). Area 5m long. On gently sloping ground immediately behind the shoreline and 15m from the Blackman River; possibly introduced.

bench immediately behind the lagoon (a similar situation as zone 1 located directly across the lagoon on the southern edge), but were not relocated during the project survey due to inadequate ground visibility in this area.

The re-survey of the eastern margin indicates that the concentrations of artefacts identified in 1984 (Cosgrove 1984b) are extant, although the actual lithics visible today may not be exactly the same suite visible in 1984 given changes in the lagoon edge and dune erosion, and differing visibility conditions. The re-survey suggests that the northern concentration (zone 8) is more extensive than Cosgrove's AH2395 as artefacts were located from along the bank of the Swampy Bay inflow creek south along the lake margin for *c.* 1,100 m.[32] Although most artefacts occurred on the beach or toeslope and deflation hollows of the eroding foredune, one artefact was located on the lee side of the present dunes at the north end of the aeolian deposits.

The results of the survey demonstrate that surface artefact scatters occur around the full margin of Lagoon of Islands, with similar types of artefact concentrations on the western shore as on the eastern shore (including in the aeolian dunes). If ground visibility and erosion and reburial factors are taken into account, then it is possible that the artefacts in fact form a single, semi-continuous, variable density, surface artefact scatter around the full margin of Lagoon of Islands, rather than being discrete scatters. The survey results indicate that there are however a greater number of artefacts around the eastern half of the lagoon (zone 7 around to AH11711 and zone 1), with the highest concentration being in the northeast at the north end of the deflated aeolian deposits. Although artefact density calculations for the identified artefact zones and previously recorded sites show that overall the zones in the eastern half of the lagoon edge have higher densities (from 0.06 to 5 artefacts/m2) compared to the western half (from *c.* 0.005 to 0.1 artefacts/m2), intra-zone concentrations of *c.* 5 artefacts/m2 or greater were located at various places around the lagoon edge, and were not confined to the eastern half of the lagoon edge.

The location of artefacts and relative densities of the identified scatters at Lagoon of Islands match well with current predicted locations for medium to large open sites on the Central Plateau, i.e., 'within 100-150m of freshwater, on source bordering dunes; at sheltered heads (N & S ends) of lakes and major valleys, on lake and swamp margins on flat-gently sloping terrain [and] ... at nodes of historic travel'

[32] Cosgrove (1984) did note however that there was a continuous, but presumably low density, artefact scatter between AH2394 and 2395.

(McConnell 2009b: 23). The only predictive factor identified by McConnell (2009b: 23) not met is 'on the edges of grasslands or heathlands', although there is open swampy terrain to the south.

Dating of the Archaeology and Lagoon Use over Time

The artefacts that occur on the beach at the eastern end of the lagoon occur almost entirely on the yellow iron-panned sand, and artefacts appear absent from the upper sand. Stone artefacts found towards the north-eastern corner of Lagoon of Islands occur in three principal situations – 1. close to the lagoon shore between a small tributary stream and the northern end of the lunette system; 2. along the sand flats immediately west of the lunette in positions where there is evidence for very pronounced recession of the lunette face; and 3. in a wide blow-out that cuts through the lunette. The lunette ridge in this area however appears to be largely sterile with respect to Aboriginal artefacts despite relatively clear ground visibility along much of the length of the lunette crest, with only one surface artefact being located on the sheltered eastern side of the lunette where there has been relatively recent deposition of re-worked lunette sediment. In addition, inspection of sand brought to the surface from deeper in the lunette by biogenic agents (e.g., burrowing and tree wind-throw) also failed to reveal any artefacts or other rock fragments.

The failure to find any concentrations of stone tools on, or in, the lunette is suggestive that the main occupation, at least on the eastern margin of the lagoon, occurred prior to the formation of the lunette (although it remains possible that the artefacts on the lower sand unit have been lowered onto it by deflation from the upper sand and may be later). Given the 15,800 ± 900 years BP age of the lunette mass[33], this indicates human presence along the eastern shoreline of Lagoon of Islands prior to that date (i.e., well within the late Pleistocene). The most likely scenario is that camp sites on the leeward eastern side of the lunette were subsequently buried as the sand mass was blown eastwards, with the artefacts being revealed on the windward side of the migrating sand.

On the south edge of the lagoon basin artefacts occur on low benches and on the floor of some embayments where they are scattered upon dolerite bedrock and on shattered detritus derived from it. Given the evidence for the rock shattering having occurred at *c.* 29,000-14,000 years BP (i.e., during MIS 2) (refer Chapter 9) these artefacts imply an Aboriginal presence subsequent to climatic amelioration (i.e., after *c.* 14,000-12,000 years BP). Some artefacts also occur on the sand that mantles bedrock slopes well above the lagoon floor along the southern edge of the lagoon basin. Here the underlying sand is yellowish in colour, unlike the upper sand unit in the lunette, but there are no ready means of determining the age of the artefacts.

Given that the Lagoon of Islands area is known to have been used by Aboriginal people in the recent past (i.e., post-1803), the available evidence indicates Aboriginal use of Lagoon of Islands prior to *c.* 16,000 years BP and from *c.* 14,000-12,000 years BP, and potentially continuously or at least semi-continuously from this time through the Holocene to the recent past, when traditional use was disrupted by colonial possession. The evidence also suggests that occupation in the late Pleistocene was focussed on the eastern side of the lagoon, presumably in the sheltered lee of the existing aeolian dunes, but post the LGM, the focus of occupation was the western margin, the shift perhaps being related to ameliorated climatic conditions.

[33] The earliest date for lunette sands on the Central Plateau is c.15,000-16,000 years BP and come from three sites dated by the present project (refer Chapter 9).

The Historic Aboriginal Use of Lagoon of Islands – an Interpretation

The evidence for past Aboriginal use of the Lagoon of Islands indicates that there was not only long-term occupation at this lagoon, but also that it was a focus of use. As Cosgrove (1984b: 10) notes 'The density of artefact scatters would indicate that this area was heavily utilised in the past and was an important zone for Aboriginal groups inhabiting the plateau region'. Cosgrove interpreted the evidence on the eastern margin as probable small staging camps for hunting parties travelling across the plateau.

The evidence from the present project supports and reinforces this general view, but the marked 'roads' that lead past Lagoon of Islands and the use of local specialised food resources noted by G.A. Robinson (cited in Plomley 2008) indicate that the area had valuable resources beyond animal food and was on major travel routes, hence it likely that the Lagoon of Islands was used by more than just hunting parties. Lagoon of Islands is therefore likely to have been a regular base because of its environment and plentiful local food resources, including some specialised resources, and as a likely road junction point way-stop on one or more established travel routes. It is not possible however to interpret the past Aboriginal use of the Lagoon of Islands in more detail on the evidence available.

The project findings also reinforce the site patterning previously identified for the eastern margin of the Central Plateau. At a general level it conforms with the pattern identified by McConnell (1995a, v2: 40) of 'moderate-high density occupation close to the lakes, marshes, and major creeks and rivers [with a] low density of sites ... away from these areas where the terrain is steeper and usually rocky'. It also fits well with later findings (McConnell and Hamilton 2001, Smith *et al.* 1996,) for the region that the larger sites (> *c.* 20 artefacts) have a particular patterning that appears to be related to routes of travel (and trade) and key resource locations as well as environmental parameters such as slope, water and shelter. Thomas (1983) also noted a different pattern for the large sites, observing that for the *yingina*/ Great Lake area such sites were generally about a day's travel apart, also indicating that the location of these sites was strongly influenced by Aboriginal travel.

The presence of large quantities of exotic stone material (as artefacts) at Lagoon of Islands strongly supports the idea that Lagoon of Islands was one of the important travel route 'nodes' in the region, in effect part of the 'nodal' patterning with larger sites generally being the nodes of various travel routes recognised by McConnell and Hamilton (2001). It also supports the notion put by Cosgrove (1984b) and Jackman (2012) that considerable distances were being travelled to and from the lagoon (either by those using the lagoon or as part of an exchange network made up of shorter distance travel segments). Most of the materials recorded, other than the hornfels[34] are likely to have been brought in from other regions.

The nearest known sources for silcrete are in the Midlands near the base of the Western Tiers, some 30 kms directly east of the Lagoon of Islands. The closest abundant sources of tool quality quartzite and quartz are the massive Precambrian quartzite units and the Lower Devonian-Cambrian quartzitic and conglomeratic units of Western Tasmania and reworked fluvio-glacial deposits in the major rivers draining north from the Central Plateau (i.e., the Mersey and Forth Rivers),[35] as well as from more restricted occurrences of Permo-Triassic conglomeratic units in the northern Central Highlands (Burrett and Martin 1989; McConnell and Hamilton 2001). The closest of these sources are >75 kms to the

[34] Although no hornfels quarries are known near the Lagoon of Islands, sources of hornfels potentially occur across most of the Central Plateau, and this material (and other Permo-Triassic metasediments) would not have needed to be brought in long distances. This is also indicated by the high proportion (82%) of artefacts recorded by the project at Lagoon of Islands as being hornfels.

[35] Cosgrove (2015) documents the sourcing of local river pebbles/cobbles to make flaked quartzite artefacts from the Mersey River on the north coastal plain.

northwest and >65 kms to the west (McConnell and Hamilton 2001; Land Tasmania 2019). Although some of the quartzite and quartz artefactual stone is likely to derive from these sources given the quantity of these materials and the diversity of the quartzite, it is possible that some is derived from exposures of Permo-Triassic rocks that contain water worn cobbles as ice-rafted erratics (usually of resistant rocks such as quartzite and quartz). The closest significant source of this type of rock is likely to be the escarpment of the Western Tiers, hence *c.* 25-45 kms to the north, northeast and east (McConnell 1995a). A small amount however may have been derived locally as the project geomorphic research identified this rock type in the Ripple Creek Diversion channel on the northwest edge of the lagoon (refer Chapter 9). Chert sources are more diverse with chert occurring in a similar conglomeratic context as quartzites and quartz, but some also occurring in the Midlands in a similar context as the silcretes (see above) (McConnell 1995a).

Jackman (2012) also recorded two pieces of brecciated chert, [36] which may indicate importation of material from the Parrawe chert quarry in the northwest Tasmania some 140 km northwest of Lagoon of Islands, and the only known source of a distinctive cream brecciated chert (McConnell 1999), although Cosgrove (2000) indicates on the basis of geochemical analysis of selected brecciated cherts that there is at least one additional source of brecciated chert (not described in detail), possibly near Ulverstone on the north coast. The Parrawe chert, which is of Early Cambrian age, is known to have been widely distributed throughout northwest Tasmania and the closest known uses of this chert are in Cradle Valley and the upper Forth River valley (McConnell 1999) and at Mersey Bluff (Cosgrove 2000) *c.* 80-100 kms to the northwest of Lagoon of Islands. Dated occurrences of this brecciated chert in archaeological sites indicate that this brecciated chert has been used in Tasmania from at least *c.* 25,000 years BP (Cosgrove 1995, 2015), with a similar brecciated chert, but not a Parrawe derived chert, being used after *c.* 2,000 years BP at Rocky Cape on the northwest coast (Cosgrove 2000).[37] Occurrences of other brecciated chert (of Cambrian age) have been mapped across western and northern Tasmania, with the closest mapped occurrences to Lagoon of Islands being Lake River, the Sheffield-Black Bluff area, south-east of Port Sorell (McConnell 1999), and the Relbia-Cluan Tier–Great Lake area (Sutherland 1972). Although no quarries have been identified in these occurrences, they are potentially a source of the brecciated chert identified at Lagoon of Islands.

The movement of stone material from the various sources noted above in the northwest, north and south seems likely given the current understanding of the key Aboriginal travel routes (Ryan 1996) (refer Figure 10.2). Material could have been easily transported from the northwest coast via the major east-west route along and below the northern edge of the Central Plateau, then up onto the Plateau via the major route which ran near Quamby Bluff, south past *yingina*/Great Lake, then past Lagoon of Islands; or from the north coast via this route or via the major north–south route that ran c. 50 kms to the west via Cradle Mountain to the Lake St Clair area, then running east, possibly via an east-west route across the Central Plateau that linked the Lake St Clair area with Bradys Lagoon, Lake Echo and the eastern lakes and lagoons, including Lagoon of Islands.[38] Material from the east and northeast could have been transported via either the major east-west route that ran from the central Midlands up onto the Central Plateau via Lake Crescent to Lagoon of Islands, or that which ran from the Midlands onto the Central Plateau via Lake River and Arthurs Lake, a day's travel northeast of Lagoon of Islands.

The geomorphic research indicates that Lagoon of Islands was used in the late Pleistocene before *c.* 16,000 years BP and then during the Holocene (possibly from as early as *c.*14,000 years BP) to present, although

[36] Jackman however does not describe the brecciated chert that he recorded.

[37] This is the material suggested by Cosgrove (2000) to have possibly come from the Ulverstone area.

[38] The western part of this possible route (and an extension west into the Franklin River valley) is suggested by McConnell and Hamilton (2001) and the eastern part is suggested by the historical information in Plomley (2008).

this use was possibly semi-continuous rather than continuous. Although there is as yet no other dated Pleistocene occupation on the Central Plateau, Pleistocene use of the Central Plateau is not inconsistent with other research that has produced dates of 30,000-34,000 years BP for earliest known occupation at the edge of the Central Plateau (Cosgrove 1989, 1995). Nor can semi-continuous occupation from the Pleistocene through the Holocene be ruled out, given the evidence from the excavations at Parmerpar Meethaner in the Upper Forth valley which indicate that this site was occupied from c.34,000 years BP relatively continuously through to the colonial period, with evidence for the use of the highlands (i.e., Central Plateau) during much of this time (Cosgrove 1995).[39]

Although it has been a common view that areas subject to extreme cold climate conditions such as glaciation are unlikely to have been occupied under such conditions, evidence such as that from the Parmerpar Meethaner and Warragarra caves (in the upper Mersey Valley) (Cosgrove 1995) and from the Fourth of July Valley in the USA (Benedict 1981) indicate that this is not the case. Benedict (1981) argues that rather than being disadvantaged by the conditions that occur near high altitude icefields, in the Fourth of July Valley in the last glacial maximum indigenous people found advantages such as increased areas of grassland and woodland/ grassland ecotone resources, as well as increased accessibility to some areas through vegetation change, and reliable water sources derived from snow and ice melt. The evidence from Parmerpar Meethaner indicates occupation during the last glacial maximum when the Forth River glacier would have reached within *c.* 9 kms of the site (Cosgrove 1995) and Warragarra has evidence for occupation at *c.* 10,000 years BP when the upper Mersey Valley would have just become ice free (Lourandos 1983). Later work at Warragarra suggests that occupation of the site may have been well before 10,000 years BP, but that such evidence has been eroded from the site (Cosgrove 1995).

The current evidence therefore indicates that there was occupation and use of Central Plateau during the late Pleistocene, including the last glacial maximum, although as McConnell and Hamilton (2001) note, the presence of glaciers and different resource availability would have required a slightly different use compared to warmer periods. As glacial geomorphic studies carried out for the region suggest that the last glacial maximum was not as extensive as earlier glaciations and the environment was probably akin to that of alpine New Zealand or Patagonia today (Kiernan 1990, 1999; Thrush, M., cited in McConnell and Hamilton 2001), it is unlikely however that major changes in Aboriginal use of the region were required for occupation at this period.

Bells Lagoon (Midlands)

Summary Description of Lagoon

Bells Lagoon is situated in the Midlands within the catchment of the Macquarie River which drains to the north, ultimately into the Tamar River (refer Figure 10.1). It is located north of the north-south Midlands divide and on the western edge of the Midlands in a low lying area of plains (*c.* 240 m asl) and low hills and ridges (up to *c.* 400 m asl). Bells Lagoon (at *c.* 240 m asl) is the largest of the abundant, large to small freshwater basins or swamps (mostly former lagoons drained for agricultural use) of the Ellinthorp Plains (Kee 1990). Ellinthorp Plains sits at the headwaters of the Isis River and the Blackmans River, both of which flow into the Macquarie River. Immediately to the west of Ellinthorp Plains are the foothills of the Western Tiers which rise to *c.* 300 m and are dissected by creeks running off the Western Tiers. West of the foothills are the Western Tiers which is a dissected escarpment which rises over *c.* 5-6 kms to the eastern rim of the Central Plateau at *c.* 1,000 m. Bells Lagoon is *c.* 9 kms directly east of

[39] ORS7 at the southern edge of the Central Plateau (Cosgrove 1989) also provides evidence of repeated, occupation from c. 31,000 years ago to c. 2,500 years ago, with probable semi-continuous occupation from c. 31,000 years to c. 18,000 years ago.

the edge of the Central Plateau, and Lake Sorell and Lake Crescent, which sit on the eastern edge of the Plateau.

Bells Lagoon is *c.* 1.5 km long and on average *c.* 0.5 km wide, with surrounding plains on the north and east, and with an undulating bench *c* .20 m above the lagoon on the west and southwest sides and a large, *c.* 15 m high aeolian dune ridge (lunette) on the southeast margin (refer Figure 10.4). Bells Lagoon is fed by several small creeks flowing in from the west and north from the foothills of the Western Tiers, including Chock n Log Creek, which is the major inflow (at the north end), and two small drainages flowing into the eastern side. The apparent outflow was on the south-southeast corner of the lagoon, but this appears to have been blocked by the Quaternary aeolian sands in this area.

The eastern and southern margins of Bells Lagoon are mantled by aeolian sands, the northern end has been impounded by other sediment, and its western and southern margin abuts a ridge of dolerite bedrock. The aeolian sands extend some 500-750 m east of the lagoon on the low lying eastern side, but on the southeast and south margins, including in the area of the high dune, are more restricted in extent (<300m from lagoon) and appear to be draped over a low ridge of dolerite. The Western Tiers and the Macquarie Tier-Kitchener Ridge to the east are of Jurassic dolerite with limited occurrences of Triassic sedimentary rocks, and the foothills of both are comprised of Tertiary sediments. The Tertiary sediments are largely fine grained and unaltered, but there are also altered sediments in the local region, including iron enriched pisolitic conglomerate and massive ochre deposits, cherts and sub-basaltic silcretes (Land Tasmania 2019; and refer Chapter 9).

The original vegetation of the Ellinthorp Plains was native grassland and the hills on the east and west sides of Ellinthorp Plains carried dry eucalypt forest-woodland, some with grassy understorey; with the dominant species being *Eucalyptus amygdalina*, *E. viminalis*, *E. rodwayi* and, at higher altitudes, *E. pauciflora* (DPIPWE 2019). Today there are some small remaining areas of grassland on the plains and most of the hills have stands of remnant native forest-woodland.

The terrain surrounding Bells Lagoon and the Ellinthorp Plains generally has been converted to farmland, many of the smaller basins (former lagoons) have been drained, and there is a network of farm roads across the plains and foothills. There is a World War II observation post on the dune crest on the southeast edge of Bells Lagoon.

Historical Background

Bells Lagoon is likely to have been within the territory of the *tyerrernotepanner* of the North Midlands people, although it is possible there was a different band based on the Isis River (Ryan 1996). The traditional name for Bells Lagoon is not known, and no other traditional Aboriginal place names are known for the local region (Plomley 2008). There is no specific Aboriginal historical information for the Bells Lagoon or greater Ellinthorp Plains area.

There is however historical evidence for two major travel routes (Central Plateau to East Coast) running close to the Ellinthorp Plains, one to the north and one to the south, indicating that Bells Lagoon was not located on a major Aboriginal route (see also below). These routes appear to have been used for seasonal travel and rapid communications across central eastern Tasmania and to access major, often seasonal resources, in particular at Campbell Town and at the Eastern Marshes (Ryan 1996; Plomley 2008).

Traditional Aboriginal life in the region was significantly disrupted from *c.* 1821 with the colonial taking up of land grants following the establishment of the Hobart-Launceston road, which ran through the Midlands, as a permanent route. By 1828, the dry eastern Midlands Plain (including the Ellinthorp Plains),

which were admirably suited to sheep grazing, had become the centre of new agricultural settlement in Tasmania (Ryan 1996). This 1820s land settlement heralded the 'frontier wars' of the late-1820s – early-1830s between the traditional owners and the colonists, that occurred across much of Tasmania.

Previous Research

The only previous heritage research known to have been undertaken at Bells Lagoon or nearby is the work by Kee (1990) as part of the Midlands regional archaeological study, and survey work undertaken as part of a water supply impact assessment (McConnell 2010). The lunette at the south end of Bells Lagoon had however been recorded (anonymously) as a site [AH 598] in 1981. This early record notes it as a 'Very rich lunette site ... Artefact scatters abound with hammerstones, anvils, etc, in the lunette materials' with '>1,000 artefacts seen. Stratified deposits with charcoal hearths at base of lunette' (AH 598 site record form, pp. 13 and 2, respectively).

Kee (1990) undertook a series of block surveys across the Midlands in a range of different environments, one of which was the southwest part of the Ellinthorp Plains and included Bells Lagoon. The Ellinthorp Plains survey area was *c.* 12 km^2 and within this area 51 sites were located. These comprised artefact scatters (including stratified sites), isolated artefacts and stone quarries. The majority of these sites were located on lagoon margins (shorelines) (and with several sites on lagoon floors) or on associated source bordering aeolian deposits; or adjacent to small creeks and drainages in the area. The sites were mainly small artefact scatters of <10 pieces. By contrast, each of the two Bells Lagoons sites (AH 598 and 3699) and two other sites in the area were estimated to contain between 2,000 and 150,000 pieces (Kee 1990).

At Bells Lagoon the surface scatter of stone artefacts encompassed the entire 5.5 km margin of the lagoon and comprised hundreds of artefacts. Kee (AH 3699 site recording form, pp. 6 and 8, respectively) notes the artefacts are 'distributed over entire margin of lagoon in pockets of varying density among a continuous background scatter', but only between low water mark and the edge of the vegetation (a 2-10 m wide band). Kee (AH 598 site recording form, p.28) comments that none of the artefacts are in-situ as they are all occur in deflated areas. Kee (1990) describes the artefact types as predominantly debitage, but also including utilised stone, a large number and variety of scrapers, and some grindstones (for ochre). Stone material types used were hornfels (dominant), quartzite, quartz, chert (chalcedony) and petrified wood. AH598 and AH3699[40] on the lagoon edge at the base of the high lunette and ridge were also found to contain stratified deposits containing stone and some charcoal and bone (Kee 1990: 64).

Kee (1990) also undertook archaeological excavations at Bells Lagoon, excavating the stratified deposits at two locations (i.e., in the southeast corner and in the southwest corner) (refer Figure 10.4). In both excavations Kee located cultural material at 30-40 cm to 80-100 cm in an intermediate brown sand or silty sand, with overlying and underlying sterile sediments, either well sorted medium-fine sands or silty-clayey sands, largely interpreted as aeolian sediments. The cultural material comprised a small number of flaked stone artefacts, generally associated with charcoal fragments. In the western excavation some small pieces of ochre were present, and in the eastern excavation microscopic bone fragments and a hearth were identified. Some cultural material (flaked stone), interpreted as re-worked or lag material, was also located at the surface of the excavations. Radiocarbon dates from the cultural layers gave upper and lower dates of 1,030+/-60BP and 3,010+/-60BP in the eastern excavation and 4,540+/-410 BP in the western excavation.

[40] There is some confusion about the extent of these two sites from the records, but there does appear to be overlap. The AH3699 site record form suggests that Kee, in her 1988 survey recording has designated AH3699 as the full site and AH598 as the stratified deposits at the south end.

Archaeological Project Findings

Given the previous survey and existing archaeological knowledge for the eastern side of the lagoon which describes a more or less continuous surface artefact scatter around the lagoon margin, but for which there is no detailed information (mapping or documentation), the project undertook a systematic survey of the full margin of Bells Lagoon. The focus of the survey was the lagoon margin, with intensive survey undertaken within *c.* 50 m of the recent water's edge and extending up to 250-300 m from the lagoon edge in some areas to include full artefact scatters and specific environments (western dolerite bench and southern lunette). The range of topographic environments around the lagoon were included (i.e., sandy beach, aeolian dunes and sand sheets (both with light grass), grassed flats and the flat-undulating dolerite bench *c.* 15-20 m above the lagoon). All the archaeological evidence located was recorded[41], except where the artefact scatters were very sparse.

Although Kee (1990) found a continuous variable density stone artefact scatter of hundreds of stone artefacts around the lagoon margin in the then *c.* 2-10 m wide zone between the low water mark and edge of the vegetation in her 1988 survey, water levels were higher during the project survey and, except at the southern end of the lagoon, the project survey was not able to re-survey this zone and instead surveyed the inland adjacent margin. The project found that away from the 'beach' zone, most of the lagoon margin had only a very sparse scatter of surface stone artefacts (<*c.* 0.0005 artefact/m^2), but identified additional denser concentrations of stone artefacts. These denser concentrations were recorded as eight discrete surface artefact zones (refer Figure 10.4 and Table 10.2).[42] Apart from one scatter on the northeast edge of the lagoon the other concentrations were located in the southern portion of the lagoon (i.e., between the centre of the western side and the southeast corner).

The largest artefact concentration recorded by the survey is that in the northeast corner of the lagoon on part of the aeolian sandsheet on the eastern side of the lagoon (zone 1). Thirty one artefacts were recorded in this flat to undulating, low lying, *c.* 40,000 m^2 area, which extended up to *c.* 250m from the lagoon edge, with the artefacts being concentrated on the top of a low rise and near to the lagoon edge on both sides of the small creek in the area. The largest artefact scatter, that on the lunette proper and which extends at least 200 m from the lagoon edge, is approximately twice the size, but is an even sparser scatter away from the lagoon-edge, lower slope of the lunette.[43] The two other large artefact concentrations recorded by the project (zones 6 and 7) were located back from the lagoon margin *c.* 150-200 m and *c.* 200-400 m, respectively, and do not appear to continue to the lagoon edge (although this may be due to poor ground visibility in the area). Zone 1 has a low-medium artefact density (*c.* 0.0008 artefacts/m^2) and zones 6 and 7 have higher densities, but still low-medium artefact densities (in the range 0.001–0.009 artefacts/m^2).

The other zones recorded by the project (i.e., zones 2 to 5, and zone 8) are all small-medium size scatters of stone artefacts which are located on the shoreline and back from the lagoon up to only 20-25 m. In one case the artefact concentration extends further back from the lagoon edge, and in one case the artefacts were all located in shallow water in the lagoon. Except for zone 8, these sites are at the south end of the lagoon and are all located at the base of, and in some cases also on the toeslope of, the local lunette or bedrock rise. The densities of these zones are variable, ranging from *c.* 0.001 to *c.* 0.08 artefacts/m^2. The artefacts in these zones are thought to be largely reworked from the dune/rise slope or by wind or wave erosion. Kee's (1990) excavations provide evidence for this type of local sediment reworking.

[41] Some survey areas were not able to be comprehensively recorded, hence have only partial data.
[42] Only three of these, zones 3, 4 and 5, resurveyed areas surveyed by Kee.
[43] This scatter was not recorded by the present study or previously.

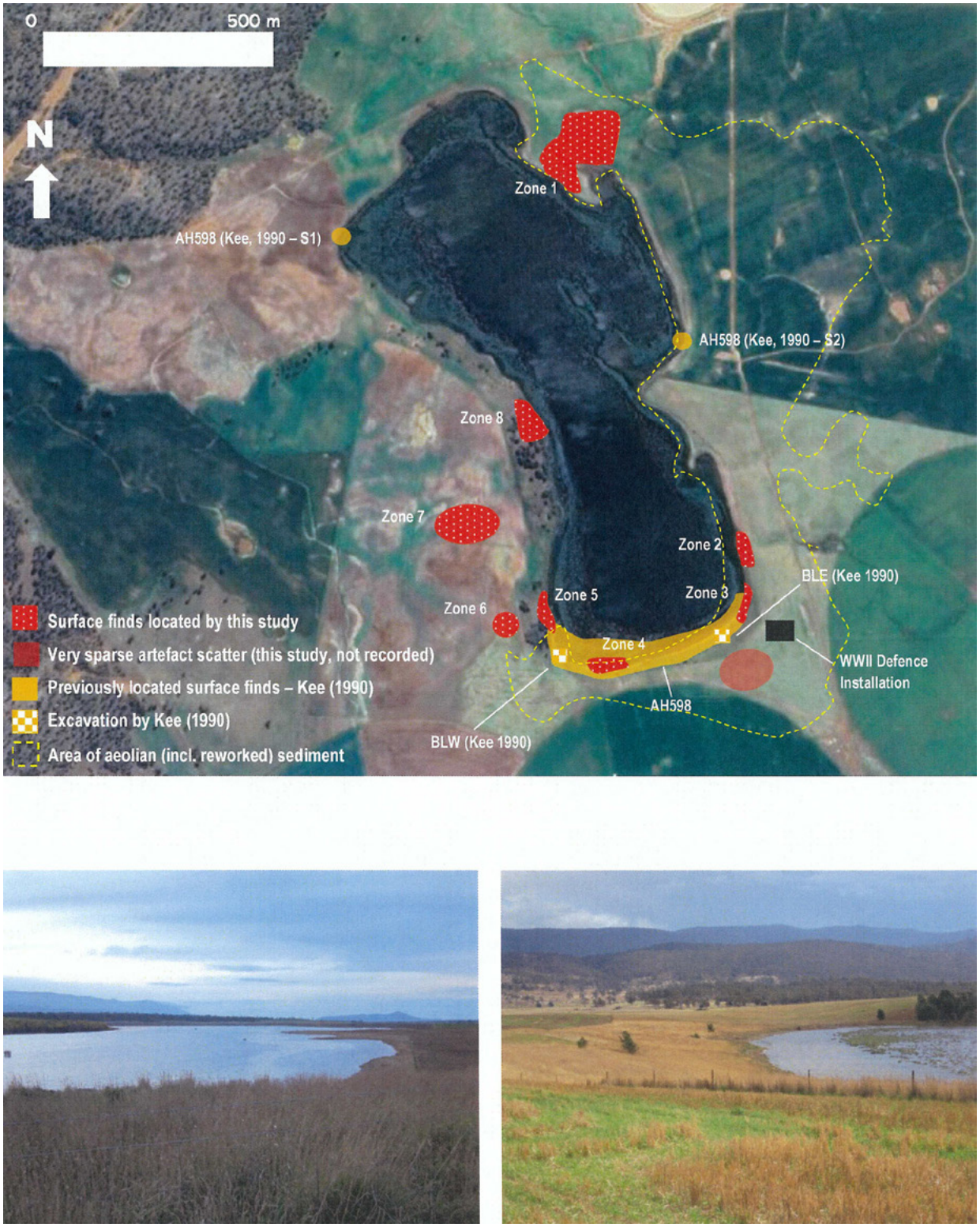


Figure 10.4 Bells Lagoon and identified archaeology. *The landscape views are north up Bells Lagoon to the Ellinthorp Plains from the lunette crest in the southeast corner (LHS); and west across the south end of the lagoon from the lunette crest to the Western Tiers (RHS). (Satellite image, 2019, from Google Earth, August 2019; images – A. McConnell, 2014).*

Table 10.2 The Archaeology of Bells Lagoon, a Summary

[Note – the artefact zones and other archaeological features are located in order clockwise around the lagoon margin starting on the northeast side of the lagoon. Refer also Figure 10.2 also Figure 10.4]

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debitage	core	utilised	tool [1]	hornfels	othermetased	quartzite	silcrete	chert	quartz	other	
1	31	84	6.5	3	6.5	64.5	10	-	22.5	3	-	✓[1]	Area c.250m by 230m. Lowlying, gently sloping-undulating land on lagoon edge with inflow creek (Chock n Log Gully) and 1 low ridge; area of thin aeolian cover sands.
2	6	100	-	-	-	100	-	-	-	-	-	-	Area – no data (survey area c.100m x 20m). Lowlying, gently sloping land on lagoon edge; small inflow at N end; area of aeolian cover sands (thin?).
3	3+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	Area c.100m by 25m. Lowlying, gently sloping beach (all artefacts under shallow water); at base of high aeolian dune; surface visibility c.10-50%.
4	17+	88	6	6	-	59	6	23	-	6	6	-	Area c.55m by 4m. Lowlying, gently sloping n lagoon edge (includes beach); at base of aeolian dune (at lower W end); artefacts located 5m+ from water.
5	4+	75	-	-	25	nd	nd	nd	nd	nd	nd	nd	Area- small-medium (no data). Gently-moderately sloping land on lagoon edge below a flat dolerite rise c.10-15m asl; on sands (aeolian?)
6	21+	90	5	5	-	67	-	10	14	10	-	-	Area – medium (no measurements) Undulating terrain; on a level bench c.15-20m above lagoon in southwest corner; c.100m+ from lagoon.
7	27	81.5	-	7	11	81.5	-	7.5	-	-	7.5	3.5	Area – large (no measurements) South half of western side of lagoon in depression on undulating bench c.15-50m above, and c.150m+ from lagoon.
8	5	40	20	-	40	60	-	20	-	-	-	20	Area – no data Central western side of lagoon on low bench c.25-50 from lagoon.
AH 598 & 3699	1,000+	✓	✓	nd	✓	✓	-	-	✓	-	-	✓	Full margin of Bells Lagoon (lwm to veg^{n} edge); recorded by Kee (1990); artefact data incomplete. AH 598 designated by Kee as stratified sites on south lagoon edge; SW corner noted as 'Extensive dense scatter stone artefacts (from images density is estimated to be 3-4 artefacts/ m^2); test excavated at 2 locations by Kee (1990).

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debitage	core	utilised	tool [1]	hornfels	othermetased	quartzite	silcrete	chert	quartz	other	
Kee 1990 BLE	35	97			3 [2]	dom	✓	✓	✓			✓ [3]	Excavation - part of AH 598 Excavation - 3m² to c.1m On lower dune slopes near water's edge on SE margin. Bone and a hearth also present.
Kee 1990 BLW	21	95			5 [4]	dom	✓			✓		✓ [5]	Excavation - part of AH 598. Excavation - 1m² to c.1.5m On lower slopes in aeolian sands on SW margin.

1 – c.3 small hard reddy clay nodules – possibly ochre or hearthstones/baked hearth clay.

2 – 1 small backed piece.

3 – basalt.

4 – 1 piece of grindstone.

5 – the grindstone is of dolerite; ochre also present.

In total the project recorded 114 stone artefacts and two probable hearth stones or pieces of ochre in artefact scatter zones 1 to 8; and in total in the survey identified *c.* 130-150 artefacts at Bells Lagoon. The types of stone artefacts and the stone types used are summarised in Table 10.2 for those concentrations which were documented.

Site Analysis

The project survey confirms that, taken with Kee's (1990) survey results, the margin of Bells Lagoon has a continuous, variable density scatter of artefacts around its full margin. Combining Kee's (1990) result with the project results, the spread of artefacts can be seen to be located between low water mark and the edge of the vegetation (approximate high water mark) around the full margin and extending out onto the grassy undulating plains, or up onto the dolerite bench and lunette that rim the southeast to southwest margin, as much as 250 m, and in some places 400 m. Ground visibility is also very variable around the lagoon (and varies over time, with considerably less surface visibility in 2014 compared to Kee's survey in 1988). It is therefore possible that the artefact scatter away from the lagoon edge is much greater than has been recorded.

While much of the lagoon margin has a very sparse background scatter, eight concentrations have been identified around the lagoon, mostly in the southern half of the lagoon. Given the generally poor ground visibility, these concentrations may only be apparent, and it is possible they may be larger sparser concentrations or, in some cases (e.g., zones 5 and 6), may be one much larger concentration. The present evidence suggests that artefact densities are in the order of 0.0002 artefact/m² to <*c.*0.001 artefacts/m² in the sparse background scatter, between *c.* 0.001 artefacts/m² up to *c.* 0.01 artefacts/m² in the larger artefact concentrations which are mostly away from the lagoon edge, and in the order of *c.* 0.001 artefact/m² to *c.* 0.08 artefact/m2 and up to 3-4 artefacts/m² in the denser concentrations on the lagoon edge, with the highest density concentrations at the south end in the low lying aeolian sediments. These southern lagoon edge concentrations however are likely to be artificially higher with erosion of

the local sediments having produced denser lag deposits. The surface scatter density of 3-4 artefacts/m^2 estimated from the AH 598 site record data applies only to the lagoon edge in the southwestern corner of Bells lagoon in the vicinity of Kee's (1990) BLW excavation which recovered artefact densities of *c.* 14 artefacts/m^3. This, and a similar artefact density for BLE, supports Kee's view that the southern lake edge surface scatters are concentrated lag deposits.

Bells Lagoon has a diverse assemblage of artefact types and includes not only various types of flaked stone artefacts, but also grindstones and ochre; and there is considerable evidence for hearths. Microscopic analysis of the excavation sediments indicates that at least in the deposits in the southeast corner there is associated faunal material, although this material was too fine to allow bone type identification (Kee 1990). This material diversity indicates a location at which a range of activities were occurring, hence a repeatedly used area for camping and for relatively long stays, although probably not generally used by large numbers of people.

The nature of the stone artefacts also is suggestive of a more regular and long term stay camp. Although debitage is most common (60-100% of assemblage) in each zone and in the two excavations, cores made up to 20% of the assemblage in these areas, and formal tools and utilised and retouched pieces were also present in all but one zone (ranging from 5% to 40% of the assemblage in different zones and 3% to 5% in the two excavations).[44] More formal tools might have been expected, but the low percentage of formal tools in the excavations suggests that the low percentages are real and not a factor of artefact collecting. The variability of different artefact types in the different zones is difficult to interpret with the available data.

The type of stone material used in the lithic artefacts is also variable and variable across Bells Lagoon. Hornfels (i.e., cherty hornfels) is the dominant material in all documented zones, ranging from 60% to 100% of the stone material in any one zone. Silcrete and quartzite are the next most common stone materials, with 0-23% of artefacts being of these stone types in different zones. In the different zones 0-10% of artefacts are of quartz and of chert, and small amounts of flaked other metasediments and basalt also occur. The AH 598 and AH3699 site record cards suggest that the cherts are very variable in nature and include banded and laminated cherts, the latter type including, and most likely generally being, fossilised tree.

Dating of the Archaeology and Lagoon Use over Time

There is limited reliable chronological evidence for the Aboriginal use of Bells Lagoon. The excavations by Kee (1990) in the sediments at the base of the lunette on the southeast edge of the lagoon (BLE) and on the southwest edge of the lagoon (BLW) have given upper and lower dates of 1,030+/-60BP and 3,010+/-60BP dates, and a date of 4,540+/-410 BP, respectively. Although there is evidence of some disturbance and introduction of material eroded from the lunette behind the southeastern excavation,[45] the dated cultural units do not appear disturbed, hence the dates are considered generally reliable. These excavations therefore provide evidence of the Aboriginal use of Bells Lagoon at least from the mid-Holocene until the recent past.

It is considered likely however that the Aboriginal use of Bells Lagoon goes back much further. Recent OSL dates from a >2 m deep trench on top of the main lunette (refer Chapter 9) provide a basal date of 20,170±1,500 years BP for well sorted medium-fine sands in the upper part of the dune, with a date of 18,700±1,200 years BP for immediately below (below a transition at 152 cm depth to fine sands and

[44] This includes a single small backed piece found in the BLE excavation.

[45] The mineralogy of the upper sediments at BLE suggests these are derived from slope wash from the large dune behind (Kee 1990).

silt-clay), and a date of 20,250±1,100 years BP at 180 cm depth. These dates indicate that the core of the lunette at the south end of Bells Lagoon dates to prior to *c.* 20,000 years BP and that there was a period of very rapid accumulation of very fine sand and dust during the LGM (refer Chapter 9). Although these dates do not directly date Aboriginal use of the area, it indicates a landscape similar to present from the late Pleistocene (from the LGM), hence the potential for Aboriginal use of this landscape at least since this time, although not perhaps at the peak of the LGM when the area appears to have been at peak aridity and landscape instability.

The Historic Aboriginal Use of Bells Lagoon – an Interpretation

As with the Lagoon of Islands, Bells Lagoon provides clear evidence for use, most likely regular, longer term stays, of the full margin of the lagoon, and for variable use of the lagoon margin. The presence of ochre and ochre grindstones indicate that 'some level of artistic, and possibly ceremonial and ritual activity' was also undertaken at Bells Lagoon (Kee 1990: 81). The heterogeneous nature and distribution of the stone artefacts at Bells Lagoon also suggest the use of different areas for different purposes, although little can be specifically said about this use given the incomplete archaeological data and the limited dating for Bells Lagoon.

These factors also make it difficult to interpret the history of Aboriginal use over time. The lagoon however has been clearly in use from the mid-Holocene to recent, and probably until forced dispossession in the early-mid 1800s given the intimate knowledge of the Aboriginal people G.A. Robinson was travelling with in 1831 of other parts of the Midlands region, and a worked bottle glass find near Cleveland Lagoon (Kee 1990: 46). Although there are no reliable dates for an Aboriginal presence in the Midlands prior to *c.* 5,000 years BP (Lourandos 1970), the long history of Aboriginal people in Tasmania and the geomorphic history of the lagoons indicating they were likely resource-rich nature over a long period, suggest that Aboriginal use of Bells Lagoon, as well as other major lagoons of the Midlands, is likely to extend back into the Pleistocene, a view also espoused by Kee (1990). The archaeological and geomorphic evidence for Bells Lagoon (see above) however indicates that within the Late Pleistocene, there were periods of aridity and lagoon edge instability, during which occupation of the lagoon may have been less likely.

It is also difficult to understand the use of Bells Lagoon in a regional context given the limited archaeological data for the Midlands lagoons and the lack of historical information for this part of the Midlands (see Section 10.2). The available historical documentation (Kee 1990; Plomley 2008; Ryan 1996) provides no information on the use of the Ellinthorp Plains region of the Midlands, suggesting the Ellinthorp Plains were not a focus of Aboriginal use in the recent historical past, including during colonial use. The historical information suggests that of the three key east-west routes of seasonal travel across the Midlands which allowed access to and from the east coast to the interior of Tasmania (refer to section, 'Context – Prior Understandings of Traditional Aboriginal Life in Central Plateau and Midlands, and of the Role of Lagoons', above), none ran via Bells Lagoon or through the Ellinthorp Plains, although the northern two routes ran close by. The closest was the central major east-west route which ran down off the Western Tiers from the south end of Lake Crescent via the headwaters of the Blackman River, then east along the river to the Macquarie River or via St Peters Pass; and which appears to have been only *c.* 3 kms south of the Ellinthorp Plains, and possibly as little as 9 kms south of Bells Lagoon. The other route appears to have dropped off the Western Tiers east of yingina/Great Lake–Arthurs Lake via Lake River, then run east, crossing the Isis River then passing through present-day Campbell Town; therefore running only *c.* 20 kms north of the Ellinthorp Plains and *c.* 35 kms north of Bells Lagoon. This suggests at least some use of Bells Lagoon during the annual cycle of travel.

Piecing together information from Plomley (2008) and Ryan (1996), it appears that there was also a significant north-south route through the Midlands which ran down the eastern side of the Midlands,

with the route passing through a number of the headwater marsh and lagoon areas on the eastern edge of the Midlands. The early observers also identify former areas of importance to Aboriginal people in the Midlands which are in the Campbell Town - Lake Dulverton - Eastern Marshes - Windfall Marshes area (refer Section 10.2). The major north-south Midlands route and identified areas of importance are all well to the east and south of the Ellinthorp Plains. Archaeological investigations in the Midlands (McConnell 2010) however have identified a locality on the Blackman River at the base of the Western Tiers as a particularly important Aboriginal place; and this location, which appears to have been on, or adjacent to the central major east-west travel route, is only *c.* 3.5-4 kms south of Bells Lagoon.

The history and archaeology therefore indicate that Bells Lagoon is unlikely to have had the high level of use of the areas of importance noted above, but the quantity of archaeological material at Bells Lagoon indicates that it, along with other large lagoons, was nevertheless an important location in the northern part of the Midlands, as well as at a broader scale. For example, Kee (1990) notes that with respect to her excavation results, Bells Lagoon has artefact densities (32-47 artefacts/m^3) comparable with Rushy Lagoon in northeast Tasmania and the Coal River sand sheet, although considerably lower than Crown Lagoon in the southeast Midlands (67 artefacts/m^3).

Within the local region, Bells Lagoon, as a site, however is significantly larger than most other sites (which were mostly of <10 artefacts) recorded by Kee (1990), with the only other large occupation site being Clarks Lagoon, one of a small number of other large lagoons on the Ellinthorp Plains. There is no clear indication of why the larger lagoons were preferred over other environments in this area (or more generally), but it is probable that it has to do with the larger water bodies having more reliable and abundant water and lagoon resources, and possibly having different and/or more diverse resources compared to the small lagoons.

In this area of the Midlands, it is also the case that the local environment of Bells Lagoon and Clarks Lagoon has a broad range of important resources (e.g., marshes, grassland resources, open woodland-forest resources, plentiful game, and relatively abundant tool quality stone sources) available nearby. This is most clearly reflected in the variety of high quality stone materials used at Bells Lagoon (e.g., various cherts including chalcedony, silcretes and hornfels) sources for all of which occur within *c.* 12 kms of Bells Lagoon (Kee 1990: 73; Painter 2001). These include some of the larger Midlands quarries – the York Lagoon hornfels quarry *c.*12 kms to the north, the Verwood hornfels quarry *c.*2.5 kms to north, the Annandale chert quarry *c.* 3 kms to the southwest (Kee 1990; Painter 2001); a smaller hornfels quarry *c.* 2 kms to the southeast of Bells Lagoon (Kee 1990); and a smaller probable quarry a short distance to the northwest of Bells Lagoon which is likely to be a procurement site for quartzite, chert and silcrete derived from the local Tertiary conglomerate (McConnell 2010).

Kee (1990: 85) concluded that Bells Lagoon 'shows a mid-Holocene economy targetting lagoon and terrestrial sources, probably on a seasonal basis'. This conclusion is supported by the project results. The evidence also shows that Bells Lagoon was part of a network of sites used in the north east Midlands, with the presence of items such as ochre and *ballewine* (ochre grindstones) demonstrating outside connections, including with other tribes, and suggesting longer stay use; and with the stratified deposits and large number of artefacts suggesting regular, repeated use over a considerable time span. Although not apparently on one of the major travel routes, or a known important or large population gathering location, it is likely that it was an important location, and perhaps an adjunct resource and/or camping site for the central major east-west travel route from the Central Plateau to the East Coast given its close proximity to this route and the associated major Blackman River site.

Tunbridge Township Lagoon (Midlands)

Summary Description of Lagoon

Township Lagoon at Tunbridge lies in the central Midlands approximately 8 kms east of the Western Tiers and 14 kms west of the Eastern Tiers (refer Figure 10.1). It is located in a relatively large (*c.* 10 km x *c.* 7 km), flat to undulating plain which lies at *c.* 200-220 m asl and drains northward via the Blackman River (*c.*1 km to the north of Township Lagoon) and Tin Dish Rivulet (*c.* 1.5 km to the east of Township Lagoon), both tributaries of the Macquarie River. The plains are bounded by several low ranges of hills that rise to a maximum elevation of *c.* 500m asl, except in the northwest where the plains extend to meet the Ellinthorp Plains. The plains on the eastern side of Tunbridge have a concentration of lagoons (*c.* 8 lagoons in total) of various sizes, all of which are located within *c.* 5-6 kms of the Township Lagoon.

The Township Lagoon is *c.* 0.5 km southeast of Tunbridge and sits in a small, shallow (*c.* 20 m deep) enclosed depression in the plains (refer Figure 10.5). The lagoon has a relatively flat floor and smooth, moderate-steep slopes, and is at *c.* 200m asl. At full water the floor of the depression, measuring *c.* 400 m by *c.*280 m, is covered by water. There are no inflow or outflow creeks; however water would drain into Tin Dish Rivulet at very high water levels (refer Chapter 9). The lagoon is hypersaline (as are other lagoons located to the east and within *c.* 4 -5 kms).

The western half of the lagoon has Jurassic dolerite bedrock. There are Upper Triassic sediments (including sandstones) in the northeast quadrant, and these possibly underlie the full eastern half of the lagoon (the bedrock of the southeastern quadrant being masked by Quaternary sediments) (Land Tasmania 2019). No aeolian sediments were identified at Township Lagoon and the local soils and sediments are predominantly clays (refer Chapter 9). The general area has been extensively cleared for agriculture and is primarily grassed pasture, but with scattered regrowth eucalypts on some rises. The lagoon is located within a Nature Reserve which is native grassland (lowland *Themeda triandra* grassland) with high species diversity, presumably a remnant of, or regenerated from, the formerly extensive Midlands grasslands (DPIPWE 2019).

Historical Background

The Tunbridge Township Lagoon is likely to have been within, and towards the south end of, the territory of the *tyerrernotepanner* of the North Midlands people who are understood to have been based in the Campbell Town area (Ryan 1996). The traditional names for the Tunbridge area and the Township Lagoon are unknown, and no other traditional Aboriginal place names are known for the local region (Plomley 2008).

There are also no known, definitive first hand historical accounts of Aboriginal use of the Tunbridge area. The only identified reference that might include the Tunbridge area is an 1829 comment that 'early in spring about the month of September some native tribes descends [sic] from the Western tier ... over the Saltpan plains, sometimes by Mr Harrison's [Antill Ponds] and sometimes by Mr Mackerseys [Oatlands]'[46] (Jorgenson's Journal 9/7/1829, cited in Kee 1990, Appendix 2: 6).

European settlement at Tunbridge occurred from 1838, and the township was established in 1858. At this time the whole area was known as the Salt Pan Plains. The salt pans in the Tunbridge area were used for commercial salt production in the 1800s to save the colonists the expense of importing salt

[46] Antill Ponds is c.7 kms south of Tunbridge and Oatlands is another c.10km further south, with the Saltpan Plains extending south to within c.3 kms northeast of Antill Ponds. Although the Saltpan Plains do not extend further south, Tin Dish Rivulet, which drains the plains, continues south past Oatlands, running c.2kms east of Antill Ponds and c.3kms east of Oatlands.

from Europe. The main pan used commercially was the Glen Morey salt pan to the east of Tunbridge (Weeding 1994). It is unclear if salt was also commercially taken from the Township Lagoon or if the lagoon was used for any purpose other than as part of local grazing land.

Previous Research

No previous archaeological research is known to have been undertaken at Township Lagoon. A single artefact scatter [AH650] however has been recorded from the lagoon (Kee 1990, Appendix 4: 30). The original site record form (1981) notes that the artefacts occur on the northern shore of the lagoon, but are largely buried by rubbish from the local rubbish dump. A revised site record (Kee 1988), presumably based on a resurvey, indicates that the scatter is *c.* 100m east-west and *c.* 10m north-south, and on cleared gently sloping ground on the northern margin and slopes of the lagoon, on sandstone, and located on, and both sides of, the vehicle track on the north side of the lagoon (refer Figure 10.5). The site is recorded as comprising three pieces of flaked hornfels, none of which are worked, and chert (chalcedony) is also indicated as being present although no artefact type is recorded for this material, suggesting it is locally occurring or dumped.

