Proceedings of the 3rd Meeting of the Association of Ground Stone Tools Research

Edited by
Patrick Pedersen, Anne Jörgensen-Lindahl,
Mikkel Sørensen, Tobias Richter

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Contents

List of Figures

List of Tables

Introduction

Ground Stone Tools and Past Foodways
3rd Meeting of the Association for Ground Stone Research

The Association of Ground Stone Tool Research (AGSTR) was created in 2015 to promote research into ground stone tools in archaeology to enhance this still emerging field. The association was started by Daniel Rosenberg from the Zinman Institute of Archaeology at the University of Haifa, where he directs the Laboratory for Ground Stone Tools Research. The first meeting of the association was held in July of 2015 in Haifa at the Zinman Institute. After a successful and stimulating conference, a second meeting was arranged, this time in Mainz in September of 2017, hosted by Johannes Gutenberg University. Both were well-attended, with more than 50 participants each, and brought together specialists and experts in ground stone from across the world, working in and on material from East Asia, Africa, North America, Europe, Australia, Southwest Asia and beyond.

The third meeting of the AGSTR, was held in Copenhagen in September 2019, and focused on ground stone tools and their role in past food procurement, processing and consumption. The tag-line proclaimed the theme:"*Ground Stone Tools and Past Foodways*". The Centre for the study of Early Agricultural Studies (CSEAS) co-hosted the conference with the SAXO-institute of History, Archeology and Ethnology at the University of Copenhagen.

This conference, and the two preceding it, were held at a time when the interest in ground stone tool studies and their potential was growing. After decades of being an artefact category taken less seriously by archaeologists, ground stone studies now appear frequently in archaeological journals and publications from sites across the world, as a select sample of studies from the last 24 months shows (e.g. Bajeot *et al.* 2020; Chondrou *et al.* 2021; Dietrich and Haibt 2020; Hamon *et al.* 2021; Hruby *et al.* 2021; Li *et al.* 2020a; Li *et al.* 2020b; Santiago-Marrero *et al.* 2021; Zupancich and Cristiani 2020). The surge in interest and publications is largely driven by the application of new approaches, mainly: residue analysis, microscopic use-wear, 3D scanning and quantitative wear data, along with related experimental studies.

The successful extraction of microbotanical remains and residues from tool surfaces, in particular phytoliths and starches, has contributed greatly to our understanding of what was processed with these tools (e.g. Aranguren *et al.* 2015; Fullagar *et al.* 2006; Fullagar and Wallis 2014; Hamon *et al.* 2021; Li *et al.* 2020b; Mariotti Lippi *et al.* 2015; Nadel *et al.* 2012; Pearsall *et al.* 2004; del Pilar Babot and Apella 2002; Portillo *et al.* 2013; Power *et al.* 2016; Santiago-Marrero *et al.* 2021; Yang *et al.* 2013; Zupancich *et al.* 2019). In addition to, or in combination with these analyses, studies conducting (microscopic) use-wear analysis of ground stone, using both qualitative (Adams *et al.* 2009; Adams 2014; Adams *et al.* 2015; Delgado-Raack and Risch 2009, 2016; Laure Dubreuil *et al.* 2015; Dubreuil and Grosman 2013; Dubreuil and Plisson 2010; Revedin *et al.* 2018) and quantitative (including 3D) methods, often in conjunction (Bofill 2012; Caricola *et al.* 2018; Cristiani and Zupancich 2021; Dietrich and Haibt 2020; Zupancich and Cristiani 2020; Zupancich *et al.* 2019; Chondrou *et al.* 2021; Martinez *et al.* 2013; Benito-Calvo *et al.* 2018) have documented a wide range of contact materials. The application of these approaches on material from a wider variety of regions and time periods, has also been the deciding factor behind the growth of the field and the unprecedented attention ground stone tools are now receiving.