Archaeological Project Findings

As the extent of previous survey in the area of the Township Lagoon was unknown, the project survey included all areas of high to medium visibility in the Township Lagoon Nature Reserve. The main high visibility areas were the lagoon margin and dry floor (>50% of the lagoon floor was exposed at the time of the survey) and the vehicular tracks. The dry lagoon bed was bare except for slightly raised areas with a sparse, low, salt tolerant (?) ground cover.

The project located a sparse scatter of flaked stone artefacts on the lagoon edge below HWM, with one artefact located well onto the dry lagoon floor. The scatter comprised eight artefacts, six of which were concentrated on the northeastern edge of the lagoon, plus one on the northwestern edge of the lagoon and one on the southern side (refer Figure 10.5). The artefacts included five pieces of flaked debitage, two pieces of utilised stone and one steep edged scraper; and were of hornfels (dominant), fine grained meta-quartzite, silcrete, and an unidentified material (probably chert) (refer Table 10.3). None of the previously recorded artefacts at the north end of the lagoon were re-located.

The lagoon margins also had an abundance of other stone, primarily a blocky siliceous material, but also unmodified pebbles of a white chert, a black and grey banded chert, and quartzite. As none of the pieces inspected had any evidence of modification it is assumed this is naturally occurring or recently imported (and spread) material.

Site Analysis

In total a sparse scatter of 11 artefacts has been located in the Township Lagoon basin. The artefact scatter covers an area of *c.* 350m by 250m, and all artefacts are located within the HWM. The majority of artefacts are located in or adjacent to the 'beach' zone just inside HWM, but two are located *c.* 20m inside the HWM and one on the lagoon bed towards the centre of the lagoon is *c.* 75m inside HWM.

The occurrence of artefacts around much of the lagoon margin (refer Figure 10.5) indicates that the full lagoon margin is likely to have been used; and the presence of artefacts well within the lagoon suggests the use of the lagoon bed in dry periods.[47]

[47] The cluster of artefacts on the northeast margin is likely to be *in situ*, but given the recent history of the Township Lagoon, it is considered possible that the single artefact near the centre of the lagoon has been moved into this location through recent



Figure 10.5 Town Lagoon, Tunbridge, and identified archaeology. *The landscape views are south to the lagoon (LHS); and northeast across the lagoon (RHS). (Satellite image, 2019, from Google Earth, August 2019; images – A. McConnell, 2014).*

Table 10.3 The Archaeology of Tunbridge Town Lagoon, a Summary

[Note – the artefact zones and isolated artefacts described below are located in order clockwise around the lagoon margin starting on the northwest side of the lagoon. See also Figure 10.4 also Figure 10.5]

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debitage	core	utilised	tool [1]	hornfels	othermetased	quartzite	silcrete	chert	quartz	other	
1	1	-	-	-	100	-	100	-	-	-	-	-	Isolated artefact recorded by project; designated as AH 650. On gently sloping-flat, sandy-clayey lagoon shore just inside HWM; bare of vegetation.
AH 650	3	100	-	-	-	100[1]	-	-	-	-	-	-	Initially recorded (no data) 1981; re-recorded by Kee (1990); not relocated by project.
2	6	67	-	33	-	33	33	-	17		-	17[2]	Recorded by project; designated part of AH 650. On gently sloping-flat, sandy-clayey lagoon shore just inside HWM; bare of vegetation.
3	1	-	-	100	-	100	-	-	-	-	-	-	Isolated artefact recorded by project; designated as AH 650. On gently sloping-flat, sandy-clayey lagoon shore just inside HWM; bare of vegetation.

1 – piece has pebble cortex.

2 – possibly a black chert.

The small site size and the limited surface visibility preclude more detailed interpretation of the archaeology, however the inability of the project to re-locate the artefacts recorded in 1988 as well as the poor ground visibility away from the lagoon suggests that there are other, as yet unrecorded, artefacts in the area, especially outside the HWM.

Dating of the Archaeology and Lagoon Use over Time

There is no information that provides an understanding of when the Township Lagoon was used.

The Historic Aboriginal Use of Township Lagoon – an Interpretation

Although there is limited information on the archaeology of the Midlands lagoons, Kee's (1990) study and the results of the present project suggest that the artefact types and stone types that occur at the site are consistent with the types found in small-medium artefact scatters and other lagoon sites in the region.

The site is a relatively small, lagoon margin site, but this may be related to the small size of the lagoon as well as it being a saline lagoon. Although salinity levels are likely to have varied, there is little evidence in the landscape today for former full basin conditions when the lagoon may not have been saline.

disturbance.

The existing landscape and archaeological evidence suggest the lagoon is likely to have been saline over much of its existence, and hence not attractive as a campsite. The presence of artefacts however suggests some use of the lagoon, possibly to acquire specialised resources, in particular specialised plant resources found only in saline and hypersaline environments.

This interpretation is supported by the historical documentation which indicates that although Aboriginal people travelled to and from, and through, the Saltpan Plains, the Township Lagoon was not on a major route and was not known as a camping place. The available historic information indicates that although the Township Lagoon lies well west of the major travel route that ran down the east side of the Midlands and well north of the southernmost major east-west travel route that ran from the Central Plateau to the coast (refer Section 10.2), it is only 1-1.5 kms south of the major east–west route that ran in part east from the base of the Western Tiers along the Blackman River (refer also to Context – Prior Understandings of Traditional Aboriginal Life in Central Plateau and Midlands, and of the Role of Lagoons above). Given this proximity, it might be expected that Township Lagoon was within, or adjacent to, the corridor of travel and hence would have attracted more use. It is probable however that the salinity of the lagoon discouraged use as a camp site and that the Blackman River, a permanent river with a broad flood plain, could easily and comfortably provide for all travellers through the area. This is supported by the large number of surface artefact finds along the Blackman River in the vicinity of Tunbridge (McConnell 2010).

The stone materials used to make the Township Lagoon artefacts are also suggestive of a local economy, with hornfels, the most common material at the lagoon, being available from a number of local sources. Research (Painter 2001; Sutherland 1972) indicates that there are at least 13 hornfels sources (bedrock or reworked and occurring as water worn pebbles-cobbles) within 20 kms of the lagoon. These are –

- a hornfels pebble source *c.* 1.5 kms northeast of Tunbridge (York Rivulet);
- at Brents Sugarloaf *c.* 3.5 kms southeast of Tunbridge;
- near Woodbury *c.* 5.5 kms southwest of Tunbridge;
- in the Western Tiers on the Blackman River *c.* 11 kms southwest of Tunbridge;
- two sources at North York Plains *c.* 12 kms southeast of Tunbridge;
- a hornfels source on the Macquarie River on the east edge of the Midlands *c.* 15 kms southeast of Tunbridge;
- at St Peters Pass *c.* 15-16 kms south of Tunbridge;
- three sources in the Lemont area *c.* 15-19 kms southeast of Tunbridge; and
- two sources in the Andover area *c.* 20 kms south of Tunbridge.

Silcretes, primarily sub-basaltic, also occur in the local region, generally on the western side of the Midlands. Sources are known within *c.* 10 kms to the northwest, and Tertiary source materials for the sub-basaltic silcretes occur within *c.* 3.5 kms of Tunbridge to the north and *c.* 5.5 kms to the west (Land Tasmania 2019). Although described as 'quartzite' by Sutherland (1972) quarries at Grimes Lagoon (to the south and *c.* 4.5km northeast of Tunbridge) and at Lemont (*c.* 15 kms to the southeast of Tunbridge) are also clearly silcrete quarries given that Sutherland records the local geology as Tertiary sediments and basalts.

The occurrence of artefacts of quartzite, clearly identified as being contact metamorphosed Permo–Triassic quartz rich sediment (sandstones-siltstones) is unusual; but can be explained as further very local stone use since this part of the Midlands is one of the few parts of Tasmania identified as having tool stone sources of this type[48], with Sutherland (1972) documenting a quartzite quarry at Lemon Hill

[48] The other area being the Richmond area on the south coast (Sutherland 1972: 15).

(*c.* 2 kms southwest of Oatlands and *c.* 22 kms south of Tunbridge) in association with Triassic sediments and Jurassic dolerite.

Rushy Lagoon (Fonthill, Midlands)

Summary Description of Lagoon

The Fonthill Rushy Lagoon is located on the eastern margin of the Midlands toward its southern end (refer Figure 10.1). This part of the Midlands comprises several ranges of hills with three discrete basin plains - that of the Jordan River headwaters at Oatlands, the central Tin Dish Rivulet basin plain, and the Eastern Marshes on the eastern edge. The actual Eastern Marshes lie on the main headwater creek of the Little Swanport River and also encompass the Hobbs Lagoon area, which has several small to large lagoons at the headwaters of the Sand River (which runs south and becomes the Bluff River).

The greater Eastern Marshes, within which Rushy Lagoon is situated, is an area of irregular plains, in effect a series of chains of interconnected basin plains with lagoons that drain via several headwater creeks, including the Eastern Marshes Rivulet, eastwards into the Little Swanport River. These chains of basins, situated at *c.* 350-400 m asl, lie between irregular low ranges of *c.* 100-250 m local relief to the west and *c.* 40-110 m local relief to the east and south. The greater Eastern Marshes are on the eastern drainage divide of the Midlands, with drainage to the east, but lie on the western side of the Eastern Tiers which rise to just over 600 m in this area, then drop steeply down *c.* 300-400 m to the narrow east coast plains. East and southeast of Rushy Lagoon this drop is *c.* 20 kms distant, the Tiers are diminished to low hills (<500m asl) and the Little Swanport River provides a pass through to the coast.

Rushy Lagoon is on the southwest edge of the Eastern Marshes Rivulet headwaters plain, which is *c.* 10 km long (N-S) by 3-4 km wide and contains several (at least eight) small–medium size lagoons, including Crown Lagoon, another archaeologically studied lagoon. Most of the lagoons drain, or formerly drained, into Eastern Marshes Rivulet, which flows from the southeast edge of the plain *c.* 5 kms through hilly terrain to join the Little Swanport River, still within the Eastern Marshes area. Crown Lagoon, which is near the north end of the Eastern Marshes Rivulet headwaters plain is *c.* 6 kms from Rushy Lagoon.

Rushy Lagoon is at 383 m asl. The lagoon has a rounded shape and is *c.* 680 m (E-W) and *c.* 580 m (N-S), with a distinct ridge with steep slopes on its eastern side and with lower and more gentle slopes on the other sides (refer Figure 10.6). Rushy Lagoon drains northwards into the catchment of Cullins Creek, a tributary of Eastern Marshes Rivulet, but on the south side within one kilometre there are several other headwater creeks that drain directly south into the Little Swanport River. One of these creeks starts immediately behind the lagoon's eastern ridge and less than 100 m from the lagoon, flowing through open marshy land *c.*500 m south of Rushy Lagoon. In its natural condition Rushy Lagoon retained water through the summer and had duck and other waterfowl (refer Chapter 9).

The geology of the area is primarily Jurassic dolerite, with irregular patches of overlying Tertiary basalt, including on the northwest margin of Rushy Lagoon. Less than 2 kms west of Rushy Lagoon the terrain is predominantly Triassic sandstones, siltstones and mudstones with limited occurrences of Jurassic dolerite and Tertiary basalt (Land Tasmania 2019). The lagoon floor is largely clay, but there is some sandy alluvium along the lower reaches of drainage lines that lead into Rushy Lagoon and some overlying the lagoon floor clays. As shown by geomorphic research undertaken by the project (refer Chapter 9), the eastern ridge of the lagoon is a bedrock ridge, presumed to be dolerite based on the geological mapping (Land Tasmania 2019).

The area has been extensively cleared for agriculture and most of the lagoons and swamps drained. The remnant native vegetation indicates that the vegetation around Rushy Lagoon was originally dominantly Dry eucalypt (*E. viminalis*) grassy forest and woodland, with native grasslands in the valley floors (DPIPWE 2019).

Historical Background

Rushy Lagoon is within the territory of the Oyster Bay people. Since Rushy Lagoon is on the inland edge of the Oyster Bay territory, it is probable that various of the east coast based Oyster Bay bands would have had rights to, and responsibilities for, this area (Ryan 1996). The traditional name for the lagoon is not known, but the nearby Eastern Marshes was originally named *pomeentateerkuner* (Plomley 2008).

The Eastern Marshes Rivulet–Little Swanport River headwaters appear to have been an area regularly visited and passed through by Aboriginal people, and the Eastern Marshes appear to have been the meeting point of several major Aboriginal routes across and down the Midlands, and up the Little Swanport River from the East Coast. The historical records (Kee 1990; Plomley 2008; Ryan 1996) indicate that at as well as the route via the Little Swanport River from the East Coast, other major routes were along the eastern edge of the Tiers from the north (from the Campbell Town area); from the Central Plateau along the Blackman River and then via the Macquarie River, then south; from further south on the Central Plateau east across the Midlands via Jericho, then via the Blue Hills to the Hobbs Lagoon area. There also appears to have been routes via Oatlands and Antill Ponds (refer to section 'Context – Prior Understandings of Traditional Aboriginal Life in Central Plateau and Midlands, and of the Role of Lagoons' above).

G.A. Robinson in his journals, and others, mention a number of specific locations in the area indicating that the Eastern Marshes and lagoons of the local region were important camping places, in a number of cases because of specific resources, with a number also clearly on the main travel routes. G.A. Robinson's diary for the 20-22 October 1831 is particularly relevant to the local area as he describes the southern part of his travel along an Aboriginal route down the Midlands eastern edge– where from Stonehouse Creek he heads southwest to the east side of a plains with lagoons and marshes (this appears to be the area of Faddens Lagoon, Crown Lagoon and Johnnys Lagoon, and possibly Harveys Lagoon and Rushy Lagoon), noting the presence of a stock keepers hut (Loane's hut) in the area[49]; then travels east in hills on north side of the Little Swanport River (and probably Eastern Marshes Rivulet), noting that the country was rough, but rich in kangaroos.[50] He is told by the Aboriginal people he was travelling with that this route is 'the native road and where they had frequently travelled' (Plomley 2008). Robinson (19 and 23/10/1831, in Plomley 2008) also notes that there is a hut (Hobb's hut) at the 'Eastern Marshes', apparently on the south edge of the Marshes, where he camped for a night. He also camps on Hobbs Farm at 'some large lagoons' slightly to the south (presumably the 'Hobbs Lagoons' area comprising Big Lagoon, Yorkys Lagoon, Charlies Lagoon, Murphys Lagoon and Holy Marsh), noting that 'The country around these lagoons is a place of great resort for the natives. There are [an] abundance of eels in these lagoons ...' (24/10/1831, in Plomley 2008).

Some accounts indicate that the Aboriginal presence in the area was regular and often large. For example, James Hobbs, an early settler near the Eastern Marshes, James Hobbs, talks of there being 300-400 Aboriginal people at the Eastern Marshes several times in *c.* 1825 (Shaw 1971, cited in Kee 1990). There is also one account of Aboriginal people at Rushy Lagoon in 1829 – 'On the day before the natives had been disturbed at the Rushy Lagoon ...' (William Grants to Constable Anstey, 4/7/1829, cited in Kee

[49] R.W. Loane was a major early land settler, having established the Lemont (originally 'Lee Mount') estate (von Steiglitz 1960).
[50] The full north-south route is described in 'Context – Prior understandings of traditional Aboriginal life in the Central Plateau and Midlands, and of the role of lagoons', above.

1990, Appendix 2: 1). There is also a first hand description of Aboriginal huts in the Lemont area in *c.* 1830 by R.W. Loane's son who also noted that they were made by tying log grass or sags in thick arches over their heads and filling in the spaces with boughs broken from surrounding trees' (cited in von Steiglitz 1960: 66).

As with Bells Lagoon, these accounts are all from a time when Aboriginal life had been severely disrupted by British colonisation and the broad scale agricultural settlement that accompanied it, for which the Midlands was a focus from the early 1820s (after the areas around the two major initial settlements (Hobart and Launceston) were established). The Aboriginal retaliation for this dispossession resulted in the 'frontier wars' of the 'settled districts' and the ultimate action in these wars, the 1830 'Black Line' (Ryan 1996). The only captures of Aboriginal people through this action was in the Eastern Marshes area at Lemont (*c.* 5 kms from Rushy Lagoon), where a man and a boy were captured and two men shot (von Steiglitz 1960: 65). A group of *c.* 60 Aboriginal people are also understood to have made a retaliatory attack on Hobbs Farm sometime during this period of conflict (von Steiglitz 1960: 21).

Fonthill, the property on which Rushy Lagoon occurs, was established on an 1831 land grant of 2,560 acres, augmented by another 1,130 acre grant in 1838 (Weeding 1994). By 1834, a homestead in log cabin style had been built near the southeast corner of Rushy Lagoon, but in 1843 a large, two storey, stone homestead was built slightly further south, overlooking the lagoon (Weeding 1994; and the author (AM), pers obsv). The 110 acre Rushy Lagoon was reclaimed (drained using cut channels) in the early 1880s and used for growing crops. It was highly productive until the peat caught fire and burnt down to the underlying lagoon floor clay (von Steiglitz 1960: 72). A reduction in productivity saw the lagoon floor, like most of Fonthill, turned into grazing land, a purpose it still serves today (refer Chapter 9).

Previous Research

No previous archaeological or geomorphological research is known to have been carried out at, or near, the Fonthill Rushy Lagoon, and there are no Aboriginal sites registered in the general area of the lagoon.

Crown Lagoon, *c.* 7 km northeast of Rushy Lagoon and located within the same undulating basin plain, has however been the subject of detailed geomorphological and archaeological research (by Sigleo (1978) and Lourandos (1970, 1972), respectively). Crown Lagoon is an irregular-shaped flat-bottomed basin of *c.* 1 km by 0.5 km with a *c.* 7 m high lunette on the southeastern margin. The research by Sigleo (1978) has shown that the lagoon has a low basalt ridge in the southeast corner and that the lunette overlies other sediments which sit on the basalt.[51] The lunette was shown by Sigleo's work to be complex, comprising carbonaceous lake floor clays overlying the basalt, a beach sand unit overlying the lake clays, in turn overlain by a basal aeolian sandy clay, which is overlain by an aeolian slightly silty, clayey sand deposit. These two aeolian units form the core of the lunette, which is overlain by a well sorted aeolian sand (referred to by Sigleo as 'coversands'). The 'coversands' comprise three units, the lowermost of which is that which contains Aboriginal archaeological material.

At Crown Lagoon the work by Lourandos revealed that that the archaeological material was stratified and included stone artefacts, bone and hearths; and that the occupation from which these remains were derived dated to *c.* 4,000-5,000 years BP. The Crown Lagoon archaeological site has been described as very high density (Kee 1990). Until Kee's (1990) regional study, Crown Lagoon was the only dated

[51] The available government geological mapping (Land Tasmania Geology 1:250,000 mapping, <https://maps.thelist.tas.gov.au/listmap/app/list/map>) shows the full area of Crown Lagoon and adjacent as Jurassic dolerite; however Sigleo's detailed mapping which describes the terrain in the vicinity of the Crown lagoon basin as being mostly Tertiary basalt. is considered to be more accurate than the 1:250,000 mapping.

Aboriginal site in the Midlands, and today is still the only well researched site in the southern Midlands uplands.

Archaeological Project Findings

At Rushy Lagoon, the project work focussed on the eastern margin of the lagoon, primarily on the ridge, which was presumed to be a lunette. A systematic survey was undertaken along the southeastern lagoon margin from the former lagoon edge east across the ridge and including the lee side of the ridge. This area is grassed pasture with a vehicular track along the ridge crest.

The project located a moderate density scatter of stone artefacts on the narrow flat crest of the ridge (refer Figure 10.6). The artefacts occurred over an elongate, curved area *c.* 170 m long (N-S along the ridge crest) by *c.* 5 m wide on the southern half of ridge. The scatter appears to be restricted to the ridge crest as no artefacts were located on the ridge slopes. The artefacts however were only located in eroded areas (vehicle tracks and other depressions of >*c.* 5 cm depth) with no vegetation. The sediment in the eroded areas was a pale grey-brown fine sand with silt and/or clay. The site is *c.* 20-30 m from the eastern edge of the floor of the lagoon and *c.* 80-100 m from another low lying, but open, drainage depression to the east. The slopes on each side of the ridge are relatively steep.

Seventeen artefacts were located (refer Table 10.4). These were all flaked stone artefacts, predominantly debitage. The artefacts however included one utilised piece and two formal tools (one round edge scraper and one single edge scraper). The artefact stone types were mainly hornfels and fine-grained quartzite (of probable Permo-Triassic metasediment origin), with some minor chert and quartz. The scrapers were on hornfels and chert and the utilised piece (possibly a scraper fragment) was also of chert (chalcedony). A small number of pieces of a sandstone and a weathered basalt or dolerite were also noted in the site area, but it is unclear whether these are manuports, or of natural or recent origin.

Site Analysis

The ridge on which the artefact scatter was located was initially assumed to be a lunette given its form and location, but the geomorphic research undertaken for this project (refer Chapter 9) has shown the ridge to be bedrock controlled (dolerite) with a thin overlying cover of a fine sediment. On the ridge crest in the site area this sediment has been shown to be an at least 23 cm deep, grey-brown fine sand with some silt/clay. This sandy veneer extends across the lee-side (eastern flank) of the rock ridge up to at least 200 m east of the lagoon edge in some areas. The sandy deposit on the lee slope is generally <0.5 m thick, although one occurrence of >1.5 m was recorded.

Given its nature and location, this sandy veneer is interpreted as an aeolian deposit draped over the rock ridge, with the lee deposits being contemporary and/or reworked from the ridge crest aeolian deposit. This draped 'lunette' with incorporated Aboriginal archaeological evidence is not unusual, with Crown Lagoon and Bells Lagoon also having sites with a similar geomorphic context (Sigleo 1978; Kee 1990). The artefact densities at Crown Lagoon and Bells Lagoon however are much higher than recorded for the site located at Rushy Lagoon. This may be real, or be a factor of the different artefact location method, with the Crown Lagoon and Bells Lagoon artefact densities being based on archaeological excavation rather than surface survey finds as at Rushy Lagoon.

The occurrence of the artefacts at Rushy Lagoon suggests that the scatter might be higher density and more extensive than recorded by the project. This is suggested by the restricted occurrence of artefacts to areas with both good ground visibility and some erosion. The occurrence of artefacts only where the present day sandy surface sediments had been eroded to at least *c.* 5 cm depth indicates that the located

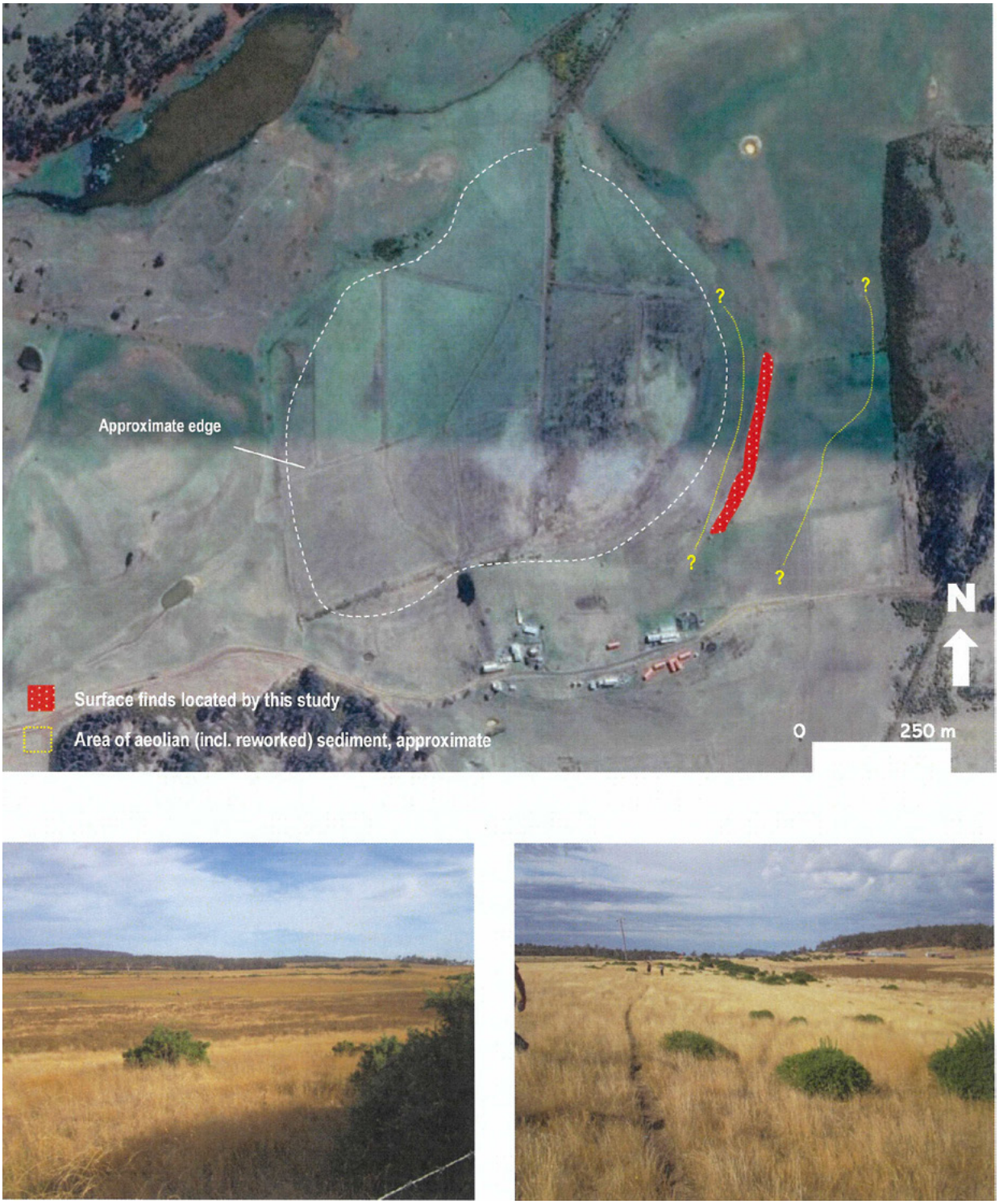


Figure 10.6 Rushy Lagoon, Fonthill, and identified archaeology. *The landscape views are north across the lagoon (LHS); and south down the ridge crest on the eastern side of the lagoon (note Fonthill buildings on the RHS) (RHS). (Satellite image, 2019, from Google Earth, August 2019; images – A. McConnell, 2014).*

TABLE 10.4 THE ARCHAEOLOGY OF FONTHILL RUSHY LAGOON, A SUMMARY

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debitage	core	utilised	tool [1]	hornfels	othermetased	quartzite	silcrete	chert	quartz	other	
1	17	82	-	6	12	35	41[1]	-	6	12	6	-	Registered as AH 13610. Area 850m^2. On flat topped narrow ridge crest, probable lunette/cover sands lag deposit. Grassed pasture with vehicle track.

1 – Permo-Triassic quartzite.

artefacts are mostly lag deposit resulting from reworking of the upper sandy sediment. This further suggests that additional subsurface (at least in the sandy sediment) artefacts can be expected in this area, and that the artefact scatter may extend into the grassed, poor visibility areas.

Although no hearths or stratified deposits were located, it is possible that some such deposits occur (or occurred) within the sandy deposits at Rushy Lagoon given their presence in similar aeolian contexts at Crown Lagoon and Bells Lagoon (Kee 1990; Sigleo 1978). Also, since the southeast margin of Rushy Lagoon is the only part of the lagoon that has been surveyed, the project results should not be taken as indicating an absence of other sites elsewhere around the lagoon. The information to date is therefore insufficient to detail the Aboriginal archaeology of Rushy Lagoon.

Although analysis is limited by the limited archaeological evidence, the stone the artefacts at Rushy Lagoon are made from, is likely to have been predominantly locally sourced stone. The hornfels and quartzite which comprises 76% of the assemblage forms at Jurassic dolerite – Permo-Triassic sediment contacts which are abundant in the local region. Although no quarried sources are known at Rushy Lagoon, quarried sources of hornfels occur at Lemont and Crown Lagoon *c.* 6.5 kms to the north, on the eastern margin of the York Plains *c.* 10 kms to the west; and a quarried source of contact-metamorphic quartzite has been identified at Lemon Hill *c.* 20 kms east of Rushy Lagoon. The silcrete and, possibly, the chert in the Rushy Lagoon site is likely to have formed in a sub-basaltic context, hence is also potentially locally available given the prevalence of Tertiary basalt in the local region. The nearest identified silcrete quarry is at Lemont[52] only *c.* 5-6 kms northeast of Rushy Lagoon (McConnell 2010; Sutherland 1972).

Dating of the Archaeology and Lagoon Use over Time

There are no dates for Rushy Lagoon, either for the sediments or for the archaeological material. It is tempting to suggest that the cultural material is of mid-Holocene age based on the dates from Crown Lagoon (4,860+/-96 BP and 4,170+/-80 BP, Lourandos 1970) and Bells Lagoon (1,030+/-60BP, 3,010+/-60BP and 4,540+/-410 BP, Kee 1990) for stratified material in a similar geomorphic context (i.e., in the uppermost aeolian unit). However, unlike Crown Lagoon and Bells Lagoon which have several well differentiated aeolian units (Sigleo 1978; and this study) the sandy aeolian deposit at Rushy Lagoon

[52] Although described by Sutherland (1972) as 'quartzite', this is clearly a silcrete quarry given that Sutherland records the local geology as Tertiary sediments and basalts.

appears to be a single unit. It also unclear which unit at Crown Lagoon and Bells Lagoon the Rushy Lagoon aeolian deposit is equivalent to. Although having a superficially similar context to the Holocene 'coversands' at Crown Lagoon and Bells Lagoon in which the archaeological material occurs, the composition and hardness of the aeolian material at Rushy Lagoon, and suggestions of extensive later re-working and deposition on the lee of the ridge, suggest it may be earlier than Holocene. Confident dating of the Rushy Lagoon site will require dating of the Rushy Lagoon sandy sediments.

The Historic Aboriginal Use of Fonthill Rushy Lagoon – an Interpretation

As noted above, the archaeological information available for Rushy Lagoon at Fonthill is not adequate for understanding the lagoon's Aboriginal archaeology or historical use. The location of the known archaeological evidence relative to the lagoon and the assemblage composition at Rushy Lagoon however is generally typical of Midlands lagoons and a number of Central Plateau lagoons and lakes. The artefact types are also generally consistent with other lagoon site assemblages in the Midlands and on the Central Plateau. The material types being used are consistent with the pattern of dominant local material use, but with some use of exotic materials, found at other Midlands lagoon sites (Kee 1990; and this study).

The historical information indicates that Rushy Lagoon was one of the lagoons used within the greater Eastern Marshes area, a major Midlands travel 'crossroads' – with routes from the East Coast, down the east side of the Midlands, and at least one (and possibly three or four) route from the Central Plateau all connecting at this point. The historic information also indicates that lagoons in this region were popular camp sites, presumably not only for having reliable water, but also for having localised, specialised food resources (e.g., waterbirds, eggs and eels), and with other important resources nearby, including abundant kangaroo in the extensive grassland and grassy woodland environments. The archaeological evidence also indicates that there were good tool stone sources in the local area.

Rushy Lagoon appears from the current evidence not to be one of the more heavily used lagoons, as for example Crown Lagoon which was directly on one of the travel routes, or the Eastern Marshes proper which was at the nexus of most of the travel routes in the area and the main focus of use in the area. The historical information however suggests that, although not directly on a major travel route, Rushy Lagoon, along with most of the other lagoons in the greater Eastern Marshes area, was used as one of the lagoons within the greater Eastern Marshes area and also within broader travel corridor of the main route down the eastern side of the Midlands. It is not possible to know why particular lagoons were chosen over others, but choice is likely to have been influenced by one or more of a range of factors such as it being the custodial responsibility of a particular band, specialised seasonal resources, or simply personal choice based on meanings, associations, or aesthetics. This interpretation can be seen as essentially similar to, but more nuanced and landscape based than, Lourandos' (1968) interpretation for the Crown Lagoon site, which he concludes is 'a terrestrial short term camp associated with the lake/ marsh system where hunting forays in to the local hinterland were undertaken to capture marsupials' (Kee 1990: 28).

Lake Tiberias (Midlands)

Summary Description of Lagoon

Lake Tiberias is located on the southwestern margin of the Midlands uplands plateau area. It, and Lake Dulverton *c.* 10 kms to the north, are two key headwater sources for the Jordan River which flows west of these two lakes along the base of the Western Tiers south into the Derwent Estuary above Hobart (refer Figure 10.1). This part of the Midlands is hilly plateau country at *c.* 440-450 m asl and comprises a series

of elongate creek-river valley bottom plains between irregular, but generally north-south trending ranges of *c.* 100-250m local relief. Other than the Jordan River, the main drainages are that of Tin Dish Rivulet, Nutting Garden Rivulet (a tributary of the Little Swanport River) and Tin Pot Creek (which flows into the Bluff River) all of which lie to the east of Lake Tiberias. South and southeast of Lake Tiberias the land drops away steeply, and the edge of the plateau in this area is heavily dissected by the Coal River and various tributary creeks.

There are much fewer lagoons and marshes in these valleys than in the main part of the Midlands to the north. In this part of the Midlands Lake Dulverton and Lake Tiberias are the dominant water bodies, with Lake Tiberias, the largest body of water, being *c.* 3 kms long and *c.* 4 kms wide. The lake, which is approximately triangular in shape, is nestled below ridges on its northwestern and southwestern sides, and drains at its northwest corner via the Jordan River, although some of the lake's discharge is subsurface and to the east, manifesting as springs on the western slope of the Coal River gorge (refer Chapter 9). The eastern third is an undulating–hilly plain. This plain is only *c.* 1-3 kms wide, with a major drop off, essentially an escarpment of the Coal River gorge, occurring within *c.* 600 m - 1 km of the eastern lake edge. Lake Tiberias sits at 437 m asl in a shallow basin within the plain.

The geological mapping (Land Tasmania 2019) indicates that the plains around Lake Tiberias are geologically controlled and are the surface expression of the horizontally bedded Triassic sedimentary units that occur in this area, in this area a quartzose sandstone. It is this resistant quartzose sandstone that creates the steep escarpments into the Coal River valley to the east. There is also one localised outcrop of Permian sediment on the eastern side of the lake. The local hills are resistant Jurassic dolerite. There is no basalt mapped in the vicinity of Lake Tiberias, and the nearest mapped sources are 4-5 kms to the east near Baden and 5-6 kms to the northwest near Jericho. The mapping also indicates that there are Quaternary alluvial sediments in the inflow creek basins, and Pleistocene dolerite talus slopes and Pleistocene sediments on the eastern margin. The Pleistocene sediments occur on the southern half of the eastern margin only and are aeolian deposits which mostly have been significantly reworked. Sigleo (1978: 234) describes these deposits as 'an extensive source bordering dune consisting of sandy clays and clays', and drilling indicates these have a maximum thickness of 20-40 m (refer Chapter 9). Lake Tiberias sits within the Triassic sedimentary units, and the floor has peat overlying inorganic lacustrine clays (Sigleo 1978). The depth of Lake Tiberias is unknown, but it is generally no deeper than 2 m.

The margins of Lake Tiberias and the plains have been cleared for agriculture and the land today is largely grassed pasture. Areas of native vegetation survive in the upper Coal River valley east of Lake Tiberias and in the hilly areas on the western side of the lake. This indicates that the more hilly country around Lake Tiberias was primarily *Eucalyptus viminalis* or *delegatensis* grassy forest and woodland, with large areas of *Poa labillardierei* grassland in the more open areas. The mapping indicates that these vegetation types also covered much of the plains around Lake Tiberias, but with *Eucalyptus pauciflora* forest and woodland on the higher terrain on the eastern side of the lake. Lake Tiberias itself has extensive freshwater aquatic sedgeland and rushland (DPIPWE 2019).

Historical Background

Lake Tiberias is within the territory of the Oyster Bay people, but near its western margin. As the Oyster Bay people were coastally focussed, it is probable that various of the east coast based Oyster Bay bands would have had rights to, and responsibilities for this area (Ryan 1996). The traditional name for Lake Tiberias is not known, and no other traditional place names are known for the local area (Plomley 2008). Lake Tiberias however was named 'Jericho Lagoon' by the early colonists and prior to 1822 was also named 'Lemon's Lagoon' (Weeding 1994). In 1829 it was described as 'a large lagoon overgrown with bushes and about 8 ¼ miles in circumference' (James Ross, cited in von Stieglitz 1960: 40).

There are no historical accounts of Aboriginal people at Lake Tiberias. One of the major east-west routes from the Central Plateau across the Midlands was however via Jericho, then east via the Blue Hills (*c.*8km directly east of the northeast corner of Lake Tiberias) to Hobbs Lagoons on the south edge of the greater Eastern Marshes (G. Robertson, cited in Kee 1990, Appendix 2: 6). It is unclear if Lake Tiberias was on this route, but it is likely that the north side was as the northern edge of the lake is on the direct route alignment. When Robinson travelled through this general area in late 1831 he was led north via Lake Dulverton by his Aboriginal guides rather than via Lake Tiberias, although it was on the direct route he expressly wished to take. This may indicate that the traditional route deviated to the north bypassing Lake Tiberias, but it was also the case that the Aboriginal people who were guiding him were trying to avoid meeting with other Aboriginal people (Ryan 1996: 157-8), and that they may have deliberately deviated from the normal route to avoid a meeting with Aboriginal people at Lake Tiberias. Comment by Gilbert Robertson in 1830 that 'the forest between the lagoon [Lake Tiberias], the Brown Mountain and Jerusalem [Colebrook] was a constant resort of the blacks' (G. Robertson's journal, 24/2/1830, cited in Kee 1990, Appendix 2: 9) indicates that the area to the east and southeast of Lake Tiberias at least had considerable Aboriginal use historically.

As with Bells Lagoon, Tunbridge Lagoon and Rushy Lagoon at Fonthill, traditional Aboriginal life in the Lake Tiberias area had been significantly disrupted in the Midlands from the early 1820s with the establishment in *c.* 1821 of the Hobart to Launceston road and with the subsequent rapid taking up of land grants, leading ultimately to the 'frontier wars' between the traditional owners and the colonists in the late-1820s – early-1830s. As von Steiglitz (1960: 18-19) observes, Aboriginal people 'were being driven from place to place at this time and were making a last stand against the people who had taken their country'. The displacement and dispossession of the Aboriginal people of the Midlands however was fully effected by the mid-1830s.

The first land grant in the vicinity of Lake Tiberias was taken up in 1822. This grant was to J.M. Hudspeth, who established Bowsden which extended from the Jordan River east to the northeast end of Lake Tiberias (Weeding 1994). This was as part of the initial land grants in the area along the Hobart to Launceston road from the early 1820s, with the next land grants at Lake Tiberias not taken up until the 1840s. The second land grant at Lake Tiberias was to George Stokell in 1840, who took up two neighbouring grants of, in total, *c.* 2,750–2,900 acres[53] (GHD 2007). This land was on the southern side of the lake at the eastern end. Aboriginal people are known to have been in the south Lake Tiberias area at least in 1822, where they carried out a retaliatory attack on a local family (Weeding 1994).

Previous Research

No previous archaeological or geomorphological research projects are known to have been carried out at Lake Tiberias. Lake Tiberias is outside the area of Kee's (1990) study and, although included within the area of Cosgrove's (1984a) Central Plateau study and Browns (1986) South Eastern Tasmania study, it was not included as a survey location in either study. A small number of Aboriginal sites however are known to occur on the north margin of Lake Tiberias (McConnell 2010).

Archaeological Project Findings

Given the limited survey time and the large size of the lake, the project survey focussed on the eastern side of Lake Tiberias in the area of the aeolian deposit as this was considered to have the greatest potential for Aboriginal sites and was also the focus of the project geomorphological research. Ultimately, the survey was limited to one property on the southeast corner of Lake Tiberias due to land access issues. This area

[53] Two different sizes are given for one of the grants.

however coincided with the area in which the project geomorphological research was undertaken. The survey area, which was bounded by the lake edge on the west side and Tiberias Road on the southeast side, was *c.* 1 km by 750 m.

Six zones of Aboriginal archaeological evidence were located (refer Figure 10.7). These zones were spread across the survey area and well separated, with between *c.* 150 m to 350 m between zones.[54] The zones included two isolated stone artefacts and four small scatters of flaked stone artefacts. The scatters each had between two and three flaked stone artefacts. Overall, 11 artefacts were located (refer Table 10.5). These were predominantly debitage, but included one utilised piece in zone 1 and one formal tool, a scraper, in zone 5. The artefacts were also predominantly made from hornfels, but zone 1 had a quartzite artefact and a silcrete artefact, and zone 3 had a quartz artefact.

The zones were located in varying contexts including on the lake edge bank close to the lake (zone 1), on the top of the high sandy bank east of the lake which forms a low ridge in the survey area (zones 2 and 3), on flat to undulating terrain behind this ridge (zones 4 and 6); and on the edge of a low lying, intermittently marshy area back from the lake and south of the ridge (zone 5). Most of the artefacts were surface finds, but in at least four zones, artefacts were located in disturbed contexts that suggested they had come from subsurface contexts (and at two locations from within *c.* 15 cm and *c.* 25 cm below the surface). The zones were spread over a *c.* 1 km distance (N-S) and located from *c.* 25-30 m from the lake edge up to *c.* 600 m from the lake edge.

Site Analysis

The project survey has provided tangible evidence for historical Aboriginal use of Lake Tiberias, at least in the southeastern corner, in part on aeolian, source bordering deposits and in part on the flat to undulating plain behind the aeolian deposits. The poor ground visibility in the grassed paddocks of the survey area and the limited area of the survey however limit the interpretation of the archaeology.

Although it is not possible to discuss site size and density, the location of the archaeological evidence indicates that past Aboriginal use extended from the lake edge to at least 600 m distant, with the range of local environments (lake edge, lake edge ridges, back lake plains and back lake marshes) being used in some way. The occurrence of artefacts at depth in the upper aeolian sand and on the back plains, as well as on the surfaces of these environments, indicates that the historic Aboriginal use was not a single short phase of use, but occurred over a substantial period of time.

The artefactual material is consistent with assemblages at other lagoons and lakes, and does not indicate any unusual historical activities.

Dating of the Archaeology and Lagoon Use over Time

The project obtained OSL dates of 7,100 ±700 BP and 17,500±1,600 BP from fine, compact aeolian units which underlie the paler, loose surface sands in, or on, which the artefactual material in the southeast corner of Lake Tiberias, at least in zones 2 and 3, and presumably zone 1, was located. These dates are insufficient to date the artefactual material more closely than to some time during the late-Pleistocene – Holocene. It is not possible to comment on the ages of the artefactual material in zones 4 to 6 given the limited current information for the sites and the lack of dating for their geomorphological context.

[54] Each artefact area has been recorded as a separate archaeological site given a separation of >c.100m.

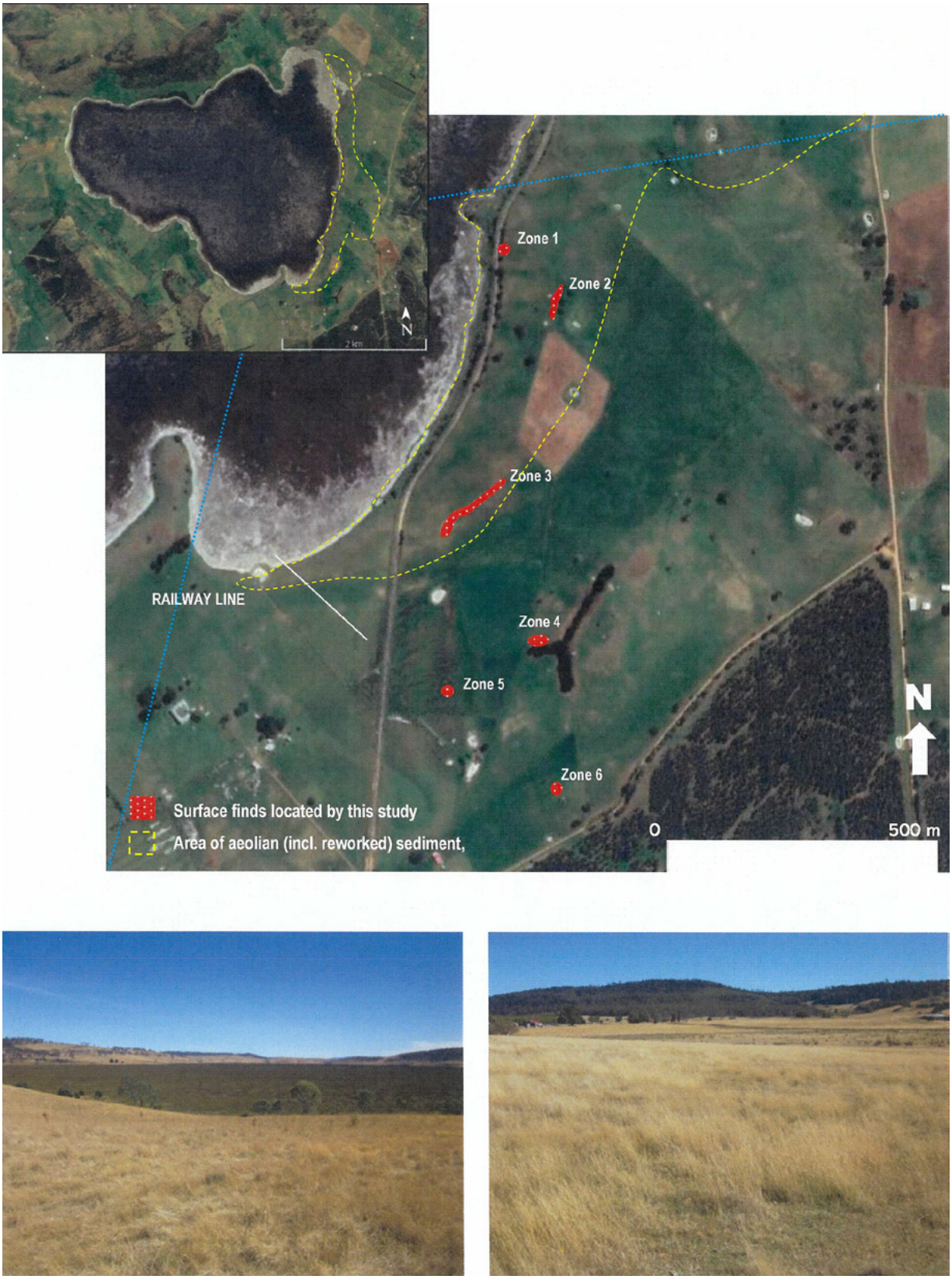


Figure 10.7 Lake Tiberias southeast and identified archaeology. *The landscape views are west across Lake Tiberias from the lunette (LHS); and south from the lunette across the low lying terrain on the southeast corner of Lake Tiberias (RHS). (Satellite image, 2019, from Google Earth, August 2019; images – A. McConnell, 2014).*

TABLE 10.5 THE ARCHAEOLOGY OF SOUTHEAST LAKE TIBERIAS, A SUMMARY

[Note – the artefact zones are listed in order from north to south. See also Figure 10.6 also Figure 10.7]

Zone/ Site	Total lithics	Artefact types (%)				Artefact composition (%)							Zone Description
		debitage	core	utilised	tool [1]	hornfels	othermetased	quartzite	silcrete	chert	quartz	other	
1	3	67	-	33	-	33	-	33	33	-	-	-	Registered as AH 13669. Located over c.2m at the base of railway cutting; presumed to have weathered out of the surface layer of aeolian sands exposed in the top of the cutting; no further artefacts noted for 50m+ both sides; c.25-30m from lake edge.
2	2	100	-	-	-	100	-	-	-	-	-	-	Registered as AH 13670. Artefacts are 60m apart. On ridge/bank on the east side of lake on first main crest (c.3-4m below main crest to east); c.100-150m from lake; c.20m above lake; gentle slope. One artefact located at 15cm depth.
3	2	100	-	-	-	50	-	-	-	-	50	-	Registered as AH 13671. Artefacts are 80-100m apart. On crest of ridge/bank on the east side of lake at south end; c.200m from lake; c.15m above lake; 1 artefact possibly from up to c.25cm below the surface.
4	2	100	-	-	-	100	-	-	-	-	-	-	Registered as AH 13672. On a flat to undulating area of sandy soils behind and below the lake edge ridge; c.350m from lake; c.5-10m above lake.
5	1	-	-	-	100	100	-	-	-	-	-	-	Registered as AH 13673. On a flat to undulating area of sandy-loam (lightly grassed); on edge of flat floored drainage (former wetland?); c.350m from lake; <.5m above lake.
6	1	100	-	-	-	100	-	-	-	-	-	-	Registered as AH 13674. On a flat to undulating area with loamy soils; c.600m from lake; c.5-10m above lake. Artefact likely to have been sub-surface (associated with fallen tree roots).

The Historic Aboriginal Use of Lake Tiberias – an Interpretation

The sites on the southeast corner of Lake Tiberias mainly occur within the area of aeolian deposits, but also extend out onto the plain behind the lake and aeolian deposits. This same pattern of broader landscape use was also noted by Kee (1990) at Bells Lagoon and Lake Dulverton (the only other Midlands lakes/lagoons to have had substantial survey away from the lagoon edge). This supports the notion that although lakes and lagoons in the region were a focus of Aboriginal use, it was only one of the many environments used. The limited survey of Lake Tiberias however means that it is not possible to examine the use of the lake as a whole.

The artefactual material also is too limited to comment on what activities occurred historically in this part of Lake Tiberias. The artefacts types are consistent with those at camp sites, and the apparent, very

low artefact densities suggest intermittent use rather than the area being a major, long term camp. The evidence to date does not support the historical documentation which indicates that Lake Tiberias was, or was on the edge of, a regularly used area of importance. It is possible however that the main camping areas were located elsewhere on the lake margin, possibly on the northeastern margin or on the plains on the south side.

The dominance of hornfels artefacts indicates the use of mainly local materials, similarly to the Tunbridge Township Lagoon and Rushy Lagoon at Fonthill. The local geology indicates considerable potential for hornfels sources in the local region; and two linear sets of hornfels procurement and associated sites are known within *c.* 8 kms of Lake Tiberias (McConnell 2010). One of these runs for 2-3 km along the eastern side of the York Plains and the other runs down the headwater reaches of Tin Dish Rivulet south of Andover. The presence of quartzite and quartz (and possibly silcrete) however indicates some importation of material into the area.

Discussion and conclusions - towards a better understanding of the past use of Central Plateau and Midlands lagoons in a Tasmanian context

The Tasmanian component of the 'Working Ancient Wetlands for Social Benefit and Cultural Understanding' project has contributed to the understanding of the archaeology of Tasmania by significantly enlarging the understanding of lagoons (and lakes) in the Midlands region, and by providing additional, largely corroborative data for the Central Plateau, but also the first associated chronological data for the Central Plateau proper. The project findings generally support the findings of the other regional Aboriginal heritage studies for the region, but also allow for some refining of our understanding of the past use of lakes and lagoons in this part of Tasmania.

The Aboriginal use of lagoons

Consideration of the archaeology of the study region, in particular that of the lakes and lagoons, together with the historical observations of Aboriginal use of the region in the early-1800s, points clearly to the main lakes and lagoons throughout the study region being important Aboriginal occupation sites.

Most lakes and lagoons that have been studied have from several discrete open sites up to a semi-continuous scatter of stone artefacts ringing them on the shoreline margin, resulting in high site densities compared to most other environments (*c.* 40 – 90 sites/km^2 on the Central Plateau and 8-8.5 sites/km^2 in the Midlands,[55] compared to a site density in the order of 5 sites/km^2 and 1 site/km^2 for these area respectively away from away from riverine and lacustrine environments (Kee 1990; McConnell 2009a; Parham 1993)). Some of these lakes and lagoons also have amongst the largest known open sites in the study region (i.e., lagoons/lakes have *c.* 80% of large site occurrences in both the Midlands and Central Plateau). This points clearly to these locations being more than occasional camp sites.[56] The historical information suggests that these were well known locations that were visited regularly, with the procurement, and in some cases enjoyment, of specialised resources being a key reason for the regular visitation. Reliability and abundance of resources is also likely to have been a factor in the

[55] Likely to be an under-estimate due to poor ground visibility conditions in this region.

[56] Kee (1990) attempted to explore whether lagoon sites are temporary or longer term camp sites, concluding that while, as suggested by Lourandos' (1970), Crown Lagoon is a seasonal base camp, Bells Lagoon was being only used for short periods of time. The present study believes that it is difficult to distinguish between highly regular repeated use over a short period, and more prolonged, but less frequent use of particular lagoon sites. This is a view also espoused by Brown (1991: 76) in relation to eastern Tasmanian sites more generally, in part due to the fact that 'occupation sites are often dispersed over extensive areas rather than concentrated at particular points'.

regular use of the lakes and lagoons, especially the larger lagoons/lakes and where these were on travel routes.

The twinned archaeological and historical evidence indicates that the resources being sought were both lagoon-based resources and near hinterland resources. It is clear from the historical information that the lagoons were targetted for lagoon specific resources such as bird eggs and for water fowl (primarily duck and swan), and also presumably for lagoon-based plants, although the use of lagoon-based plants is not recorded in the historic observations or evident in the site archaeology.[57] Other lagoon-based resources, such as eel, are mentioned in historical observations, but as noted by Brown (1991) it is not stated that these resources were eaten or used in some other way. Most lagoons are located in areas with native grassland, and in some cases, such as in the Midlands, in areas of extensive grassland, generally good kangaroo hunting grounds. This indicates that the ability to hunt kangaroo in the immediate hinterland of the lakes and lagoons was also an important drawcard. Other 'near hinterland' resources noted as being important are possums, trees of particularly good quality for spears, and the cider gum (*Eucalyptus gunnii*).[58] These other resources only occur in specific environments (e.g., *E. gunnii* does not occur in the Midlands) or are only mentioned for specific lagoons or lakes (e.g., possums at Lake Dulverton in the Midlands, and spear trees at Arthurs Lake on the Central Plateau). A small number of lagoons in the Midlands, including the Township Lagoon at Tunbridge, are hypersaline, and it is possible (but not established) that these were historically an inland source of salt and for collecting specific salt tolerant plants.

The presence of tool stone sources near specific lakes and lagoons was potentially another factor in determining which lakes and lagoons were most used. This is strongly indicated in the very high percentages of artefacts being made on local stone in all lake and lagoon sites studied to date; and also supported by the correlation of stone tool types at heavily used lakes and lagoons with known quarries in the Midlands. Although in the Midlands all the lagoons and lakes that have been studied have at least one quarry within *c.* 6-7 kms, the lakes and lagoons with large sites and/or high sites densities (i.e., Bells Lagoon, Clarks Lagoon, Crown Lagoon and Lake Dulverton) all have one or more quarries located within 1.5 – 3 kms. It is however difficult to establish a lagoon/lake and quarry relationship confidently at this time as not all tool stone quarries in the study region are known; and, at least in the case of the Midlands, tool stone sources occur relatively abundantly across the landscape.

On the Central Plateau quarries have been identified on the actual margins of two lakes/lagoons (Great Lake (Thomas 1983) and Arthurs Lake (Cosgrove 1984a)), but this seems to be unusual, both on the Central Plateau and more broadly in the study region. Given that the lakes and lagoons on the Central Plateau are frequently located at Jurassic dolerite and Permo-Triassic boundaries (e.g., Laughing Jack Lagoon, Bradys Lake, Lake Echo (Lands Tasmania 2019); *yingina*/Great Lake and Arthurs Lake (Cosgrove 1984a); Lake Crescent (McConnell 2009a); and Lagoon of Islands (this study)) there would seem to be no geological reason that hornfels and possibly quartzite quarries would not exist on additional lagoon and lake edges. The paucity of quarries in direct association with lakes and lagoons, and also rivers, may in Tasmania be primarily, or partly, a cultural factor as suggested by Painter (2001).[59]

[57] Although grindstones are found frequently at the lagoon sites, in Tasmania these are usually small flat ballewinne stones, the use of which is associated with the preparation of ochre, and their presence does not necessarily imply plant grinding.

[58] E. gunnii is not a lagoon specific resource, but is most frequently found in the vicinity of lagoons and marshes, usually occurring as a band at lagoon and lake proximal forest edges.

[59] As suggested by an account by G.A. Robinson (Plomley 208: 942) of visiting a cave and being told by the Aboriginal men he went with that they thought 'he should be washed away by the water because [he] disturbed or displaced the stones in the river', which act they said 'is sure to make the water come'.

Although there is likely to have been a strong seasonal focus of lagoon and lake use given the important seasonal resources such as bird eggs, and to a lesser extent the waterbirds that were known to have been used and that would have been presumably more numerous at particular seasons, the historical observations also suggest that seasonal movement was not a strongly prescribed or a strict annual practice (Ryan 1996). This in turn indicates that what lagoons and lakes were used might vary from year to year and the timing of use might vary, including within a year. Brown (1991) articulated a similar view in his eastern Tasmanian study, noting that seasonal resources such as water birds and birds eggs will be available in a number of locations, both inland and coastal at the same time, allowing people considerable choice in where they obtain these resources at any one time. Brown further notes that taphonomic factors make it extremely difficult to reliably interpret seasonal use from the archaeological record. Brown (1991: 77) also noted that seasonal movements would need to have been modified from year to year 'to compensate for 'low yield' years of resources such as swans' which he demonstraes vary considerably in number over time.

The varied presence of specialised resources at or near particular lakes and lagoons combined with reliable seasonal resources, including staples, being available at most lagoons and lakes,[60] suggests that different lakes and lagoons were visited for particular suites of resources, further suggesting that particular lagoons and lakes were not seen as the only places to be visited, and that people would have visited several different lagoons while in a particular part of the Midlands or Central Plateau to acquire the different resources, much in the way that in a city one generally does not shop at just the one shop, but prefers to visit various specialist shops for the best range or quality of goods. It is also likely that various lagoons and lakes were visited for a range of other reasons, such as to fulfil custodial responsibility, or simply because of personal aesthetics and attachments. These reasons however are not evident in the historical observations or the archaeological evidence, although several of the lakes and lagoons do contain artefactual ochre (and ochre grindstones), indicating that social and possibly ceremonial activities took place at the longer-term lakeside and lagoon edge camps. Smith *et al.* (1996) also propose that site locations on the Central Plateau strongly reflect deliberate selection of well sheltered camping locations.

The lagoons that have been relatively well studied by earlier studies (e.g., Cosgrove 1984a; Kee 1990; McConnell 2009a; Smith *et al.* 1996; Thomas 1983) or by the present study reveal a spread of use around individual lagoons, generally as a number of discrete or semi-continuous activity areas of varying density, but no clear patterning of where sites are located in relation to the lagoon, no patterning of site types at a lagoon, and no patterning within sites, including the extensive low density artefact scatters. This intra-site and lagoon-wide heterogeneity appears ubiquitous throughout the region, with no apparent particular patterning based on lake or lagoon size.

What has become clear from those studies that have surveyed full lagoon and lake edges (Kee 1990 McConnell 2009a; Smith *et al.* 1996; Thomas 1983) is that a spread of sites can be expected around the full lagoon margins. On the Central Plateau, where a number of lagoons and lakes have been fully or largely surveyed, there appears to be some clustering of sites and/or the largest artefact scatters at the northeast end and on the western side in the southern half and, to a lesser extent, at the south end. This pattern is also evident at Bells Lagoon (results this study), but is not evident in the Midlands more generally on the basis of the available evidence (to date Bells Lagoon is the only lake/lagoon to have been fully surveyed).

[60] The widespread nature of lagoon resources is highlighted by the following 1830 description of the Central Plateau to the west of Great Lake – 'the country stretches out in every direction into large open plains watered by various lagoons. ... These sheets of water are universally inhabited by innumerable black swans and ducks, and it is singular, also by the white breasted sea-fowl, or diver ... (Ross 1830: 118).

There is no obvious explanation for this clustering, particularly given that the clustering at each lake or lagoon is not the same (see below). It is possible that the clustering at these locations reflects the preferential selection of camp sites to provide the best shelter from the strongest prevailing winds (i.e., those from the northwest, west and southwest), while still being on the margin of the lagoon or lake. This is consistent with site locations more generally for the Central Plateau, where relatively large numbers of open sites away from lagoons were located on the east, northeast and northern sides of landforms or at the boundary of forests and open areas, and interpreted as providing shelter from the prevailing winds, in particular the strong westerly winds that sweep across the relatively open Central Plateau (Cosgrove 1984a; Smith *et al.* 1996). The preferential location of open sites at forest and plain (heathland or grassland) boundaries was viewed by Cosgrove (1984a: 87) as the most advantageous position for climatic protection and for maximising access to food resources, and consequently as a 'decisive sub-alpine adaptation' required for year round use of the Central Plateau.

The results of the present study and earlier studies (Kee 1990; McConnell 2009b) do however indicate that some lagoon edge landforms are more likely to have evidence of past occupation than others. Those landforms more likely to have had occupation are associated lunettes and sandsheets; easily accessible rock shelters near the lagoon edge; on low rock benches adjacent to the water; on gentle even slopes leading away from the lagoon edge, particularly where these are sandy; in the lee of wind breaking landforms (e.g., ridges and headlands); and on dry ground close to inlet/outlet creeks or backswamp areas. The widespread evidence for artefacts on lagoon edge shorelines, including below natural high water level (Kee 1990; McConnell 2009a; this study) indicates that lagoon and lake beaches were heavily used.

These site-landform associations occur at lakes and lagoons throughout the study region, but the nature of landform use varies from lagoon to lagoon, even when taking into account the local environment of each lagoon. For example, it is only at Great Lake that sites occur in the lee of ridges, promontories and headlands rather than on them (Thomas 1983); Arthurs Lake has little evidence of the use of benches (Stanton 2000); and at Lake Echo sites were only located on rock benches and promontories that defined major embayments (McConnell 2009a). Embayments generally appear to be a lake/lagoon landform that was variably used, at least on the Central Plateau, with few studies specifically commenting on site location relative to embayments and no strong embayment related patterning observed. Although McConnell (2009a) found that there was a strong preferential siting of sites in small to large embayments at Lake Echo, with the large embayments having amongst the largest sites, prior to damming these locations would have been gently sloping valley floor locations rather than lake edge sites, hence Lake Echo is unlikely to reflect a true embayment-site location pattern. The evidence to date therefore points strongly to each water body having its own unique site-landform association signature, and to an absence of widespread strong site-landform associations at lakes and lagoons.

No recognisable patterning of artefacts within the open sites, either with respect to artefact types or densities has been identified, with all open sites being heterogeneous, variable density scatters of stone artefacts suggestive of generalised camping activities or, in the case of the smaller scatters, single activities. Apart from the quarries known on two of the Central Plateau lakes (*yingina*/Great Lake and Arthurs Lake) there is no evidence of specialised use areas on the lagoons and lakes. This, combined with the site-landform associations and the pattern of sites distribution at lagoons, suggests that the key use of the lakes and lagoons in the study region was as camp sites, and that decisions about where to camp were inherently practical decisions related to comfort and resource access, but most likely influenced by personal or social preferences.

The present analysis, with its limited dating and archaeological analysis, is not able however to resolve interpretative issues which relate to the lagoon surface sites being a palimpsest of different occupation

events over time. At each lagoon, as per Bailey (2007) the site evidence would appear to occur both as a cumulative palimpsest due to repeated occupation and the operation of landforming processes and, at the lagoon scale, also a spatial palimpsest with little understanding of the contemporaneity of the use of the different areas of the lagoons. This clearly limits the ability to interpret the long-term history of any particular lagoon. For example, does the concentration of sites at the north-northeast end of lagoons and lakes and at their north east, southwest and south ends reflect different contemporaneous camp site location preferences, or might it reflect different seasonal use, or different patterns of use in different climatic conditions? The presence of concentrated surface scatters of debitage of the one material at some lagoons (e.g., Lagoon of Islands (Jackman 2012; this study)) however gives some confidence that away from areas that have been subject to erosion and reworking, individual sites have some integrity and can indicate discrete activities.

The place of lagoons and lakes within the Aboriginal landscape

Given that the archaeological data indicates that there has been relatively dense occupation of lagoons, and that the historical observations support this and also indicate that various lakes, lagoons, and marshes were on major routes of travel, are all or some of the more important lake and lagoon sites more than small group, base camps focussed on day to day living?

This is a difficult question to answer based on current understandings of what constitutes larger group gathering and camping sites (i.e., aggregation) in Tasmania, sites that would have been used for meetings or gatherings between members of different tribes, generally for social, ceremonial and/or economic (trade) reasons. It is something that has not been particularly explored in Tasmania, with Brown (1986: 101) noting that no 'specifically ceremonial or ritual site' (excluding burials) had been identified at that time in Tasmania.

The presence of large sites or site clusters however has been noted in various, mainly regional, archaeological studies, but they have been primarily regarded as small group, base camp areas in food resource-rich areas (Brown 1986, 1991; Cosgrove 1984a; Kee 1990). These studies mostly regard open sites as either 'transitory' or 'ephemeral' sites representing single, mainly day-time activities by individuals or members of a family group; or 'base camps' that represent long and/or repeated stays by family groups or bands, and which, on the basis of the historical observations, would generally have had associated dwellings (i.e., huts of timber and bark). In relation to the base camps Kee (1990: 62) for example comments that lacustrine-lagoonal environments, the highest site density areas, have 'a wealth of resources available' that would 'enable prolonged occupation'.

Brown's (1986) Southeast Tasmania regional study is one of the few studies to suggest larger sites might have more complex functions, with Brown (1986: 88) commenting that the archaeological rich Coal River Colebrook Park area 'may have been sufficiently rich in resources (especially terrestrial fauna) to support large social or ritual gatherings (of 200 or more people)'. McConnell (1995b), in assessing a particularly extensive (but low density) open inland site with an unusually high percentage of formal tools, also noted the unusual nature of such sites in Tasmania and suggested that these were 'nodes' of occupation and use located where there was an unusually large range of resources and also, generally on major travel routes. McConnell (1995b: 9) also suggested that other nearby sites, particularly local specialised resource sites will all be interrelated through contemporaneous use; observing that 'this interrelationship is extremely important in understanding how Aboriginal people lived historically, and in understanding their links and relationship to the land and the landscape'.

The site being assessed by McConnell (1995b) was on the Orielton Rivulet in coastal southeastern Tasmania. Identified through a road line survey, the site was found to extend for *c.*1 km along the road

(also up valley and near the Rivulet), and potentially to have extended semi-continuously for another kilometre up valley. It was also considered probable (but not tested) that the site, which was located in a headwater valley context at the junction of several headwater tributaries, extended out across the flood plain in this area. The riverine environmental situation, the site clustering (or semi-continuous site spread), and the low artefact density, but very high percentage of formal tools (in this case >40% in the area surveyed), makes this site very similar to the Midlands Blackman River site at the base of the Western Tiers (McConnell 2010).[61] Other than for the Blackman River 'node', known sites on the Central Plateau and in the Midlands that might be considered inland 'nodes' of historical occupation use are Lake Dulverton, Crown Lagoon, Bells Lagoon and Clarks Lagoon (Kee 1990; this study), and on the Central Plateau are Lake MacKenzie, Talinah Lagoon, Lake Augusta (west), Bull Hill, *yingina*/Great Lake, Arthurs Lake, Lagoon of Islands, Laughing Jack Lagoon, and the Clyde River in the Dennistoun area (Cosgrove 1984a; Smith *et al.* 1996; Thomas 1983; this study).

An assessment of the nature of these sites suggests that while these locations can all be considered 'nodes' of regular occupation and use, and important because they have a range of reliable and abundant resources, they did not all potentially operate, and possibly only a small number of these places operated, as larger group aggregation sites.

Although there appear to be no clear archaeological indicators to distinguish between important 'nodes' and aggregation sites, given the purpose and frequency of use of larger group aggregation sites, then potential indicators might be – location on one or more major travel routes used by more than one tribal group; extensive (in order of several hectares or greater) low density sites and/or large clusters of sites (reflecting infrequent use by large numbers of people); presence of artefacts on imported stone (and possibly high percentages of formal tools given limited focus on day to day activities); the presence of ochre and ochre grindstones; and abundant seasonal resources, but not necessarily a wide range of resources. On this basis, only the following locations within the study region would be regarded as larger group aggregation sites – the Eastern Marshes–Hobbs Lagoon area, Lake Dulverton and the Blackman River at the base of the Western Tier. This assessment is based mainly on the archaeological evidence, however the Eastern Marshes is included on the basis of historical reporting of gatherings there of 300-400 people (Shaw 1971, cited in Kee 1990). The archaeological data is insufficiently detailed to identify probable aggregation sites on the Central Plateau.

It is tempting to also include Bells Lagoon and Crown Lagoon into this site type on the basis of their being large sites with very large numbers of artefacts, and also having evidence for the use of ochre. However given that these two locations do not have as extensive or low density occupation evidence, but have archaeological signatures more similar to the other lagoons and lakes (except for Lake Dulverton), we propose that rather than representing large group aggregation sites, Bells Lagoon and Crown Lagoon,[62] along with other lagoons with archaeological evidence of a high level of use, represent one end of the range of base camps, that of long-term to prolonged stays, and repeated stays, by multiple family groups (i.e., various members of a band), as opposed to single family groups,[63] with the longer-term use and

[61] Cosgrove (2015) reports on another similar site [AH9666] which is at the junction of the Mersey and Dasher River, on the northern coastal plains outside the study region.

[62] It should be noted that although Kee (1990) accepts Lourandos' (1970) interpretation of Crown Lagoon as a seasonal base camp, she interprets Bells Lagoon as being only used for short periods of time, suggesting that it is the broader Ellinthorp Plains, with its large number of lagoons in close proximity, that is the 'base camp'.

[63] Aboriginal Tasmanians are understood to have been organised historically at three different levels – the basic 'hearth group' or family group of c.2-11 people that generally formed a single travelling party; the 'band' which was made up of a number of hearth groups, had a recognised territory and usually a recognised leader; and the 'tribe' or 'nation', made up of various bands who collectively had responsibility for a single demarcated area of Tasmania, and had different practices to other tribes or nations (Ryan 1996).

larger group size resulting in a range of activities being undertaken at the site, including with respect to social and cultural practices.

On this basis the Aboriginal landscape of the Central Plateau–Midlands study region might be seen as comprising several levels of archaeologically reflected use[64]:

- single activity sites (e.g., single resource exploitation or use site, meal site or campsite), generally termed transitory or ephemeral sites in the Tasmanian literature (e.g., as per Cosgrove 1984a; Kee 1990; Brown 1991);
- regularly used resource exploitation sites (e.g., larger quarries with associated reduction sites and campsites) (as per Painter 2001);
- base camps which were regularly used or medium to long-term use camping locations, generally by one or a few family groups (e.g., as per Cosgrove 1984a; Kee 1990);
- 'nodes' of use and occupation, in effect very large base camps, which due to abundant reliable local resources were used for extended periods by groups comprising more than one family group up to a band, or members of a number of bands in the one tribe, and which had repeated use (often seasonal) (as per McConnell and Hamilton 2001); and,
- 'large group aggregation sites' where large numbers of people, generally from different bands and tribes, gathered primarily for social, ceremonial and trade reasons

The lagoons and lakes in the study region, and the associated sites, appear to fall generally into the 'base camp' and 'node' use categories, although all base camps will operate as nodes or foci to some extent as they are the point people come back to after undertaking a range of other, usually daily, activities. Standard base camps and the more heavily used nodes however will have different patterns of use, with standard base camps likely to have use patterning related to highly frequent immediate lagoon/lake resource use, frequent near-hinterland resource use, and regular but occasional far-hinterland resource use. They may, or may not, be located on regular travel routes that are used to move from one base camp to another. The nodes, in effect large base camps, will have a similar use to the standard base camps, but will have more complex patterns of use (and hence associated sites) reflecting the use of a greater range of resources and/or more abundant (often seasonal) specialised resources to support the larger groups of people or regular use by large groups of people.

This use of the landscape and the resultant archaeological site distribution and patterning, in particular the nodal pattern, closely resembles the 'meshwork' concept proposed by Ingold (2015) that regards the historical landscapes of nomadic people as being made up of a complex interweaving of lines (conceptual and travelled), with 'knots' where these lines join, recombine, and re-start. It is also generally the pattern of use proposed by both McConnell and Hamilton (2001) and Smith *et al.* (1996) in their studies of the northern Central Plateau and Central Highlands. Using this framework and looking at the landscape as a taskscape (Ingold 1993), the lagoons and lakes in the study region can be seen as knots, with larger more complex knots representing the larger group base camps; the travel between them can be visualised as heavy threads forming a large scale meshwork; and the day to day living related-travel as more numerous, finer threads of the interwoven meshwork.

The complexity of established travel routes (described in section 'Context – Prior Understandings of Traditional Aboriginal Life in Central Plateau and Midlands, and of the Role of Lagoons' above) and described by this model, was recognised by Cosgrove (1984a: 47) who described the Central Plateau routes as 'a sophisticated network of radiating walking tracks across the high plateau'. Cosgrove also

[64] There will be other cultural types of site that are not generally evident archeologically so are not dealt with here (e.g., purely ritual or ceremonial sites, burial sites, places people went for various personal reasons such as enjoyment or to remember events/people or for learning).

provides the following summary description of the travel routes, which is generally supported by the present study's findings. He describes the established routes (or the thicker lines of the meshwork) as 'known trails which negotiated rough country, often intersecting rivers at shallow crossing places or wadeways ... and connecting grassy plains with lakes, lagoons and the coast', and which 'coincided with lines of least resistance, passing through flat plains where game was abundant and the campsites were sheltered but open ...'. Cosgrove (1984a: 47-48) also suggested that, on the Central Plateau at least, the 'network was also an insurance against the capricious weather pattern of the highlands, the tracks enabling a swift return for hunting parties back to base camps'. Thomas (1987) also proposed a similar view in relation to the Central Highlands, but proposed that as well as the 'fast routes (i.e., the established travel routes) there was another type of 'less constrained' route, in effect 'side routes' which when combined created a 'wheels within wheels approach' which allowed 'full play in a system where tribal groups can splinter and coalesce according to resource availability, social obligation and weather constraints' (Thomas 1987: 18). This again comes back to the concept of travel as a complex meshwork on, and in, the landscape.

From the present study it is clear that not all the lagoons, even the more heavily used lagoons, are on major travel routes. This is most evident in the case of Bells Lagoon and Clarke Lagoon on the Ellinthorp Plains where the major routes run 5 kms or more to the north and south of these lagoons, yet these lagoons have amongst the largest sites identified in the Midlands. On the Central Plateau, there are also some lakes and lagoons with major sites that are not known to be linked to a major travel route, for example Lake MacKenzie and Laughing Jack Lagoon. It is unclear why this is the case, but in both cases these lakes/lagoons are in regions for which there are minimal contemporary historical observations. The most likely suggestion is that they were on a major or secondary established travel routes (and this is suggested by McConnell and Hamilton (2001) for Laughing Jack Lagoon), but that for various reasons this information was not conveyed to the historical observers whose records we rely on for this information, hence is lost from the historical record.

The greater Eastern Marshes area also provides an interesting example of one lagoon, Crown Lagoon, that is a very large site and a known stopping place on the major north-south route down the eastern side of the Midlands, while the other lagoons (including Rushy Lagoon) on the same plains appear to have had only small scale, if any, use. In this case the major travel route in fact deviates west to Crown Lagoon, but then instead of following the easiest and most direct route though the plains to the Eastern Marshes proper, the route appears to deviate east 'over stony hills, across deep gullies and through passes in the tiers along steep acclivities over rocks' before heading south then southwest back to the Eastern Marshes proper (Plomley 2008: 523). The rugged deviation is however described as being particularly rich in kangaroo (Plomley 2008).

This strongly indicates that resource availability, and possibly specific resource availability, was in some circumstances a more important factor in determining travel routes than the ease of travel or unvaried lagoon and marsh resources. It is also likely, in a situation where a major route has one particular lagoon, lake or marsh on the travel route, that although the focus of use was that location, travellers in fact regularly or occasionally used the other lagoons and marshes, with the use of a particular lagoon or marsh based on various factors including family ties or tradition, or other personal preferences. This notion of dispersion of use off major travel routes is supported by other the historical observation of use in the eastern Midlands, with several locations within large areas of plain and marsh being used, including in the Windfall Marshes–Mahoneys Sugarloaf area, and on the Saltpan Plains (Constable Anstey and Jorgenson, cited in Kee 1990, Appendix 2: 10-11)).

In relation to explaining the use and role of lagoons and lakes in Tasmania, in particular on the Central Plateau and in the Midlands, the model proposed here is seen as a refinement of the model of short-term

camps or activity sites represented by small open sites, and base camps represented by large open sites with high numbers of artefacts and more diverse artefact assemblages proposed by Cosgrove (1984a) and Kee (1990) for the region. For the Central Plateau, Cosgrove (1984a: 88-89) related the smaller 'ephemeral camps' to places used only in times of optimum weather conditions, and the base camps as being 'around the large shallow lakes of Arthurs and Great Lakes' on the lower eastern edge of the Central Plateau, presumed to have had a less extreme climate. Du Cros (1992: 42) proposed a slightly different model to Cosgrove's for the Central Plateau, suggesting that *yingina*/Great Lake was the major focus of activity, with the smaller lagoons and lakes to the east and west operating as 'satellite' camps which people visited on an intermittent basis, although not attributing particular seasonality to this use.

Collectively, the archaeological studies on the Central Plateau do not support either the seasonally based use model or the satellite site model, but instead suggest a much more complex usage based on a complicated variety of environmental values, and probable social values. Smith *et al.* (1996) and McConnell and Hamilton (2001) also urged caution in interpreting historic Aboriginal land use primarily on the basis of archaeological evidence given the limitations of the surveys on which the present knowledge is based and the need to also factor in non-environmental determinants of site location (i.e., social and cultural factors), and the probability of the present patterning being a palimpsest of different patterns of historic usage over time.

As Ingold (2000: 223) has commented 'the environment within which people find their way about is not … 'a great God-given maze', with all its landmarks, routes, openings and obstructions already laid out in advance. It is rather an immensely variegated terrain of comings and goings, which is continually taking shape around the traveller even as the latter's movements contribute to its formation'.

Land use variability over time

Existing dating demonstrates Aboriginal occupation of Tasmania, both in the north and south, from at least 34,000-40,0000 years ago (Cosgrove 1995; Paton 2010). There has however been considerable uncertainty around the timing of Aboriginal use of the Midlands and Central Plateau-Central Highlands. Although it was considered that the evidence from other areas such as the Mersey valley (Lourandos 1983) and the Franklin valley (Kiernan *et al.* 1983) indicated that Aboriginal Tasmanians had already adapted to sub-alpine living by *c.* 20,000 years ago (Cosgrove 1984a), it was generally held until Cosgrove's (1995) evidence from Parmerpar Meethaner in the Forth Valley that Aboriginal people did not use the high altitude Central Plateau-Central Highlands area until climatic amelioration in the Holocene (i.e., from *c.* 9,000-8,000 years ago) on the basis that the high altitude conditions that existed in this region during the last glacial were too extreme for Aboriginal survival (Cosgrove 1984a; Smith *et al.* 1996).[65]

Due to its altitude and location, the Central Plateau has been significantly modified by glacial processes during the Quaternary (refer Chapter 9), including as recently as the last glacial maximum (LGM) (*c.* 25,000-16,000 years ago and peaking at *c.* 18,000 years ago) when there were small cirque glaciers and glaciers in the major highland drainages (i.e., in the Derwent, Mersey and Forth systems) with evidence of continuous ice cover across the Derwent–Mersey divide, in effect on the western edge of the Central Plateau (Kiernan 1990, 1999).

The present study provides the first direct evidence for late Pleistocene Aboriginal occupation of the Central Plateau, in this case at Lagoon of Islands. This evidence indicates that the Lagoon of Islands was used prior to *c.* 16,000 years BP, then from *c.* 14,000-12,000 years BP, the time by which the Central

[65] Cosgrove (1984: 3) however also hints at a possible slightly earlier entree onto the Central Plateau in his comment 'initial exploitation of the Tasmanian Central Plateau had probably taken place by 9,000 years BP'.

Plateau and Central Highlands are thought to have been deglaciated (Kiernan 1990), and potentially continuously or at least semi-continuously through to the recent past, when traditional use was disrupted by competing colonial land use. This dating is based on an OSL date of 15,800 ± 900 years BP for the present lunette, a probable date *c.* 29,000-14,000 years BP (i.e., during MIS 2) for frost shattering of the local dolerite bedrock, and the geomorphic context of the surface artefact scatters at Lagoon of Islands, as well as on historical observations for the recent date (refer to section, 'Archaeological research results' above and Chapter 9).

This data, together with the evidence from the excavation at Parmerpar Meethaner in the upper Forth Valley which indicated continuous occupation on the edge of the Central Plateau-Central Highlands from *c.* 34,000 years ago, as well as the use of high altitude resources (i.e., resources from the Central Plateau-Central Highlands), including during the late Pleistocene (Cosgrove 1995), and the evidence from ORS7 on the lower Shannon River which indicates occupation of the area immediately south of the Central Plateau by *c.* 31,000 years ago (Cosgrove 1989), provide good evidence for widespread use of the Central Plateau-Central Highlands in the late Pleistocene, at least since the LGM, and possibly earlier. Given that Aboriginal people were using the Central Plateau–Central Highlands in pre-Holocene cold climatic conditions (or even earlier in immediately post-LGM conditions), it seems reasonable to suppose that Aboriginal people continued to use the Central Plateau–Central Highlands during the Holocene when the climate was closer to present, especially given traditional Aboriginal use of the area immediately prior to their forced dispossession in the early 1800s.

It is also argued here that the use of the Central Plateau since the late Pleistocene is likely to have been widespread. Although Jones (1974) suggests that the higher northern Central Plateau was unlikely to have been used at all, this has been disproved by Smith *et al.*'s (1996) survey of this area which located numerous sites, including very large sites at relatively high altitudes (i.e., at 1,000–1,200 m asl). Widespread use is also supported by the relatively similar patterning of sites and nature of sites across the Central Plateau, and now dated sites that provide evidence for Pleistocene use in quite different parts of the Central Plateau (i.e., Parmerpar Meethaner, Lagoon of Islands and ORS7). A particular assumption that has underpinned the view that the Central Plateau was not occupied during the Pleistocene is that there were insufficient staple foods available throughout the year to support this occupation. This assumption however has also been shown to be incorrect (Cosgrove 1984a; Smith *et al.* 1996).

Broad based use of the Central Plateau in the late Pleistocene, in alpine conditions which included glaciers, is further supported by studies elsewhere, in particular Benedict's (1981) study of the Fourth of July Valley in the USA, which found that rather than being disadvantaged by conditions in areas with ice fields in the last glacial period, indigenous people have found advantages in these areas, in particular increased grassland and grassland/woodland ecotone resources, reliable water at glacier margins, and greater accessibility due to reduced forest. Smith *et al.* (1996: 13) also suggested the possibility of hunting in glacier edge 'alpine grasslands', although more in the form of occasional forays onto the Central Plateau, rather than as part of semi-permanent occupation of the Central Plateau. They support this view by citing Cosgrove's (1989: 1708) conclusion that 'people were less concerned with extreme climatic conditions and more intent on the systematic exploitation of a range of environments economically important to them', and, we would argue, also concerned with cultural maintenance of the environment. McConnell and Hamilton (2001) also argued that Pleistocene occupation of the Central Plateau was likely given the limited extent of actual glaciation, and further argued that glacial conditions may have assisted this, suggesting that short glacier crossings such as at the Derwent–Mersey/Forth divide, particularly if snow covered, may have provided more rapid and direct passage from northern Tasmania onto the Central Plateau and to the south of Tasmania, than during warmer periods.

The project however has not been able to provide new information on the Aboriginal occupation and use of the Midlands. The earliest evidence for Aboriginal use of the Midlands continues to be *c.* 5,000-4,500 years BP to present, based on maximum dates of 4,860+/-96 years BP from Crown Lagoon (Lourandos 1970) and 4,540+/-410 years BP from Bells Lagoon (Kee 1990), with evidence that Aboriginal occupation continued up until the early 1800s when the Aboriginal people were dispossessed by European land settlement.

It is argued here that the dating in the Midlands, which is limited to the two sites above, remains inadequate for understanding the history of Aboriginal occupation and use of the Midlands. The existing dating, which comes from only two lagoon sites and, in both cases from the youngest lunette units at these lagoons, is considered inadequate for understanding the Holocene, in particular the early Holocene, Aboriginal occupation of the Midlands. Greater investigation of older units and of additional sites would appear to be needed to address this.

It is relevant here that the only other dates from inland freshwater lagoons in Tasmania are from Rushy Lagoon in northeast Tasmania (Cosgrove 1985) and Lagoon of Islands on the Central Plateau (this study, refer Chapter 9), both sites indicating much earlier Aboriginal use of inland lagoons. Dated cultural deposits in the Rushy Lagoon lunette gave an age of 8,300 +/-80 years BP in the most recent lunette, and it was postulated that the surface scatters may represent late Pleistocene occupation given their geomorphic context (Cosgrove 1985). At Lagoon of Islands artefact scatters in a similar geomorphic context to those at Rushy Lagoon are considered likely to reflect Aboriginal use since at least *c.* 16,000 years BP based on their context and dating of the lunette sediments (refer above and Chapter 9).

Based on this evidence and evidence of a range of occupation dates in Tasmania, including evidence for Aboriginal occupation since *c.* 30,000-34,000 years BP to the northwest, southwest and south of the Midlands (refer Section 10.2 it is considered that Aboriginal occupation of the Midlands may also date to at least the LGM, and probably earlier. Again, more dating of Midlands' sites is required to test this. As the older aeolian units have to date only been investigated by limited coring or test pits at two Midlands sites and one Central Plateau site (Sigleo 1978; this study (refer Chapter 9)) further examination of the older units in particular would appear warranted. Also, since lagoons are likely to have been dry and hence not resource-rich during the drier colder periods, and the lunettes, which have provided the only dates thus far, form predominantly in these periods and are highly erodible environments, it is likely that older dates will more likely be found in environments other than lunettes.

One of the intentions of the present study in examining lakes and lagoons in the Midlands and on the Central Plateau was to explore possible differences in use, hence Aboriginal land use, between the two regions with their different environments. The results of the present study however suggest that although the actual plant and animal subsistence resources and nearby specialised resources may have been different, the lakes and lagoons in both environments were used similarly. In both regions the pattern of use at a lake or lagoon, and at the landscape scale appears similar with a range of environments at individual lakes/lagoons being used and showing similar local environment preferences. At the regional scale, it appears that most lakes and lagoons were used to some extent, with those on travel routes, or with more abundant or varied resources being used to a greater extent, as is evident in the large numbers of sites and/or site clustering at these lakes/lagoons. In both regions the historical data suggests that marshes, at least on established travel routes appear to have had a similar importance to lakes and lagoons, i.e., as base camps, although there has not been sufficient archaeological investigation of marshes to confirm this.[66]

[66] Although there has been some survey of marsh areas in inland eastern Tasmania (e.g., Brown 1991; du Cros 1992; Cosgrove 1984; Kee 1987; Ross *et al.* 1993), ground surface visibility has been too poor to locate sites.

Two regional differences have been noted however, but these are minor. One difference is the slightly different proportions of different tool stone in the artefact assemblages. On the Central Plateau, artefacts in sites are dominantly of hornfels, but a range of other stone is used including quartzite (generally a non-contact metamorphic type) and silcrete, and more minor quartz and chert, reflecting a predominant use of locally available tool stone, but with differing availability of local stone. The stone present in Central Plateau lake/lagoon sites however also indicate some importation of stone from beyond the Central Plateau to the west and northwest, and from the Midlands to the east, probably due to the more limited range of types of tool stone available on the Plateau. Artefacts in Midlands' sites are also dominantly hornfels with a similar range of stone being used, however silcrete and quartzite (both the contact metamorphic type and non-contact metamorphic types) are the most common minor stone types used, while cherts and quartz are relatively rare. The Midlands sites also show very little evidence of imported material, presumably because of the wide range of stone types that are locally available.[67] Dominant local use of tool stone however seems to be a cross-Tasmania feature, with Cosgrove (2000: 195) commenting 'In Tasmania exotic lithic materials rarely travelled in large quantities over large distances although people did'.

The other difference noted between the two regions is that although both regions have a number of large sites, the extremely extensive (but low density) sites with very high percentage of formal tools, which have been interpreted as aggregation sites, to date have only been located in the Midlands and not on the Central Plateau. If this is a real difference[68], it might be because of the greater resource abundance at these Midlands locations than is found on the Central Plateau. The location of these Midlands sites approximately half way between the east coast and the Central Plateau and close to the boundary of three different tribes however suggests that centrality and ease of access for diverse groups may have been equally as important as abundant resource availability in determining the location of major, inter-tribal gatherings.

Implications for heritage management

Not only does this lagoon focussed review provide a clearer picture of the historical Aboriginal landscape of the Central Plateau and Midlands, but the findings also assist cultural heritage management. This is primarily in relation to establishing the sensitivity of the Central Plateau and Midlands sites to enable better protection when new developments are proposed.

To date in Tasmania approaches to sensitivity assessment (or, site predictive assessment) have taken a strongly environmental deterministic approach based on relatively broad environmental parameters such as distance to water, slope, bedrock geology, or location at forest-heath/grassland interfaces (e.g., Brown 1986; Brown 1991; Cosgrove 1984a; Kee 1990, 1991; McConnell 1995a, 2009b; Smith *et al.* 1996).[69] This to some extent reflects what is possible given the quality and coverage of the available archaeological and historic data. The value of the present study is that it has been able to bring together

[67] Some importation is likely to be hidden unless artefacts can be matched to stone sources as has been shown through Theys *et al.*'s (2019) chemical analysis of artefactual hornfels in the Midlands. Although demonstrating the dominant use of very local materials, the study demonstrates that there is a small amount of importation of hornfels of up to 73 km within region (including to other quarries) and to the east coast. Interestingly, the lines of connection of this importation correlate closely with the southern Midlands historical routes of travel.

[68] This difference may not be real, and may instead reflect inadequate survey. This however is considered unlikely given the relatively large amount of survey that has been conducted on the Central Plateau.

[69] Some of these studies (e.g., McConnell 1995a; Smith *et al.* 1996) have noted that social factors, not only environmental factors will play a role, but have not been able to include this in the assessments other than superficially because of a lack of information on how the social factors operate. To date it is mainly travel routes that have been included and then only at a general level, for example identifying 'nodes of historical travel' as high potential sensitivity (McConnell 2009b: 23) or mapping known historic routes of travel (McConnell 1995a). McConnell (1995a) also included known historic Aboriginal places and areas

a greater body of data for lakes and lagoons and look at the archaeology of this environmental type in detail.

Firstly, the understanding the role of lagoons and lakes in the Aboriginal landscape gained from the present study clearly indicates that established Aboriginal travel routes will have high sensitivity for archaeological sites that reflect this large scale landscape use, at least for the Central Plateau and Midlands. The apparent importance of food and other more specialised resources along these travel routes indicates that these routes, and associated places, may also be important locations of traditional Aboriginal resources (assuming these have not been heavily disturbed), hence have Aboriginal landscape values, as well as being indicators of higher densities of sites and larger, more complex sites. Lagoons, lakes and river margins in grassland or marshy areas on these routes are likely to be of very high sensitivity for archaeological sites.

Secondly, as all lakes and lagoons surveyed (which also have had some ground surface visibility) have been found to have associated Aboriginal archaeological evidence, lakes and lagoons can be regarded as being of high sensitivity for Aboriginal archaeological sites. Lakes and lagoons have demonstrated higher densities of sites than most other inland environments (McConnell 2009b; this study) and, similarly to sand sheets and a small number of less predictable locations,[70] have the largest inland sites and the most complex sites other than at major quarries. Lake and lagoon sites also have artefactually rich and variable sites, and include relatively rare stratified sites. Similarly to established travel routes, lakes and lagoons that retain areas of remnant native vegetation may have Aboriginal landscape values as important locations of traditional Aboriginal resources. Not all lakes and lagoons however have the same sensitivity. The findings of this study indicate that the larger lakes and lagoons, as well as lakes/lagoons on established travel routes, generally have the higher densities of sites and larger sites. Also, care should be taken not to rule out lakes and lagoons with seemingly inhospitable environments, with the Tunbridge Township lagoon demonstrating that there is occupation evidence even at hypersaline lakes (possibly reflecting specialised saline lagoon resource use).

Thirdly, the findings of the present study indicate that Aboriginal archaeological evidence will potentially be found around the full margin of lakes and lagoons. Sandy beaches and gentle slopes into the water have been found to most consistently to have surface artefacts. Comparison of low and high water level full lagoon/lake surveys at Bells Lagoon and at Lake Crescent (Kee 1990; McConnell 2009a; Thomas and Associates 1986; this study) indicate that surface artefacts can extend well out onto the lake bed (original low watermark) and are not constrained to above high watermark. Sand sheets, even where low lying, also appear to be high sensitivity environments for surface artefacts.

Lunettes, which have been generally regarded as the main lake or lagoon environment in which sites will occur, however have been found in this study to only contain very sparse surface artefacts. Lagoon of Islands and Bells Lagoon are good examples of this, as also is Wet Marsh on the East Coast (McConnell and Stanton 1997). The exception is eroded situations along the foreshore, where dense lag deposits of artefacts may occur. It is possible that in many of these cases the artefacts were originally deposited on sandy beaches or in sandy back dune areas, but have been reworked as the lunettes have formed and/or migrated. This appears to be very much the case at Lagoon of Islands, and is possibly the case at Bells Lagoon. In some cases, such as at Brumbys Creek on the northeast edge of the Midlands, no sites appear to occur on riverine source bordering dunes, even where there is good ground visibility (McConnell *et al.* 2001). In this case McConnell *et al.* concluded that the reason was likely to be that the area was relatively

of especial significance to the Aboriginal community, however very few zones of these types were mapped since the predictive zoning applied only to forested areas.

[70] I.e., the Midlands Blackman River headwaters site (McConnell 2010) and the Bull Hill site on the Central Plateau (Smith *et al.* 1996).

inaccessible and resource poor scrubland and the focus of occupation was instead transferred to the riverine margins of the larger, nearby rivers.

Other than for the above, the available site data for lakes and lagoons does not allow for reliable predictive assessment of sites at the landform level. The findings of the present study indicate that while there are other preferred landform situations and micro-environments, they may, or may not, be used from one lagoon to another. The existing data suggests that the northeast end and west-southwest-south margin of lakes and lagoons were preferentially used historically hence will be most sensitive for sites, but they will not be the only parts of a lake or lagoon edge with site evidence.

Finally, the findings of this regional study generally reinforce the findings of McConnell's (2009b) analysis of predictive approaches to impoundment areas of the Central Plateau (which also incorporated the other lake and lagoon studies for the Central Plateau). This correlation suggests that there is patterned and predictable use of lakes and lagoons, and the current understanding of this can generate a predictive assessment that gives a relatively high level of confidence, at least at the regional and sub-regional levels.

A key element of the approach recommended by McConnell (2009b) was the importance in predictive assessment of taking into account what appear to be different levels of site patterning, with the different levels reflecting different scale (resulting from different use) sites. McConnell (2009b: 33) proposed the following five levels of site patterning:

- a generalised regional pattern (based on universal needs/aspirations for shelter and resources);
- subregional patterns (due to coarse grained environmental and/or social differences);
- a regional pattern (network) of large sites and key resources,
- local area patterns that relate to the regional network pattern (i.e., with smaller sites patterned around key sites and resources);
- a local environmental pattern that is determined by micro-environmental variation (e.g., while sites may be concentrated around a lake edge, the pattern around the lake edge will vary due to variable environmental factors such as slope, sediments/soil, geology, aspect, other freshwater sources).

The results of the present study support the existence of multi-level site patterning, and a similar patterning as recognised by McConnell (2009b). The findings of the present study also indicate that where these multi-level patterns occur in landscapes in which lakes and lagoons provide important resources, lakes and lagoons will be a significant element at some levels of site patterning.

The findings of the present study also reinforce the importance of other matters that McConnell (2009b: 33) saw as critical for reliable predictive assessment, in particular that:

- understanding, to the extent possible, the historical land use patterns and changes in environmental conditions is important; and.
- understanding the pre-inundation environment and using this knowledge as a basis for describing and assessing the landscape context of sites is of critical importance.

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Chapter 11:
The Tasmanian and New England Research in a Global Setting

Wendy Beck and Robert Haworth

Introduction: Goals of the Project

This project aims were to investigate lagoon heritage and to increase opportunities for Aboriginal people to partner researchers in educational settings. The general goals were:

1) To establish whether archaeological research into ancient landscapes could contribute to the theory and practice of community heritage engagement and help 'close the gap' in Aboriginal higher education by using Fraser's ideas (2001) about the 'politics of recognition' as well as work integrated learning.

2) To undertake a comparative landscape archaeology of the Tasmanian Midlands region and the New England Tableland region, focussing on lagoons and lunettes, to see whether the apparent sparsity of Aboriginal occupation in the environmentally similar regions of the NSW New England Tableland and the Tasmanian Midlands is due to the paucity of archaeological fieldwork or to other factors. What was the mode of the occupation in these areas: was it permanent, transitory or perhaps an alternating pattern of the two affected by climatic and social conditions?

Part 1: Community Engagement

Community engagement in Indigenous archaeology has been steadily increasing world wide, particularly since the early 2000s (Li *et al.* 2020). However, critiques of the process of this engagement still concentrate on how archaeologists use a 'deficit' model of communities (Fredheim 2020) and that more sophisticated cross-cultural understandings are needed (Menzies and Wilson 2020). Wylie (2019) provides the most comprehensive critique of community archaeology in terms of its goals, its viability, how to do it well, and whether it makes a break from traditional 'extractive' archaeology. She divides general critiques into three types:1) archaeologists' practice engaging with social activism not only in communities, but also within their own institutions; 2) archaeology being complicit in the systems of oppression 3) multiple ways to do collaborative practice where the focus should be on the quality of the process not the product.

> The hope, courage, compassion, and solidarity of commitment to an "ethic of human emancipation" require radically different tools, ones grounded in a stance of epistemic and political humility that take a recognition of uncertainty and the need for situationally tuned and responsive engagement as their point of departure (Wylie 2019: 284)

The role of community based field schools in Indigenous archaeology has been assessed in both Australian contexts (May *et al.*, 2017, Smith *et al.* 2021) and others (Cipolla and Quin 2016, Gonazalez and Edwards 2020, Schmidt 2014). Field schools like ours are seen to have positive effects such as building cross-cultural understandings and relationships which can lead to changes in the way that archaeology is taught as well as capacity building by all. As well as challenges such as clashes between expectations and differences between European and other ways of knowing and being.

This project encouraged community engagement and education with Aboriginal NSW and Tasmania. The diversity of views within all the communities, both archaeological and Aboriginal provided many participants with examples of social activism. In most Australian projects Aboriginal people are involved in commercial archaeology but this project was about archaeological research rather than site management or the legalistic aspects of the work. In this sense we hoped to make archaeological ideas more creative and less constrained, but at the same time allowing for technical training, which might be useful for further study or for work as paid commercial heritage workers. We also tried to demystify the University as an institution, by staying in accommodation on campus and by visiting other parts such as the Historical Archives and the library, as well as working in teams with undergraduate students. We tried to encourage the community to consider that they could take over as Indigenous archaeologists in the future. Community Elders participated fully in the project: they were equal partners in the team during research fieldwork and training. However, Aboriginal organisations were given the opportunity not to participate if they so wished. Knowledge holders and scientists were both valued, and we were able to take field trips, such rock art site visits or historical site visits, where the Elders' knowledge was paramount. We see this as falling within Fraser's 'politics of recognition' for social justice (Smith 2010). As well, all the participants were paid for their time, which allowed for a more democratic approach to field training. The Aboriginal people we worked with talked about the benefits of the project in terms of training and increased work opportunities for them and for passing their knowledge onto the next generation. The researchers were challenged to rethink their 'expert' identities (Smith 2010), especially when working in Tasmania, where a moratorium on archaeological excavation was in place during our field work (Price 2017). Tasmanian communities have a long and strong history of fighting for sovereignty and their cultural heritage (Mansell 2016). Questioning the researchers (as well as the community) is an aspect of community work that we would emphasise more in future projects. In addition, more time spent on discussing Aboriginal pedagogy would be productive.

Because the project took place over a four-year period, with three field schools and then several excavations, we felt that the partnership with the community came from a place of mutual understanding and negotiated processes. Living and working on regional lands together also helped to cement the relevance of the project to local life. Progress in community heritage engagement is hard to achieve rapidly, especially given the political realities. In eastern Australia, the number of funded research projects is very small compared with the numbers of short-term commercial projects. There is little opportunity for most archaeologists to carry out lasting work in Aboriginal communities. In longer-term research, however, some of the advantages of community archaeology are intangible and so as not easily measured as dollars or hours. In our project, we felt that good-will was visible throughout and a real agreement to partner in research was sustained on both sides.