Not only limited to these methods, several new ethnoarchaeological studies have also appeared in recent years, which have shown the potential of ethnoarchaeology to inform our understanding of ground stone artefacts, especially with regards to the study of past foodways and the technological choices of practitioners engaged in “traditional” food processing (Alonso 2019; Hamon and Le Gall 2013; Nixon-Darcus and D’Andrea 2017; Robitaille 2016; Searcy 2011; Shoemaker *et al.* 2017).

The volume here thus contributes to this growing field within archaeology. It presents a selection of papers from that 3rd meeting of the Association of Ground Stone Tool Research. Though having a particular focus on “Ground Stone Tools and Past Foodways”, the volume also includes contributions dealing with sourcing, technology, use-wear and residue analyses and other aspects of the study of ground stone tools, such as ethnoarchaeology. Geographically, the papers cover a wide geographic range from Western Asia, Central Asia, Europe and Africa, and periods from the Palaeolithic to the present day.

By focusing on food, we wished to explore how ground stone analysts can approach ancient foodways through ground stone, using new methods and approaches. Foodways, explores the myriad of activities, people and tools involved in the procurement, processing, consumption and discard of food, and how these activities are situated within a web of social, material and ecological relations. Ground stone tools played a huge role in these activities up until the recent past and still in some regions of the world today. As research within and beyond these proceedings show, there is immense knowledge about foodways to be gained from studying ground stone tools. It may allow us to recognise different products being produced, and ways of producing them, what resources were being exploited, including resources that challenge our traditional understanding of what was processed with these tools.

This volume is structured chronologically, starting with the earliest material, the Upper Palaeolithic, though not discriminating between geographic locations. Studies explicitly dealing with foodways are thus interspersed with studies that also deal with other economic and social aspects of ground stone technology. This hopefully provides the reader with a broad range of insights that go beyond a strict adherence to foodways studies. This is done purposely, as we feel it important to consider the complex webs of meaning and structures these tools would have been entangled in. As the “foodways” approach also highlights, food production does not happen in isolation, but in conjunction with other activities, tools, tasks and people (Graff 2018; Hastorf 2017).

Ground stone technology and past foodways in pre-agricultural societies are explored in both Revedin *et al.* and Pedersen (Chapters 1 and 2 respectively). Revedin and colleagues focus on the production of flour in the Upper Palaeolithic Gravettian of Europe, through experiments in processing *typha* and oats, along with trace residues on the surface of archaeological stone implements, argue for the importance of starch rich foods for Palaeolithic foragers. Pedersen, by applying a *gesture*-based analysis of two assemblages from eastern Jordan, explores technological traditions and change within food processing ground stone among foragers in the late Pleistocene and early Holocene (Natufian to early Neolithic periods) of Southwest Asia. Cagnato and colleagues, like Revedin *et al.*, also look at plant food processing in Europe, though from a Neolithic perspective. They also conduct experiments in processing cereals and pulses, and through residue analysis examine how starch grains are affected by processing and by taphonomic processes.

A specific focus on consumption, discards and deposition of food processing ground stone is found in Chondrou & Valamoti and Bekiaris and colleagues, both dealing with evidence from the late Neolithic and Bronze age in Greece respectively. While, Bekiaris *et al.* stresses the importance of more intensive and extensive studies of ground stone assemblages and technology of the Bronze Age in Greece, Chondrou & Valamoti examine the spatial organisation of tool use and daily life activities in the Late Neolithic.

Additional studies of Neolithic assemblages are found in Vučković, Orijimie and Dubreuil *et al.* Vučković sheds important light on ground stone use in the central Balkans. Dubreuil *et al.* finds evidence of plant processing in the Gobi desert from microscopic use-wear analysis. Non-food tools, felling or ceremonial tools, and their social importance is explored by Orijimie looking at ground stone axes of the Late Stone Age, in Africa. Another example of a tool not directly involved in food processing, but rather tilling (plant tending), is found in Robitaille, who examines digging sticks weighted by special perforated ground stone, so-called *nougouil*, in Ethiopia and their Late Stone Age origin in Africa.