This project makes a very small contribution to addressing the complex interplay of social, economic, educational, and cultural factors resulting from White colonisation that create barriers to Aboriginal communities playing a greater role in the cultural, economic and social life of the study regions. Inequities of status between academic researchers and Aboriginal people remain and remain to be considered further in future projects. Following community-outlined goals for heritage and higher education studies, groups of Aboriginal young people from eastern Australia successfully participated in work integrated learning at their heritage places, where Indigenous knowledge and scientific knowledge were valued jointly between Elders and academics.

The design and operation of our research provided opportunities to outline a contemporary, practical vision of heritage education which can be linked to caring for the land, potentially joining the future of heritage management to the future social and economic health of the region. Realistically, the future of heritage management lies in the commercial archaeological surveys and excavations which the students

will be a part of. In our project all participants in partnership added to creating new knowledges about ancient landscapes in eastern Australia.

The definition of 'landscape' used here is that of Johnson, who defines landscape as a 'way of seeing, a way of thinking about the physical world' (Johnson 2007: 4). Equally significantly, participants have been able to assert their presence, and the ongoing presence of their people over thousands of years, in landscapes from which colonists have historically erased them (McKenna 2002: 205). Simply describing the physical realities alone is not enough to explain landscape. As Johnson goes on to say 'For the indigenous peoples of Australia, for example, the notion of distinction between a process of living in the world and one's spiritual or emotional preconceptions about it is a quite alien concept' (Johnson 2007:4). Similarly, Schama (1995: 3-5) notes that we comprehend personal and social identity through awareness of the past and our construction of the physical world as landscape, mediated through memory, tradition and history.

The next section of the chapter addresses the second aim of the project to investigate the archaeology and geomorphology of the lagoons in New England and Tasmania.

Part 2: Landscape Archaeology and Geomorphology

This book has collected the results of investigations into ancient wetlands of the lagoon/lunette type in two regions, the New England (Northern Tablelands) region of NSW and the Northern Midlands of Tasmania. While the two are at opposite ends of the 'fertile crescent' of south-east Australia, they have similar dry, relatively cool climates, with open woodland environments and important wetlands. Also, little detailed archaeological study has been done in either area since the 1980s.

The key theme was 'ancient wetlands': wetlands because water is always central to human activity, and ancient because lagoon/lunette systems can establish and reproduce themselves over extended cycles of climatic change. In this specific landform we can trace change far back over time, with radio-isotopic decay schedules, into the glacial epoch. This special type of wetland is scattered throughout the two regions. Its biological diversity is centred on a ponded area with concentric zones of vegetation shifting with the seasons (Bell *et al.* 2008) and accumulative sand or clay landforms known as lunettes formed by wind or current on their lee shores. These closed basin water bodies contrast with hydrologically open wetlands in the same region which often take the form of mires, bogs and fens (Hunter 2013), the lagoons being mainly on basalt or other volcanic lithology, while the open wetlands are generally on granite. The erosion products of basalt which include heavy clays and duricrusts tend to impede drainage and retain sediments in an already low relief landscape, while granite is more likely to produce sandy sediments that allow a free flow of water and detritus. The open wetlands may frequently shift down valley with major weather events or climatic changes. In contrast, the closed basin wetlands can be truly ancient, as they can persist over great lengths of time preserving a record of their accretion and associated fauna and flora. Hence the term 'ancient wetlands', on which this research is founded.

Global Lunettes

Lunettes, so named because of their crescentic 'new moon' shape, are a minor sub-type of the large assemblage of potential dune forms (Bagnold 1941; Goudie 2013), distinguished from more mobile dunes by their fixed position on the lee shores of lakes, ponds, and pans. The so-called lakes are usually intermittently dry ponded features less than one metre deep, most often referred to in our study area as 'lagoons'. Their shape is usually ovoid, with wave cut shores on the windward side and accumulation of dunes on the lee shore, accentuated both by prevailing winds and a clockwise lake current circulation determined by global coriolis effects.

It is the interaction with water bodies that mark lunettes as one of a kind, as they make up a special hybrid landform of lagoon/lunette that has complex interactions with all levels of climatic and environmental change. However, they are sufficiently small to contain and preserve a concentrated imprint of any human or other faunal activity. These lagoon/lunette systems contain not one but two separate sediment stores capable of recording past events, one in the accretions of the lunette itself and the other in the silts and detritus of the adjacent ponded basin (Bowen *et al.* 2018).

What we refer to as lagoon-lunette systems occur on all continents in similar geomorphic locations, but they occur in greatest number in areas of aridity and have been most extensively studied as features of the arid environment, where those performing the research tend to refer to the associated ephemeral water bodies as 'pans' or 'playas' (for instance, Goudie and Thomas 1986; Goudie and Wells 1995; Holmes 2015). They are particularly prevalent in southern Africa (Holmes *et al.* 2008), the Patagonian plateau in Argentina and the Andes (Sitzia *et al.* 2019), the plateaus of northern Mexico, and Kazakhistan in Central Asia (Goudie and Wells 1995) as well as the High Plains of the central USA (Bowen *et al.* 2018, Matsuda 2021). It is not that these researchers reject the notion that lagoon-lunette systems exist in non-arid zones, it is just that the overwhelming majority exist in deserts and semi-deserts, both in Australia and the world. Those situated in more humid areas are regarded as outliers and are little studied. As a result, people who do study them tend not to use the terminology associated with arid landforms, and instead use the descriptive terms in use in the local research areas.

One interesting comparison is from the upper coastal plain of South Carolina, where lagoon-lunette systems in a similar climate and latitude to ours are referred to as 'Carolina Bays'. These several hundred 'ponds and wetlands...occur in shallow ellipsoidal depressions, usually without apparent surface inlet or outlet on undissected land surfaces...from southeast New Jersey to northeast Florida' in upland landscapes (Brooks *et al.* 1996, 482). They are associated with sandy rims on their downwind sides, apparently equivalent to our lunettes and like ours, the lunettes appeared to have accreted slowly in sub-humid conditions which prevailed even in the Last Glacial Maximum. The hydrological regime has also changed markedly over time between permanent and temporary wetlands, especially in the last 3000 years. Their formation age range and size variation are similar to our project sample. Based on extensive sub surface sampling, the archaeological sites show that the most intensive occupation was during the early and mid Holocene, with subsequent use being ephemeral (Brooks *et al.* 2010). However, as with our sample, some Bays 'were little utilised' (Brooks *et al.* 2010: 158). The later use pattern is thought to be due to large riverine wetlands forming at the same time, together with more sedentary groups.

Lunettes in Australia

Lagoon/lunette systems are usually associated with semi-arid environments, and where they exist in sub-humid conditions today climatic change is often invoked to explain their presence. However, semi-aridity is not a necessary condition, it simply amplifies the presence of necessary materials and processes, such as sand and wind, which may be available in non-arid areas, such as coastal dune systems. In our case many of the sites are presently in sub-humid zones, and even in the extremes of the last glacial maximum the New South Wales sites tended to have positive water balances (Ellerton *et al.* 2017; Slee and Shulmeister 2015). However, moisture at these high altitudes in glacial ages would be most likely to take the form of frost and snow in bleak and windy sub-alpine herbfields (Galloway 1965, Williams *et al.* 2006).

The great majority of lunette features accompanying water bodies in Australia are on the semi-arid inland plains and have long featured in archaeological and geomorphic research (Mitchell 1838, Bowler 1983). Those that have formed on the terminal lakes of the inland plains tend to be massive, fed as they

are by distributary streams hundreds of kilometres long carrying regular seasonal moisture of snow melt (for instance Lake Mungo in southern New South Wales) or monsoonal rains (Narran Lakes in northern New South Wales). The Willandra Lakes system of which Lake Mungo is part have lunettes up to 30 km long and evidence of intensive Aboriginal occupation from before the LGM down to the present (Fitzsimmons *et al.* 2019). Less attention has been paid to the much smaller, seemingly anomalous lagoons in more humid regions of the eastern highlands in both the mainland and Tasmania. These are particularly widespread in the tableland areas of New England in the north (Bell *et al.* 2008) and the south of Canberra (Pillans and Walker 1995), as well as central Tasmania. These lagoon/lunette systems are found all over the world in similar upland locations, usually on the drier side of tablelands such as the South African high veldt, typical of the tectonically uplifted blocks with subdued relief which develop parallel to passive continental margins (Ollier 1978).

Discussion: archaeology

The archaeological findings in New England, reinforce much of what has been surmised previously. The overall density of sites in New England is low: between three and four square kilometre and the surface site size is also low – on average less than 20 artefacts/site (Godwin 1990, Desic 2018). The densest excavated assemblages are at rock shelters and axe grinding groove sites. There are similar assemblages at the lagoon sites and those away from lagoons, although that the lagoon assemblages usually cover a smaller in area and have fewer artefacts. One suggestion that could account for the small site size at lagoons is that the major tools used for lagoon resource are nets and wooden tools, rather than stone tools (Godwin 1990). As the lagoons are only a metre or so deep when full, and with high evaporation rates, they may dry out within weeks but even the largest lagoons still retain subsurface water (Beck *et al.* 2015), When they are partly full the lagoons are rich in plant and animal resources (Beck *et al.* 2015), which are different to those in streams.

The site patterning around lagoons is very like the low artefact densities found at high altitudes in the southern uplands of NSW (see Chapter 7). The New England data, so far, only indicate one sure early Holocene age for human occupation on the high Tableland, while by comparison the significance of the occupation of humans is etched in a multitude of mid-late Holocene sites. This project has provided a revised benchmark for subsistence activity and ceremonial infrastructure that could be related to lagoons and other water sources for continuing occupation, from the early Holocene to the time of European settlement (Beck *et al.* 2015).

This paucity of visible early sites in New England, in comparison to Tasmania, throws into relief the attraction for humans in eastern mainland Australia for the rich aquatic resources of the neighbouring lowland provinces on the big western rivers. This would have been especially marked during the last glacial maximum. The positive water balance on the high tableland in the LGM (Ellerton *et al.* 2017) produced river runoff that made the otherwise arid downstream region to the west a major refugia for humans (Williams *et al.* 2013). In contrast, adequate water alone (often in the form of ice or snowpack) was not enough to make the uplands attractive, especially given that there were few endemic Australian river fish species adapted to cooler waters.

The archaeology of the Tasmanian Central Midlands represents a sharp contrast. The first direct The archaeology of the Tasmanian Central Plateau represents a sharp contrast. The first direct evidence was found for pre-Holocene Aboriginal use of the climatically challenging Tasmanian Central Plateau, thus supporting Cosgrove's research in some of the valleys that drain it, such as the nearby Parapar Meethana site (Cosgrove 1989). Presumably there were sufficient resources to justify occupation of this icy and partially glaciated highland in the depths of the Last Glacial Maximum. There was no nearby climatically benign region to act as a refugia, as in northern New South Wales, but rather the Tasmanian

lower Midlands to the east appeared to tend towards extreme aridity with little input from snowmelt as in similar locations on the mainland.

However, both the Central Plateau and the Midlands were used throughout glacial times, and there appears to have been no real difference between the use of lagoons in the Tasmanian Midlands and the Central Plateau. There appears to be a more significant difference occurring between different lagoons within these regions, though overall lakes, lagoons and marshes appeared to have a similar use.

Understanding the role of lagoons and lakes in the Tasmanian Aboriginal landscape clearly indicates that established Aboriginal travel routes around the lagoons will reflect large scale landscape use, at least for the Central Plateau and Midlands. All lakes and lagoons surveyed with some ground surface visibility have been found to have associated Aboriginal archaeological evidence. Unlike New England large stone artefact scatters are found around the lagoons, and the density of sites is up to 90/sq. km. Lakes and lagoons have demonstrated higher densities of sites than most other inland environments (McConnell 2009b; Chapter 10, this volume).

In both the New England Tableland and central Tasmania the human use of lakes and lagoons was related primarily to small scale resource use, although they could be related to aggregation sites close by. For an example in New England, the Barley Field Lagoon, Uralla, was perhaps not coincidentally close to an historical aggregation site (MacDonald 1845). It was also close to pathways that could quickly connect people to the eastern coast, the inland western rivers and the fertile Liverpool Plains region to the south, and adjacent to an area rich in rock art at the southern end of the Tableland. Even here, the oldest site in the study, the ages of occupation of this small sample did not seem to go beyond the early Holocene (See Chapter 7).

A similar contrast is present in Tasmania where, as mentioned earlier, despite the cold conditions LGM ages are associated with Aboriginal artefacts in the partially glaciated and higher Central Plateau. However, there was an absence of any sign of human occupation in the lower Midland sites until the mid-Holocene. Apart from intense LGM cold in both Tasmania and the mainland (though colder in northern New South Wales with a drop of 10.5^0 C from present as opposed to 5^0 C in Tasmania) (Slee and Shulmeister 2015), the northern Midlands, at the Bells Lagoon site, displayed greater aridity during the LGM. This suggests that the northern part of the Tasmanian Midlands, because it was adjacent to an exposed land surface in what is now Bass Strait, was the southernmost extension of the Australia-wide continental arid desert regime during and around the LGM. However, the higher Central Plateau with its colder temperatures and therefore lower evaporation rates appears to have a more positive moisture balance. This was also one of the features of the New England Tableland in the LGM (Slee and Shulmeister 2013, Ellerton *et al.* 2017). Because it suffered the extremes of cold caused by both high altitude and greater continentality, it experienced a positive water balance especially in the form of greater snowpack (Reinfelds *et al.* 2014). The effect of seasonal snow melt on the high country feeding the inland streams enhanced the capacity of the adjacent but more arid lowlands to offer refugia for humans in the depths of glacial conditions climatic (Williams *et al.* 2013). This advantage may have persisted until warmer and wetter Holocene conditions overall lessened the contrast between highland and lowland in northern New South Wales.

Although there are differences between the New England and the Tasmanian sites, in both regions the resources available to people camping in the past would be very similar- stone sources, waterfowl, eels, and water plants, together with the nearby resources such as possums and kangaroos. The unique factors forming and maintaining the lagoons suggest that each should be studied individually.

Discussion: geomorphology

The investigation into the lunette geomorphology of both New England and Tasmania produced the first comprehensive (that is, in a sample of lagoons across the Tableland) long-term dating of lunettes and other dunal features, and by implication their associated lagoons, to be carried out in upland Australia.

OSL ages in both Tasmania (oldest age 50.5+/-4.3 ka for Lake Tiberias) and northern New South Wales (72.6 +/- 7.3 ka for Lake Llangothlin) for lunettes and dunes point to formation of some of these features long before the Last Glacial Maximum and its extreme conditions usually associated with drying and aridity. They also indicate that the accompanying ponds and lakes were extant at least by the time of human arrival in Australia after 65,000 years BP and Tasmania after 50,000 years BP. By and large lunette sites in Tasmania show evidence of greater mobility and disruption during the LGM, whereas the sites in New England display formation dates over a wider and usually older age range, suggesting local rather that regional forcing. The exceptional conditions illustrated by large dust strata at Lake Llangothlin northern dune point to some disruptive factor between 60,000 and 70,000 years BP, which does not seem to correlate with climatic conditions (Williams *et al.* 2006). Whether unknown cultural or ecological factors were responsible is open to speculation. These ages seem to broadly correlate with the beginning of the process of megafauna extinction around 60,000 years ago (Johnson 2006), as well as the first appearance of humans (Clarkson *et al.* 2017).

Conclusions

The overall comparison between Tasmania and northern New South Wales shows that lagoons and lunettes in New England Tableland were more variable in formation date than Tasmania. Tasmanian lunettes seemed to result from what were probably climatically disrupted conditions in the LGM. Tasmania appears to be drier during the LGM, perhaps forming part of the southernmost extension of the Australian LGM arid zone, if the results from Bells Lagoon and lunette are a reliable indicator. New England was cooler than Tasmania but with a better water balance, and formation of lunettes was spread over a much longer time span, around the LGM in parts of the Llangothlin lakes, over 48,000 years ago in two of the more southern Uralla lagoons, and well before 70,000 years ago for the dune in the north of Llangothlin lake.

The archaeological evidence appears to be much older in Tasmania than New England, going well back into the Pleistocene in Tasmania, even in glaciated regions of the Central Plateau—but the sample sizes are very small. In contrast nothing was found before the early Holocene or possibly the terminal Pleistocene in the New England Tableland, and even then, there appears to be no intense occupation until the late Holocene. There was, of course, a much wider choice of movement in mainland Australia than Tasmania, but this does not explain the paucity of occupation in New England during the climatic optimum of the early Holocene—indeed occupation increased as climate deteriorated in the last few thousand years. This deterioration occurred all over inland eastern Australia, so it may have been that the Tableland simply became the least-worst place to occupy. On the other hand, there is much evidence of mid Holocene cultural intensification involving interclan ceremonial and art (see also Chapter 8 on the multiplicity of axe grooves in central New England about this time), so it may be that larger populations could be supported by greater cultural connection between dispersed populations, thus overcoming environmental constraints. If so, it was not any change in the Aboriginal use of the landscape that enhanced the numbers of people, but a change in social organisation. This emphasises the significance of Aboriginal heritage, and the need for insight into this to be applied to land management, an example being the extreme importance of learning more about cultural burning to manage the landscape in the present and into the future.

The Lagoons project provides scientific and historical knowledge of landscape change and human environmental interactions in the New England region of New South Wales and in the Northern Midlands of Tasmania; knowledge that should aid in managing this landscape into the future. The project combined strong archaeological methodology with participatory heritage research with a view to sustainable and long term social and economic benefits for the local communities.

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Appendix A:
Analyst Report for Radiocarbon Dating

The following report has been reformatted from the Radiocarbon Dating Report prepared by The University of Waikato Radiocarbon Dating Laboratory (Hamilton, New Zealand) and presents the ages obtained from nine charcoal samples collected from Barley Field Lagoon (n=1), Big Llangothlin (n= 4), Reddestone Creek (n=1) and Thomas Lagoon (n= 3). Chemical pretreatment of all nine samples included washing in hot hydrochloric acid (HCl) followed by the rinsing and treatment with multiple hot sodium hydroxide (NaOH) washes. The NaOH insoluble fraction was further treated with hot HCl, filtered, rinsed and dried.

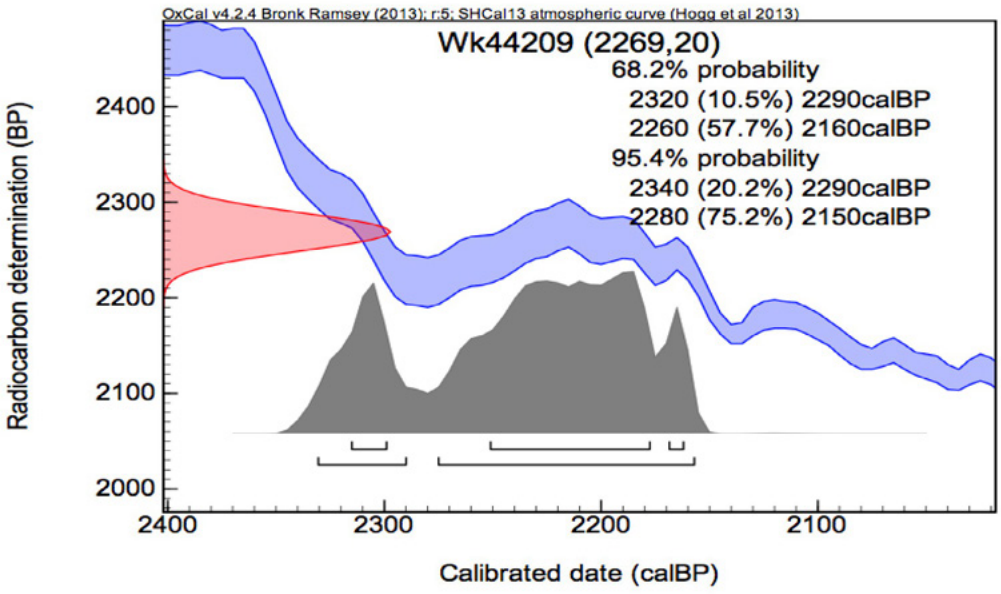
Ages are presented as *Conventional Ages* or *Percent Modern Carbon* (*pMC*) following References Stuiver, M. and Polach, H.A., 1977: Discussion reporting of 14C data. Radiocarbon, 19(3), pp.355-363. This is based on the Libby half-life of 5568 years with correction for isotopic fractionation applied. Quoted errors are given as 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier. The isotopic fractionation, $\delta^{13}C$, is expressed as ‰ wrt PDB and is measured on sample carbon dioxide ($CO_{2)}$. Explanation of the calibrated Oxcal plots can be found at the Oxford Radiocarbon Accelerator Unit's calibration webpage: (http://c14.arch.ox.ac.uk/embed.php?File=explanation.php).

Wk- 44209

Submitter	W. Beck
Submitter's Code	BFU 32/4
Site & Location	Barley Field Lagoon (Uralla), Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-26.2 ± 0.3‰ (CRDS)
$D^{14}C$	-246.1 ± 1.8 ‰
Percent modern carbon ($F^{14}C$%)	75.4 ± 0.2%
Radiocarbon Age	**2269 ± 20 BP**

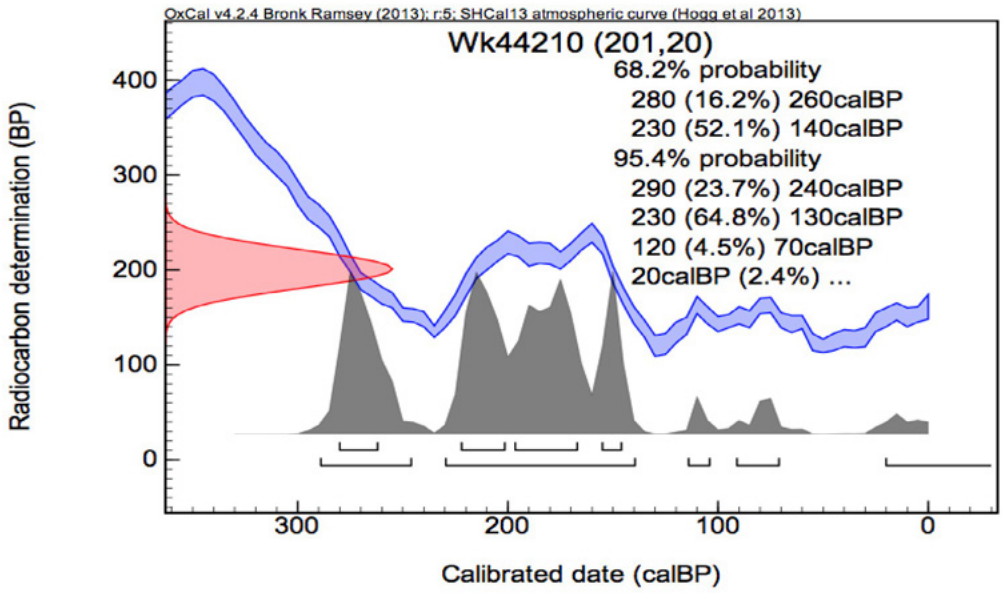


Wk- 44210

Submitter	W. Beck
Submitter's Code	BGLL 2A/1
Site & Location	Big Llangothlin Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-27.3 ± 0.3‰ (CRDS)
$D^{14}C$	-24.7 ± 2.5‰
Percent modern carbon ($F^{14}C$%)	97.5 ± 0.2%
Radiocarbon Age	**201 ± 20 BP**

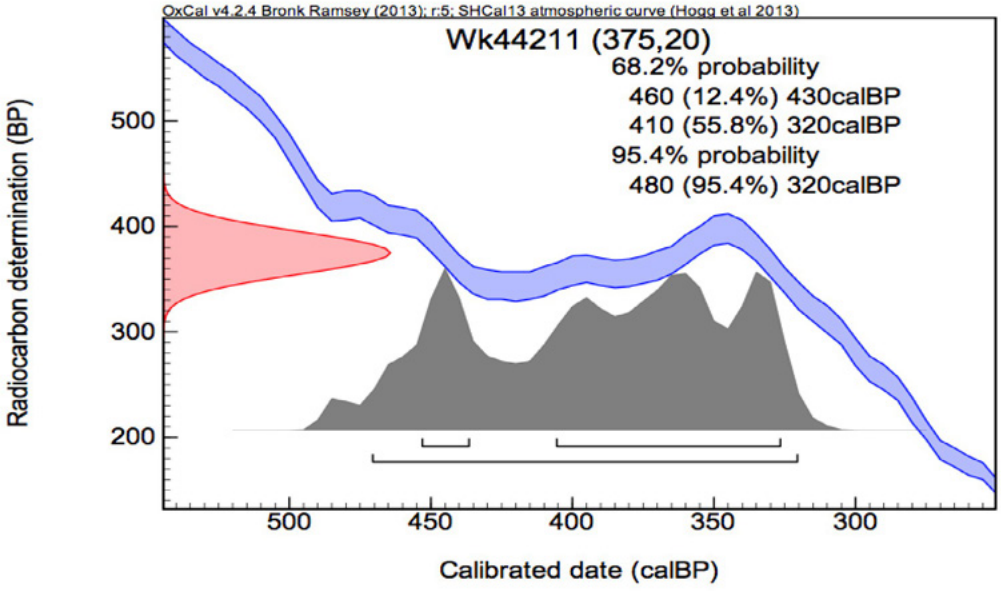


Wk- 44211

Submitter	W. Beck
Submitter's Code	BGLL 2A/4
Site & Location	Big Llangothlin Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-25.5 ± 0.3‰ (CRDS)
$D^{14}C$	-45.6 ± 2.4‰
Percent modern carbon ($F^{14}C$%)	95.4 ± 0.2%
Radiocarbon Age	**375 ± 20 BP**

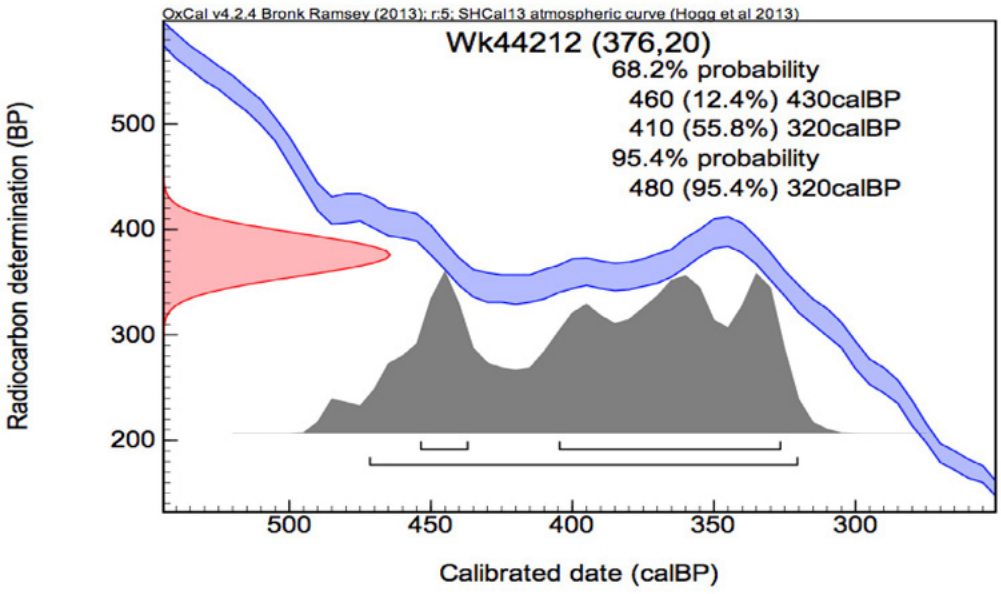


Wk- 44212

Submitter	W. Beck
Submitter's Code	BGLL 2A/5
Site & Location	Big Llangothlin Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-26.1 ± 0.3 ‰ (CRDS)
$D^{14}C$	-45.8 ± 2.4‰
Percent modern carbon ($F^{14}C$%)	95.4 ± 0.2%
Radiocarbon Age	**376 ± 20 BP**

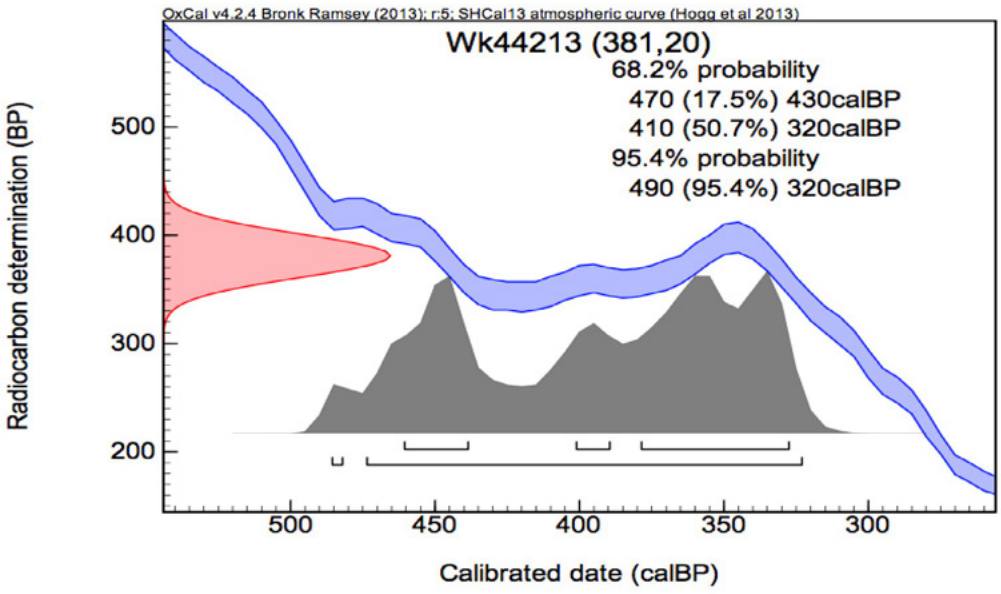


Wk- 44213

Submitter	W. Beck
Submitter's Code	BGLL 2A/6
Site & Location	Big Llangothlin
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-25.3 ± 0.3 ‰ (CRDS)
$D^{14}C$	-46.3 ± 2.4‰
Percent modern carbon ($F^{14}C\%$)	95.4 ± 0.2%
Radiocarbon Age	**381 ± 20 BP**

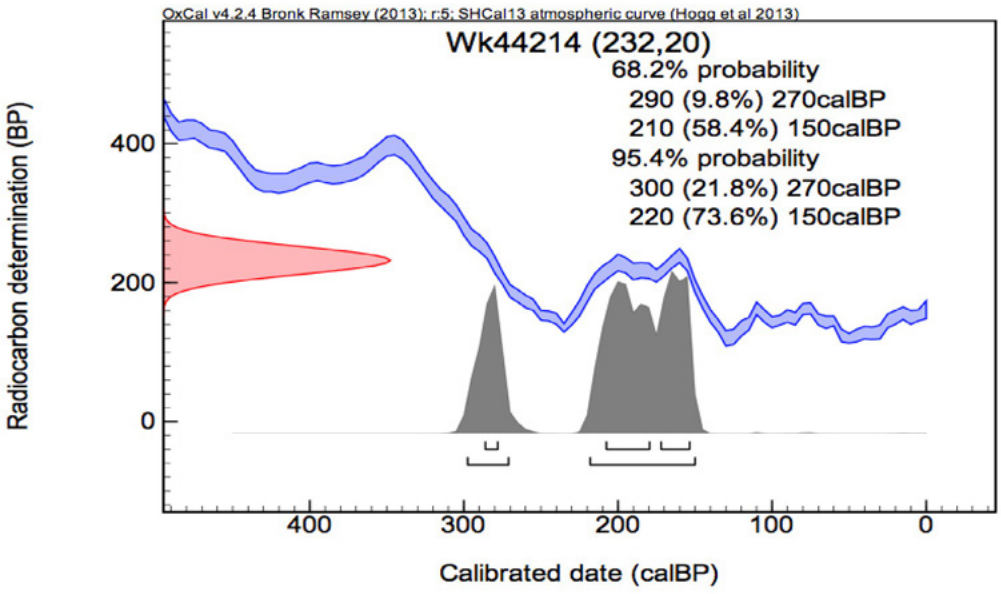


Wk- 44214

Submitter	W. Beck
Submitter's Code	R300/2
Site & Location	Reddestone Creek Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-25.1 ± 0.3 ‰ (CRDS)
$D^{14}C$	-28.5 ± 2.4‰
Percent modern carbon ($F^{14}C$%)	97.2 ± 0.2%
Radiocarbon Age	**232 ± 20 BP**

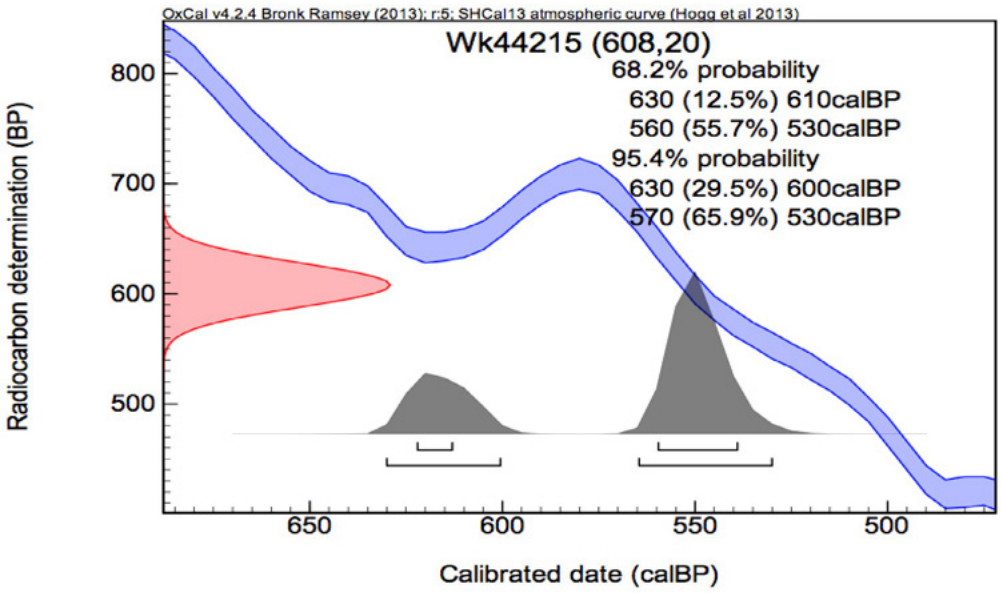


Wk- 44215

Submitter	W. Beck
Submitter's Code	TH 1M/6
Site & Location	Thomas Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-28.3 ± 0.3‰ (CRDS)
$D^{14}C$	-72.8 ± 2.3‰
Percent modern carbon ($F^{14}C\%$)	92.7 ± 0.2%
Radiocarbon Age	**608 ± 20 BP**

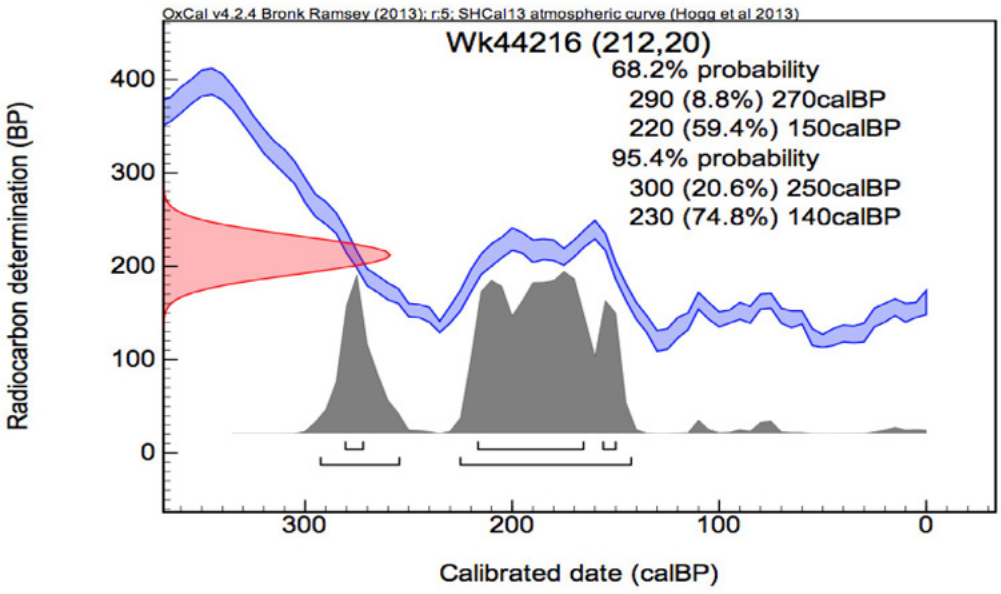


Wk- 44216

Submitter	W. Beck
Submitter's Code	TH27C/3
Site & Location	Thomas Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-26.2 ± 0.3‰ (CRDS)
$D^{14}C$	-26.1 ± 2.4‰
Percent modern carbon ($F^{14}C$%)	97.4 ± 0.2%
Radiocarbon Age	**212 ± 20 BP**

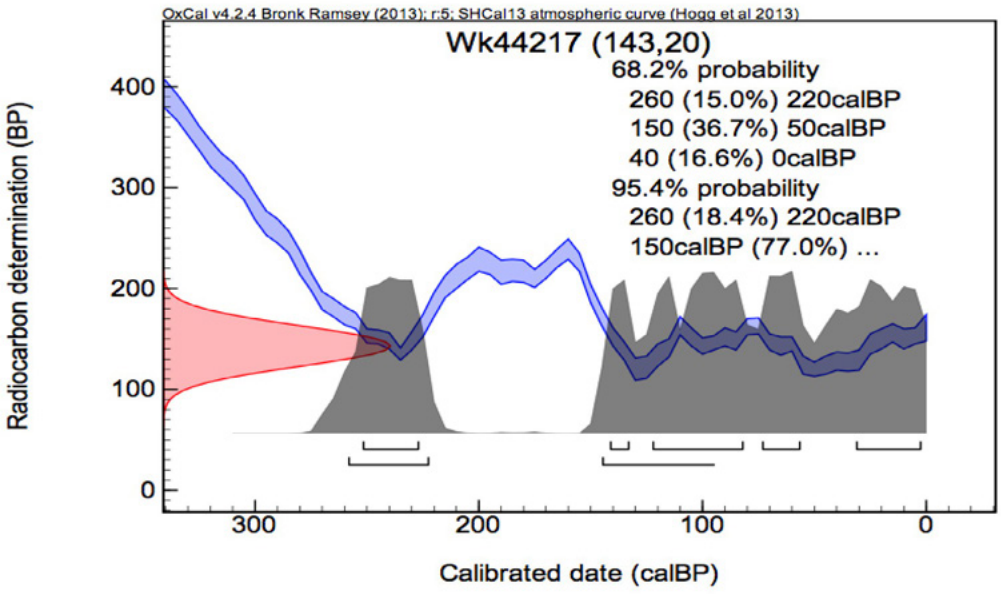


Wk- 44217

Submitter	W. Beck
Submitter's Code	TH27T/3
Site & Location	Thomas Lagoon, Australia
Sample Material	Charcoal
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

Results

$\delta^{13}C$	-26.7 ± 0.3‰ (CRDS)
$D^{14}C$	-17.6 ± 2.5‰
Percent modern carbon ($F^{14}C\%$)	98.2 ± 0.3%
Radiocarbon Age	**143 ± 20 BP**



Appendix B:
Luminescence Dating of Sediments from Wetland Sites in New England, New South Wales, and Tasmania, Australia

Introduction

Optically stimulated luminescence (OSL) dating of sediment samples from the New England and Tasmanian wetlands was undertaken in three stages at two institutions (University of Wollongong, UOW, and University of Washington, UW), primarily due to the limited availability of facilities. A total of 54 sediment samples collected from nine sites were dated using single-grain (n=17, measured and analysed at UW by James Feathers) and multi-grain OSL techniques (n=37, measured and analysed at UOW by Nathan Jankowski (n=10) and Elspeth Hayes, Yujie Guo and Zenobia Jacobs (n=27)). Final age estimates were calculated using one of two parametric statistical models—the central age model (CAM, used by NJ and EH, YG & ZJ) and the finite mixture model (FMM, used by JF). Reports prepared by each analyst(s) are presented in Appendix C.

OSL Background

OSL dating is a method in which ages are obtained by measuring the cumulative effect of ionising radiation on crystalline materials (e.g., quartz and feldspars) that typically comprise sedimentary deposits, to indicate when the materials were last exposed to sunlight. When sediments are transported by wind or water, constituent quartz and feldspar minerals are exposed to sunlight, causing the any previous luminescence signal to be 'zeroed'. Following deposition, buried mineral grains are exposed to incoming radiation from the surrounding sediment and a latent luminescence signal is gradually built up as a function of accumulating stored energy (Aitken and Valladas 1992). When stimulated by light in the laboratory, a measurable OSL signal is produced, the intensity of which is proportional to the radiation dose the mineral has received since burial. This is referred to as the equivalent dose, D_e, which can be measured on individual sand-sized (180–220μm) grains of quartz or on multiple grains of quartz composed on a single disc or 'aliquot'. The rate at which this radiation is supplied to the mineral is referred to as the environmental dose rate, *Dr*, and corresponds to the rate in which the trapped charge population was accumulated (Stokes 1999).

The natural radiation supply is predominately comprised of gamma, beta, and alpha radiation derived from the natural decay of radioactive elements ^{238}U, ^{235}U, ^{232}Th and their decay products, and ^{40}K, with minor contributions from ^{87}Rb (Aitken 1985). The SI unit for absorbed radiation dose is measured the gray (Gy), where 1 Gy = 1J kg^{-1} (Jacobs and Roberts 2007).

To determine the OSL age of the sediment, the following equation may be applied:

Estimating De values using single-grain and multi-grain OSL

De estimates can be made for individual sand-sized grains of quartz ('single-grain' OSL) or on aliquots composed of multiple quartz grains ('multi-grain' OSL), where ages are given as an average of multiple grains. A key feature of single-grain OSL is that it allows an analyst to identify and discard any grains with aberrant OSL behaviours before D_e and age determination. Aliquots composed of multiple grains, which produce age estimates by averaging multiple grains (typically between 10 and 100), can give rise to inaccurate D_e estimates (and OSL ages) if they contain grains with aberrant behaviours (e.g., grains that have received different amounts of beta-dose radiation in the burial environment, grains that have

been insufficiently or heterogeneously exposed to sunlight prior to burial, grains that have moved from younger or older depositional contexts, and/or grains that originate from the decomposition of unbleached sandstone blocks). Aliquots composed of multiple grains often conceal the effects of the depositional and post-depositional history of a sample and are therefore more often better suited for dating sediments from geological contexts rather than archaeological deposits that are more likely to be composed of a mixed population of grains. A range of standard rejection criteria has been developed to identify and isolate grains aberrant OSL behaviours so that they may be removed from the data set so that they do not influence final age determination (see Report by JF in Appendix B).

Single aliquot regenerative-dose (SAR) procedure

When exposed to an external stimulus such as heat or light, trapped electrons within quartz and feldspar grains are released to emit a faint yet measurable light, the intensity of which is proportional to the amount of stored energy, and thus time since the electron traps last emptied. In the laboratory, these minerals are exposed to an external stimulus (blue-green light) that causes the trapped electrons are released to provide the D_e value. Following the single-aliquot regenerative (SAR) method of Murray and Wintle (2000, 2003), D_e values are calculated by first measuring the natural luminescence of a sample followed by several known laboratory doses of radiation, referred to as regenerative doses. The regenerative dose data can be fit with a saturating exponential to construct a luminescence dose-response curve. The D_e is calculated by projecting the natural OSL signal onto the curve.

De distribution analysis

Once a series of independent D_e estimates have been obtained, these values can be displayed in the form of a radial plot to provide a visual means of evaluating the *De* distribution and so that one may easily recognise the amount of spread (aka the 'overdispersion') in the data (Galbraith 1988, 1990). The D_e values are displayed in radial plots separately as data points (one per aliquot or one per individual grain measured) and are read by extending a straight line from the origin of the standardised estimate axis through the data point onto the radial axis on the right, where the intercept is the D_e value. The uncertainty of the D_e value is estimated by extending a straight line vertically from the data point onto the x-axis; the point of the interception is the relative error (as a percentage of the D_e). The most precise D_e will, therefore, fall to the right of the plot and the least precise D_e value to the left. It is possible to evaluate whether the D_e values are statistically consistent with each other or not: if at least 95% of the D_e values fall within any two standard error bar which can be obtained by extending two lines from the ± 2 standardised estimate axis on the left to the radial scale, then all the D_e values are consistent with each other.

Age models

Several parametric statistical models are available to combine *De* values meaningfully for accurate age determination and to provide an estimate of the amount of spread (overdispesion, OD) in the data (Galbraith *et al.* 1999; Roberts and Galbraith 2012). The choice of model is dependent on the interpretation of the shape of the radial plot and the overdispersion value (given as a percentage). Where D_e distributions are interpreted to represent a single well-bleached population of grains (i.e., there is a single component D_e distribution), the central age model (CAM) can be used to calculate average D_e values. This model assumes that the D_e values for all grains are centered on an average value of D_e (similar to the weighted mean) and the estimated uncertainty takes into account any overdispersion (Galbraith *et al.* 1999). For radial plots that display two distinct dose rate populations (i.e., the data points mostly lie within two radial bands), the minimum or maximum age models (MAM) can be applied to determine the maximum and minimum dose rate populations and their standard error. Samples that have two distinct

dose rate populations may represent grains that have been fully bleached and then subsequently mixed with younger, intrusive grains. Under these circumstances, the timing of primary deposition can be estimated from the D_e values of the well bleached, host grains—that is, the grains that with the highest D_e values (Galbraith and Roberts, 2012). For radial plots that display more scattered distributions (i.e., those that display one or more discrete dose components), the finite mixture model (FMM) can be used. The model enables the number of dose components (discrete population bands), the D_e value of each dose component (which is the CAM of that component), and the proportion of grains belonging to each component. To obtain this information, the overdispersion value and expected number of components need to be specified. This is done using the Bayes Information Criterion (BIC) and maximum log likelihood (llik). When an optimum BIC and llik combination is obtained, the corresponding overdispersion and number of components are assumed to be the most appropriate.

Radioactivity measurements

Obtaining accurate age estimates requires an equally sound approximation of the environmental dose rate, i.e., the rate of supply of ionising radiation received by a given sedimentary grain. As stated above, the natural radiation supply is predominately comprised of gamma, beta and alpha radiation derived from the natural decay of radioactive elements (^{238}U, ^{235}U, ^{235}U, ^{232}Th and K). The environmental dose rate of a given sample can be separated into (i) an internal dose rate (resulting from alpha and beta radiation from within sedimentary grains themselves) and (ii) an external dose rate (resulting from alpha, beta and gamma radiation in the bulk sediment matrix surrounding the grains). As quartz grains contain inherently low uranium, thorium and potassium concentrations, their internal dose rates are likely to be low (Aitken 1998). The external dose rate component, however, is of crucial importance and may be determined using a range of different techniques. Some techniques such as beta counting provide a direct measurement of the external beta dose rate, whereas other techniques such as thick-source alpha counting (TSAC), X-ray fluorescence (XRF), atomic emission, and spectrometric methods such as inductively couple plasma optical emission spectrometry (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS), provide radionuclide concentrations that must be converted into dose rates. These conversions can be made following the calculations presented in Guérin *et al.* (2011).

Summary of results

The Table below summarises all the OSL ages for the New England and Tasmanian wetlands sites as determined by NJ, JF and EH, YG and ZJ. Ages for samples analysed at UOW by NJ and EH, YG and ZJ, calculated using the OSL age equation (above), in which D_e values were measured using the SAR protocol on aliquots composed of multiple quartz grains and calculated using the CAM and MAM. Radioactivity concentrations for the UOW samples were obtained using ICP-OES and ICP-MS analyses undertaken at the Genalysis Intertek Laboratory in Perth, Western Australia, and translated into dose rates following Guérin *et al.* (2011). D_e values for samples analysed at UW by JF were obtained on individual quartz grains using the SAR procedure and the FMM. Radioactivity concentrations were measured using a combination of alpha counting, beta counting and atomic emission and converted into dose rates following Guérin *et al.* (2011). Cosmic dose rates for both the UOW and UW samples were determined using the equations presented in Prescott and Hutton (1988).

The reports of Jankowski, Feathers and Hayes *et al.* express concern with the significant spread of D_e values for some samples, beyond what is statistically expected. Despite using 1 mm aliquots of grains, Jankowski notes in his report that the spread of D_e values in some samples is so significant that he could not resolve this using the multi-grain method, and he recommended making single-grain measurements to determine the true extent of the spread and help give more confidence in the sample D_e determinations. Likewise, 12 samples measured by Hayes *et al.* display high overdispersion values (exceeding 20%) that

would benefit from single-grain analysis. Unfortunately, single-grain measurements of these same samples have not been possible. Although from different locations in the study area, the single-grain equivalent dose distributions of Feathers also suggest that the spread of D_e values for many samples is also significant. If this significant degree of spread of D_e values is also typical of the samples that Jankowski analysed, his use of the central age model may not be appropriate.

As a consequence of using different methods, different age models (central and minimum), and generally high overdispersion values, any comparison of the resultant chronologies at each locality should be undertaken cautiously.

Table 1. OSL ages for New England and Tasmanian wetlands sites

Site	Field Sample ID	Depth below surface (cm)	Age (ka)	Dating team	Age range (ka)	Location detail
Barley Field	KK_BFL_01	32	10.6 ± 0.7§	EH, ZJ		lunette lagoon side pit 1
Barley Field	KK_BFL_04	70	47.8 ± 2.7§	NJ		lunette lagoon side pit 1
Barley Field	KK_BFL_03	57	27.2 ± 2.4§	EH, ZJ		lunette crest pit 2
Barley Field	KK_BFL_02	84	14.9 ± 1.3§	NJ		lunette crest pit 2
Barley Field	BFL-E1-01	31	6.34 ± 0.566*	JF	4.5–7.3	lunette
Barley Field	BLF-E1-02	40	8.69 ± 0.696*	JF	5–9	lunette
Barley Field	BFL-E1-03	42	6.75 ± 0.623*	JF	5–9	lunette
Barley Field	BFL-E2-01	22	3.23 ± 0.515*	JF	0.6–5.0	track site/sq 12
Barley Field	BFL-E2-02	24	3.53 ± 0.447*	JF	1.4 to 4.6	track site/sq 25
Barley Field	BFL-E2-03	47	12.4 ± 1.22*	JF	?min 12k?	track site/sq 25
Barley Field	BFL-E2-04	51	7.47 ± 0.673*	JF	4.3–10	track site/sq 25
Barley Field	BFL-E2-05	30	3.14 ± 0.331*	JF	1.8– 7.6	track site/sq 32
Barley Field	BFL-E2-06	47	8.36 ± 1.19*	JF	3.8–15.4	track site/sq 32
Big Llangothlin	KK_BL_02	200	26.3 ± 3.1§	EH, YG		scarp site (N end)
Big Llangothlin	KK_BL_06	50	29.5 ± 1.7§	EH, ZJ		Pit 1/Site B (N end of lake)
Big Llangothlin	KK_BL_05	65	32.9 ± 1.6§	EH, YG		Pit 1/Site B (N end of lake)
Big Llangothlin	KK_BL_04	118	60.5 ± 4.1§	NJ		Pit 1/Site B (N end of lake)
Big Llangothlin	KK_BL_03	165	72.6 ± 7.3§	NJ		Pit 1/Site B (N end of lake)
Big Llangothlin	KK_BL_07	40	4.7 ± 0.4§	EH, YG		Anne's dig (N end)
Big Llangothlin	KK_BL_09	43	9.1 ± 0.6§	EH, ZJ		Pit 4(AM)/kk Site F (N end of lake)
Big Llangothlin	KK_BL_08	88	21.2 ± 1.1§	EH, ZJ		Pit 4(AM)/kk Site F (N end of lake)
Big Llangothlin	KK_BL_13	32	2.6 ± 0.3§	NJ		Pit 1/east side of lake
Big Llangothlin	KK_BL_11	114	12.8 ± 0.8§	NJ		Pit 1/east side of lake
Big Llangothlin	KK_BL_10	147	15.7 ± 0.7§	EH, YG		Pit 1/east side of lake
Big Llangothlin	KK_BL_12	200	7.4 ± 0.4§	EH, YG		Pit 1/east side of lake
Big Llangothlin	BGL-20	20	1.83 ± 0.203	JF	0.8–4	Square 1B
Big Llangothlin	BGL-50	50	6.45 ± 0.624	JF	3.3–6.2	Square 1B
Big Llangothlin	BGL-75	75	13.0 ± 1.58	JF	15.8	Square 1B

Site	Field Sample ID	Depth below surface (cm)	Age (ka)	Dating team	Age range (ka)	Location detail
Big Llangothlin, laterite gully	KK_BG_02	88	29.5 ± 1.5§	EH, ZJ		laterite gully
Big Llangothlin, laterite gully	KK_BG_10	58	NOT MEASURED			laterite gully
Dangars	KK_DGL_02	70	16.3 ± 1.4§	NJ		Pit A
Dangars	KK_DGL_01	112	36.8 ± 1.4§	EH, YG		Pit A
Dangars	KK_DGL_03	105	30.1 ± 1.5§	EH, ZJ		Pit B
Dangars	KK_DGL_04	120	48.1 ± 6.1§	NJ		Pit B
Dangars	DGL-E2-01	38	1.88 ± 0.247*	JF	0.52–2.9	Square 0- 0.05
Dangars	DGL-E1-01	42	6.81 ± 0.630*	JF	4.3–13.5	Square 20
Dangars	DGL-E1-02	43	7.30 ± 0.875*	JF	5.9–17.7	Square 20
Kings Plains		12	5.21 ± 0.66*	JF	3.7–9	Re-dig square
Kings Plains		16	3.76 ± 0.451*	JF	2.3–7.1	Re-dig square
Racecourse	KK_RCL_03	35	12.8 ± 1.0§	EH, ZJ		Lunette lower slope
Bells Lagoon	KK_BSLE_02	150	20.17 ± 1.5§	EH, ZJ		main pit
Bells Lagoon	KK_BSLE_03	154	18.7 ± 1.2§	EH, ZJ		main pit
Bells Lagoon	KK_BSLE_01	180	20.25 ± 1.1§	EH, ZJ		main pit
Lagoon of Islands	KK_LOI_S1	50	15.8 ± 0.9§	NJ		130cm below dune
Lagoon of Islands	KK_LOI_S2	60	15.6 ± 1.0§	NJ		dune-below blowout
Lagoon of Islands	KK_LOI_S3	50	13.6 ± 0.8§	EH, ZJ		below lake floor
Lagoon of Islands	KK_LOI_S4	60	16.6 ± 0.7§	EH, ZJ		dune
Lagoon of Islands	KK_LOI_S5	85	16.4 ± 0.7§	EH, ZJ		dune
Lake Crescent	KK_TLC_1B	120	0.1 ± 0.01§	EH, YG		Sandbank shore dune
Lake Crescent	KK_TLC_1A	204	16.9 ± 1.2§	EH, YG		Sandbank shore dune
Lake Sorell	KK_LS_02	265	0.1 ± 0.01§	EH, YG		sand dunes ne corner
Lake Sorell	KK_LS_01	315	0.6 ± 0.1§	EH, YG		sand dunes ne corner
Lake Tiberias	KK_LT_01	60	7.1 ± 0.7§	EH, ZJ		Pit 1
Lake Tiberias	KK_LT_02	60	17.5 ± 1.6§	EH, ZJ		Pit 1
Lake Tiberias	KK_LT_03	112	50.5 ± 4.3§§	EH, ZJ		Pit 1

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Appendix C:
Luminescence Dating of Sediments from New England and Tasmanian Wetland Sites

Analyst reports for OSL dating

The following three reports describe the specific methods of sample preparation, instrumentation, data acquisition and data analysis for each of the 54 analysed samples presented in Table 1 of Appendix A. All D_e, overdispersion and D_r values are presented together with final age determinations separately in each Report. Radial plots that indicate the spread of D_e values are also illustrated in each Report.

Luminescence Dating of Sediments from New England and Tasmanian Wetland Sites

A Report Prepared for Richard Fullagar and Wendy Beck
by

Elspeth Hayes and Yujie Guo
University of Wollongong

Introduction

Twenty-six sediment samples from nine wetland sites in Tasmania and within the New England bioregion of New South Wales were dated using multi-grain optically stimulated luminescence (OSL) techniques at the University of Wollongong, Australia (Table 1). These included 13 samples from four sites in New England (Barley Field, n=2; Big Llangothlin, n=8; Dangars, n=2; and Racecource, n=1) and 13 samples from five sites in Tasmania (Bells Lagoon, n=3; Lagoon of Islands, n=3; Lake Crescent, n=2; Lake Sorell, n=2; and Lake Tiberias, n=3). Samples were prepared by two laboratory assistants (Elspeth Hayes and Yasamin Jafari), nine of which were measured and analysed by Yujie Guo (YG) with the remaining 17 samples measured and analysed by Zenobia Jacobs (ZJ) (Table 1).

Table 1. List of sediment samples analysed at UOW from the New England and Tasmanian wetland sites.

Site name	Field Sample ID	Analyst	Depth below surface (cm)	Location Detail
NEW ENGLAND				
Barley Field	BFL_01	ZJ	32	lunette lagoon side pit 1
Barley Field	BFL_02	ZJ	57	lunette crest pit 2
Big Llangothlin	BL_06	ZJ	50	Pit 1/Site B (north end of lake)
Big Llangothlin	BL_05	YG	65	Pit 1/Site B (north end of lake)
Big Llangothlin	BL_07	YG	40	Anne's dig (north end)
Big Llangothlin	BL_09	ZJ	43	Pit 4(AM)/kk Site F (north end of lake)
Big Llangothlin	BL_08	ZJ	88	Pit 4(AM)/kk Site F (north end of lake)
Big Llangothlin	BL_10	YG	147	Pit 1/east side of lake
Big Llangothlin	BL_12	YG	200	Pit 1/east side of lake
Big Llangothlin, laterite gully	BG_02	ZJ	88	laterite gully
Dangars	DGL_01	YG	112	Pit A
Dangars	DGL_03	ZJ	105	Pit B
Racecourse	RCL_03	ZJ	35	Lunette lower slope
TASMANIA				
Bells Lagoon	BSLE_02	ZJ	150	main pit
Bells Lagoon	BSLE_03	ZJ	154	main pit
Bells Lagoon	BSLE_01	ZJ	180	main pit
Lagoon of Islands	LOI_S3	ZJ	50	below lake floor
Lagoon of Islands	LOI_S4	ZJ	60	dune
Lagoon of Islands	LOI_S5	ZJ	85	dune
Lake Crescent	TLC_1B	YG	120	sandbank shore dune
Lake Crescent	TLC_1A	YG	204	sandbank shore dune
Lake Sorell	LS_02	YG	265	sand dunes ne corner

Site name	Field Sample ID	Analyst	Depth below surface (cm)	Location Detail
Lake Sorell	LS_01	YG	315	sand dunes ne corner
Lake Tiberias	LT_01	ZJ	60	Pit 1
Lake Tiberias	LT_02	ZJ	60	Pit 1
Lake Tiberias	LT_03	ZJ	112	Pit 1

Methods

Sample preparation

Twenty-six sediment samples were received in metal pipes and prepared at the luminescence laboratory at the University of Wollongong under subdued red light using standard laboratory procedures (Table 1). This involved the removal of carbonates with hydrochloric acid (10%) and digestion of organic materials with 15% hydrogen peroxide (H_2O_2) solution. The sample was sieved to obtain the 180–212 µm grain-size fractions from which the feldspar and heavy minerals were separated from the quartz using sodium polytungstate solutions at densities of 2.62 and 2.70, respectively, to isolate the quartz grains. The quartz grains were then etched in 40% hydrofluoric (HF) acid for 45 minutes to dissolve any remaining feldspar grains and to remove the outer ~10 µm alpha-irradiated rind of each grain (Porat *et al.* 2015). The etched quartz grains were then washed in 10% HCl solution for 2 hrs to remove any precipitated fluorides, followed by a second dry sieving to obtain only those grains >180 µm in diameter. Single-aliquots comprising multiple quartz grains were then constructed by applying a 1 mm diameter coating of silicon spray oil to stainless steel discs (10 mm in diameter) followed by a single layer of the HF-etched quartz grains. The purity of the quartz fractions was examined by IR stimulation.

A subsample of sediment was prepared for dose rate (D_r) determinations, taken from the ends of each metal pipe. Moisture contents were determined by weighing the sediment immediately after it was removed from the metal pipe to obtain the "wet" weight, followed by drying the sample in a 100°C oven for several days to obtain the "dry" weight. The moisture content percentage was calculated by subtracting the dry weight from the wet weight and dividing it by the dry weight. Each sample was milled to produce a fine powder and left for at least one week to allow for the in-growth of short-lived daughter nuclides. Measurements to determine concentrations of gamma (γ), and beta (β) radiation within the milled sediment samples were undertaken at the Genalysis Intertek Laboratory in Perth, Western Australia.

Equivalent Dose (De) measurements

Aliquots composed of quartz grains were measured using the same automated Risø DA-20 TL/OSL reader (Bøtter-Jensen *et al.* 2000, 2003). Optical stimulation of the samples was achieved using blue (~470 ± 30 nm) LEDs and regenerative doses administered using a calibrated $^{90}Sr/^{90}Y$ beta irradiator that delivered a dose of ~1.8 Gy/min. The luminescence signal was detected using an Electron Tubes 9235B photomultiplier fitted with two Hoya U-340 filters. These filters block the stimulation (blue) wavelength but allow the passage of the UV luminescence signal (Spooner and Questiaux, 2000).

Single-aliquot regenerative-dose (SAR) procedure

The *De* of each of the aliquots was determined using the single-aliquot regenerative-dose (SAR) procedure in which sensitivity-corrected estimates of an unknown dose received by sedimentary grains (quartz) may be obtained (Galbraith *et al.* 1999; Murray and Wintle 2000, 2003). The method involves making

repeated OSL measurements on a single aliquot to produce a dose response curve (DRC) from which the D_e can be determined by projecting the natural OSL signal onto the curve and interpolating onto the dose axis (Figure 1). Construction of a SAR DRC typically requires the use of three regenerative doses (R_X) bracketing the expected D_e estimate as well as a zero dose ($R_X = 0$) to monitor for recuperation and a repeat dose point to monitor the appropriateness of the sensitivity correction (Jacobs and Roberts 2007; Murray and Wintle 2003). In this procedure, after the natural (L_N) and each of the regenerative-dose OSL signals (L_X) have been measured, a test dose (T_D) of fixed dose is applied and the induced signal measured to obtain T_N and T_X. The test dose OSL signals are used to monitor and correct for any sensitivity changes that commonly occur in quartz grains as they are repeatedly dosed, heated and illuminated as part of the SAR procedure. The L_N and L_X signals are divided by their corresponding T_N and T_X signals to produce a set of 'sensitivity-corrected' values (L_N/T_N and L_X/T_X) to make up a sensitivity-corrected dose response curve from which the D_e is obtained. An additional regenerative dose cycle at the end of the SAR sequence (using an infrared stimulation for 40 s at 50˚C before measuring the OSL signal) to determine the OSL IR depletion ratios and check for any remnant feldspar contamination (Duller 2003). The net OSL signal was determined using the sum of counts in the first 0.8 s of OSL decay curve minus a background estimated from the mean count rate over the final 3.2 s. Aliquots were held for 0.8 s before and after optical stimulation to monitor and minimize any interference from isothermal decay. Typical OSL decay curves and DRCs are shown in Figure 1 for quartz aliquots from several samples in this study.

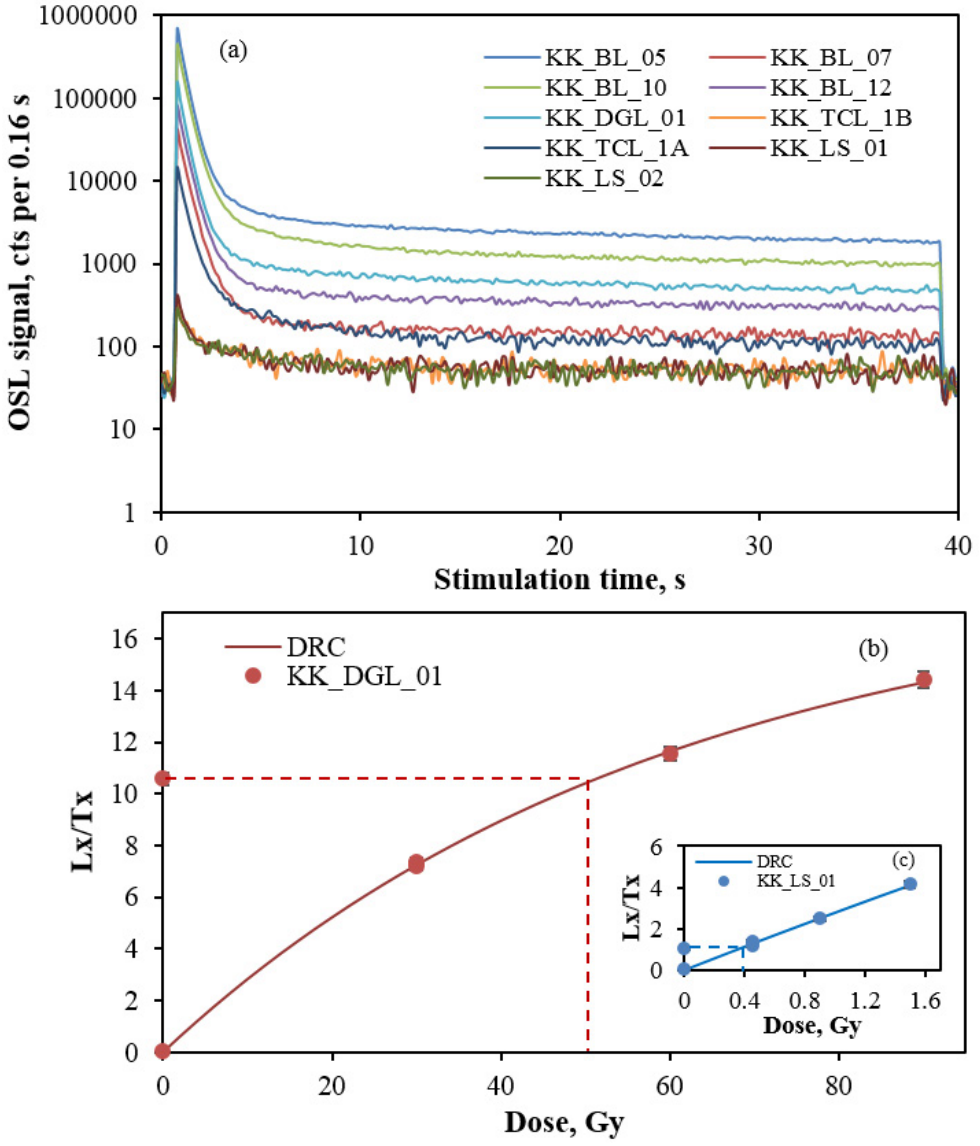


Figure 1 *(a) Typical OSL decay curves and (b,c) dose response curves for aliquots of quartz from several samples in this study. The dose response curves are fitted using a single saturating exponential function, D_e is obtained by projecting the sensitivity corrected natural OSL signal (the upper point on the y-axis) on to the fitted curve and interpolating the dose (dashed line). To choose a suitable preheat temperature, D_e measurements were made on single aliquots of sample BL_05 using the SAR procedure listed in Table 2a and preheat temperatures of between 180 and 260°C (step 2). The main purpose of these preheats is to remove any accumulated trapped charge within thermally unstable traps that would otherwise exist in the natural signal, which would have thermally eroded away over the burial period. The weighted mean D_e values and the recycling and recuperation ratios are plotted as a function of preheat temperature in Figure 2. This plot shows that a D_e 'plateau' (32.0 ± 0.7 Gy) is obtained preheat temperatures of 180–260°C and that the recycling ratios are consistent with unity at 1σ and the recuperation ratios are less than 1.3% at all preheat temperatures. This experiment indicates that preheat temperatures of between 180 and 260°C should be suitable for determining D_e values for the samples.*

Dose recovery test

A dose recovery test (Galbraith *et al.*, 1999) was conducted using sample BL_05 (Figure 2). Measurement conditions included a natural and regenerative dose preheat of 220˚C and a test dose preheat of 180˚C, based on the preheat plateau test results. Four aliquots were first bleached for about 1hr using a Hönle solar simulator (Model: UVACUBE 400) and a dose of 30 Gy was then given to the bleached grains as the surrogate 'natural' dose. The grains were measured using the procedures listed in Table 2b, with the test dose fixed at 3 Gy. The dose recovery ratio (average mean value of the measured dose/given dose) is 0.99 ± 0.01. Thus, heat of 220˚C and 180˚C before Lx (Ln) and Tx (Tn) measurements were adopted for systematic D_e measurements for samples in this study.

Table 2 summarises the parameters used in the SAR procedure to determine the D_e of samples. Steps 2 and 5 were set as 220 and 180°C for the *De* measurements for all samples. For the preheat test on sample BL_05, Steps 2 and 5 were set as 180, 160°C; 200, 160°C; 220, 180°C; 240, 200°C and 260, 220°C, respectively. In Step 4, test doses were set as 3 Gy for samples BL-05,-07,-10,-12 and DGL-01 and 0.3 Gy for samples LS-01, -02 and TLC-1A, -1B. In Step 7, the 'hot optical bleach' involved OSL stimulation using blue light-emitting diodes with the sample held at a temperature 40°C higher than the corresponding preheat in Step 2, to erase any remnant OSL signal.

Table 2. Summary of the SAR procedure and parameters used by YG.

Single-aliquot procedure: preheat temperature test [a]		
Step	**Treatment**	**Signal**
1 [a]	Give regenerative dose, D_i	
2	Heat at 180–260 °C for 10 s	
3	Measure OSL at 125 °C for 40 s	L_n, L_x
4	Give test dose, D_t	
5	Heat at 20–40 °C less than step 2 for 10 s	
6	Measure OSL at 125 °C for 40 s	T_n, T_x
7	Bleach at 40 °C more than step 2 for 40 s	
8	Return to step 1	
Single-aliquot procedure: dose recovery test and De estimation		
Step	**Treatment**	**Signal**
1 a	Give regenerative dose, D_i	
2	Heat at 220°C for 10 s	
3	Measure OSL at 125°C for 40 s	L_n, L_x
4	Give test dose, D_t	
5	Heat at 180°C for 10 s	
6	Measure OSL at 125°C for 40 s	T_n, T_x
7	Bleach at 40 °C more than step 2 for 40 s	
8	Return to step 1	

[a]: For the natural dose, i = 0 and Di = 0 Gy.

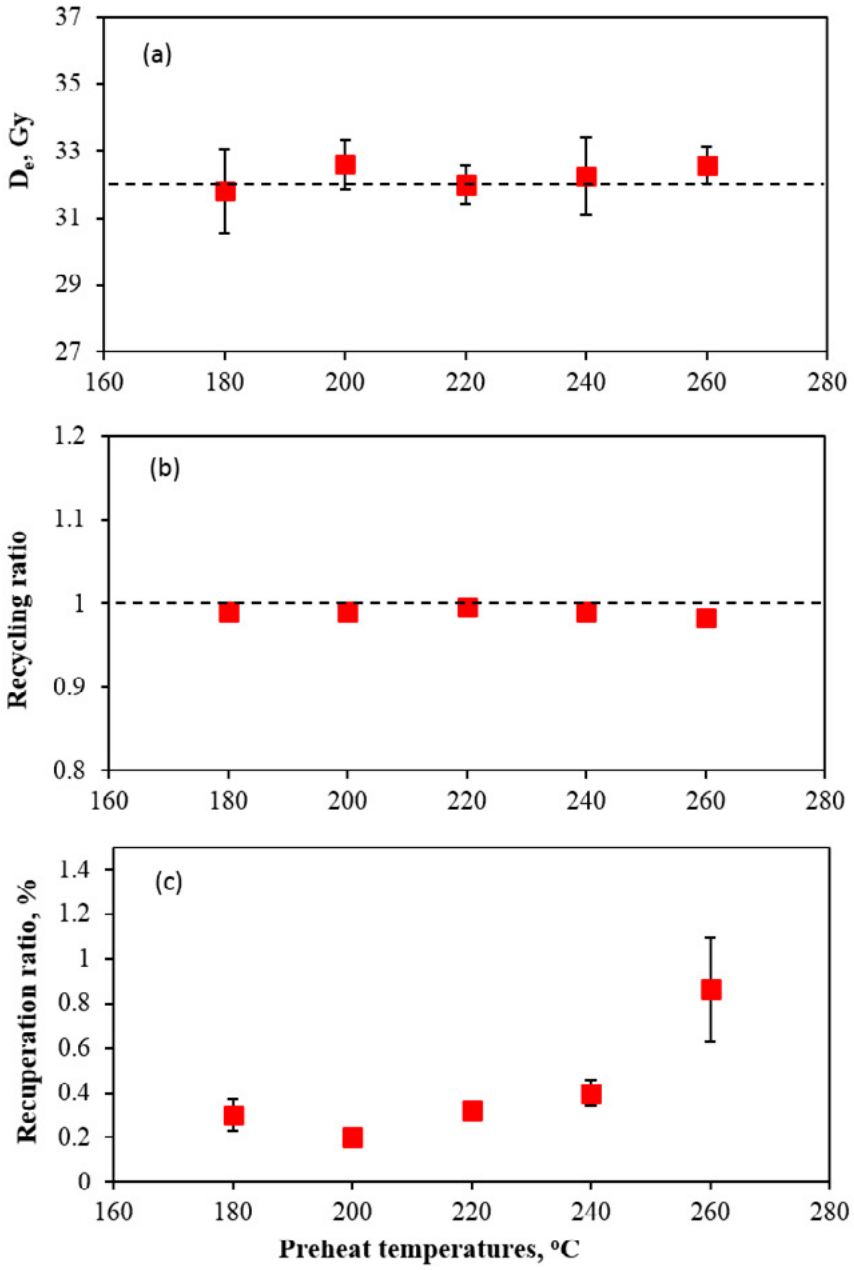


Figure 2 *Results of the preheat temperature test on sample BL_05, conducted using the single-aliquot regenerative-dose procedure in Table 2a. The D_e values and corresponding recycling and recuperation ratios are plotted as a function of preheat temperature in (a), (b) and (c), respectively. Each data point represents the mean value for 3–20 aliquots and the vertical bars indicate the corresponding 1σ errors.*

De distribution analysis and age models

The D_e estimates for each sample measured as part of this study are presented as radial plots in Figure 3. D_e and overdispersion values were calculated using the central age model (CAM) for all samples. For samples that also appeared to have two dose populations, the minimum age model (MAM) was

also applied to determine the maximum (and minimum) D_e value and thus the maximum age of the sediments.

Dose Rate (Dr) measurements

The dose rate for each sample was determined by calculating the sum of beta, gamma and cosmic-ray dose radiation. Elemental concentrations of K, U and Th for each sample were measured at the Genalysis Intertek Laboratory using a combination of inductively couple plasma optical emission spectrometry (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS), to determine concentrations of K and the concentrations of U and Th, respectively. These were then converted into beta and gamma dose rates following Guérin *et al.* (2011) and corrected to account for their respective soil moisture contents using the equations given in Aitken (1985) and Aitken and Xie (1990). The attenuation of the beta dose rate was corrected using the equations described in Brennan (2003) and adding a 3% uncertainty to the associated beta dose rate uncertainty. The cosmic dose rate was calculated using the equations presented in Prescott and Hutton (1994), which accounts for the geomagnetic latitude, longitude, elevation above sea level and the thickness of sedimentary overburden of each of the samples at each of locations. A 10% uncertainty was assigned to each cosmic-ray dose rate estimate.

Results and discussion

De and Dr values

The *De* values and overdispersion percentages for the analysed samples are presented in Table 3 and displayed graphically in Figure 3 as a radial plots. The total D_r values are listed in Table 3 and radioactivity measurements of Th, U and K, measured water contents and calculated cosmic, gamma and beta dose rates are listed in Table 4.

De values ranged from below 1 Gy (e.g., for samples from Lake Sorell: LS_01 and 02) to indicate younger samples; to ~56 Gy (e.g., BG_02), to indicate older samples or high radioactivity in the surrounding sediment. The overdispersion percentages also varied considerably. Overdispersion (or "OD") is the amount of spread in the data after all measurement uncertainties have been accounted for (Galbraith *et al.* 1999). It is commonly accepted that D_e distributions with less than 20% OD are representative of well-bleached samples; any OD greater than this requires much closer scrutiny of the accompanying radial plot. Of the 27 samples analysed, 12 had high OD values that exceeded 20%. These included all samples from Lake Tiberias (n= 3), Lake Sorell (n=2), and the single sample from Racecourse, as well as some of the samples from Lake Crescent (n=1), Bells Lagoon (n=2), Big Llangothlin Lagoon (n=2) and Barley Field Lagoon (n=1). The radial plots for these samples show that the D_e values are randomly distributed around a central value for all but one (LS_01 from Lake Sorell) of these samples (Figure 3). Consequently, the high OD values observed in these samples may be the outcome of variations of the OSL signal properties inherent to the quartz, or variations in environmental beta irradiations of grains during the burial period. For sample LS_01, which had a very high OD value of 91 ± 14% (much higher than any other sample measured), the distribution of D_e values in the radial plot suggests that sediments from this sample might have been incompletely bleached before burial. Thus, the MAM was applied to obtain a final D_e value for this sample to determine the maximum dose population, with the **σb** value (representing the expected over-dispersion for a well-bleached and non-disturbed sample) assumed to be 0.2, which is typical for samples that are thought to be partially bleached.

The total environmental dose rate (D_r) for each sample varied from site to site with smaller variation observed in samples collected from different depositional contexts at the same site (Table 4). The lowest total dose rate values were recorded at Big Llangothlin Lagoon and Lake Crescent, which ranged from

0.81 ± 0.05 to 1.49 ± 0.07 and 0.56 ± 0.03 to 1.33 ± 0.06, respectively. The highest dose rates were recorded at Racecourse Lagoon and Bells Lagoon with values of 2.95 ± 0.14 and 2.31 ± 0.10 to 2.46 ± 0.11 Gy/ka, respectively (Table 4). Gamma and beta dose rates were calculated from the ICP-OES and IC-PMS measured concentrations of K, U and Th, and range from 0.038 ± 0.020 to 0.977 ± 0.064 Gy/ka and 0.486 ± 0.033 to 1.709 ± 0.115 Gy/ka, respectively (Table 4). Gamma and beta dose rates were highest in samples from Bells Lagoon and Racecourse Lagoon and have contributed to their higher total dose rates.

The measured water contents for each sample show significant variation, ranging from 0 to over 20% (Table 4). Although many samples had water contents of <2%, samples from Lake Crescent, Lagoon of Islands, Bells Lagoon and Lake Sorell all had measured water contents exceeding 5%. As water attenuates incoming radiation, sediments with higher water contents will have reduced dose rates. The calculated cosmic dose rate values indicated some variation between sites and very minor variation between samples from different depositional context of the same site. The highest calculated cosmic dose rates were recorded for the NSW sites, which ranged from 0.236 to 0.256 Gy/ka, while lower cosmic dose rates were calculated for the Tasmanian sites, which ranged from 0.180 to 0.216 Gy/ka.

TABLE 3. D_E VALUES, OVERDISPERSION (AS CALCULATED BY THE CAM), ENVIRONMENTAL DOSE RATES, AND OPTICAL AGES FOR OSL SAMPLES COLLECTED FROM SITES IN THE NEW ENGLAND AND TASMANIAN WETLANDS.

Field sample ID	*De* (Gy)	Overdispersion (%)	Environmental dose rate (Gy/ka)	Optical age (ka)
BFL_01	18.7 ± 1	24.0 ± 4.0	1.78 ± 0.08	10.5 ± 0.8
BFL_02	17.5 ± 1.3	36.0 ± 5.0	1.19 ± 0.06	14.7 ± 1.4
BL_06	23.5 ± 0.6	12.4 ±1.8	0.81 ± 0.05	29.0 ± 2.0
BL_05	32.0 ± 0.8	6.0 ± 0.9	0.998 ± 0.05	32.1 ± 1.9
BL_07	4.1 ± 0.3	35.3 ± 5.2	0.89 ± 0.05	4.6 ± 0.4
BL_09	8.0 ± 0.4	25.0 ± 4.0	0.90 ± 0.05	8.9 ± 0.7
BL_08	18.2 ± 0.4	9.5 ± 1.4	0.88 ± 0.05	20.7 ± 1.3
BL_10	22.8 ± 0.8	14.6 ± 2.1	1.49 ± 0.07	15.3 ± 0.9
BL_12	9.6 ± 0.4	18.9 ± 2.8	1.35 ± 0.07	7.1 ± 0.5
BG_02	56 ± 2.0	19.0 ± 3.0	1.94 ± 0.09	28.9 ± 1.8
DGL_01	52.3 ± 1.3	4.3 ± 1.2	1.46 ± 0.07	35.8 ± 2.1
DGL_03	30.2 ± 0.7	11.3 ± 1.7	1.07 ± 0.06	28.2 ± 1.8
RCL_03	38.0 ± 3.0	35.0 ± 5.0	2.95 ± 0.14	12.9 ± 1.2
BSLE_02	45.0 ± 3.0	31.0 ± 5.0	2.44 ± 0.11	18.4 ± 1.5
BSLE_03	42.0 ± 2.0	26.0 ± 4.0	2.46 ± 0.11	17.1 ± 1.2
BSLE_01	43.2 ± 1.7	18.0 ± 3.0	2.31 ± 0.10	18.7 ± 1.2
LOI_S3	15.8 ± 0.5	17.0 ± 2.0	1.17 ± 0.05	13.5 ± 0.8
LOI_S4	29.0 ± 0.5	8.5 ± 1.3	1.81 ± 0.08	16.0 ± 0.8
LOI_S5	25.1 ± 0.4	8.1 ± 1.3	1.54 ± 0.07	16.3 ± 0.9
TLC_1B	0.13 ± 0.01	49.7 ± 7.1	1.33 ± 0.06	0.1 ± 0.0
TLC_1A	9.0 ± 0.3	14.5 ± 2.4	0.56 ± 0.03	16.1 ± 1.1
LS_02	0.15 ± 0.01	44.5 ± 6.6	1.39 ± 0.07	0.1 ± 0.0
LS_01	0.87 ± 0.17	90.7 ± 13.84	1.87 ± 0.09	0.5 ± 0.1

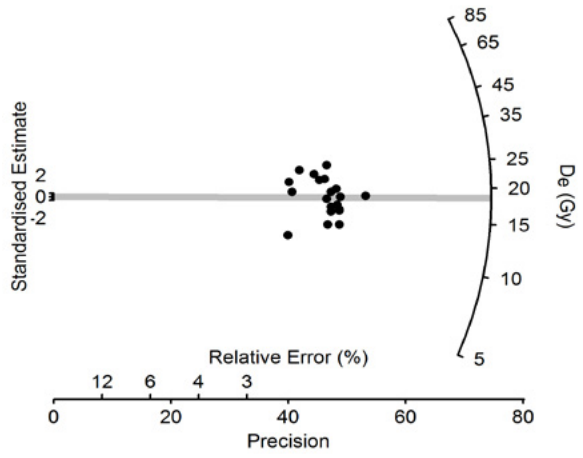
Field sample ID	*De* (Gy)	Overdispersion (%)	Environmental dose rate (Gy/ka)	Optical age (ka)
LS_01*	4.4 ± 1.0	90.7 ± 13.84	1.87 ± 0.09	2.4 ± 0.5
LT_01	13.5 **±** 1.2	39.0 **± 6.0**	1.91 ± 0.09	7.1 ± 0.7
LT_02	31.0 ± 3.0	41.0 ± 6.0	1.780 ± 0.082	17.4 ± 1.9
LT_03	78.0 ± 6.0	35.0 ± 6.0	1.549 ± 0.070	50.4 ± 4.6

***** D_e value and ages estimated using the MAM

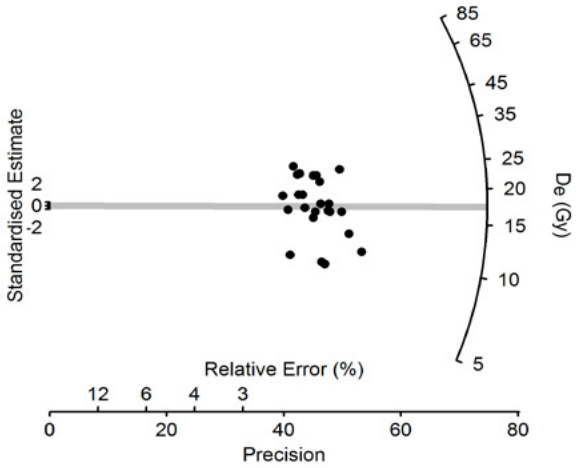
Table 4. Radioactivity measurements (in ppm) and converted dose rates (Gy/ka).

Sample ID	Water content, %	K, %	Th, ppm	U, ppm	Gamma dose rate	Beta dose rate	Cosmic dose rate	Total dose rate
BFL_01	0.051	0.3765	10.83	1.58	0.778 ± 0.052	0.716 ± 0.049	0.242 ± 0.036	1.778 ± 0.082
BFL_02	0.018	0.2628	6.51	0.85	0.472 ± 0.031	0.443 ± 0.030	0.242 ± 0.036	1.189 ± 0.060
BL_06	0.514	0.3323	1.61	0.44	0.208 ± 0.014	0.321 ± 0.022	0.254 ± 0.038	0.814 ± 0.050
BL_05	0.913	0.3637	2.85	0.74	0.307 ± 0.020	0.407 ± 0.028	0.253 ± 0.038	0.998 ± 0.054
BL_07	0.731	0.386	1.9	0.45	0.235 ± 0.016	0.365 ± 0.025	0.254 ± 0.038	0.885 ± 0.051
BL_09	0.196	0.3839	1.97	0.48	0.243 ± 0.016	0.371 ± 0.025	0.255 ± 0.038	0.901 ± 0.052
BL_08	0.000	0.3598	2.06	0.49	0.239 ± 0.016	0.357 ± 0.024	0.256 ± 0.038	0.882 ± 0.052
BL_10	1.034	0.8057	3.27	1	0.464 ± 0.031	0.750 ± 0.051	0.253 ± 0.038	1.487 ± 0.073
BL_12	0.786	0.7115	3.14	0.75	0.408 ± 0.027	0.653 ± 0.044	0.254 ± 0.038	1.346 ± 0.067
BG_02	1.469	0.6213	8.34	2.13	0.779 ± 0.051	0.880 ± 0.059	0.252 ± 0.038	1.942 ± 0.089
DGL_01	0.155	0.8454	3.28	0.7	0.445 ± 0.030	0.747 ± 0.051	0.240 ± 0.036	1.463 ± 0.071
DGL_03	0.000	0.5287	2.53	0.49	0.038 ± 0.020	0.486 ± 0.033	0.240 ± 0.036	1.065 ± 0.056
RCL_03	1.352	2.0514	7.26	1.19	0.977 ± 0.064	1.709 ± 0.115	0.236 ± 0.035	2.953 ± 0.138
BLSE_02	7.735	1.759	6.32	1.33	0.819 ± 0.052	1.401 ± 0.090	0.189 ± 0.028	2.440 ± 0.108
BLSE_03	9.239	1.8936	5.75	1.22	0.801 ± 0.050	1.437 ± 0.091	0.186 ± 0.028	2.455 ± 0.108
BLSE_01	12.102	1.6691	6.76	1.46	0.796 ± 0.049	1.306 ± 0.081	0.180 ± 0.027	2.314 ± 0.099
LOI_S3	15.354	0.7841	3.48	0.53	0.360 ± 0.022	0.583 ± 0.035	0.191 ± 0.029	1.166 ± 0.052
LOI_S4	5.479	1.3107	3.42	0.79	0.545 ± 0.035	1.017 ± 0.066	0.212 ± 0.032	1.806 ± 0.083
LOI_S5	9.438	1.1378	3.02	0.7	0.458 ± 0.029	0.848 ± 0.054	0.203 ± 0.031	1.541 ± 0.070
TLC_1B	5.403	0.3575	8.84	0.77	0.565 ± 0.036	0.521 ± 0.034	0.216 ± 0.032	1.333 ± 0.061
TLC_1A	20.305	0.2165	1.97	0.31	0.149 ± 0.009	0.189 ± 0.011	0.186 ± 0.028	0.556 ± 0.034
LS_02	8.434	1.0762	1.99	0.47	0.380 ± 0.024	0.770 ± 0.049	0.209 ± 0.031	1.391 ± 0.065
LS_01	8.406	1.6054	1.97	0.61	0.514 ± 0.032	1.117 ± 0.071	0.209 ± 0.031	1.872 ± 0.086
LT_01	2.048	0.8158	8.84	1.29	0.754 ± 0.049	0.913 ± 0.061	0.209 ± 0.031	1.907 ± 0.086
LT_02	0.524	0.8438	6.53	1.2	0.653 ± 0.043	0.883 ± 0.060	0.213 ± 0.032	1.780 ± 0.082
LT_03	3.995	0.6511	7.29	1.01	0.598 ± 0.039	0.716 ± 0.047	0.204 ± 0.031	1.549 ± 0.070

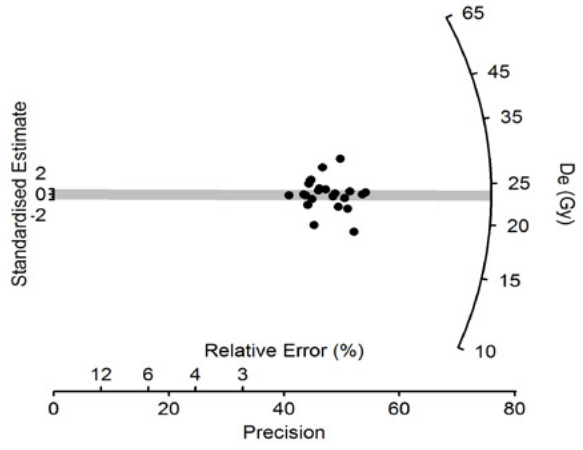
BFL_01



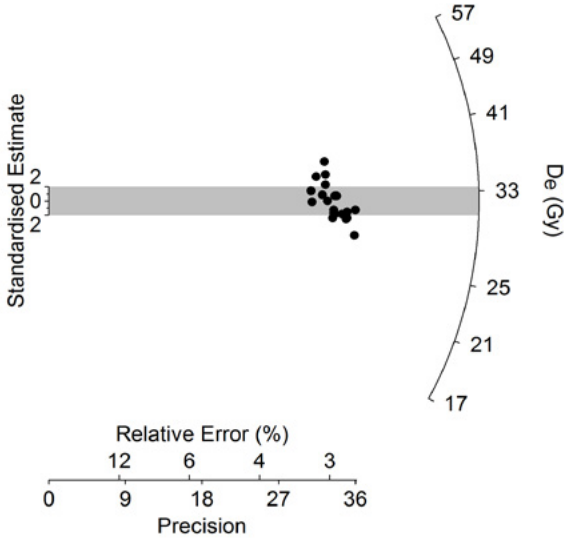
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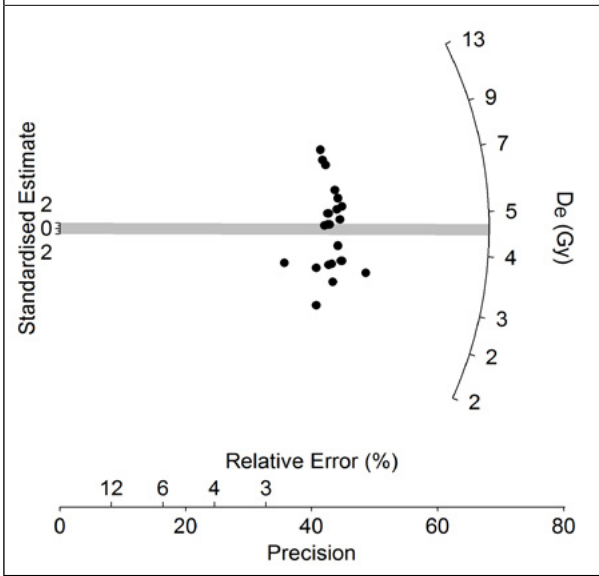
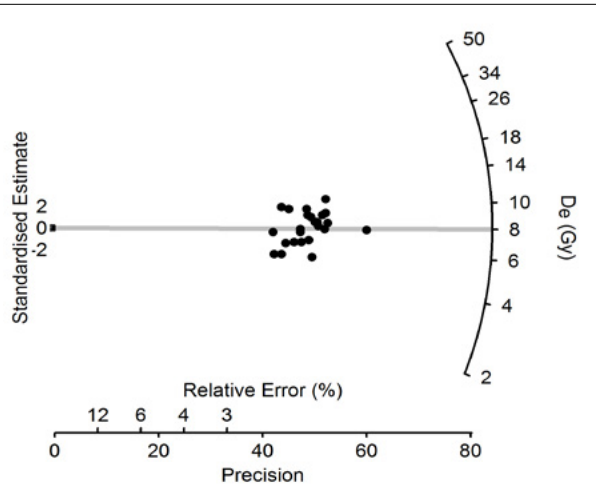
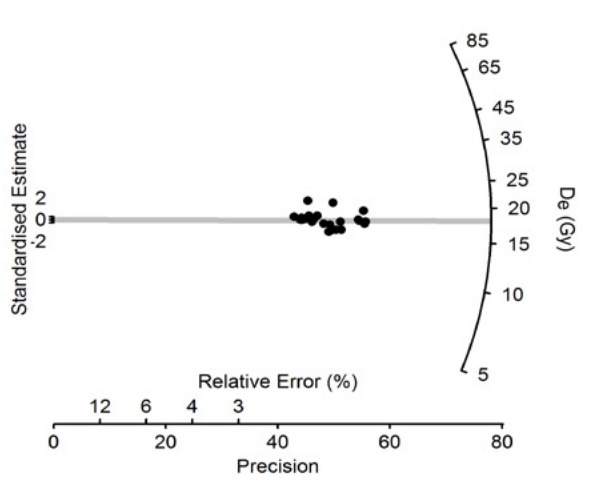
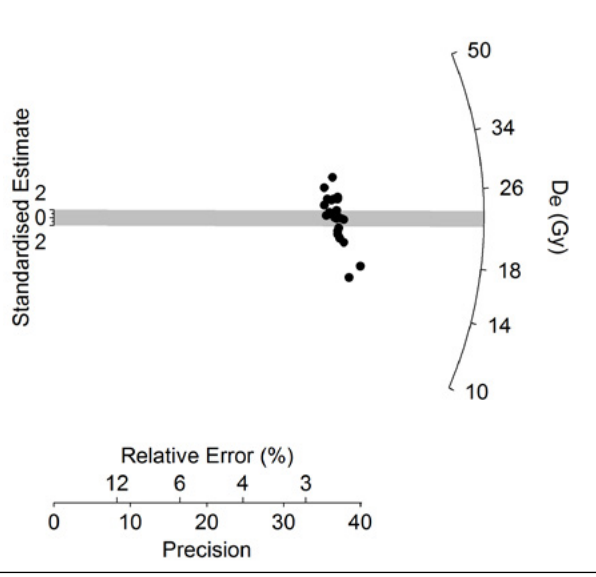


BL_06

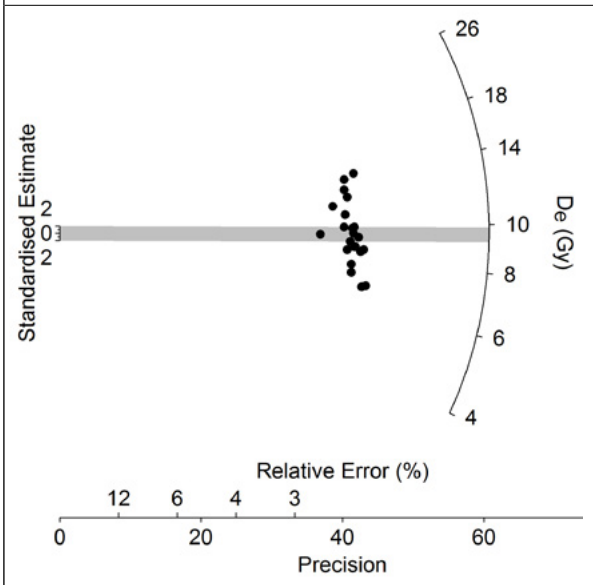


BL_05

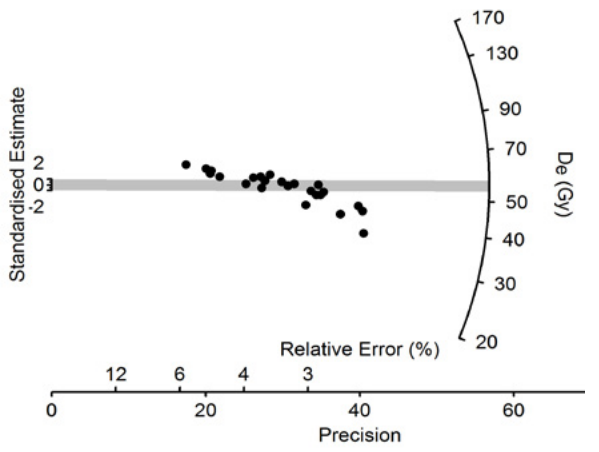


BL_07	BL_09
	
BL_08	**BL_10**
	

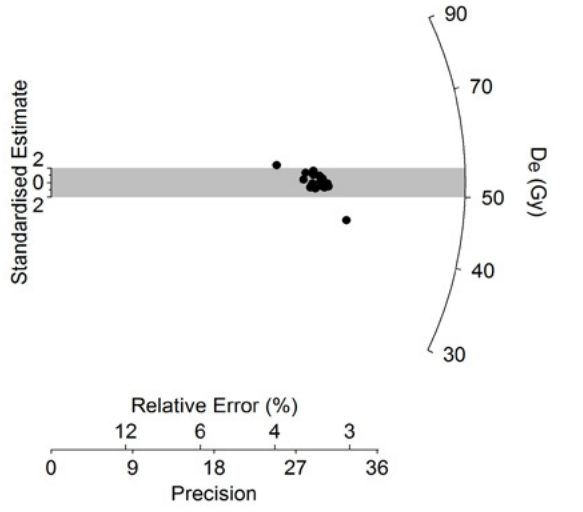
BL_12



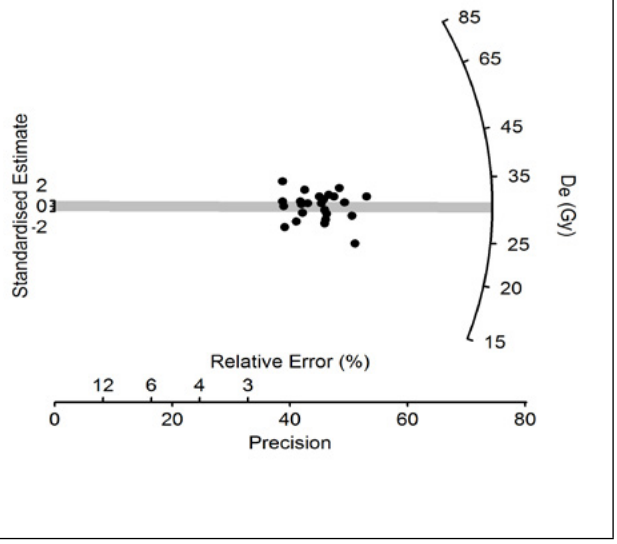
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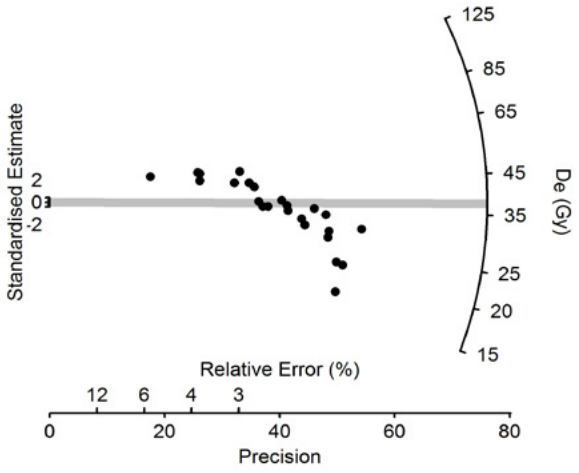
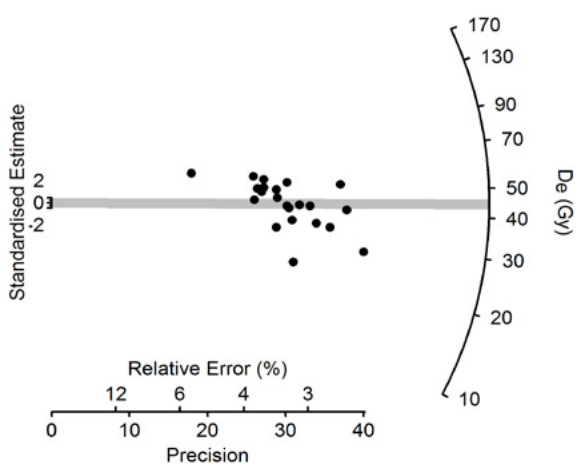
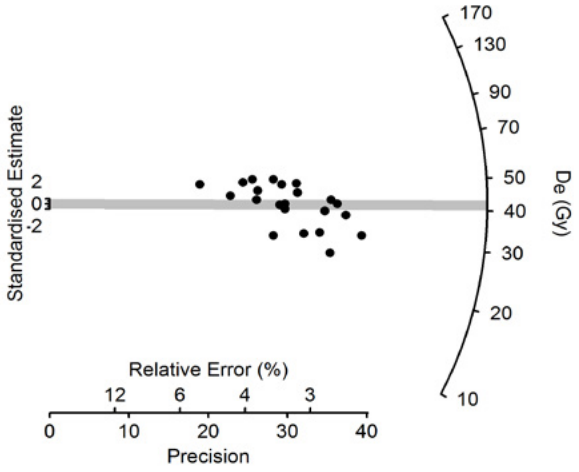
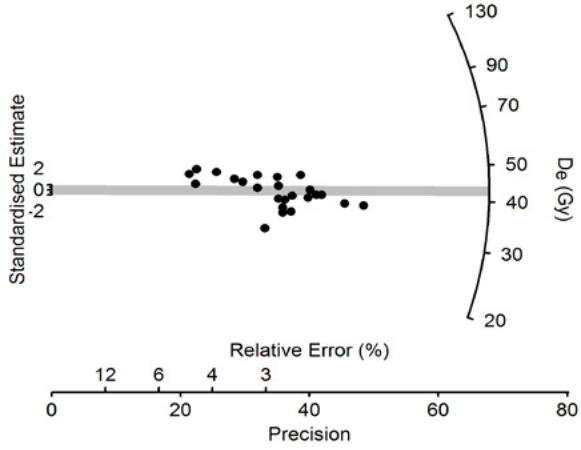


DGL_01

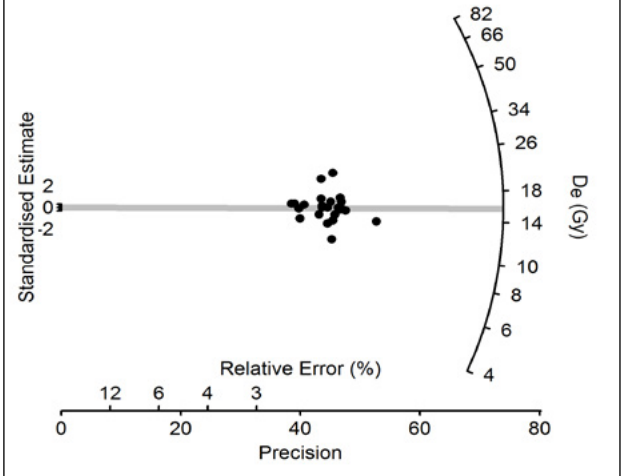


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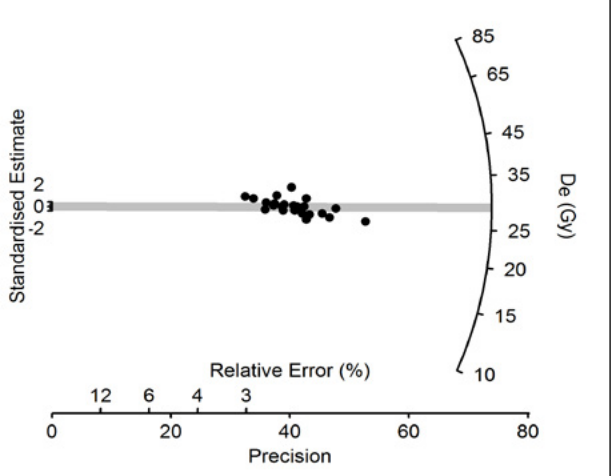


RCL_03	BSLE_02
	
BSLE_03	**BSLE_01**
	

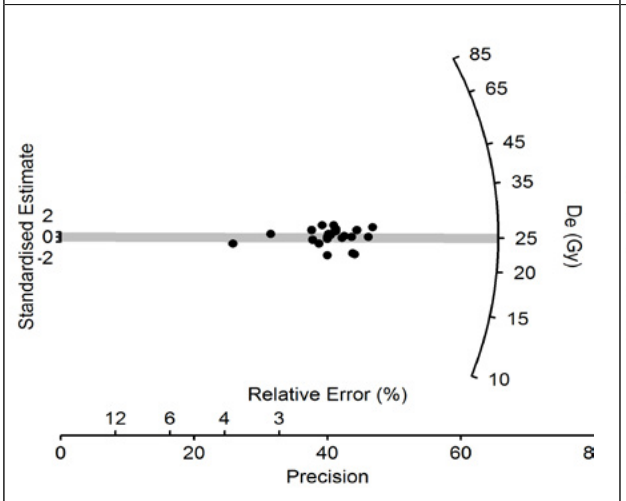
LOI_S3



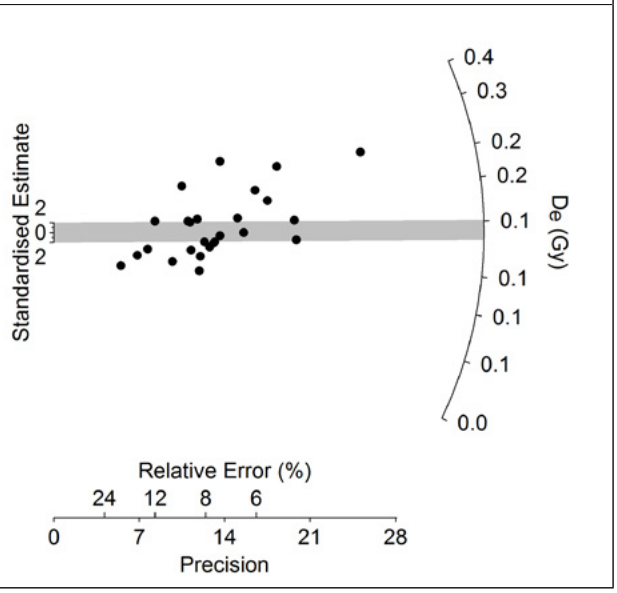
LOI_S4

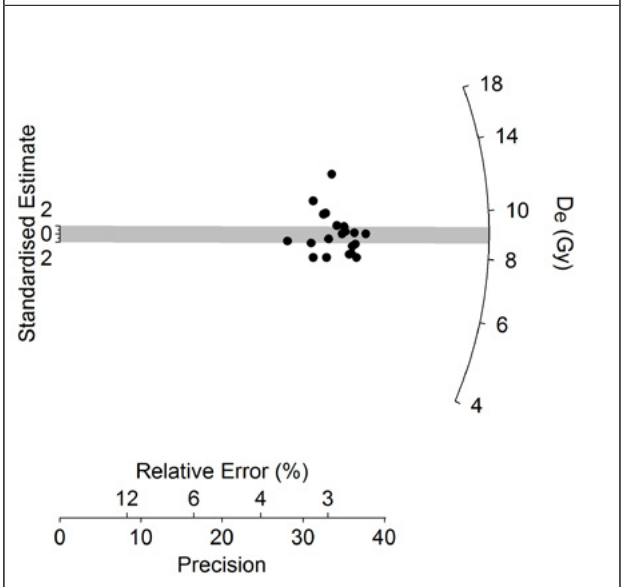
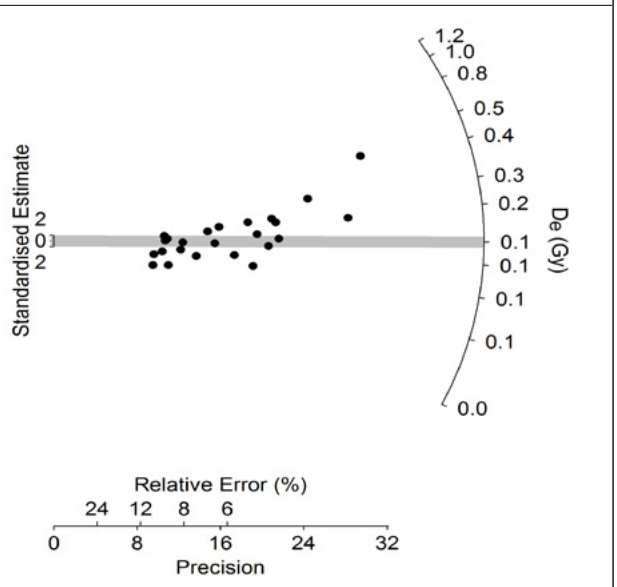
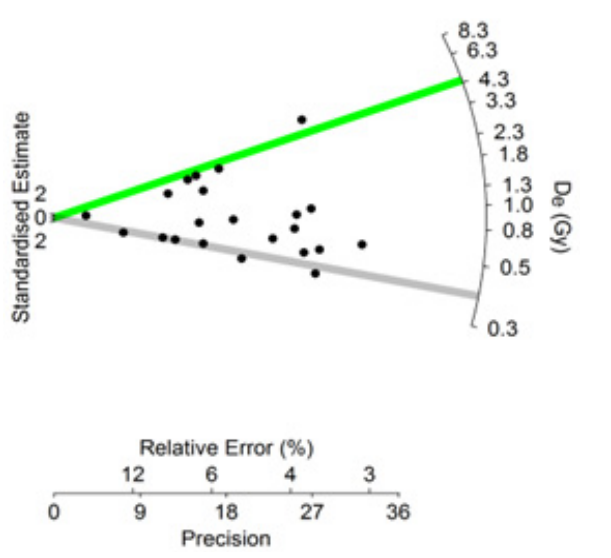
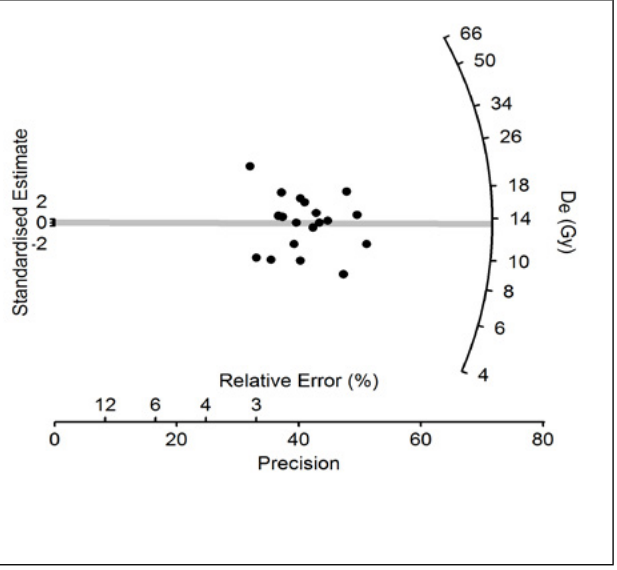


LOI_S5



TLC_1B



TLC_1A	LS_02
	
LS_01	**LT_01**
	

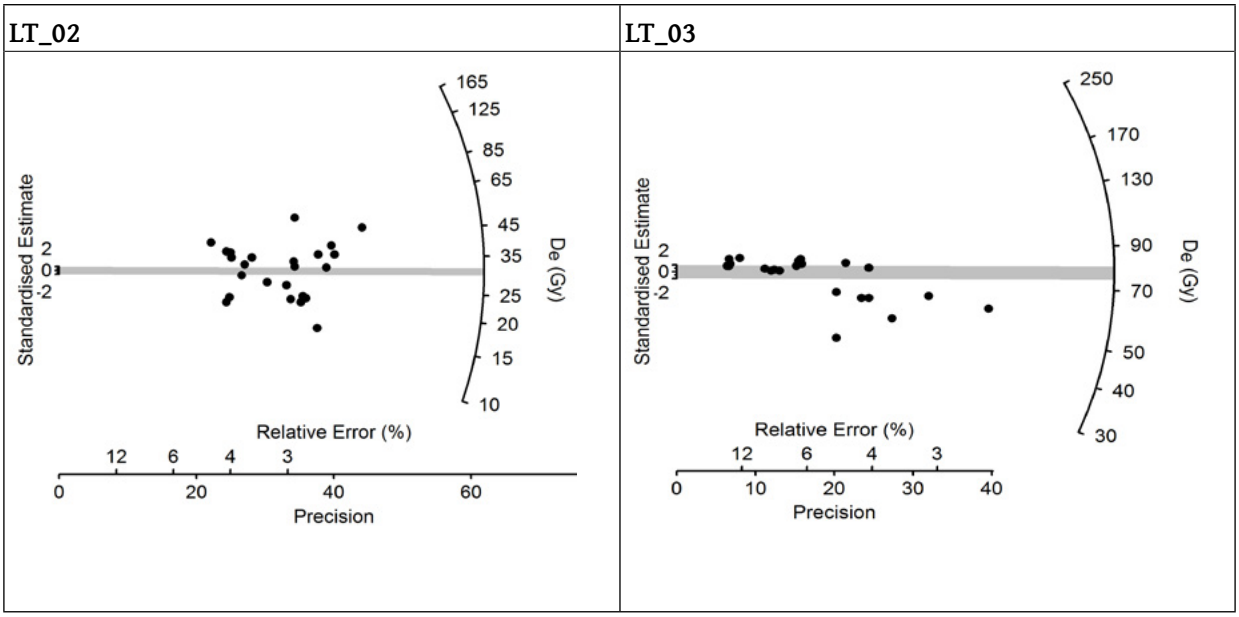


Figure 3 *Radial plots for each of the dated samples. Solid dots indicate the accepted De values for each aliquot. The grey band indicates the weighted mean De value as determined by the central age model.*

Optical ages

Ages for each sample were determined using the optical age equation (Age ka = D_e / D_r) and are presented in Table 3. Unless otherwise stated, CAM D_e values were used for the final age determination.

Barley Field Lagoon (BFL)

The D_e values for the two samples from Barley Field Lagoon in NSW (BFL_01 and BFL_02) were determined using the CAM, although high OD values are observed. These samples have OSL ages of 10.5 ± 0.8 thousand years (ka) and 14.7 ± 1.4 ka, respectively, and are in the correct stratigraphic order. The high OD values for these samples (24 ± 4% for BFL_01 and 36 ± 5% for BFL_02) are likely related to variations of the OSL signal properties that are inherent to the quartz grains or variations in environmental beta irradiations of grains during the burial period, and not sediment mixing.

Big Llangothlin (BL, BG)

Ages for the eight samples analysed from Big Llangothlin Lagoon in NSW range from 4.6 ± 0.4 ka (BL_07) and 32.1 ± 1.9 ka (BL_05). In general, ages obtained on samples collected from the same sequence (i.e., the same pit or wall face) are in correct stratigraphic order, apart from samples BL_10 and BL_12 sampled from Pit 1 on the east side of the lake. These samples were collected at depths of 147 cm and 200 cm and have optical ages of 15.3 ± 0.9 ka and 7.1 ± 0.5 ka, respectively. Interestingly, both these samples had higher calculated D_r values compared with the other BL samples measured from other locations within the lagoon site (Table 4). Two samples, BL_07 and BL_09 had high OD values exceeding 20% (35.3 ± 5.2% and 25 ± 4%, respectively). These higher values can be attributed to variations of the OSL signal properties inherent to the quartz grains or variations in environmental dose rates during the deposition, rather than sediment mixing.

Dangars Lagoon (DGL)

The two samples analysed from Dangars Lagoon in NSW were collected from Pit A (DGL_01) and Pit B (DGL_03) and have optical ages of 35.8 ± 2.1 ka and 28.2 ± 1.8 ka, respectively. The radial plots (and low OD values of <12%), indicate that the samples were composed of a single population of well-bleached grains (Figure 3) to support accurate D_e values and final age determinations.

Racecourse Lagoon (DGL)

The one sample analysed from Racecourse Lagoon in NSW (RCL_03) has an optical age of 12.9 ± 1.2 ka. Although the OD value for this sample was high (35 ± 5%), this can be attributed to variations of the OSL signal properties inherent to the quartz or variations in environmental dose rates, and is unlikely to be the outcome of sediment mixing.

Bells Lagoon (BSLE)

The three samples from Bells Lagoon in Tasmania were sampled from the same main pit from depths ranging from 150 to 180 cm. All three samples are of similar age ranging from 17.1 ± 1.2 ka and 18.7 ± 1.2 ka, and in reasonable stratigraphic order when the error margins are considered. Two samples had high OD values exceeding 20% (31 ± 5% for BSLE_02 and 26 ± 4% for BSLE_03), but indicate variations of the OSL signal properties within the quartz grains or variations in environmental dose rates, rather than sediment mixing.

Lagoon of Islands (LOI)

The three samples analysed from the Lagoon of Islands in Tasmania are of similar age, with the two samples analysed from the dune deposit (LOI_S4 and S5, sampled from depths of 60 and 85 cm) aged between 16.0 ± 0.8 ka and 16.3 ± 0.9 ka, respectively. The remaining sample (LOI_S3) was taken from below lake floor at a depth of 50 cm and has an optical age of 13.5 ± 0.8 ka.

Lake Crescent (TLC)

The two samples analysed from Lake Crescent in Tasmania collected from the sandbank shore dune have optical ages of 0.1 ± 0.0 ka (TLC_1B) and 16.1 ± 1.1 ka (TLC_1A). The OD value of the former sample (TLC_1B) was very high at 38.7 ± 7.3%. We attribute this high OD value to variations of the OSL signal properties within the quartz grains or variations in environmental dose rates, rather than sediment mixing.

Lake Sorell (LS)

The two samples analysed from the Lake Sorell in Tasmania have very young optical ages of 00.1 ± 0.0 ka (LS_02) and 0.5 ± 0.1 ka (LS_01), despite being taken from depths of 265 cm and 315 cm, respectively. For sample LS_01, which had a very high OD value of 91 ± 14%, the distribution of D_e values in the radial plot suggests that sediments from this sample might have been incompletely bleached before burial. Thus, the MAM was applied to obtain a final D_e value for this sample to determine the maximum dose population, which was measured at 4.4 ± 1 Gy, giving it a maximum optical age of 2.4 ± 0.5 ka.

Lake Tiberias (LT)

Ages for the three samples analysed from the Lake *Tiberias* in Tasmania range from 7.1 ± 0.7 ka (LT_01) and 50.4 ± 4.6 ka (LT_03). Interestingly, there is a 10 ka difference in the ages obtained for samples LT_01

and LT_02 (7.1 ± 0.7 ka and 17.4 ± 1.9 ka, respectively), which were both sampled from Pit 1 at a depth of 60 cm. It is unclear why these samples vary so greatly in optical age, but both samples had high OD values (ranging between 35 and 41%) that we attribute to differences in the OSL signal properties within the quartz grains and/or variations in environmental dose rates.

Conclusion

In general, optical ages for each site occur in good stratigraphic order with only a few exceptions from Big Llangothlin lagoon and Lake Tiberias, the latter showing a large difference in ages from the same depositional context. Only one sample, LS-01 from Lake Sorell in Tasmania, appears to have probable mixing of sediments. For this sample, the maximum or minimum age models can be applied to determine D_e values for calculation of the maximum and minimum ages. Other samples with high OD values (n=11) are likely composed of grains with different OSL signal properties or have been subject to varied environmental dose rates during their burial period. Thus, the CAM is considered an appropriate means for determining De values for all samples (apart from LS-01) that were then used in final age calculation.

Acknowledgements and author contribution

We thank Terry Lachlan, Yasamin Jafari and Maria Schaarschmidt for technical support, help in the laboratory and discussions on data analysis and interpretation. YG and Zenobia Jacobs determined the D_e values for final age calculation and constructed the radial plots. EH determined the final dose rate values and age estimates with help from YG, ZJ and MS. EH compiled the report with contributions from YG.

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Luminescence Dating of Ten Sediment Samples from Lagoon Sites

A Report Prepared for Richard Fullagar
by
Nathan Jankowski
University of Wollongong

Introduction

Optically stimulated luminescence (OSL) provides an estimate of the time elapsed since sediment grains (usually quartz or feldspar) were last exposed to natural sunlight (Huntley *et al.* 1985, Aitken 1998). Quartz grains have been used exclusively in this study. The OSL signal in quartz is produced as a result of ionising radiation exposure throughout the period of burial. The radiation flux, termed the dose rate (Dr, measured in Gray [Gy] per thousand years [ka]), is derived from the decay of radionuclides in the surrounding sediments, with a contribution also coming from cosmic rays. Once the quartz grains are buried and no longer exposed to sunlight, the electrons released during the ionisation of the quartz crystal begin to accumulate within defects in the crystal lattice, known as electron traps. The longer the period of burial, the larger the number of electrons that accumulate in the electron traps, the larger the OSL signal. The amount of radiation received over the period of burial is known as the equivalent dose (D_e) and is measured in Gy. If both the D_e (Gy) and Dr (Gy/ka) are known, then the optical age of the sediments (in ka) can be estimated by dividing the former by the latter.

Sample preparation and measurement

A total of ten samples were delivered to the OSL dating laboratory at the University of Wollongong, NSW and were prepared and measured by N. Jankowski. Each tube was opened under dim red light conditions, with the light-exposed sediment at the end of each tube used in the determination of the sediment moisture content and Dr. The remaining 'light-safe' material was then prepared using standard laboratory procedures as outlined in Wintle (1997) for D_e determination. The sediments were sieved to obtain the 180–212 µm grain size fraction, and washed in 10% hydrochloric acid (to remove any carbonates) and then in 10% hydrogen peroxide (to oxidise any organic material). These chemical pre-treatment washes were carried out until any sign of reaction ceased. The remaining material was then density separated using heavy liquid (sodium polytungstate) to remove any heavy minerals and feldspar grains to obtain a 'purified' sample of, predominantly, quartz. The 180–212 µm quartz fraction was then given a 40 min etch in 48% hydrofluoric (HF) acid. This step not only removes the outer alpha particle-irradiated rind of the quartz grains but also preferentially attacks any feldspar grains that may have not been removed during density separations. The grains were rinsed in 32% hydrochloric acid to remove any fluoride precipitates. The HF-acid etched quartz was again sieved to 180–212 µm to remove any of the now, much smaller, feldspar grains, before being stored in black plastic until sample measurement.

De determination

All samples were measured in this study using the same automated Risø DA-20 TL/OSL reader (Bøtter-Jensen *et al.* 2000, Bøtter-Jensen *et al.* 2003). Optical stimulation of the samples was achieved using blue (~470 ± 30 nm) LEDs and regenerative doses administered using a calibrated $^{90}Sr/^{90}Y$ beta irradiator that delivered a dose of ~1.8 Gy/min. The luminescence signal was detected using a bi-alkali EMI 9635Q photomultiplier tube after passing through two U-340 filters. These filters block the stimulation (blue) wavelength but allow the passage of the UV luminescence signal (Spooner and Questiaux 2000).

All D_e measurements were made using aliquots of HF-acid etched quartz. Single-aliquots were constructed by applying a 1 mm diameter coating of silicon spray oil to stainless steel discs (10 mm in diameter). This was achieved using a 'mask' plate that was placed over the stainless steel discs with apertures of 1 mm diameter drilled into the surface. A monolayer of quartz grains (~10 grains) was then applied to each stainless steel disc. For each sample, at least 22 aliquots of HF-acid etched 180–212 μm quartz grains were measured.

The D_e of each of the aliquots was determined using the single-aliquot regenerative-dose (or SAR) procedure of Murray and Wintle (2000, 2003). The SAR procedure (presented in Table 1) entails making a number of OSL measurements to construct a dose-response curve, from which the D_e can be determined by projecting the OSL intensity of the natural (burial) dose onto the dose-response curve and interpolating onto the dose axis. Prior to the measurement of the natural and regenerative dose OSL signals, all aliquots were preheated to 160˚C for 10 s (Step 1), and the OSL signal measured using blue LEDs for a period of 40 s (Step 2). The aliquots were given a fixed test dose (Step 3) to both track and account for any sensitivity changes throughout the successive SAR cycles. The aliquots were again preheated to 160˚C for 5 s (Step 4) before the test dose OSL signal was measured (Step 5) in the same way as Step 2. A 0 Gy dose, (Step 8), repeated dose (Step 9) and an IR-depletion ratio test (Duller 2003) (Step 12) were also included in the SAR procedure to check for signal recuperation, monitor the effectiveness of the test dose correction procedures and check for the presence of feldspar contamination, respectively.

Table 1. SAR procedure (Murray and Wintle 2000, 2003) used throughout this study for both dose recovery and determination of D_E values for naturally-irradiated quartz grains.

Steps	Treatment	Purpose
1	Preheat to 160 ˚C for 10 s	-
2	Stimulate with blue LEDs for 40 s at 125 ˚C	Induce OSL from natural or regenerative dose
3	Test dose	-
4	Preheat to 160 ˚C for 5 s	-
5	Stimulate with blue LEDs for 40 s at 125 ˚C	Induce OSL from test dose
6	Regenerative dose	-
7	Return to Step 1 and repeat at least 3 times altering the size of the regenerative dose over each cycle	-
8	Give 0 Gy regenerative dose and Steps 1–5	Check for recuperation
9	Repeat first regenerative dose and Steps 1–5	Check recycling ratio
10	Repeat first regenerative dose point	-
11	Stimulate using infrared diodes for 40 s at 50 ˚C	-
12	Repeat Steps 1–5	Check for feldspar contamination

The D_e values were estimated from the integral of the OSL decay curve over the first 1.6 s of optical stimulation. A contribution of the OSL signal background and instrument 'noise' was estimated from the average OSL count over the final 2.4 s of optical stimulation and was subtracted from the OSL signal. The dose-response curves generated in this study could be best explained using a saturating exponential function or a saturating exponential with an additional linear term. The associated uncertainty on each D_e measurement was calculated using Monte Carlo simulations (Duller 2007) (N=50) and includes contributions from counting statistics, dose-response curve fitting and a 1.5% uncertainty on the

reproducibility of the Risø reader. These error calculations were carried out using the Analyst v. 3.24 software program. The final age uncertainty also includes an additional 2% uncertainty associated with the calibration of the beta radiation source.

The use of the SAR measurement parameters (as outlined in Table 1) was verified using a series of dose-recovery tests (Murray and Roberts 1998) performed on a small sub-sample of one sample from each locality. Each sub-sample was exposed to natural sunlight for a period of at least 1 week during the austral summer, to remove the natural OSL signal. A series of 1 mm aliquots were then made using these 'bleached' quartz grains and the same methods as outlined above (Table 1). Prior to running the SAR procedure, a 'surrogate' natural dose was administered and treated as an unknown. In the four samples tested (LOI-S1, BL13, BFL03 and DGL02), the SAR procedure as outlined in Table 1 was able to recover the given dose at either 1 or 2σ. The results are given in Table 2.

TABLE 2. DOSE-RECOVERY TEST RESULTS FOR THE FOUR SUBSAMPLES OF SUN-BLEACHED QUARTZ FROM EACH OF THE FOUR STUDY LOCALITIES. THE D_E OF THE RECOVERED DOSE WAS CALCULATED USING THE CENTRAL AGE MODEL OF GALBRAITH *ET AL.* (1998).

Sample name	Preheat 1 temperature (°C)	Preheat 2 temperature (°C)	Given Dose (Gy)	Recovered Dose (Gy)	Recovered/given dose ratio	Number of aliquots (N)
LOI-S1	160/10 s	160/5 s	30.1 ± 0.6	28.5 ± 0.5	0.94 ± 0.03	11
BL13	160/10 s	160/5 s	10.0 ± 0.2	9.9 ± 0.2	0.99 ± 0.03	8
BFL03	160/10 s	160/5 s	39.6 ± 0.8	38.5 ± 0.4	0.97 ± 0.02	10
DGL02	160/10 s	160/5 s	30.1 ± 0.6	30.5 ± 0.5	1.01 ± 0.03	6

The quality of each aliquot was screened using a series of objective rejection criteria based upon those outlined in Jacobs *et al.* (2003, 2006a, 2006b). An aliquot was rejected if:

1. The test dose OSL signal following the natural OSL signal was less than 3 times the respective background or had an error of >20%
2. The recycling ratio (the ratio of the two equivalent regenerative dose points given at the beginning and the end of the SAR procedure) were < or > than 2σ from unity
3. The IR-depletion ratio test was <2σ from unity
4. The sensitivity-corrected natural dose was either saturated or failed to intersect the dose-response curve
5. The 0 Gy dose gave a sensitivity-corrected OSL signal that was > 5% of the associated sensitivity-corrected natural OSL signal.

The remaining aliquots that were not rejected were then used in the determination of the sample D_e and, by extension, optical age.

Dr measurements

The sediment removed from the end of each of the sample tubes were used to estimate the Dr delivered to the sediments during the period of burial. Initially, the weight of the dosimetry sediments was recorded before being placed in a 100°C oven for at least 1 week. The dry weight was then recorded and an estimate of sediment moisture content calculated as the proportion of water within the sediments. As a general rule, an increase of ~1% in the sediment moisture content results in an ~1% decrease in the

associated Dr and therefore a corresponding increase of ~1% in the age. An uncertainty of 25% at 1σ was added to each estimate of sediment moisture content to encompass a range of likely moisture contents experienced throughout the period of burial.

To determine the Dr for each sample, the dried sediments were pulverised and homogenise into a fine powder. A small portion of each sample (~5 g) was then shipped to the Genalysis Intertek Laboratory in Perth, Australia. The elemental concentrations of K (%), U (μg/g) and Th (μg/g) were then determined for each sample. The K content was measured using inductively couple plasma optical emission spectrometry (ICP-OES), whereas the concentrations of both U and Th were determined using inductively coupled plasma mass spectrometry (ICP-MS). Uncertainties of 2.5, 3 and 4% (at 1σ) were assigned to the K, U and Th concentrations, respectively. These uncertainties were based on previous reproducibility analyses conducted at the Genalysis Intertek Laboratory.

The concentrations of K, U and Th were converted into beta and gamma dose rates using the conversion factors of Guerin *et al.* (2011). Both the beta and gamma dose rates for each sample were then adjusted to account for their respective soil moisture contents using the equations of Aitken (1985) and Aitken and Xie (1990). The attenuation of the beta dose rate was corrected for using the equations presented in Brennan (2003) and a 3% uncertainty added in quadrature to the associated beta dose rate uncertainty. The cosmic dose rate was calculated using the equations presented in Prescott and Hutton (1994) and accounts for the geomagnetic latitude, elevation above sea level and the thickness of sedimentary overburden of each of the samples at each of the four locations. A 10% uncertainty was assigned to each cosmic-ray dose rate estimate. The total environmental dose rate therefore, represents the sum of the beta, gamma and cosmic-ray dose rates. An internal alpha dose rate contribution was also included (0.032 ± 0.011 Gy/ka) in the total dose rate based upon measurements made by Bowler *et al.* (2003) on quartz grains from south-eastern Australia. The total uncertainty on the Dr was calculated as the quadratic sum of all measured and calculated (estimate) uncertainties.

Results

De results

The majority of the aliquots were not rejected during the data screening process. Of those rejected aliquots, the recuperation of the OSL signal following a 0 Gy regenerative dose was the main reason for their rejection. The OSL behaviour of all samples is therefore considered favourable. The OSL signals are bright and appear, in the majority of cases, to be dominated by a fast-decaying OSL component.

The D_e values for each sample, following data screening, were then displayed graphically as radial plots (Galbraith 1990). These radial plots are shown in Figure 1. The use of radial plots, as described by Galbraith (1990), provides a means of visually evaluating the D_e distribution of samples in terms of its overall patterning and precision of the individual accepted D_e. A distinctive feature of the radial plot is that all D_e values lying along a radial line from the standardised estimate axis to the log D_e axis arc on the right-hand side of the plot have the same D_e (Galbraith 1990). Furthermore, a 95% confidence interval can be fitted to the plot, extending +2σ and -2σ from the standardised D_e estimate. Where these intervals cross the log dose axis, the 95% confidence interval can be read off (Galbraith *et al.* 1999). In addition, the precision associated with the D_e values can also be read from the radial plot. Relative precision arises from the inherent difference in the luminescence intensities between quartz grains (i.e., counting statistics) along with errors associated with variability in the fitted dose-response curve and instrument reproducibility (Duller 2007). Through the use of radial plots, the range of precisions can be easily observed as the imprecise grains fall to the left of the plot, whereas the higher precision grains fall towards the right, along the relative error axis at the base of the plot.

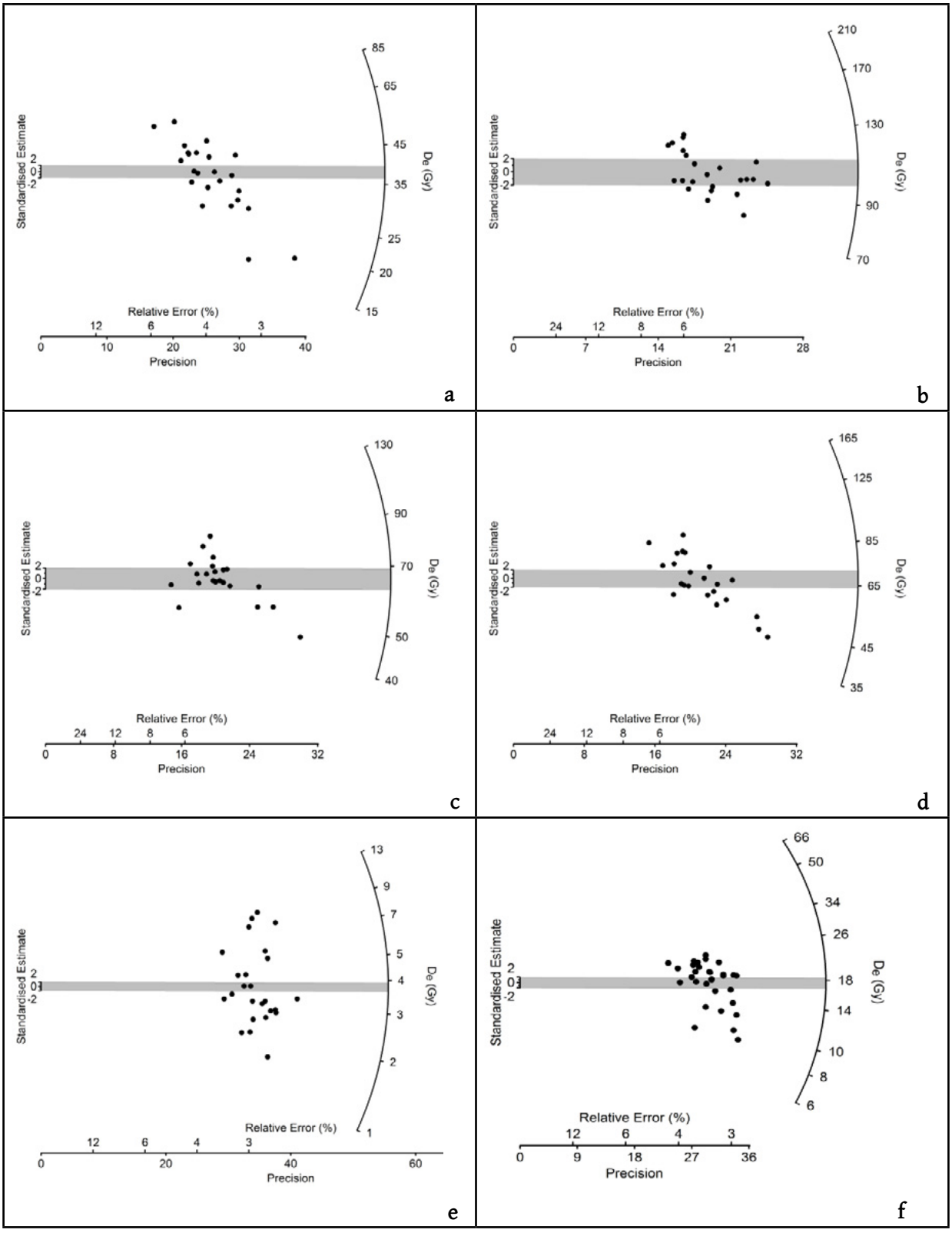
A common feature throughout each of the samples measured is the greater than statistically-anticipated spread between the D_e values for the same sample. To clarify, it is expected that 95% of the data ought to fall within 2σ of the mean, however this is not the case in any of the samples measured. This additional spread is referred to as overdisperison (OD; Galbraith *et al.* 1999). OD is commonplace in OSL dating studies, with values of ~20% being observed even under favourable conditions (Olley *et al.* 2004), i.e. where the sediments are assumed to be well bleached prior to burial and not mixed post-deposition. The OD for each of the samples was calculated using the central age model (CAM) of Galbraith *et al.* (1999), with values ranging between 14 ± 2% (LOI-S2) to 51 ± 7% (BL13). The OD present within these sample could be due to a number of factors including, but not limited to: partial bleaching of the OSL signal prior to burial (Pietsch *et al.* 2008), microscale variations in the beta dose rate (Murray and Roberts 1997, Nathan *et al.* 2003), and/or post-depositional mixing (David *et al.* 2007).

Currently, it is difficult to draw any conclusion regarding which type of factor may be influencing each sample. This situation may be overcome by measuring single-grains of quartz, rather than aliquots, to better elucidate that D_e distribution patterns within each sample. At present, the most appropriate means of determining the sample D_e is the CAM of Galbraith *et al.* (1999) that provides a weighted mean D_e value (± standard error) for the sample. The standard error on the D_e takes into account the extent of the measured OD within each sample. The D_e values for each of samples measured are presented in Table 3. Over the 10 samples and four study localities, the D_e values range from 3.8 ± 0.4 (BL13) to 105 ± 4 Gy (BFL04).

Dr results

The results of the moisture content and Dr determinations are also shown in Table 3. The moisture content results show substantial variability within some sites, but little within others. This result may be due to fluctuating water levels or even variations in sedimentology associated with clay content. For example, BL04 (upper sample) and BL03 (lower sample) were collected ~50 cm apart, vertically, and have measured water contents of 14.2 and 37.5%, respectively. In contrast, within the same locality, BL13 (upper sample) and BL11 (lower sample) were collected ~80 cm apart and have more similar moisture contents of 5.3 and 8.5%, respectively.

The total environmental dose rates range from 0.94 ± 0.07 (BL03) to 2.20 ± 0.08 Gy/ka (BFL04). As was the case with the moisture content results, the Dr results also show varying degrees of similarity between the sample locations. The two samples collected from BFL show the largest disparity between the measured Dr (1.40 ± 0.05 and 2.20 ± 0.08 Gy/ka), whereas the LOI samples have the least amount of internal variability (1.77 ± 0.05 to 1.72 ± 0.09 Gy/ka).


Standardised Estimate
De (Gy)
Relative Error (%)
Precision
a
b
c
d
e
f

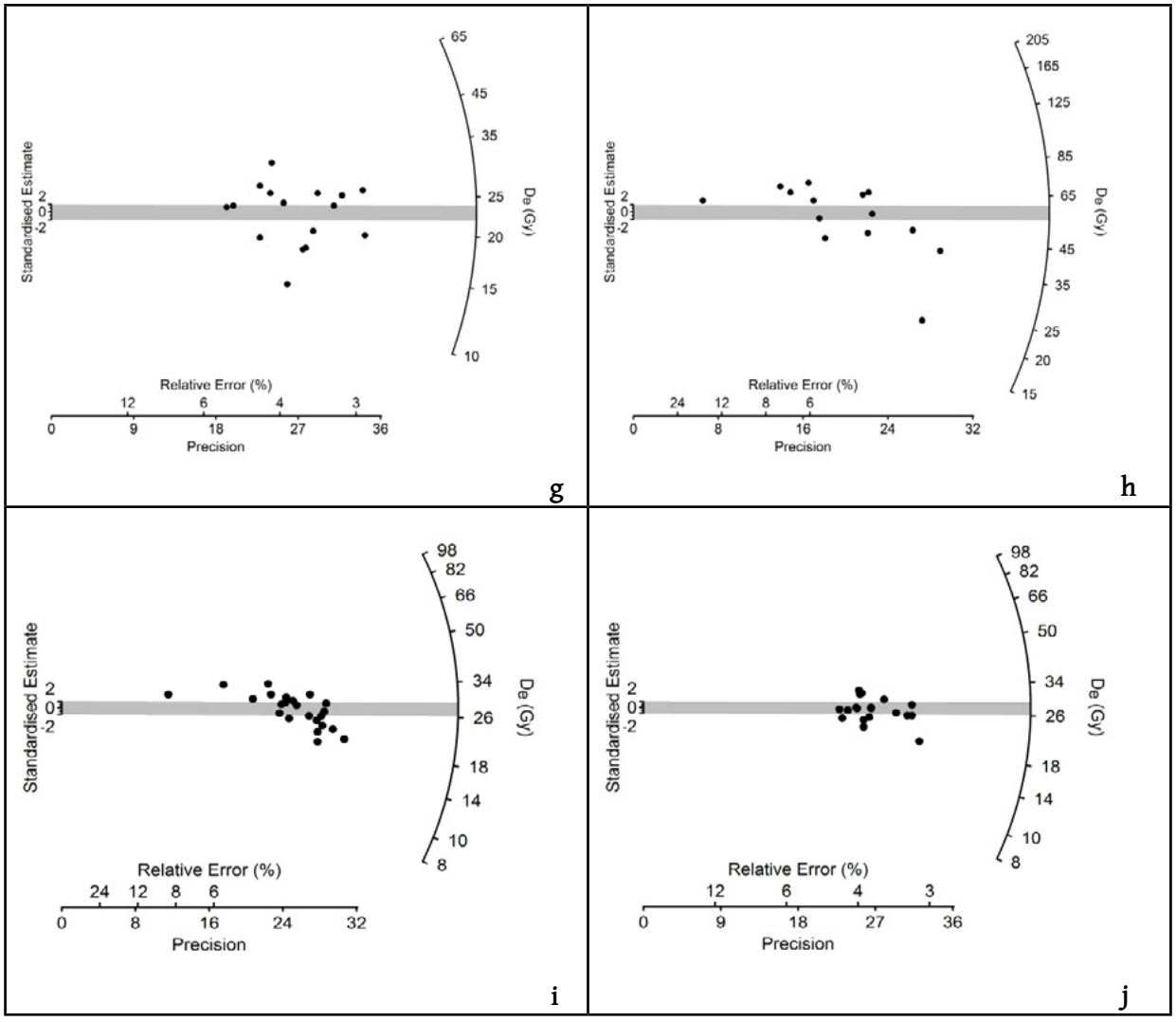


Figure 1. *Radial plots for the accepted D_e values for samples: a) BFL03; b) BFL04;c) BL04; d) BL03; e) BL13; f) BL11; g) DGL02; h) DGL04; i) LOI-S1; and j) LOI-S2. In each Radial plot the grey band extended from the 'standardised estimate' axis on the left is centred upon the weighted mean D_e value determined for each sample using the central age model of Galbraith et al. (1999).*

Table 3. Moisture contents, environmental dose rates, D_E values, OD values and optical ages for the ten samples measured in this study.

Sample Name	Sample depth (cm)	Measured water content[a]	Environmental dose rate (Gy/ka)[b]				Number of aliquots accepted/ measured	D_e (Gy)[d]	OD (%)	Optical age (ka)[e]
			Beta	Gamma	Cosmic	Total[c]				
BFL03	53	5.3 ± 1.3	0.55 ± 0.02	0.58 ± 0.01	0.23 ± 0.02	1.40 ± 0.05	24/24	38 ± 3	36 ± 5	27.2 ± 2.4
BFL04	70	7.7 ± 1.9	0.90 ± 0.03	1.04 ± 0.03	0.22 ± 0.02	2.20 ± 0.08	23/24	105 ± 4	16 ± 3	47.8 ± 2.7
BL04	118	14.2 ± 3.6	0.46 ± 0.02	0.37 ± 0.01	0.23 ± 0.02	1.09 ± 0.05	22/24	66 ± 3	18 ± 3	60.5 ± 4.1
BL03	165	37.3 ± 9.3	0.40 ± 0.02	0.34 ± 0.01	0.17 ± 0.02	0.94 ± 0.07	23/24	68 ± 4	26 ± 4	72.6 ± 7.3
BL13	32	5.3 ± 1.3	0.73 ± 0.03	0.45 ± 0.01	0.25 ± 0.03	1.47 ± 0.05	25/36	3.8 ± 0.4	51 ± 7	2.6 ± 0.3
BL11	114	8.5 ± 2.1)	0.69 ± 0.02	0.42 ± 0.01	0.23 ± 0.05	1.37 ± 0.05	31/36	18 ± 1	28 ± 4	12.8 ± 0.8
DGL02	70	4.3 ± 1.1	0.71 ± 0.02	0.41 ± 0.01	0.23 ± 0.02	1.38 ± 0.04	16/24	23 ± 2	29 ± 5	16.3 ± 1.4
DGL04	105	3.4 ± 0.9	0.58 ± 0.02	0.36 ± 0.01	0.23 ± 0.02	1.20 ± 0.04	14/24	58 ± 7	42 ± 8	48.1 ± 6.1
LOI-S1	50	1.0 ± 0.3	0.97 ± 0.03	0.54 ± 0.01	0.23 ± 0.02	1.77 ± 0.05	23/38	28 ± 1	21 ± 3	15.8 ± 0.9
LOI-S2	60	19.2 ± 4.8	0.96 ± 0.04	0.54 ± 0.01	0.19 ± 0.02	1.72 ± 0.09	19/22	27 ± 1	14 ± 2	15.6 ± 1.0

Field water content was calculated as the % mass of water per unit of dried sediment. The dried dose rates were then adjusted to the weighted mean (± 1σ) water content for age determination.

Measured and calculated dose rates ± (1σ). Beta and Gamma dose rates were determined from elemental concentrations of U, Th and K conducted by Genalysis Intertek laboratory in Perth, Western Australia. These concentrations were converted into dose rates using the conversion factors presented in Guérin *et al.* (2012). The cosmic dose rate determined using the equations of Prescott and Hutton (1994) and assigned a ± 10% uncertainty.

Mean ± total (1σ) uncertainty. Uncertainty calculated as the quadratic sum of all known and estimated random and systematic uncertainties associated with each dose rate component. Total dose rate includes an assumed internal alpha dose rate value of 0.03 ± 0.01 Gy/ka for all samples based on the estimate presented in Bowler *et al.* (2003) for south-east Australian quartz.

Mean ± total (1σ) uncertainty. The uncertainty of this term includes a ± 2% uncertainty associated with the calibration of the beta source irradiator.

Mean ± total (1σ) uncertainty. Uncertainty calculated as the quadratic sum of the random and systematic uncertainties associated with D_e and dose rate estimates.

Optical ages

The optical ages for each of the 10 samples were calculated by dividing the D_e by the Dr and are presented in Table 3. The two samples from Barley Fields Lagoon have optical age estimates 27.2 ± 2.4 (BFL03—upper sample) and 47.8 ± 2.7 ka (BFL04—lower sample). At Big Llangothlin Lagoon, the optical age estimates of BL04 and BL03 are concordant at 2σ having ages of 60.5 ± 4.1 (upper sample) and 72.6 ± 7.3 ka (lower sample), respectively. The remaining two samples from this location are significantly different with BL13 (upper sample) having an optical age estimate of 2.6 ± 0.3 ka, whereas the optical age of BL11 (lower sample) is significantly older at 12.8 ± 0.8 ka. The two sample from Dangars Lagoon are also significantly different. Here the upper sample (DGL02) has an optical age estimate of 16.3 ± 1.4 ka, while the lower sample (DGL04) is much older at 48.1 ± 6.1 ka. The samples from the Lagoon of Islands also have concordant ages at 1σ. The upper sample (LOI-S1) has an optical age of 15.8 ± 0.9 ka, while the lower sample (LOI-S2) has an age estimate of 15.6 ± 1.0 ka.

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Luminescence Dating of Sediments from New England Uplands, Southeast Australia

A Report Prepared for Richard Fullagar and Wendy Beck
by

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University of Washington

Introduction

Seventeen sediment samples for luminescence dating were collected from shallow upland lagoons in the New England bioregion of Southeast Australia. The samples were submitted by Richard Fullagar and Elspeth Hayes of the University of Wollongong as part of a project to establish the nature and chronology of Aboriginal occupation of the upland wetlands. Some of the samples were from adjoining lunettes and some from the lake shores. In the excavations no visual stratigraphy was present and charcoal for radiocarbon dating was rare. The sediments were clayey silts deposited by aeolian and alluvial processes, but contained sufficient fine-grained quartz sand for OSL dating. Sample numbers and provenience information are given in Table 1. They are listed by site, square and stratigraphic order, not by UW sample numbers (which were assigned rather arbitrarily).

Table 1. Sample numbers and provenience information for each of the analysed samples

Lab sample #	Site	UOW sample #	Square	Depth (cm)
UW3425	Kings Plains		REDIG	12
UW3426	Kings Plains		REDIG	16
UW3479	Barley Field	BFL-E1-01	E1	31
UW3483	Barley Field	BLF-E1-02	E1	40
UW3482	Barley Field	BFL-E1-03	E1	42
UW3484	Barley Field	BFL-E2-01	12	22
UW3481	Barley Field	BFL-E2-02	25	24
UW3480	Barley Field	BFL-E2-03	25	47
UW3485	Barley Field	BFL-E2-04	25	51
UW3487	Barley Field	BFL-E2-05	32	30
UW3488	Barley Field	BFL-E2-06	32	47
UW3490	Dangars	DGL-E1-01	20	43
UW3486	Dangars	DGL-E1-02	20	42
UW3492	Dangars	DGL-E2-01	0.5	38
UW3491	Big Llangothlin	BGL-20	1B	20
UW3489	Big Llangothlin	BGL-50	1B	50
UW3493	Big Llangothlin	BGL-75	1B	75

Methods

Sample preparation

Sample material is removed from the collection container, leaving aside any portions (such as the ends of tubes) that may have been exposed to light. The latter may be used for dose rate information. From the unexposed portions, about one quarter is set aside as a voucher (material that can be used at a later date if necessary). If separate samples for measuring moisture content have not been collected, the voucher can be used for this. For moisture the sample is simply weighed wet, and then dried for several days at 50°C before weighing again. The wet minus the dry weight divided by the dry weight gives the percent moisture by weight.

Remaining unexposed material is separated into size fractions by sieving. If the material contains abundant silt or clay, the sample is wet sieved through a 90 µm screen. Otherwise, it is sieved dry. The greater than 90 µm fraction is treated with HCl and H_2O_2, rinsed three times with water and dried. It is then dry sieved to retrieve the 180-212 µm fraction (or any other fraction deemed appropriate). This fraction is etched for 40 minutes in HF and then rinsed with water, HCl and water again. After drying, it is passed through the 180 µm screen to remove any degraded feldspar. The material caught in the screen is density separated using a lithium metatungstate solution of 2.67 specific gravity.

Equivalent Dose

Grains are placed in specially-manufactured discs for single-grain measurement. Luminescence is measured on a Risø TL-DA-15 reader with single-grain attachment. Stimulation is by a 532 nm laser delivering 45 W/cm^2. Detection is through 7.5 mm U340 (ultraviolet) filters. Exposure is for 0.8s on each grain at 125°C. The first 0.06 s is used for analysis and the last 0.15 s for background. Measurements using different preheats are made to determine a "preheat equivalent dose plateau." A preheat within the plateau region is chosen for analysis. Most commonly, a preheat of 240°C for 10 seconds follows each dose, except for the calibrating test doses after which a 200°C for 1 second preheat is employed. The test dose usually employed is about 3 Gy. Doses are delivered by a ^{90}Sr beta source which provides about 0.1 Gy per second to coarse-grained quartz.

Equivalent dose (D_e), which is a measure of the total absorbed dose through time, is determined using the single-aliquot regenerative dose (SAR) protocol (Murray and Wintle 2000; Wintle and Murray 2006). The SAR method measures the natural signal and the signal from a series of regeneration doses on a single aliquot. The method uses a small test dose to monitor and correct for sensitivity changes brought about by preheating, irradiation or light stimulation. SAR consists of the following steps:

1. preheat,
2. measurement of natural signal (OSL or IRSL), L(1),
3. test dose,
4. cut heat,
5. measurement of test dose signal, T(1),
6. regeneration dose,
7. preheat,
8. measurement of signal from regeneration, L(2),
9. test dose,
10. cut heat,
11. measurement of test dose signal, T(2),
12. repeat of steps 6 through 11 for various regeneration doses.

A growth curve is constructed from the L(i)/T(i) ratios and the equivalent dose is found by interpolation of L(1)/T(1). A zero-regeneration dose and a repeated regeneration dose are employed to ensure the procedure is working properly.

An advantage of single-grain dating is the opportunity to remove from analysis grains with unsuitable characteristics by establishing a set of criteria grains must meet. Grains are eliminated from analysis if they: (1) had poor signals (as judged from errors on the test dose greater than 30 percent or from net natural signals not at least three times above the background standard deviation); (2) did not produce, within 20 percent, the same signal ratio (often called recycle ratio) from identical regeneration doses given at the beginning and end of the SAR sequence, suggesting inaccurate sensitivity correction; (3) yielded natural signals that did not intersect saturating growth curves; (4) had a signal larger than 10 percent of the natural signal after a zero dose; (5) produced a zero D_e (within 1-sigma of zero); or (6) contained feldspar contaminates (judged visually on growth curves by a reduced signal from infrared stimulation before the OSL measurement; done on two doses to lend confidence the reduction in signal is due to feldspar contamination). At the end of each SAR sequence, linear-modulated OSL (where the laser power is ramped from 0 to 90% power in 30 seconds) is measured for each grain. Grains clearly dominated by a component other than the fast component (judged visually) are marked, and if the D_e from these differ significantly from those of fast-component grains, they are also removed from analysis.

A dose recovery test is performed on some grains. The luminescence of the grains is first removed by exposure to the laser (using the same parameters mentioned earlier). A dose of known magnitude is then administered. The SAR procedure is then applied to see if the known dose can be obtained. Successful recovery is an indication that the procedures are appropriate.

A D_e value is obtained for each suitable grain. Because of varying precision from grain to grain, the same value is not obtained for each grain even if all are of the same age. Instead, a distribution is produced. The common age model and central age model of Galbraith (Galbraith *et al.* 1999, 2005) are statistical tools used in evaluation of D_e distributions. These models are used in reference to D_e and not "age" per se, although dividing the D_e values by the bulk dose rate provides an "age" for each grain (not accounting for differential dose rates for individual grains). The common age model controls for differential precision by computing a weighted average using log D_e values. The central age model is similar except rather than assuming a single true value it assumes a natural distribution of D_e values, even for single-aged samples, because of non-statistical sources of variation. It computes an over-dispersion parameter (σ_b) interpreted as the relative standard deviation (or coefficient of variance) of the *true* D_e values, or that deviation beyond what can be accounted for by measurement error. Empirical evidence suggests that σ_b of between 10 to 20 percent are typical for single-aged samples (Jacobs *et al.* 2006; Olley *et al.* 2004). For samples of mixed ages, either a minimum age model or a finite mixture model is employed for evaluation. The minimum age (Galbraith *et al.* 1999) calculates a statistical minimum using a truncated normal distribution and is suitable for partially bleached samples. Finite mixture model (Roberts *et al.* 2000) uses maximum likelihood to separate the grains into single-aged components based on the input of a given σ_b value and the assumption of a log normal distribution of each component. The model estimates the number of components, the weighted average of each component, and the proportion of grains assigned to each component. The model provides two statistics for estimating the most likely number of components, maximum log likelihood (llik) and Bayes Information Criterion (BIC). The finite mixture model is appropriate for samples that have been mixed post-deposition (although with limitations). For many of the samples in this application, unlogged versions of these models were used, because many values were close to zero. This followed Arnold *et al.* (2009).

Dose Rate

Radioactivity is measured by alpha counting in conjunction with atomic emission for ^{40}K. Samples for alpha counting are crushed in a mill to flour consistency, packed into plexiglass containers with ZnS:Ag screens, and sealed for one month before counting. The pairs technique is used to separate the U and Th decay series. For atomic emission measurements, samples are dissolved in HF and other acids and analyzed by a Jenway flame photometer. K concentrations for each sample are determined by bracketing between standards of known concentration. Conversion to ^{40}K is by natural atomic abundance. Radioactivity is also measured, as a check, by beta counting, using a Risø low level beta GM multicounter system. About 0.5 g of crushed sample is placed on each of four plastic sample holders. All are counted for 24 hours. The average is converted to dose rate following Bøtter-Jensen and Mejdahl (1988) and compared with the beta dose rate calculated from the alpha counting and flame photometer results.

Additional soil samples are analyzed where the environment is complex, and gamma contributions determined by gradients (after Aitken 1985: appendix H). For some samples, *in situ* measurements are done using a $CaSO_4$:Dy dosimeter. About 0.1 g of the powder is sealed in a copper capsule. After heating to remove any latent luminescence, the capsule is placed in the ground as near to the location of the sample as possible and left for one year. The dosimeter is returned to the laboratory accompanied by a travel dosimeter which measures any radiation absorbed en route. In the laboratory, the luminescence from the $CaSO_4$ is measured by thermoluminescence and the signal calibrated against a beta source. The source is used with the shutter closed to provide a low calibrating dose, about 0.001 Gy/1000s.

Cosmic radiation is determined after Prescott and Hutton (1988). Radioactivity concentrations are translated into dose rates following Guérin *et al.* (2011).

Age calculation

Age is calculated using a laboratory constructed spreadsheet based on Aitken (1985). All given error terms are computed at one-sigma. Calendar dates are based on years before 2010.

Results

Dose Rate

Table 2 gives the concentration of the major radionuclides, and the beta dose rate calculated in two ways. The beta dose rate is calculated from flame photometry and alpha counting, assuming secular equilibrium, and also is derived directly from beta counting. The difference between the two measures is significant for all but seven samples. In all but three cases where there is a significant difference the beta counting results are lower than the alpha counting/flame photometry results. This suggests some disequilibrium, probably in the ^{238}U decay chain. I interpret the results as suggesting uranium leaching. The beta counting results, as a more direct measure, was used in the age calculation. This assumes any leaching (or enrichment) happened early on. Total dose rates are given in Table 3. Moisture content was taken as 6 ± 3 % for all samples, which is higher than what was actually measured from the samples, which appeared to have dried out some.

TABLE 2. RADIOACTIVITY

*Sample**	*238U (ppm)*	*233Th (ppm)*	*K (%)*	*Beta dose rate (Gy/ka)*	
				ß-counting	α-counting/flame photometry
UW3425	1.79 ± 0.15	7.16 ± 0.99	0.25 ± 0.01	*0.69 ± 0.06*	*0.53 ± 0.04*
UW3426	1.81 ± 0.12	2.97 ± 0.52	0.21 ± 0.01	*0.71 ± 0.09*	*0.52 ± 0.02*
UW3479	2.59 ± 0.24	15.73 ± 1.57	0.34 ± 0.01	0.91 ± 0.12	1.09 ± 0.06
UW3480	2.02 ± 0.15	5.93 ± 0.82	0.39 ± 0.01	*1.03 ± 0.13*	*0.78 ± 0.03*
UW3481	4.40 ± 0.32	16.04 ± 1.64	0.37 ± 0.01	*0.98 ± 0.12*	*1.39 ± 0.06*
UW3482	2.75 ± 0.25	16.30 ± 1.75	0.34 ± 0.01	1.03 ± 0.11	1.13 ± 0.11
UW3483	3.12 ± 0.26	14.93 ± 1.54	0.45 ± 0.02	*0.90 ± 0.10*	*1.24 ± 0.06*
UW3484	2.94 ± 0.26	11.52 ± 1.65	0.42 ± 0.03	1.05 ± 0.10	1.10 ± 0.06
UW3485	2.83 ± 0.32	26.25 ± 2.31	0.44 ± 0.01	*1.09 ± 0.09*	*1.50 ± 0.08*
UW3486	1.42 ± 0.12	5.01 ± 0.78	0.76 ± 0.03	*0.74 ± 0.10*	*0.97 ± 0.04*
UW3487	4.37 ± 0.40	28.97 ± 2.54	0.27 ± 0.01	*1.20 ± 0.12*	*1.66 ± 0.09*
UW3488	4.24 ± 0.29	13.12 ± 1.46	0.30 ± 0.01	*1.09 ± 0.11*	*1.22 ± 0.06*
UW3489	2.47 ± 0.20	9.16 ± 1.26	0.86 ± 0.03	1.28 ± 0.12	1.32 ± 0.05
UW3490	0.65 ± 0.13	11.64 ± 1.29	0.47 ± 0.03	0.80 ± 0.15	0.80 ± 0.05
UW3491	1.12 ± 0.21	19.44 ± 1.89	0.82 ± 0.02	1.21 ± 0.14	1.37 ± 0.06
UW3492	1.09 ± 0.09	2.99 ± 0.63	0.84 ± 0.03	0.83 ± 0.09	0.93 ± 0.03
UW3493	2.35 ± 0.17	5.89 ± 0.91	1.02 ± 0.04	*1.16 ± 0.11*	*1.34 ± 0.05*

TABLE 3. TOTAL DOSE RATES (GY/KA)

Sample	alpha	beta	gamma	cosmic	total
UW3425	0.01 ± 0.01	0.54 ± 0.04	0.45 ± 0.05	0.24 ± 0.05	1.23 ± 0.08
UW3426	0.01 ± 0.01	0.47 ± 0.03	0.30 ± 0.03	0.23 ± 0.05	1.01 ± 0.06
UW3479	0.02 ± 0.01	0.78 ± 0.06	1.01 ± 0.09	0.23 ± 0.05	2.05 ± 0.12
UW3480	0.01 ± 0.01	0.80 ± 0.04	0.57 ± 0.04	0.23 ± 0.05	1.60 ± 0.07
UW3481	0.02 ± 0.01	0.74 ± 0.05	1.23 ± 0.09	0.25 ± 0.05	2.25 ± 0.12
UW3482	0.02 ± 0.01	0.81 ± 0.06	1.05 ± 0.10	0.22 ± 0.05	2.11 ± 0.12
UW3483	0.02 ± 0.01	0.70 ± 0.05	1.10 ± 0.08	0.24 ± 0.05	2.05 ± 0.11
UW3484	0.02 ± 0.01	0.84 ± 0.06	0.89 ± 0.08	0.26 ± 0.05	2.01 ± 0.11
UW3485	0.01 ± 0.01	0.57 ± 0.04	0.93 ± 0.07	0.23 ± 0.05	1.75 ± 0.10
UW3486	0.01 ± 0.01	0.64 ± 0.04	0.55 ± 0.04	0.23 ± 0.05	1.43 ± 0.07
UW3487	0.03 ± 0.02	0.88 ± 0.07	1.82 ± 0.13	0.25 ± 0.05	2.97 ± 0.16
UW3488	0.02 ± 0.01	0.81 ± 0.05	1.07 ± 0.08	0.23 ± 0.05	2.12 ± 0.11
UW3489	0.01 ± 0.01	1.06 ± 0.05	0.87 ± 0.07	0.24 ± 0.05	2.18 ± 0.10
UW3490	0.01 ± 0.01	0.63 ± 0.04	0.70 ± 0.06	0. 23 ± 0.05	1.57 ± 0.09
UW3491	0.02 ± 0.01	1.08 ± 0.06	1.13 ± 0.10	0.27 ± 0.06	2.50 ± 0.13
UW3492	0.01 ± 0.01	0.78 ± 0.04	0.44 ± 0.03	0.24 ± 0.05	1.46 ± 0.07
UW3493	0.01 ± 0.01	0.92 ± 0.06	0.72 ± 0.06	0.21 ± 0.04	1.86 ± 0.09

Equivalent dose (De)

The sensitivity of the quartz grains was high. Table 4 gives the number of grains measured, those rejected for various reasons, the number of accepted grains, and the rate of accepted to measured. The average acceptance rate is 35.4%.

A dose recovery test was performed on about 100 grains each from UW3482, UW3486, UW3490, and UW3492 s as a test of procedures. Of these, 128 gave suitable signals. In this test, grains are first set to zero by exposure to the laser and then given a known dose. The SAR procedure is then applied to see if this known dose can be obtained. The ratio of obtained/administered dose was 0.988 ± 0.013 and the over-dispersion 7 ± 1 %. This is satisfactory. Despite the low over-dispersion, 10 percent over-dispersion was assumed to be typical of a single-aged sample for the different age models discussed next.

Table 4. Acceptance rates

Sample	N	No signal	Failed Recycle	Too high	Recuperation/ Zero dose	Feldspar	Accepted	Rate (%)
UW3425	192	22	2	2	49	0	117	60.9
UW3426	192	18	3	1	63	0	107	55.7
UW3479	288	101	13	22	2	1	149	51.7
UW3480	291	111	42	35	0	0	103	35.4
UW3481	186	50	7	3	17	0	109	58.6
UW3482	476	255	14	16	21	1	109	35.5
UW3483	191	82	8	16	1	0	78	40.8
UW3484	187	80	3	11	25	0	68	36.4
UW3485	290	94	13	8	4	3	168	57.9
UW3486	574	344	22	4	40	5	159	27.7
UW3487	386	173	15	29	10	0	159	41.2
UW3488	187	55	7	57	6	1	61	32.6
UW3489	376	210	10	11	10	0	135	35.9
UW3490	371	243	15	22	5	5	81	21.8
UW3491	382	244	9	2	17	2	108	28.3
UW3492	576	409	20	9	10	5	123	21.4
UW3493	379	247	41	23	2	2	64	16.9
total	**5524**	**2738**	**244**	**271**	**288**	**25**	**1958**	**35.4**

* "No signal" refers to grains that lacked a measurable signal, as judged by an error greater than 30% on the test dose or a natural signal that was not at least three standard deviations above background. The other criteria for rejection were for those grains where the designated criterion was the only problem. "Failed recycle" refers to grains where the recycle ratio did not fall within 0.8 and 1.2. "Recuperation" refers to grains where the signal from a zero dose was more than 10% of the natural signal. "Too high" refers to grains where the natural signal was larger than the signal from the highest regeneration dose and thus did not intersect the growth curve. "Zero dose" refers to grains where the derived equivalent dose was not significantly different from zero. "Feldspar" refers to grains where the signal lost intensity due to an infrared exposure. All grains falling under these criteria were rejected for analysis.

The natural D_e distributions are summarized in Table 5. This gives the number of grains for which a D_e could be derived, the central tendency expressed as the central age model (see appendix), and the over-dispersion. It also gives the D_e in terms of the minimum age model, which would be appropriate for partially bleached sediments. Over-dispersion ranges from 46 to 122%, with all but two over 80%, much higher than the 10% assumed for a single-aged sample. The samples are therefore composed of different aged grains, either because of mixing or partial bleaching. Partial bleaching is not a likely explanation. Some of the samples were from aeolian-deposited lunettes formed when the lakes were ephemeral. Others are from the lakeshore—probably reworked aeolian material by waves to form beaches and berms when the water was high. No streams feed these lagoons. Shallow depths and quiet water probably assured full bleaching.

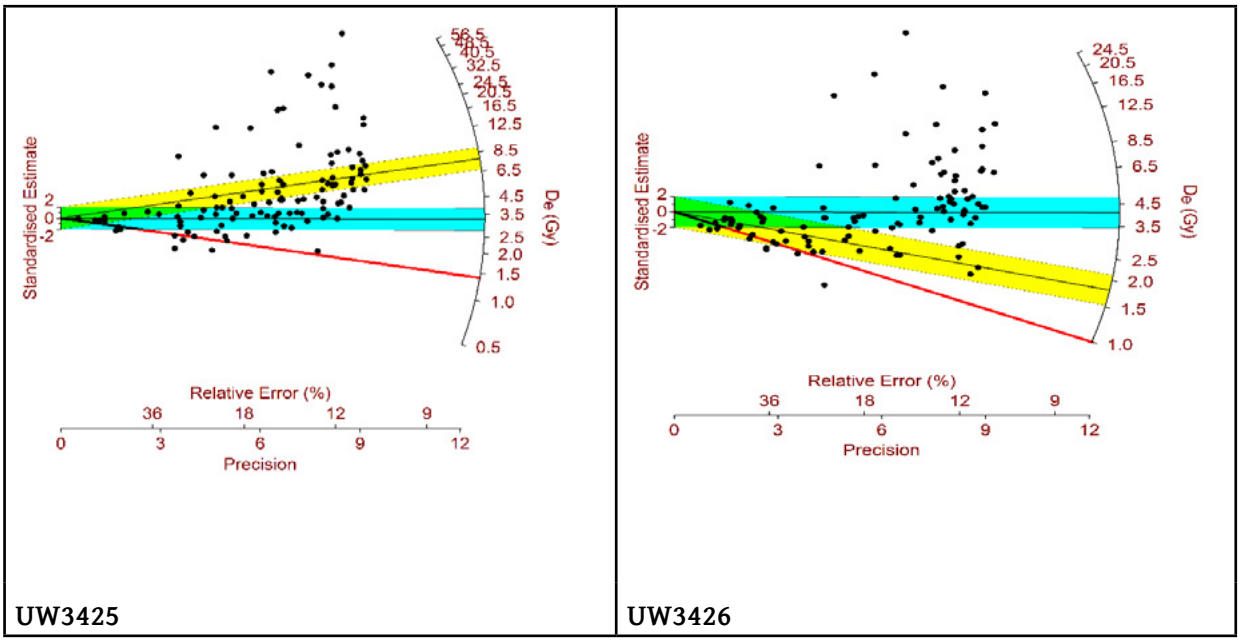
TABLE 5. D_E (GY) DISTRIBUTIONS

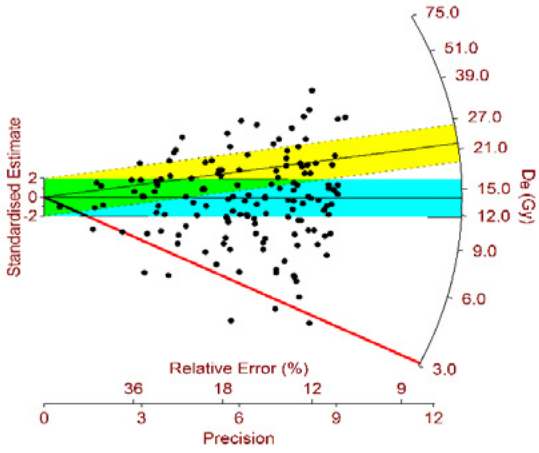
Sample	*N*	*Central age De (Gy)*	*σb (%)*	*Minimum age De* (Gy)
UW3425	117	6.40 ± 0.679	112 ± 7.6	1.36 ± 0.27
UW3426	107	3.78 ± 0.374	99 ± 7.2	0.96 ± 0.12
UW3479	149	12.9 ± 0.800	73 ± 4.5	3.09 ± 0.25
UW3480	102	19.9 ± 1.64	81 ± 5.9	3.06 ± 0.30
UW3481	109	7.95 ± 0.885	113 ± 8.0	1.01 ± 0.16
UW3482	169	14.2 ± 0.920	81 ± 4.7	1.30 ± 0.20
UW3483	78	17.8 ± 1.01	46 ± 4.2	8.37 ± 0.78
UW3484	68	6.50 ± 0.949	114 ± 11	1.32 ± 0.16
UW3485	168	13.0 ± 0.853	82 ± 4.7	3.60 ± 0.38
UW3486	159	9.74 ± 0.787	83 ± 5.2	2.34 ± 0.23
UW3487	159	9.35 ± 0.796	104 ± 6.2	1.35 ± 0.13
UW3488	61	17.8 ± 2.30	99 ± 9.3	1.50 ± 0.21
UW3489	135	14.1 ± 1.13	91 ± 5.8	2.19 ± 0.20
UW3490	81	11.4 ± 1.15	85 ± 7.5	2.99 ± 0.45
UW3491	108	4.59 ± 0.431	90.8 ± 7.0	1.37 ± 0.18
UW3492	123	2.76 ± 0.327	122 ± 8.8	0.68 ± 0.12
UW3493	64	24.1 ± 2.57	81 ± 7.9	7.67 ± 0.81

To evaluate mixing, the finite mixture model was applied to assess the structure of the data. The finite mixture model divides the equivalent dose distributions into single-aged components, assuming a normal distribution and an over-dispersion of 10%. Best fits isolated from 3 to 8 components for each sample. Table 6 gives the D_e for the three most abundant components and the percentage of grains making up that component. Figure 1 shows radial graphs of the D_e. Radial graphs plot D_e against precision, with the D_e standardized by the number of standard errors each value is away from a reference, in this case the most abundant component (blue) and the 2nd most abundant component (yellow). The shaded areas represent all points within two standard errors of the reference. Lines drawn from the origin through any point intersect the right-hand axis at the estimated D_e value. The red line is the equivalent dose of the third most abundant component. The graphs show significant scatter in all samples.

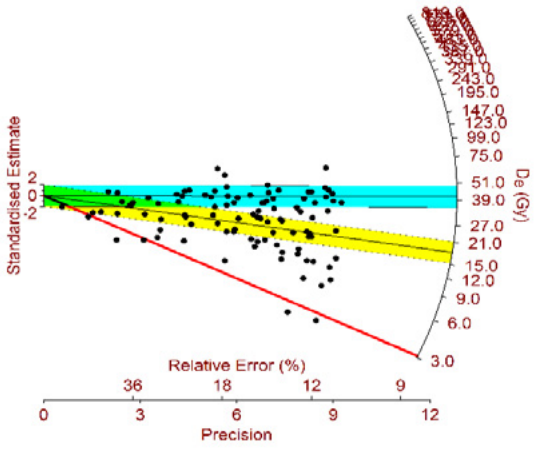
TABLE 6. FINITE MIXTURE MODEL

Sample	Most abundant Component		Second most abundant Component		Third most abundant Component	
	D_e (Gy)	%	D_e (Gy)	%	D_e (Gy)	%
UW3425	3.28 ± 0.363	23.1	7.84 ± 0.925	22.2	5.00 ± 1.01	21.7
UW3426	4.12 ± 0.139	43.2	1.79 ± 0.131	28.8	8.33 ± 0.502	13.4
UW3479	13.9 ± 0.440	30.5	22.2 ± 0.975	20.6	8.67 ± 0.358	19.6
UW3480	41.9 ± 1.74	30.7	18.4 ± 0.949	20.2	28.9 ± 3.50	14.5
UW3481	16.0 ± 0.643	23.2	4.70 ± 0.189	19.9	7.62 ± 0.366	14.7
UW3482	18.2 ± 0.414	55.9	10.8 ± 0.715	11.9	27.3 ± 2.37	8.8
UW3483	19.2 ± 1.23	50.8	12.7 ± 1.74	20.8	34.2 ± 1.86	18.6
UW3484	1.37 ± 0.113	20.3	8.98 ± 0.655	18.9	15.2 ± 1.03	16.3
UW3485	9.62 ± 0.51	31.4	12.6 ± 0.845	20.8	19.4 ± 0.902	14.4
UW3486	11.5 ± 0.631	24.6	1.7.9 ± 1.08	22.3	6.77 ± 0.533	16.6
UW3487	14.3 ± 0.578	22.7	9.85 ± 0.524	17.2	5.72 ± 0.235	15.2
UW3488	30.7 ± 1.36	28.9	8.85 ± 0.392	28.2	15.7 ± 0.652	22.3
UW3489	12.9 ± 0.372	27.7	45.1 ± 1.57	23.5	7.84 ± 0.401	18.5
UW3490	25.9 ± 0.888	40.9	9.96 ± 0.396	35.1	3.76 ± 0.234	24
UW3491	2.19 ± 0.200	22.5	5.96 ± 0.365	18.2	9.34 ± 0.469	18.2
UW3492	0.84 ± 0.054	31.6	1.74 ± 0.251	25.6	12.1 ± 0.597	13.6
UW3493	31.6 ± 1.22	52.2	60.6 ± 4.39	18.4	13.8 ± 0.972	13.9

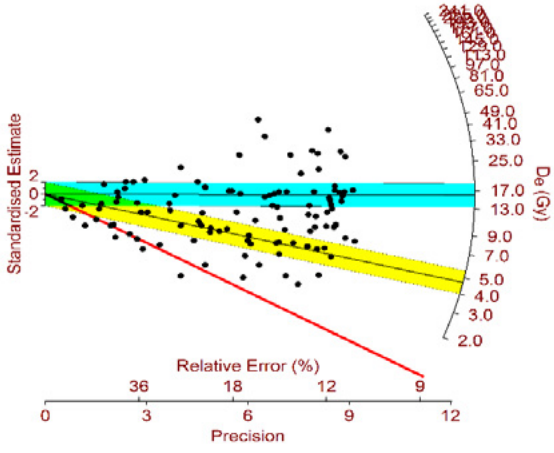




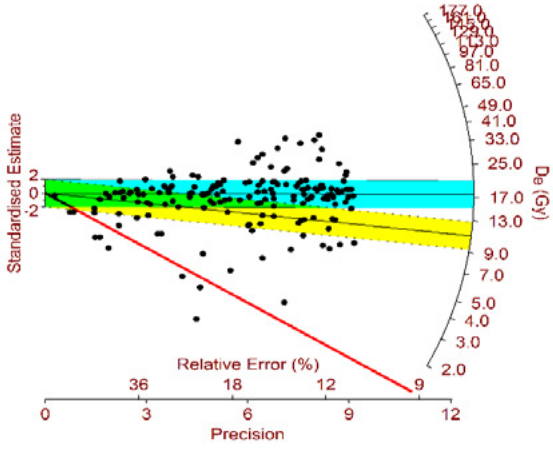
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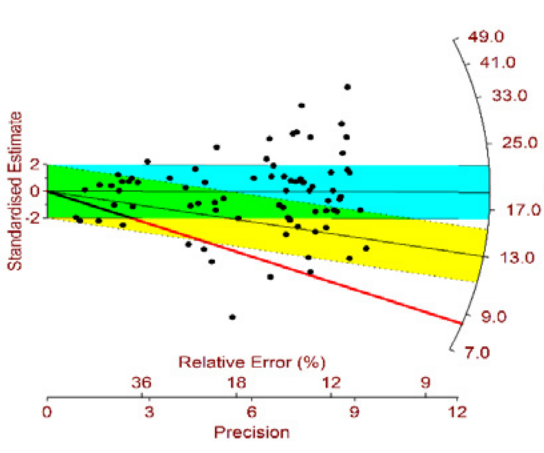
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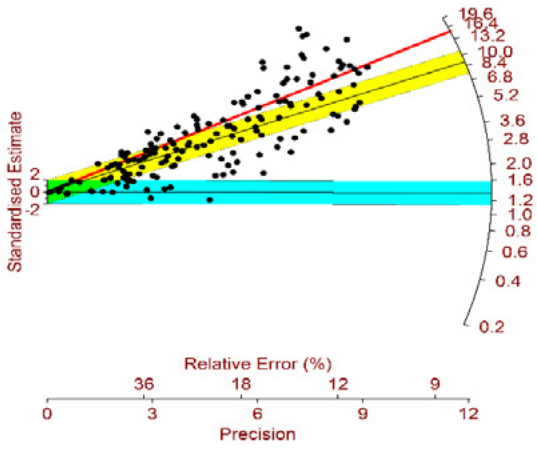
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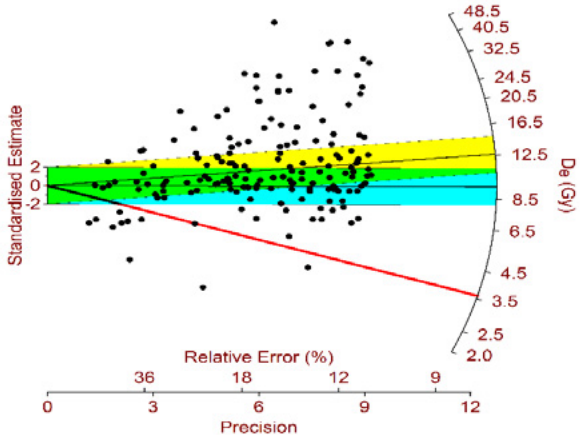
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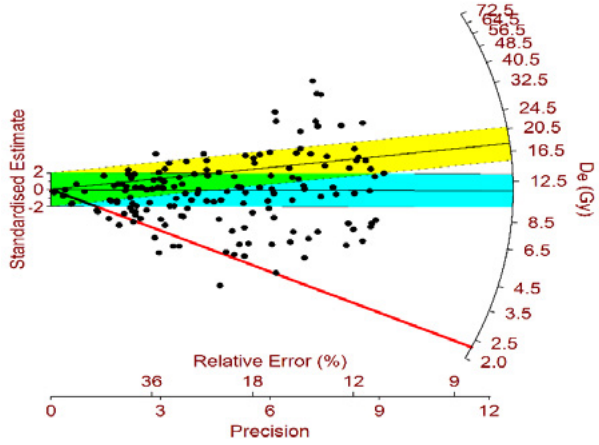
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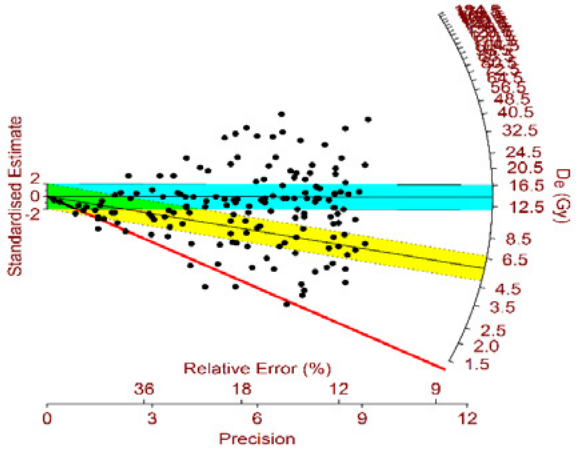
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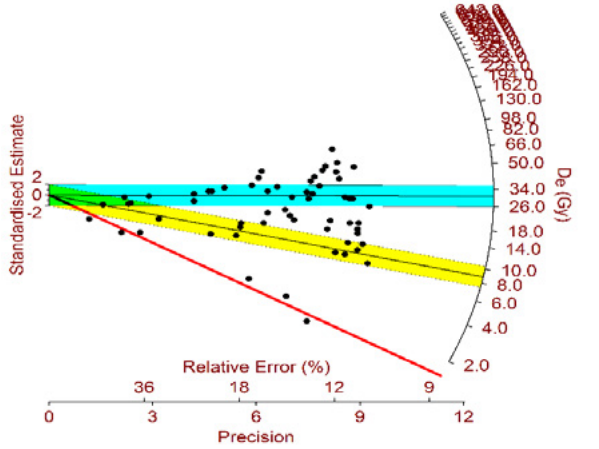
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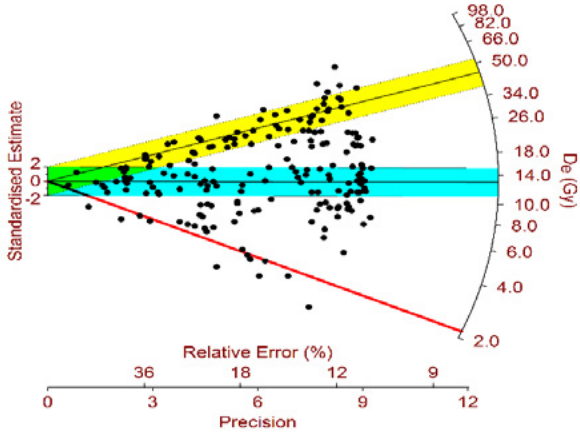
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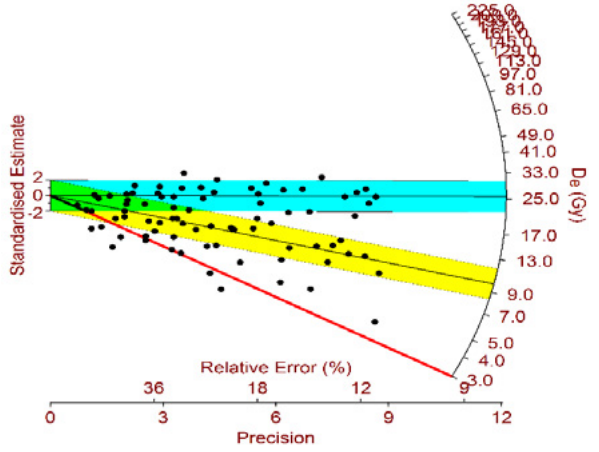
UW3487



UW3488



UW3489



UW3490

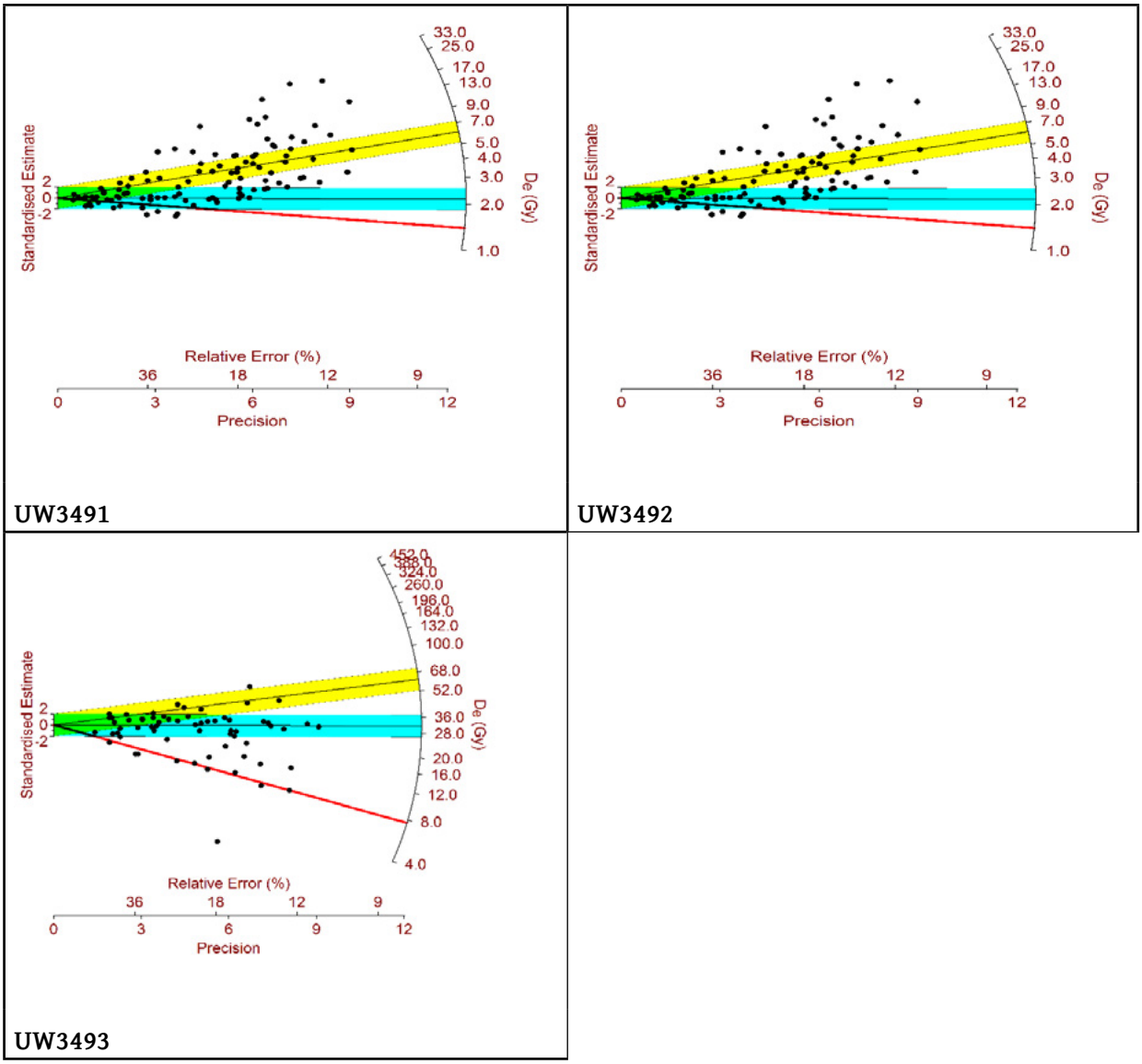


Figure 1: *Radial graphs of the D_e.*

Age

With so much scatter due to mixing, it is difficult to pin down the depositional age without a model for turbation processes. Each sampling location will be considered separately, taking into account the stratigraphic relationship.

Kings Plain

Table 7 gives the ages from the central age model and the three most abundant components. UW3426 has a larger percentage of younger grains (2nd component), but these cannot be right because UW3426 is stratigraphically the older sample. The older grains, those older than 4.09 ± 0.309 ka, appear to better reflect the age of this sample, which I estimate to be anywhere between 3.7 and 9 ka, with the highest

probability being toward the younger end of that range. UW3425 could date from 2.3 to 7.1 ka, again with the highest probability toward the younger end.

Table 7. Ages (ka) for Kings Plains

Sample	Depth (cm)	Central age	2nd component		3rd component		4th component	
			Age	%	Age	%	Age	%
UW3425	12	5.21 ± 0.660	2.67 ± 0.349	23.1	4.07 ± 0.869	21.7	6.38 ± 0.873	22.2
UW3426	16	3.76 ± 0.451	1.78 ± 0.177	28.8	4.09 ± 0.309	43.2	8.28 ± 0.750	13.4

Barley Field lunette

In the same format as Table 7, Table 8 gives the ages for the lunette at Barley Field. More than 70% of the grains for UW3483 are in the 5.3 to 10.1 ka range. Nearly 60% of the grains for UW3482 are in the 4.7 to 9.2 ka range. These ranges overlap in the 5 to 9 ka range which might be the best estimate for these two samples. UW3479 must be younger, and 50% of the grains are in the 3.9 to 7.3 ka range. Given the 5 to 9 ka range for UW3482 and UW3483, the most likely estimate for UW3479 is between 4 and 5 ka.

Table 9. Ages (ka) for Barley Field lunette. Note that for UW3483, the components are actually the 2nd, 3rd and 4th

Sample	Depth (cm)	Central age	3rd component		4th component		5th component	
			Age	%	Age	%	Age	%
UW3479	31	6.34 ± 0.566	4.24 ± 0.325	19.6	6.80 ± 0.489	30.5	10.8 ± 0.847	20.6
UW3483	40	8.69 ± 0.696	6.21 ± 0.930	20.8	9.34 ± 0.826	50.8	16.7 ± 1.36	18.6
UW3482	42	6.75 ± 0.623	5.13 ± 0.479	11.9	8.62 ± 0.601	55.9	12.9 ± 1.41	8.8

Barley Field track site

The ages are in Table 10. UW3480 seems discordant. It is much older than any of the other samples and also of the samples from the lunette. It appears to be at least 11 ka. For UW3484, given the lower ages for deeper samples, the high end around 7.5 ka is probably not realistic. A more likely range is from 0.6 to 5 ka. UW3481 and UW3487 have similar distributions, with the possible age ranging from 1.8 to 5.1 or 7.6 ka. UW3485 and UW3488 are older, ranging from 3.8 to 15.4 ka.

TABLE 10. AGES (KA) FOR BARLEY FIELD TRACK SITE. NOTE THAT FOR UW3484, THE COMPONENTS ARE ACTUALLY THE 1ST, 5TH AND 6TH, FOR UW3481 3RD, 4TH AND 6TH, FOR UW3480 4TH, 5TH, AND 6TH', AND FOR UW3488 2ND, 3RD AND 4TH.

Sample	Depth (cm)	Central age	3rd component		4th component		5th component	
			Age	%	Age	%	Age	%
Square 12								
UW3484	12	3.23 ± 0.515	0.680 ± 0.071	20.3	4.46 ± 0.433	18.9	7.52 ± 0.703	16.3
Square 25								
UW3481	24	3.53 ± 0.447	2.09 ± 0.151	19.9	3.39 ± 0.261	14.7	7.12 ± 0.516	23.3
UW3480	47	12.4 ± 1.22	11.4 ± 0.863	20.2	18.0 ± 2.39	14.5	26.0 ± 1.80	30.7
UW3485	51	7.47 ± 0.673	5.51 ± 0.449	31.4	7.22 ± 0.660	14.4	11.1 ± 0.862	12.4
Square 32								
UW3487	30	3.14 ± 0.331	1.92 ± 0.143	15.2	3.31 ± 0.271	17.2	4.82 ± 0.358	22.7
UW3488	47	8.36 ± 1.19	4.17 ± 0.304	28.2	7.39 ± 0.527	22.3	14.4 ± 1.05	28.9

Dangars

The ages are in Table 11. UW3492 is clearly much younger than the other samples. The estimated age range is 0.52 to 2.9 ka. For UW3490, 76% of grains range from 5.9 to 17.7 ka. UW3486 has a slightly younger age range (4.3 to 13.5 ka), representing more than 60% of the grains.

TABLE 11. AGES (KA) FOR DANGARS. NOTE THAT FOR UW3486, THE COMPONENTS ARE ACTUALLY THE 3RD, 4TH, AND 5TH.

Sample	Depth (cm)	Central age	1st component		2nd component		3rd component	
			Age	%	Age	%	Age	%
UW3492	38	1.88 ± 0.247	0.576 ± 0.049	31.6	1.18 ± 0.184	25.6	2.65 ± 0.254	20.0
UW3486	42	6.81 ± 0.630	4.73 ± 0.468	16.6	8.07 ± 0.655	24.6	12.5 ± 1.06	22.3
UW3490	43	7.30 ± 0.875	2.40 ± 0.216	24	6.36 ± 0.484	35.1	16.5 ± 1.21	40.9

Big Llangothlin

The ages are in Table 12. The three samples are more distinguishable than for other localities. UW3491 is clearly much younger than the other two, with the estimate ranging from 0.8 to 4 ka. UW3489 is estimated to range from 3.3 to 6.2 ka. The older component is probably not realistic given the ages for UW3493. For the latter, more than 70% of the grains give ages greater than 15.8 ka.

Table 12. Ages (ka) for Big Llangothlin. Note that for UW3491, the components are actually the 2nd, 5th, and 6th, and for UW3489 3rd, 4th, and 6th.

Sample	Depth (cm)	Central age	3rd component		4th component		5th component	
			Age	%	Age	%	Age	%
UW3491	20	1.83 ± 0.203	0.876 ± 0.095	22.5	2.38 ± 0.202	18.2	3.74 ± 0.288	18.2
UW3489	50	6.45 ± 0.624	3.59 ± 0.267	18.5	5.89 ± 0.361	27.7	20.7 ± 1.33	23.5
UW3493	75	13.0 ± 1.58	7.44 ± 0.684	13.9	17.0 ± 1.20	52.2	32.6 ± 3.05	18.4

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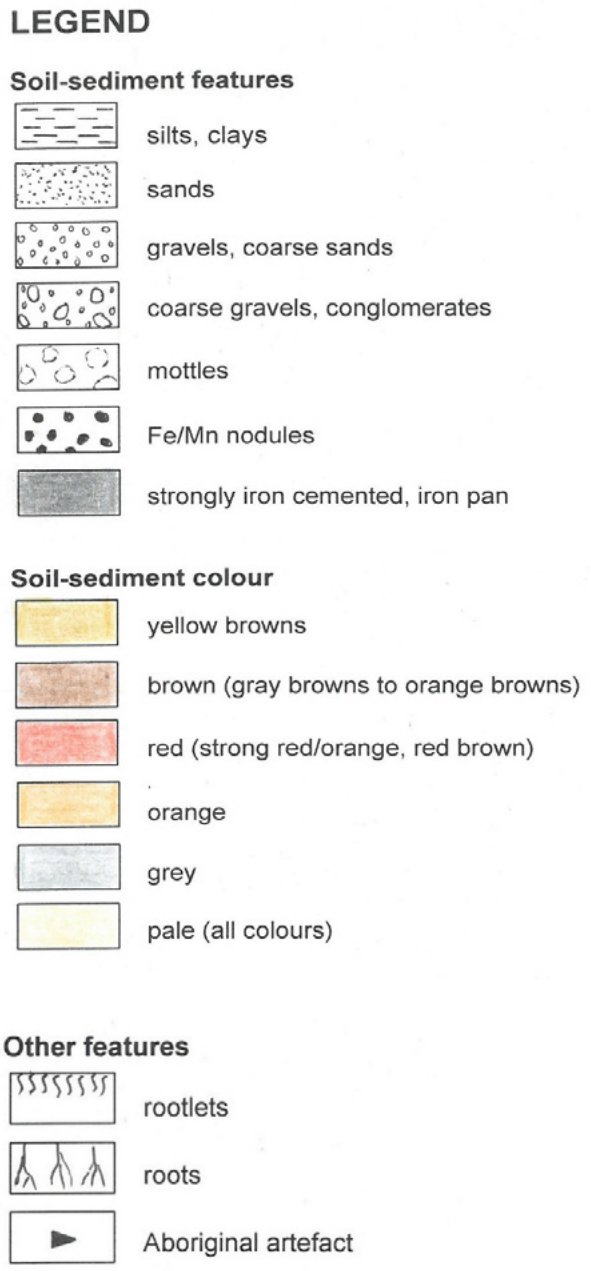
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Wintle, A.G. and A.S. Murray 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Radiation Measurements* 41: 369–391.

Appendix D:
New England Tablelands Sediment Profile Descriptions

Anne McConnell

Legend



BIG LLANGOTHLIN NORTH SEDIMENT PROFILES

BIG LLANGOTHLIN NORTH SEDIMENT PROFILES continued

P 3

Auger hole at northern end on upper slope above lagoon south of sandy blowout
(auger hole by AM, recorded AM 13/2/13) (GPS 0381111.6675795 (GDA94))

Surface – pasture grass.
- reddish brown (7.5YR3/2); slightly silty and clayey medium sand; soft.

- a stronger reddish brown (7.5YR4/3-4); slightly silty and clayey medium sand; soft.

- a more orangey brown (5-7.5YR4/6); well sorted medium sand; loose.

- paler orangey brown (10YR5/4) grading to a paler more yellowey brown (10YR6-5/3) at the base of the unit; coarse-medium sand; loose.

- pale grey-brown (7.5YR3/2); very slightly clayey and silty medium sand; soft-compact (similar to 0-26cm)
- brown (7.5YR5-4/3); slightly clayey and silty coarse-medium sand; soft
- reddish brown (5-7.5YR4/4); very slightly clayey and silty coarse-medium sand; soft-compact. Grades with depth to a slightly reddy grey (7.5YR5-4/4); coarse-medium sand; looser than above

wet below this – water table ?

- 3cm thick band of brown (10YR5-4/4) clayey sand with diffuse strong orange (7.5YR5/8) mottles
- as for 195-250cm but a stronger orangey brown colour (10YR5/4)
- similar to above but of soft black nodules (Fe-Mn?); becomes slightly yellower with depth (but still 10YR5/4 at the base); weakly banded texturally alternating between very slightly clayey coarse-medium sand and clayey coarse-medium sand; soft

base of augering (still in wet clayey sands)

P 4

Trench at northern end on upper slope above lagoon south of sandy blowout [OSL samples collected]
(excavated by AM, recorded AM 13/2/13) (GPS 0381146.6675789 GDA94 (GDA94))

Surface – pasture grass.
- grey brown (7.5YR4/2); slightly humic enriched medium-coarse sand with a trace of silt-clay; medium hard.

- paler grey brown (7.5YR5-4/3); slightly silty clayey medium sand; medium hard. Grades with depth to a slightly looser/softer and paler grey brown (7.5YR5-4/4); very slightly silty clayey medium-coarse sand; medium hard.
- distinctively red-orange (7.5YR4/4-6); slightly silty clayey medium sand; medium hard – compact

grades to

- slightly paler red-orange (10YR5-4/4); slightly clayey coarse-medium sand; soft

- pale grey brown (10YR5/3); coarse-medium sand; soft

base of trench

P 5

Auger hole at northern end on upper slope above lagoon south of sandy blowout (near P4 and P6 – see map)
(augered by AM, recorded AM 13/2/13)

Surface – pasture grass.
- dark grey brown (7.5YR3/1-2); very slightly silty clayey medium-coarse sand; loose; humic; has clumps of root mass binding the sand.
- greyish brown (7.5YR5/3-4); very slightly silty clayey medium-coarse sand; loose. Grades with depth to a slightly redder (10YR4/3), looser, coarser (still coarse-medium) sand with a trace of silt-clay.

- grey (10YR5/2); coarse sand (no silt or clay); loose - soft.

base of augering (wet sand)

BIG LLANGOTHLIN NORTH SEDIMENT PROFILES continued

P 6

Auger hole at northern end on upper slope above lagoon south of sandy blowout (augered by AM, recorded AM 13/2/13) (GPS 0381153.6675786 GDA94 (GDA94))

Surface – pasture grass.

- greyish brown (7.5YR4/2); medium-coarse sand; loose; roots common (grass and a tree).

- slightly reddish grey brown (7.5YR5-4/2); medium-coarse sand; loose.

- darkish grey (7.5-10YR4/1); medium-coarse sand; loose.

base of augering (wet sand)

BIG LLANGOTHLIN NORTH EAST SEDIMENT PROFILES

P 2

Auger hole on top of bank (above and behind the OSL dating site) (augered by RH & AM, recorded AM, 13/2/13) (GPS 0381417.6675375 (GDA94))

Surface – pasture grass

- pale brown grey (7.5YR4/2); slightly silty and clayey fine-medium sand; soft, loose; dense grass root mass in upper 5cm with some roots at depth.

- brown (10YR4/3); fine-medium sand; soft.

- yellow grey-brown (10YR-2.5Y5/4); clayey loam (with fine-medium sand); compact; small orange mottles (7.5YR4/6) which increase and grade with depth to Fe-Mn nodules

- orange and grey - mottled (5YR5/8 & 10YR5/1); clayey silty (sand not noted).

- grey and orange - mottled; gritty clay loam; grades texturally to base of augering to a grey and orangey brown mottled silty clay

base of augering (too clayey to easily auger deeper)

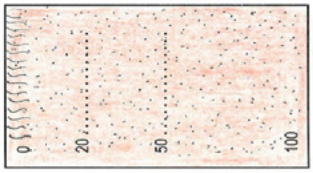
Note – colours are moist colours.

BIG LLANGOTHLIN EAST SEDIMENT PROFILES

BIG LLANGOTHLIN EAST SEDIMENT PROFILES continued

AH GPS 339

Auger hole (screw auger) on plain behind lagoon edge (near fence) [c.80-100m E of top of lagoon edge bank] **(augered by AM; recorded AM 14/2/13) (GPS 0381752. 6672891** (GDA94))



Surface – pasture grass.
- reddish; very slightly silty and clayey medium sand

- reddish; very slightly clayey medium sand (some silt)

grades to
- reddish; medium sand

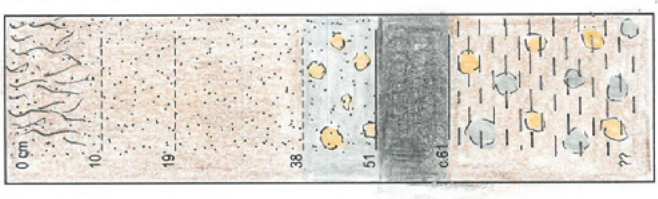
base of augering

Note – colours are moist colours.

BARLEY FIELD LAGOON SEDIMENT PROFILES [Based on May 2013 fieldwork]

PIT 1 (OSL1)

Trench on E side of lagoon, excavated 7/5/2013 to take OSL samples
(excavation by KK, RH et al., stratigraphy recorded AMcC 8/5/2013) (GPS 0358849.6611030 (GDA94))



Surface – pasture grass
- grey brown (7.5YR5/1-2); loamy fine-medium sand; soft, with roots & rootlets.

-- brown (10YR5/2); slightly loamy fine-medium sand; compact.

- pale brown (10YR6/2); slightly loamy fine-medium sand; compact, pH - 5.5.

grades to (undulating boundary) -
- grey (7.5YR5/1) with orange mottles (10YR6/8); loamy fine-medium sand; compact.

- hard, cemented layer of iron (Fe-Mn) nodules; nodules up to c.1cm diam.

- more strongly coloured and mottled, and clayey material: brown with orange (7.5YR5/8) and grey (10YR7/2) medium size mottles; very slightly gritty silty clay; compact.

Base of trench not recorded.

BARLEY FIELD LAGOON SEDIMENT PROFILES continued

PIT 2 (OSL2)

Trench on NE side of lagoon, excavated 8/5/2013 to take OSL samples
(excavation by KK et al, stratigraphy recorded AMcC 8/5/2013) (GPS 0358889.6611000 (GDA94))

Surface – pasture grass.
- light grey (10YR7/1); very silty (& slightly clayey) fine-medium sand; firm-soft, with roots & rootlets.

- greyish brown (10YR5/1); very slightly clayey & silty fine-medium sand; firm-compact.

- light grey brown (10YR7/1) with small (<1cm) sparse orange mottles (10YR5/8); very slightly clayey & silty fine-medium sand; compact.

- nodular iron (Fe-Mn) cemented sand; nodules are up to 10cm diam.

- iron (Fe-Mn) cemented layer with small nodules of silty clayey sand.

- grey (7.5YR7/2) and orange (7.5YR5/8) mottled; very slightly gritty, slightly silty clay; compact.

grades with depth to more grey material with smaller (<c.2cm diam) sparser orange mottles.

- grey (10YR7/1) with orange (7.5YR5/8) mottles; slightly gritty clay; hard-compact; pH – 5 (generally greyer and clayier).

Base of excavation

Note – colours are dry colours

AUGER HOLE 1

On upper slope/bank in southeast corner (augered & stratigraphy recorded AM 8/5/2013) (GPS 0358738.6611064 (GDA94))

Surface – pasture grass.
- pale grey brown (10YR5/3 - slightly clayey sandy silt; soft.

- brown (7.5YR5-6/2); sandy loam; soft (B horizon)

- very pale brown (10YR6/3); slightly clayey silt-sand; soft; pH – 6.

grades to -
- light brown (10YR6/3) with orange mottles (10YR6/8); gritty silt-sand; soft-compact.

- similar to above but with dense iron nodules.

- orangey brown (10YR6/4) with pale brown (10YR7/4) and orange (10YR6/8) mottles; slightly gritty silt-clay; soft-compact.

grades to –
- a darker orange (5YR4/6) with large (>c.1cm) grey (10YR7/1) mottles; clayey silt.

Continues to grade to -
- orangey (7.5YR5/8) with large-medium grey (10YR7/1) mottles; silty clay (ie, a more strongly mottled and more clayey material).
- starts to become paler with less red mottling, and clayier

- orangey (7.5YR5/8) with large-medium whitish (2.5Y8/1) mottles; silty clay; pH – 5-5.5.

base of augering

Note – Below c.56cm the sediment contains very fine mica flakes.

General Notes:
1. Colours are generally moist, except where noted otherwise.
2. Structure is only noted where this occurs (these sediments generally have no-little structure/pedality).

BARLEY FIELD LAGOON SEDIMENT PROFILES continued

- SELECT EXCAVATION SQUARES [Based on March 2016 excavations]

SQUARE 12

Square in line of excavated squares and c.50cm south of the farm track edge; excavated 7-8/3/2016 as part of archaeological excavations excavated to c.35cm then augered to c.1.05m
(excavated by KK & AMcC; stratigraphy recorded AMcC 8/3/2016)

Surface – pasture grass
- grey brown; slightly clayey and silty sand; loose, with roots & rootlets.
- pale brown; slightly clayey and silty sand; compact; some Fe-Mn nodules.

- pale brown with small orange and yellow mottles; slightly clayey and silty sand; hard - compact; contains fine charcoal, a few pieces of stone, and abundant–moderate Fe-Mn nodules.
grades to -
- pale pinkish brown with yellow, orange & black mottles; very slightly clayey silty sand; very hard & compact; contains angular charcoal fragments, a few stones, and abundant Fe-Mn nodules; contained 1 **stone artefact** (@ c.23-24cm).
- whitish with red-brown hard nodules; matrix appears to be a slightly clayey sand; hard-pan layer (ie, Fe-Mn cemented layer; nodules abundant.
Base of excavation at c.35cm
- red-orange with some grey mottling; sandy silty clay; firm-compact; sparse scattered nodules.

grades to -

- similar material, but with an increase in the number and size of grey mottles (which are clay rich).

- grey and orangey-gray mottled; clay; hard.

base of augering

SQUARE 17

Square in line of excavated squares and on the north edge of the farm track; excavated 15/3/2016 as part of archaeological excavations; excavated to c.54cm then augered to c.60cm
(excavated by AMcC and others; stratigraphy recorded AMcC 8/3/2016)

Surface – pasture grass
- grey brown (7.5YR5-4/3); sand; loose, with rootlets; pH 7.

- pale brown (7.5YR6/3-4); slightly loamy gritty sand (medium-fine grained); firm-hard & compact; pH 6; contains scattered Fe-Mn nodules which increase in number with depth; **stone artefact rich** layer.

- pale brown (7.5YR7/4) with orange mottling; sand (medium-fine grained) with minor clay; hard (clay cemented); pH 6; orange mottling increases with depth; abundant Fe-Mn nodules; a small number of subangular pebbles occur in middle of unit.

(base of excavation) grades to -
- strong orangey brown (7.5YR5/8); slightly loamy clay; hard; pH 4.5.
base of augering.

Note – Munsell colours are dry soil colours.

Notes –
► – approximate artefact location
Munsell colours were not recorded, but were generally in the 7.5YR range for dry samples.

BARLEY FIELD LAGOON SEDIMENT PROFILES - SELECT EXCAVATION SQUARES continued

SQUARE 32

Square in line of excavated squares and c.16m north of the farm track edge; excavated 11&14/3/2016 as part of archaeological excavations; excavated to c.46cm then augered to c.80cm
(excavated by AMcC and others; stratigraphy recorded AMcC 8/3/2016)

Surface – pasture grass

- brown; sand; loose; pH 6.5; with roots & rootlets.

- brown; slightly loamy sand (medium-fine grain); firm & compact; Fe-Mn nodules present and increase with depth; pH 6-6.5; **stone artefacts** occur from 10cm – c.23cm (13 located in this layer in this square).

- brown; slightly loamy sand (medium-fine grain); very hard (clay cemented); abundant Fe/Mn nodules (up to 8cm diameter, but decreasing in size at the base, and becoming dark brown); pH 6; **stone artefacts** (5) located at c.28cm to 36cm.

Undulating boundary

- orangey brown with very pale brown mottles; sandy (medium?) and slightly silty (?) clay grading to a loamy clay with depth; hard & compact; pH 5.5

Base of excavation at 46cm

- red brown (5YR5/6-8) with small grey – pale brown mottles (10YR6/3 – 7/4); clay (possibly with some silt); firm.

base of augering.

Note – Munsell colours were mostly not recorded, but were generally in the 7.5YR range on dry samples.

General Notes:

1. Structure is only noted where this occurs (these sediments generally have no-little structure/pedality).

DANGARS LAGOON EAST SEDIMENT PROFILES

Pit 1 (OSL Pit)

Trench on east side of lunette - top of pit is c.80cm below lunette crest (on east side of road, east of lagoon)
(excavated by KK & RH; recorded KK 14-17/3/2016) (GPS 0357035.6604931 (GDA94))

Surface – pasture grass.

- yellowish brown (10YR5/4); slightly silty fine sand; pH – 6.

- pale brown (10YR6/3); very fine sand; pH – 6.

- pale yellow brown (10YR6/4); very fine sand; pH – 5.5.

- dark yellowish brown (10YR4/6); very fine sand; pH – 5.5.

- yellowish brown (10YR5/4); fine sand; soft; with Fe/M nodules; pH – 5.5.

- very pale brown (10YR7/3); fine-medium sand; soft; with Fe/M nodules; pH – 5.5.

- light yellowish brown (10YR6/4); fine sand soft; with Fe/M nodules.

- paler yellowish brown; fine sand.

- grey (10YR5/1)) with orange mottles; silt clay, becoming increasingly clayey with depth

base of pit - grey (10YR5/1)); silty clay – clay; pH – 5.5.

DANGARS LAGOON EAST SEDIMENT PROFILES

Pit 2 (OSL Pit) **Trench on east side of lunette - top of pit is c.145cm below lunette crest (east of lagoon, between lagoon and road,)**
(excavated by KK & RH; recorded KK 14-17/3/2016) (GPS 0357022.6604935 (GDA94))

Surface – pasture grass.
- brown (7.5YR4/3); fine-very fine sand, loose; pH – 5.
- brown (7.5YR5/4); fine sand, loose; pH – 5.
- yellowish brown (10YR4/4-6); fine sand; pH – 5.
- pale yellowish brown (10YR5/8); fine-medium sand; with soft Fe/M nodules; pH – 6-6.5.
- pale yellowish brown (10YR6/2) *pale brownish grey*; slightly clayey fine-medium sand; pH – 5.5.
base of pit @ 130cm; start of augering
- paler yellowish brown; with Fe/M nodules.
- increasingly clayey.
- clay rich; with orange mottles
base of pit

DG E2 SQUARE 0.5 **Square (near eastern end) of E-W excavation trench on west side of lunette, on east side of lagoon (, GR GDA94)**
(excavated by team, recorded AM, 18/3/16) (GPS 0357029.6604842 (GDA94))

Surface – pasture grass
- grey brown; sand (medium/medium-coarse grain); loose; with rootlets; contained contained white glazed **domestic ware** fragments at 8-10cm.
- pale pinkish grey brown (7.5YR5-6/2-3); very slightly loamy sand (medium-coarse grain); firm; contained 1 **stone artefact** at c.38cm.
- pale pinkish grey brown with brown mottles (mottles are weakly-moderately cemented); very slightly loamy sand (medium-coarse grain); very firm.
- mottles continue but are less well cemented; - similar to above but colour grades to a darker pinkish brown (7.5YR6-7/3-4) at the base.
- (colour not recorded); very slightly loamy sand (medium-coarse grain); soft-firm.
base of pit

Note – colours are moist colours.

RACECOURSE LAGOON EAST SEDIMENT PROFILES

RCL Pit A / Pit1

Trench on gently sloping sandy bank (c.3.5 below and 80m W of sandy crest, and 75m E of lagoon edge and c.4m above mean lagoon level) [OSL samples taken]
(excavated by team, recorded AM, 9/5/13) (GPS 0355831.6605530 (GDA94))

Surface – pasture grass

- grey brown (10YR6/3); very slightly loamy fine-medium sand; humus rich.
- grey brown (10YR6/3); slightly clayey and silty well sorted fine-medium sand; firm-hard.
- pale brown (10YR5/3); slightly silty clayey well sorted medium-coarse sand; hard – grades with depth to a brown (10YR7/2); slightly clayey and silty medium-coarse sand; roots (<c.1cm diam); pH – 5.5.
- grey brown (10YR5/2-3) with small orangey brown mottles <c.2cm (7.5YR6-5/8); silty clay, possibly some sand; very hard.

base of pit not recorded

Note – colours are moist colours.

Appendix E:
Mapping and Characterisation of Silcrete and Axe Grinding Grooves in the New England Region, NSW

Nancy Vickery

Introduction

The use of Australian silcrete to make flaked stone tools is well documented (Hughes *et al.* 1973; Sullivan and Simmons 1979; Webb and Domanski, 2008; Webb *et al.* 2013). The intrinsic properties of compressive and tensile strength are important in determining the usefulness of the primary material. Fine-grained silcrete has high compressive strength but lower tensile strength, leading to edge fracturing of tools. Medium-grained silcrete has poor flaking properties as it has lower compressive and tensile strength. The grain size and amount of microcrystalline cement in a silcrete largely determines the suitability of silcrete for flaking or grinding.

The strong covalent atomic bonds between silicon (Si) and oxygen (O) in quartz and non-crystalline silica are important in providing high compressive strength. Uniformity and fineness of grain size will lead to more regular, smoother fractures, which are important flaking properties. Similarly, grain size determines the type of fractures that occur, either transgranular along cleavage planes or intergranular, along grain boundaries. In fine-grained silcrete, intergranular fractures are more prevalent and produce a stronger material whereas in coarser material, transgranular fractures are dominant. Added to this, impurities and heterogeneity in grain size are more likely in coarser-grained material. Coarser material produces fractures with step terminations that render them unsuitable for manufacture of flakes and sharp edges (Webb and Domanski 2008).

The use of silcrete for grinding is less well documented. The properties required for grinding material is significantly different to that of blade or flaking properties. Axe grinding grooves in the New England region were made on silcrete. This Appendix investigates general properties of silcrete with specific emphasis on silcrete formations in the New England region and silcrete varieties likely to be preferred by Aboriginal people for grinding activities.

What is silcrete?

Silcrete is a silica-rich rock formed by surficial processes involving the movement of groundwater. It is a type of duricrust, forming hard, indurated bodies that are highly resistant to weathering. Silcrete is composed of silicon dioxide (SiO_2) (commonly greater than 95%) with minor impurities of zirconium (Zr), iron (Fe) and titanium (Ti). In Australia, silcrete (being resistant to weathering and erosion) is relatively abundant in arid environments, forming prominent caps on breakaways. It also forms proximal to Palaeogene and Neogene aged basalts on the eastern seaboard. In the latter, it typically displays conchoidal fracturing, producing low rounded surfaces on hills and rises.

Silcrete is texturally and geomorphologically diverse. Most authors agree that it forms by precipitation of dissolved silica from groundwater (Ullyott *et al.* 1998; Taylor and Eggleton 2017). The silica is transported and deposited to produce a cement, entraining the regolith and fragments of rock substrate through which the groundwater flows, or replaces soil through illuviation processes. Significant variation of the

cementing matrix may result from the original regolith and substrate components of the stone and the efficiency of groundwater to invade, deposit silica and replace these components. Most silcrete has low porosity due to the very fine-grained (microcrystalline) to amorphous silica cement.

Anatase, a titaniferous mineral (TiO_2), is a common accessory mineral accompanying silica deposition which forms as coatings, geopetal caps or rims around silicified clasts within the silcrete. Textural evidence suggests that anatase is either precipitated or concentrated during illuviation as groundwater migrates vertically downwards and is precipitated *in situ* with quartz (Taylor and Eggleton 2017; Eggleton and Taylor 2017).

The classification of silcrete has evolved over several decades but no clear consensus has been reached due to textural and mineralogical diversity of many silcretes and because field characteristic features are influenced by local environmental factors. Dividing silcrete between pedogenic and non-pedogenic (groundwater) forms is the most commonly adopted system. Recently, Taylor and Eggleton (2017) documented the limitations of this system. The difficulty in classifying silcrete is due to the highly variable and local nature of formation, and partly a reflection of the heterogeneity of primary features in the original rock or regolith that has been silicified.

In some districts in Australia, including New England, there is a spatial link between Palaeogene to Neogene aged basalt and silcrete. A chemical link has not been clearly established between the two in all districts where this relationship is observed. Previous studies (e.g. Taylor and Smith 1975) indicate that basalt acts only as a cap rock to enable silcrete formation in the underlying sediments in a confined aquifer environment. Young and McDougall (1982) note that basalt post-dated silcrete in the Ulladulla district. However, other studies (e.g. Ollier 1978) suggested that some of the silica may be derived from the weathering basalt. It is likely that the source of silica may be from the host sediments, saprolite and weathering basalt (Taylor and Eggleton 2017), and is unique to each district, dependent on local climatic and geochemical factors.

Silcrete in New England

Silcrete in New England is formed by groundwater rather than pedogenic processes, preserving features of the underlying alluvial substrate formed by cement infill and partial replacement by quartz. The spatial distribution is widespread but volumetrically minor, forming elongate ridges and rises in the relatively flat landscape of the Northern Tablelands, typical of groundwater silcrete elsewhere (Ullyott *et al.* 1998). The isolated and restricted nature of outcrop has precluded inclusion on published large-scale geological maps (e.g. Stroud and Brown 1992).

Connelly (1985), in a PhD study on the landform evolution of the Armidale-Uralla region, included detailed descriptions of silcrete and proposed a broad classification scheme using sedimentological and petrographic features in which silcrete is divided into three variants. Two variants were identified on the basis of sorting of clasts (moderately to well—variant 1; and unsorted—variant 2); and the third variant being silica-cemented brecciated chert. Connelly's classification scheme, however, was independent of the silicification process and therefore not useful in identifying some features of the silcrete such as outcrop distribution and style. None-the-less, it gives a broad indicator of palaeochannels in the district where silcrete development took place.

Silcrete in the New England district is often, but not always, spatially associated with basalts of Palaeogene to Neogene age (Figure E.1). Connolly (1985) recognised the non-spatial relationship between the silica-cemented brecciated chert variant with basalt, which is confirmed in one location in this study. The more common association between basalt and silcrete has given rise to the term "sub-basaltic" by some

researchers (Webb and Golding 1998, in Webb and Domanski 2008), or "basalt associated" (Taylor and Eggleton 2017). The silcrete is considered to be silica infill or replacement of the matrix of fluvial deposits below and between basaltic flows, or silicified regolith, similar to those in the Monaro district of southern NSW (Taylor and Smith 1975).

Connolly (1985) examined quartz clast populations in the clastic silcrete variants he recognised. He classified quartz grains on the basis of extinction properties under the polarising microscope and the abundance of fluid inclusions. The dominant population of grains included those that displayed straight to slightly undulose extinction, typical of an igneous provenance or vein source. Undulose extinction in grains indicates post-formation deformation whereas straight, or uniform extinction, infers the grains are undeformed. In an attempt to further distinguish between these sources, Connolly (1985) examined the abundance of fluid inclusions. These are tiny fluid bubbles that are trapped within the crystal as it forms. Generally, vein quartz of hydrothermal origin contains more fluid inclusions than those of igneous origin. He found that two distinct populations with abundant and rare fluid inclusions existed. He therefore postulated that quartz clasts were derived from weathering from nearby granites and vein quartz from the older, metamorphosed Sandon beds. Significantly, a sample from Thomas Lagoon indicated significant populations of both igneous and vein quartz clasts.

The source of silica to produce intense silicification is controversial (Langford-Smith 1978; Ollier 1978) and has been postulated as the basalt (having up to 50% SiO_2 and being susceptible to chemical weathering to liberate silica). Locally, however, there are other rocks that contain silica and must also be considered as a silica source such as the widespread basement sediments of the Sandon and Girakool beds. The spatial association between silcrete and basalt may be due to physical characteristics as well as chemical. The base of the basalt flows may have provided favourable locations for aquifers. They are hard, have a sub-horizontal, local to extensive interface, which can be marked by permeable sediments or fossil regolith. The basalts are also impermeable and produce significant barriers to groundwater,



Figure E.1 *Photograph showing contact between basalt (top) and silcrete (base). The lens cap rests on this contact. Photo taken by N. Vickery in Zone 5, Cressbrook Station GR 374077E 6608271N.*

thereby promoting channel formation underneath the flows to transport low temperature groundwater containing dissolved silica in the underlying regolith.

In the Armidale district, conglomeratic silcrete is relatively common, e.g. at Cressbrook, where the older (Palaeogene) Armidale beds may be been silicified (Figure E.2). Silcrete here is formed by the preferential replacement of early minerals such as clays by silica (as crystalline quartz or amorphous chalcedony), whilst the primary fabric and texture of the precursor rock is commonly preserved. For this reason, local variation in silcrete fabric and texture is a direct representation of the original material it is replacing.

Methods

Field-work was undertaken to map and characterise silcrete variants on Cressbrook Station and Thomas Lagoon, south of Armidale, NSW (Figures E.3 and E.4) where grinding grooves were identified on scattered outcrops within larger occurrences of silcrete. It was considered essential to characterise the silcrete, with an emphasis on understanding local variation and the key features of the material used as grinding surfaces.

Silcrete outcrops on Cressbrook Station were mapped using mobile GIS (ESRI Arcpad 8 on a GPS-enabled hand-held computer). Widely scattered outcrops with little or no intervening outcrops were mapped into zones according to their location. During the mapping process, silcrete was classified according to features such as grain size, fabric, outcrop style and colour. Several areas representing discrete and discontinuous outcrop were identified. From these outcrops, 14 samples were collected representing four silcrete types. Approximately 1 kg of sample was collected of representative silcrete types from areas away from archaeological investigations. Sample details including locations are given in Table E.1. At Thomas Lagoon, a further six samples were collected from an area where grinding grooves were identified for comparative studies.



Figure E.2: *Conglomeratic silcrete (CGS) showing rounded to angular white quartz clasts in a fine quartz cement. Photo taken by N. Vickery in Zone 5, Cressbrook Station GR 374138E 6608238N.*

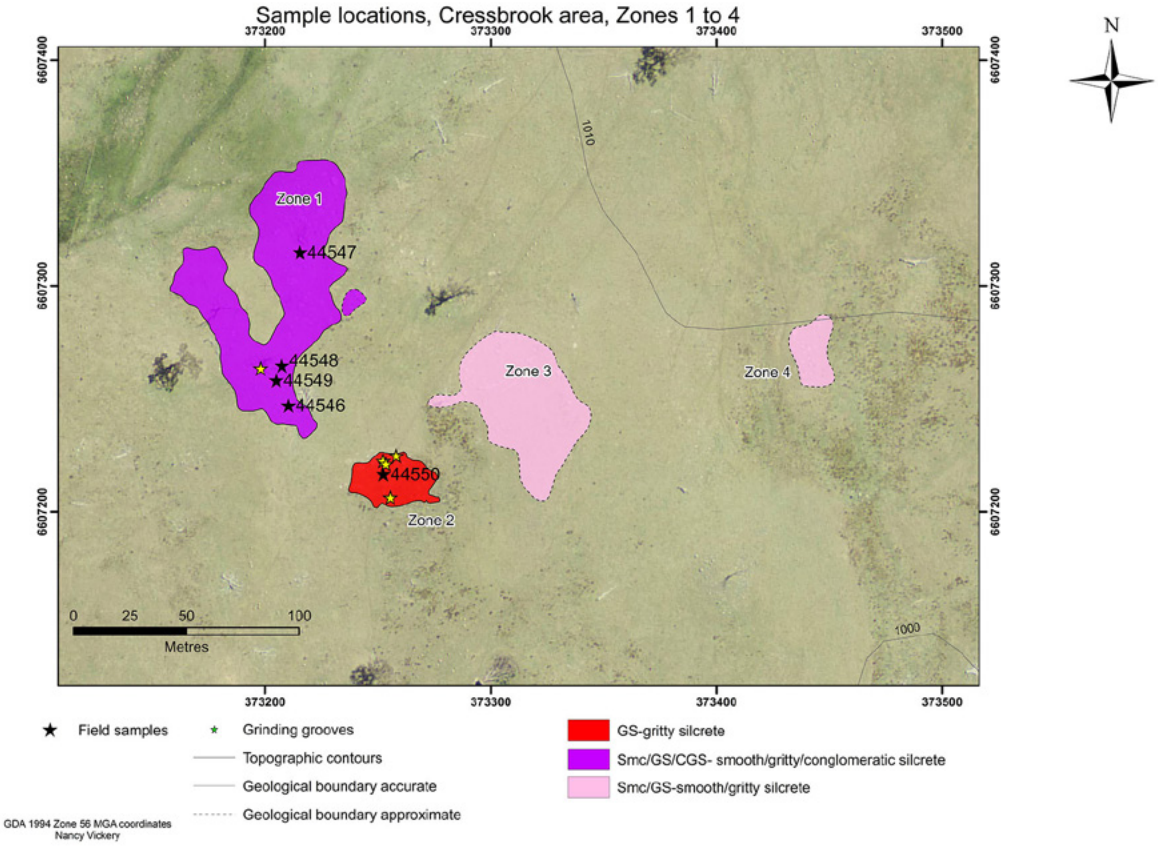


Figure E.3: *Map showing distribution of silcrete in Zones 1–4 on Cressbrook Station with reference to grinding groove locations.*

Samples were cut with a diamond saw and prepared for thin section. Thin sections were produced by Mr Malcolm Lambert (Earth Sciences UNE). Samples were examined using a polarising light microscope.

Table E.1. Location and field description of silcrete samples. CS, Cressbrook Station; TL, Thomas Lagoon.

Sample number	Location	Field description	Silcrete classification	Easting	Northing
44546	CS	fine grained sand grade silcrete	Smc	373210	6607247
44547	CS	massive, poorly sorted sand grade silcrete	Smc	373215	6607315
44548	CS	red sand grade silcrete	GS	373207	6607265
44549	CS	buff coloured sand grade silcrete	GS	373205	6607258
44550	CS	sand grade silcrete	GS	373252	6607217
44540	CS	pebble grade silcrete conglomerate	CGS	374246	6608380
44539	CS	silcrete conglomerate	CGS	374296	6608631
44538	CS	fine grained, massive pale brown silcrete	Smc	374293	6608644
44536	CS	pale orange, massive fine grained silcrete	GS	375410	6607190
44537	CS	pale grey, massive sugary silcrete	GS	375406	6607180
44545	CS	red porous, sand grade silcrete	GS	375343	6607128
44544	CS	pale, fine grained silcrete	GS/CGS	375687	6606966

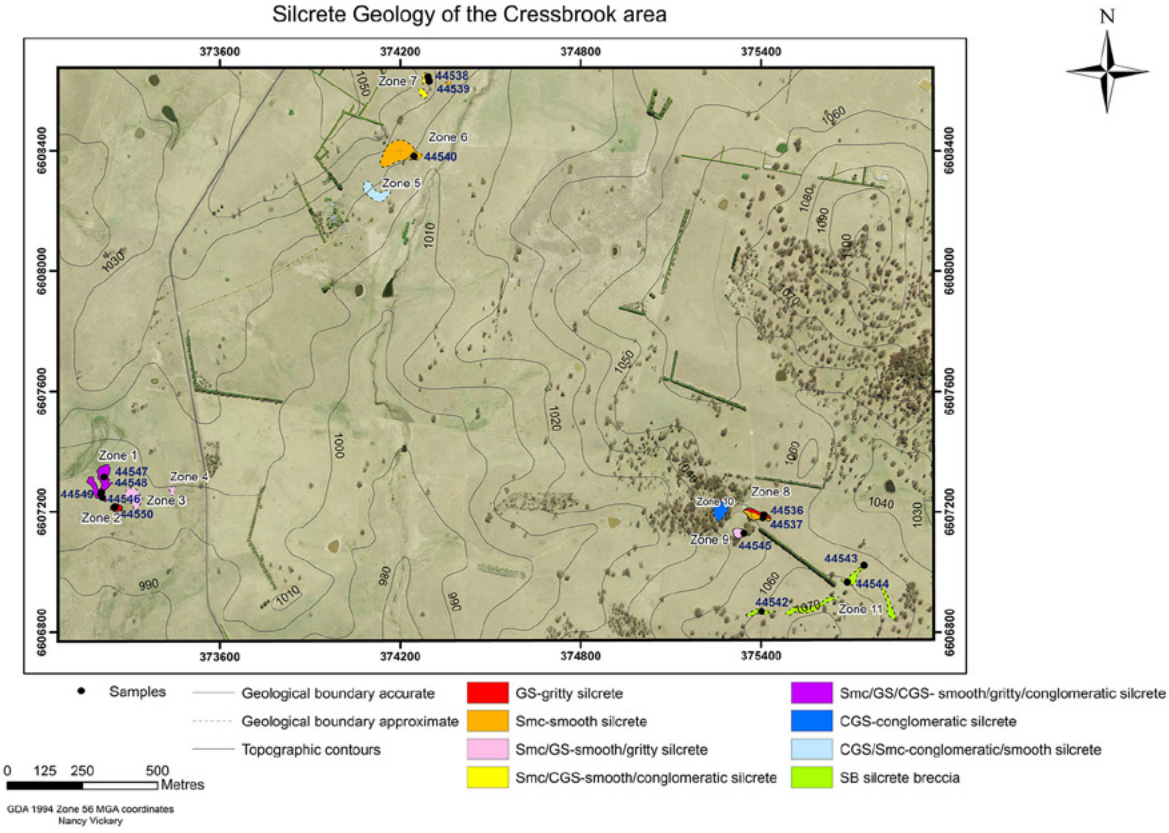


Figure E.4: *Map showing distribution of silcrete outcrops on Cressbrook Station. Zones and sample locations are also shown.*

Sample number	Location	Field description	Silcrete classification	Easting	Northing
44543	CS	coarse pebble conglomerate to breccia	SB	375743	6607022
44542	CS	pebble conglomerate to breccia	SB	375401	6606869
TL1a	TL	laminated white and red sand grade silcrete	GS	360996	6620018
TL1b	TL	fine sand grade silcrete with haematitic staining	GS	360997	6620014
TL3	TL	pale grey, fine sand grade silcrete	GS	361041	6620012
TL4	TL	dark grey coarse sand silcrete	GS	361023	6620051
TL5	TL	pale, porous sand grade silcrete	GS	361028	6620061
TL6	TL	pale grey, fine sand grade silcrete	Smc	361078	6620095

Results

Silcrete outcrop forms low ridges or isolated small flat outcrops in cleared grazing land. The silcrete in the study area is nearly always massive, which is typical of the non-pedogenic silcrete associated with basalts in eastern Australia (Taylor and Eggleton 2017). Outcrop styles are directly related to the main method of silicification. Cement infill leading to low-porosity, smooth surfaces produces prominent,

rounded outcrop whereas silicification by syntaxial overgrowth results in recessive, rough textured subcrop. Figure E.4 shows the scattered distribution of silcrete on Cressbrook Station.

Original features of the clastic component are well preserved within the silcrete. This includes grain size, fabric, texture and other sedimentological features. Many variants are spatially associated with nearby basaltic outcrops (Figure E.1). It is likely in some localities that basalt has been removed by erosion, leaving the silcrete exposed on surface.

Four main types of silcrete were identified during mapping: smooth silcrete (Smc), gritty silcrete (GS), conglomeratic silcrete (CGS) and silcrete breccia (SB). The variation is based on sedimentological features similar to those identified by Summerfield (1983, in Webb *et al.* 2013) in which grain-supported, matrix-supported and conglomeratic features are used. Added to this, coherence and surface features are also noted. Some samples represent hybrids according to the field classification. All four variants were recognised on Cressbrook Station whilst two were recognised at Thomas Lagoon (Table E.1).

Smooth silcrete (Smc)

Pale grey, massive, cement-supported, fine grained silcrete. This variant forms low, rounded and smooth outcrop. It is the most abundant in the field and is recognised at Cressbrook Station and Thomas Lagoon (Figure E.5).

In thin section, the finest-grained silcrete samples comprise significant cement (up to 50%), with variation in framework characteristics from clast- to matrix-supported. The cement is dominantly chalcedonic to microcrystalline. They are poorly sorted (grain size of clasts ranges from 15 microns to 1.8 mm in some samples) and comprise clasts that are sub angular to sub rounded (Figure E.6). Clasts



Figure E.5: *Typical outcrop of smooth silcrete on Cressbrook Station Zone 6, GR 374189E 6608428N. Photo by N. Vickery.*

are made up nearly entirely of detrital quartz grains, which are dominantly clear and unstrained, with subordinate weakly undulose, heavily included and rarely polycrystalline variants.

The cement is dominantly quartz, but in some samples anatase is abundant and imparts a pale honey brown colour to the rock. Where coarser quartz clasts are apparent, rare syntaxial overgrowth is observed. In many grains however, this is difficult to recognise due to poor optical contrast between core and rim. The rock has been indurated by precipitation of the siliceous cement and has low porosity due to the cement infilling spaces between clasts. Zircon grains are an abundant accessory mineral in the matrix.

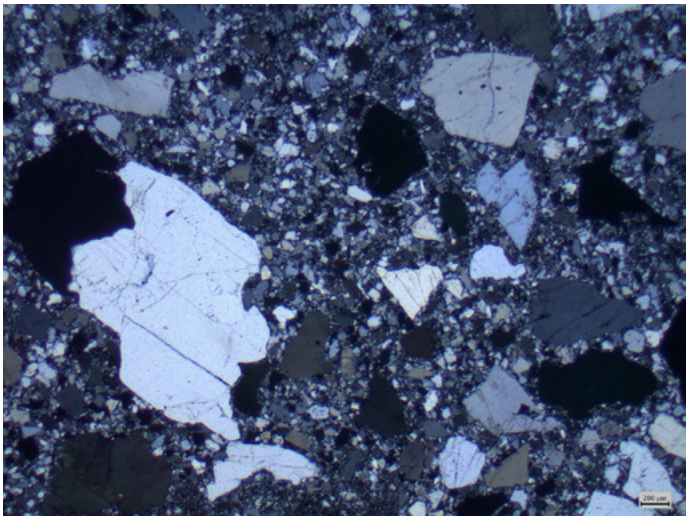


Figure E.6: *Photomicrograph of sample 44546 under crossed polarised light showing poorly sorted Smc. Note the fine matrix and cement. This sample is matrix supported. Most quartz clasts show straight extinction, though some are cracked and have inclusion trails. Photo by N. Vickery.*

Gritty silcrete (GS)

Gritty silcrete features silt to fine sand-sized particles (up to 0.5 mm in size) and is identified in the field by its relatively poor coherence and rough surface texture. In contrast to Smc, this variant is typically



Figure E.7: *Outcrop photograph of typical GS on Cressbrook Station. Note the colour and typical low angle outcrop style. From Zone 8, GR 375411E 6607191N. Photo by N. Vickery.*



Figure E.8: *Banded gritty silcrete from Thomas Lagoon GR 360996E 6620018N. Photo by N. Vickery.*

buff to red/brown in colour indicating possible iron and titanium oxide trace geochemistry. This variant is massive and homogenous in outcrop. GS forms low, rounded outcrops which are generally less prominent than Smc variants (Figure E.7). There are no nearby basalt outcrops associated with GS at Cressbrook Station, however, at Thomas Lagoon there is a spatial relationship between the two. GS is commonly spatially associated with Smc. Grinding grooves are developed in this variant at Cressbrook and Thomas Lagoon.

At Thomas Lagoon, there is an unusual variant of GS that is banded with iron oxide-rich and iron oxide-poor bands. These are approximately 0.5–2 mm wide and are variably cream and red/pink in colour (Figure E.8). Connolly (1985) interpreted the origin of these bands as a product of groundwater movement with variable precipitation of iron oxides. This is plausible, however, the regular laminated nature of the bands is not readily explained but closely resembles bedding laminae.

In thin section, samples are dominated by sand-sized grains that range from sub rounded to sub angular, and size from 20 µm to over 2 mm. There is a reasonable degree of sorting of the grains and a syntaxial overgrowth is common. There is very little cement in these samples (generally less than 5%); most grains are in physical contact with their neighbours and, therefore, are clast supported. Syntaxial overgrowth is particularly obvious where grains have clear cores, a rim of fine opaque oxides (haematite) or have heavily included cores (Figure E.9). The overgrowth is always a clear outer rim of quartz. The red colour in some samples is due to fine iron oxide, mostly within grains as rims but also in veinlets and overgrowths between grains. Many grains are clear and display unstrained extinction, being of igneous or vein origin. The lesser grains that have strained extinction are deformed or are cracked, indicating a metamorphic origin. These account for less than 2% of the total clast population and are common in only one sample (44537). All samples have a high degree of porosity due to the even grain size of clasts and lack of cement. Accessory zircon and tourmaline grains (less than 1%) are present in most samples.

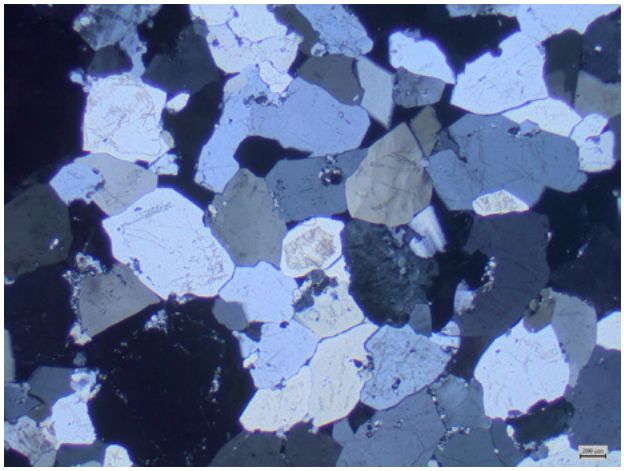


Figure E.9: *Photomicrograph of sample 44537 under crossed polarised light, typical of GS. Note the well sorted grain size, the lack of matrix of cement and the clear rims on some grains indicating induration by syntaxial overgrowth by quartz on some grains. Photo by N. Vickery.*

The banded variant at Thomas Lagoon shows heterogeneity between the cream and pink/red bands. The cream bands show silicification by syntaxial overgrowth of clastic quartz grains with minor microcrystalline quartz cement. In contrast, syntaxial overgrowth is common in the darker bands but there is a lack of microcrystalline cement. The lack of cement in the latter gives rise to greater porosity and hence the ability of oxidised Fe-bearing groundwater to permeate into these bands preferentially. These characteristics support a model of original bedding structures undergoing differential silicification to produce the banding.

Conglomeratic silcrete (CGS)

This silcrete is common in narrow outcrops where it forms low ridges. The elongated nature and relict coarse clastic features of the outcrop suggests this variant may have been a gravelly fluvial sediment prior to silicification. The outcrop is more prominent than Smc and GS variants. CGS are dominantly pebble grade conglomerates that vary from cement (or matrix) to clast supported. Clasts are of quartz (white to grey) and chert/jasper (grey or red) and typically range from 2 mm to up to 5 cm in size and are angular to rounded in shape (Figure E.2). The conglomerates are generally poorly sorted (grain size is variable), and comprise angular clasts, indicating limited transport and abrasion of the original sediment. These features are interpreted as preserved sedimentological characteristics of the Palaeogene Armidale beds. The cement ranges from very fine grained (silt or finer) to sand-sized and ranges in colour from pale grey to red/brown, reflecting variation in Fe/Ti oxide abundance.

In thin section, quartz clasts include unstrained vein and igneous populations similar to other variants (Figure E.10). However, a significant proportion of polycrystalline grains, some showing complete recystallisation and others with sutured boundaries, are indicative of metamorphic environments (Young 1976). The cement comprises chalcedony, fine microcrystalline quartz and honey brown anatase, the latter showing geopetal characteristics (Figure E.11). Some quartz grains display syntaxial overgrowth, however, a lack of optical contrast may occur, indicating that this is far more abundant than observed. The cement is comprised of chalcedony and microcrystalline quartz. There is significantly more strained metamorphic quartz (up to 30% more) in the conglomerate samples compared to other variants.

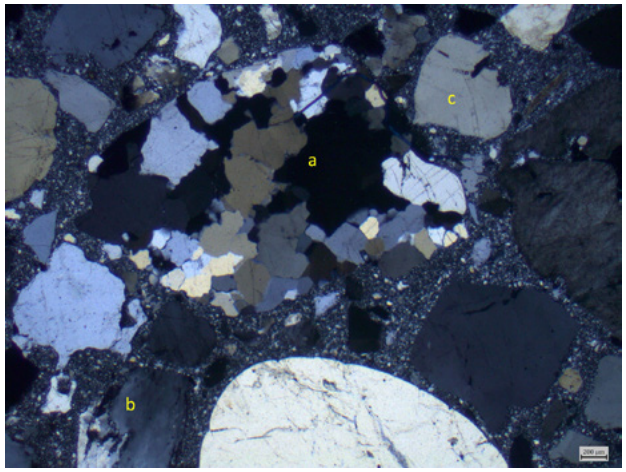


Figure E.10: *Photomicrograph of sample 44544 under crossed polarised light, typical of CGS. Note the heterogeneous suite of quartz clasts including the following grain features: (a) polycrystalline rounded quartz clast derived from a metamorphic provenance (b) quartz clast showing strain and sutured boundaries, typical of a metamorphic provenance (c) unstrained quartz clast of either vein or igneous origin. Photo by N. Vickery.*

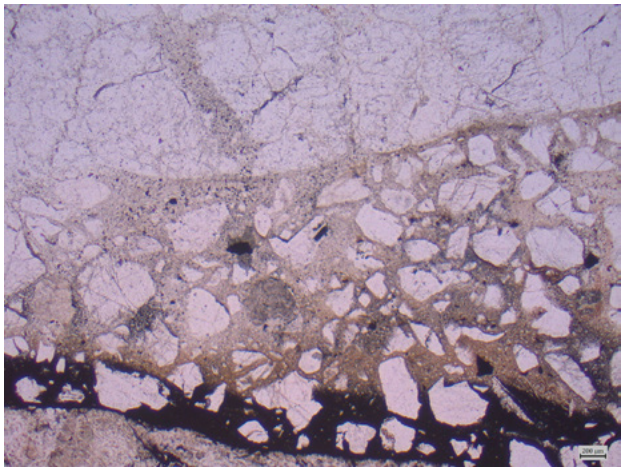


Figure E.11: *Photograph of sample 44539 under plane polarised light. Note the poorly sorted sub-rounded to angular quartz clasts. The matrix is pale to dark brown and comprises anatase. Photo by N. Vickery.*

Silcrete breccia (SB)

This variant is spatially restricted to one location on Cressbrook Station, where it forms low, flat "whale back"-style outcrops. It occurs on the top of a broad, elongate ridge. This silcrete corresponds to Connelly's silica-cemented brecciated chert variant. It features very fine grained, pale grey silcrete cement supported by coarse, poorly sorted rounded to angular chert, jasper and white vein quartz clasts that range in size from less than 1 mm to over 7 cm (Figure E.12). Many vein quartz clasts show deformation and partial recrystallization textures typical of metamorphic quartz. In hand specimen, these samples have a brecciated texture (the coarsest clasts are angular), although in thin section, the smaller clasts have a higher degree of rounding. Chert clasts locally contain earlier quartz veins, now strongly recrystallised and coarser grained than the chert cement.

The matrix in hand specimen of these samples is buff coloured. In thin section it is dominated by a microcrystalline quartz cement. The cement contains abundant scattered grains of coarser quartz, up to 100 µm. These grains commonly show strained extinction. A fine dusting of anatase and opaque minerals

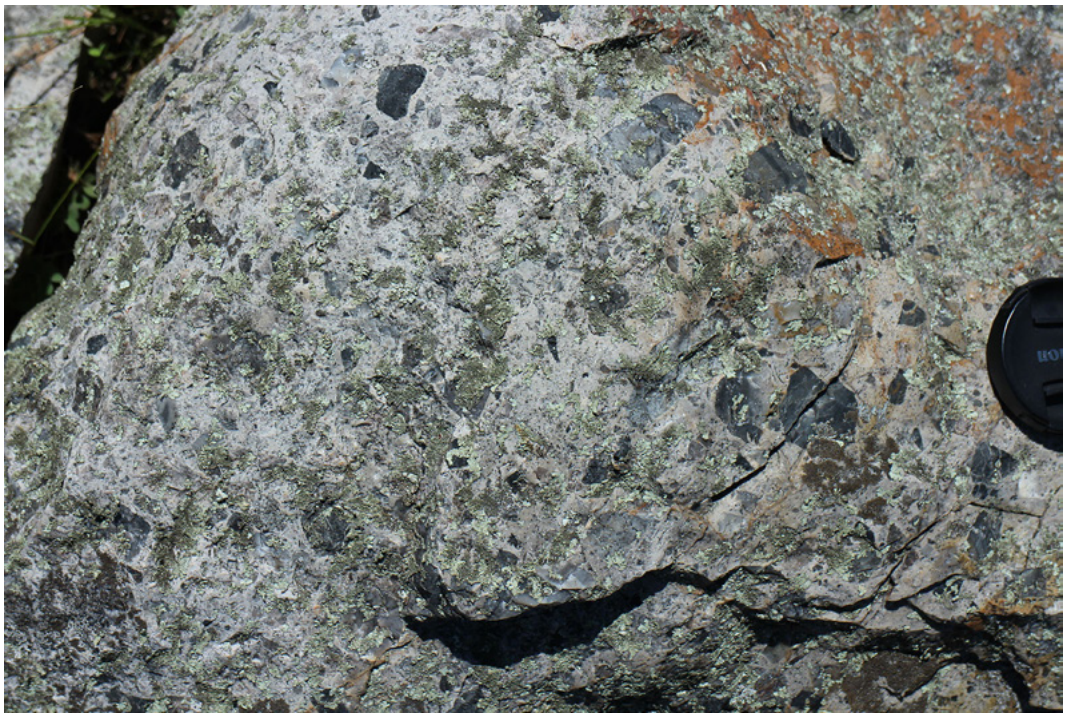


Figure E.12: *Outcrop photograph of typical SB. Note the poorly sorted, sub-rounded to angular dark grey chert clasts in the rock. The matrix comprises chert and white quartz clasts with a fine grained quartz cement. Photo taken by N. Vickery from Zone 11 from Cressbrook Station GR 375829E 6606854N.*

are apparent in the cement, commonly rimming larger clasts. These samples contain approximately 40% matrix to 60% clasts. This variant is not present at Thomas Lagoon.

Discussion and Conclusion

The four variants of silcrete are characterised by relict primary rock features such as clast shape, rounding and sorting as well as petrographic features including grain size and distribution, relative cement and clast abundance and induration mechanism (syntaxial overgrowth or cementation). Outcrop style is closely related to the primary sedimentological features and overprinting textures of the silcrete.

A diversity of quartz clasts exist within the silcrete that are not restricted to any one variant, but indicative of the detrital population at each location. The dominant variety is quartz with straight extinction of igneous or vein origin and most likely eroded from nearby granitoids and quartz veins within the accretionary complex sediments, either the Sandon or Girakool beds. Quartz displaying weak undulose extinction with or without inclusions, is also of probable igneous source, most likely granitic in origin. Smaller populations of polycrystalline quartz clasts indicate recrystallisation or significant deformation in a regional metamorphic environment. These clasts are probably detrital grains liberated during erosion of the Sandon or Girakool beds.

Smc and GS variants are dominated by simple, unstrained quartz clasts of either igneous (granitic) or vein origin. Their wide distribution on Cressbrook Station and at Thomas Lagoon reflects the detrital populations at these locations. The conglomeratic variants, CGS, in contrast, have significant populations of highly strained, polycrystalline metamorphic quartz grains. This variant occurs in three localities on Cressbrook Station (Zones 6, 7 and 11). CGS variant at Zone 1, where grinding grooves are found, is dominantly of simple, unstrained quartz clasts.

GS has been used preferentially as grinding surfaces at Cressbrook Station and Thomas Lagoon. This variant represents a small percentage of the overall silcrete outcrop in the study areas, which is dominated by Smc. GS is easily recognisable in the field, due to the pale brown colouration, poor coherence, massive, sandy appearance, low outcrop pattern and gritty texture that can easily be felt with the hand. This variant produces a regular surface due to its homogenous and well sorted sand sized clastic components. GS is clast supported, well sorted and comprises a high clast to matrix ratio. It is indurated by syntaxial overgrowth on quartz grains, rather than by silica cementation, thus maintaining the original sandy texture of the rock, which may have been a non-lithified quartz-rich sand or sandstone. Importantly, gritty silcrete displays significant porosity compared to other variants, a product of induration by syntaxial overgrowth and consequently a lack of cement. This porosity is likely to have enabled the ingress of oxidising groundwater, producing the red/brown colour, diagnostic of this variant. The gritty property of these rocks has provided a suitably abrasive surface for the purpose required.

GS is restricted in occurrence on Cressbrook Station and Thomas Lagoon. However, grinding grooves have not been identified at all localities where this variant crops out. While there is significant potential to find more grinding grooves exists in the wider district, the selections of particular sources may be influenced by factors other than the geology. For example, the use of particular sources by Aboriginal people in the past may have been conditioned by demography, mobility, resource distributions and social factors all of which might affect access to particular places at particular times.

The other silcrete variants identified in this study (Smc, CGS, SB) all comprise similar populations of quartz clasts, many of which also show induration by syntaxial overgrowth but are cemented with either microcrystalline quartz or chalcedony. The presence of cement produces a smooth, non-porous

silcrete which, while potentially suitable for flaking, would not provide the necessary abrasive qualities to use for grinding. Additionally, some of the conglomerate and breccia variants have irregular, bumpy surfaces that would be difficult to work for the purposes of grinding.

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