Alexandrovsky and colleagues provides a view of a unique assemblage of ground stone vessels and other artefacts from underground chambers at the late Chalcolithic site Tsomet Shoket in the Levant. Another unique assemblage from the Levant is of bedrock features high up in mountain caves of the Judean desert, which may have served as refugiums for people in the Late Chalcolithic, is presented in Davidovich. Lisowska presents an excellently discrete example of medieval foodways and the biography of buildings, through a (micro-archaeological) study of a baker's house from Wrocław, Poland. Verbrugghe then surveys the history, manufacture and trade of stone mortars in Northern and Western Europe, from the Iron Age and into the medieval period and their role in medicinal practices. Nixon-Darcus shows the usefulness of ethnoarchaeological studies of technological practices and how these may inform our archaeological interpretation. By working with modern operators of food processing grinding tools in Northern Ethiopia, it shows how these practitioners consciously engage with the raw material of their tools, maintaining differently textured grinding surfaces for specific end-products.

It appears as if there are exciting times ahead for the field of ground stone studies. We hope that this volume will spark the interest of fellow experts within the field and within the broader field of stone tool studies, and of scholars of past societies, economies and foodways generally. The chapters within, will provide some interesting points for future discussions.

Patrick Pedersen, Anne Jörgensen-Lindahl, Mikkel Sørensen, Tobias Richter, Copenhagen 2021

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1. Making Flour In Palaeolithic Europe. New Perspectives On Nutritional Challenges From Plant Food Processing

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Introduction

Until a decade ago, it was widely believed that the main source of food for the hunter-gatherers of the Palaeolithic derived from hunting and the main staple of the diet was meat, which is rich in energy in form of protein. The progress of research on the diet of the Upper Palaeolithic has reduced the importance of animal proteins for *Homo sapiens* (Piperno *et al.* 2004; Revedin *et al.* 2010; El Zaatari and Hublin 2014; Mariotti Lippi *et al.* 2015; Power and Williams 2018), and - more recently - also for Neanderthals (Power 2019).

The archaeozoological remains are generally overrepresented in the Palaeolithic excavations compared to plant residues that are much more perishable. This fact has long supported the idea that meat consumption was very common. Moreover, it is believed that hunting is a culturally more relevant activity than harvesting, also because of the depictions of Palaeolithic rock art. The collection of plants, mainly performed by women in modern foraging societies (see for example Kelly 2013), still has an important social role, because it can involve children and the elderly. We can assume that it contributed to at least 60% of subsistence, given that many of the essential nutrients and micronutrients derive from plants (Kuipers *et al.* 2012, Archer and Braun, 2013). Until now, the evidence of use of plant resources is rare, but plant remains have been found starting from at least the Acheulian (Melamed *et al.* 2016). During Middle Palaeolithic is documented the presence of abundant charred plant remains referable to human nutrition in the Mousterian of Kebara Cave in Israel, dated to between 50,000 and 60,000 BP. In particular, in this site the charred remains belonged to many seeds and fruits, among which wild legumes and hazelnuts (Lev *et al.* 2005). The evidence for plant consumption by Neanderthals is recently increasing, in particular thanks to studies on plant residues found in dental calculus, documenting also the cooking of plant foods (Hardy *et al.* 2012; Henry *et al.* 2014; Power, 2019).

In this paper we focus on the technology related to wild plant food processing. In the course of the last ten years, the production of flour from wild plants has been unequivocally documented starting from the Upper Palaeolithic. This has opened up new prospects for studying both the nutrition and the technological skills of *Homo sapiens* in Europe from 30,000 years ago (Aranguren *et al.* 2007; Revedin *et al.* 2010, 2015; Mariotti Lippi *et al.* 2015).

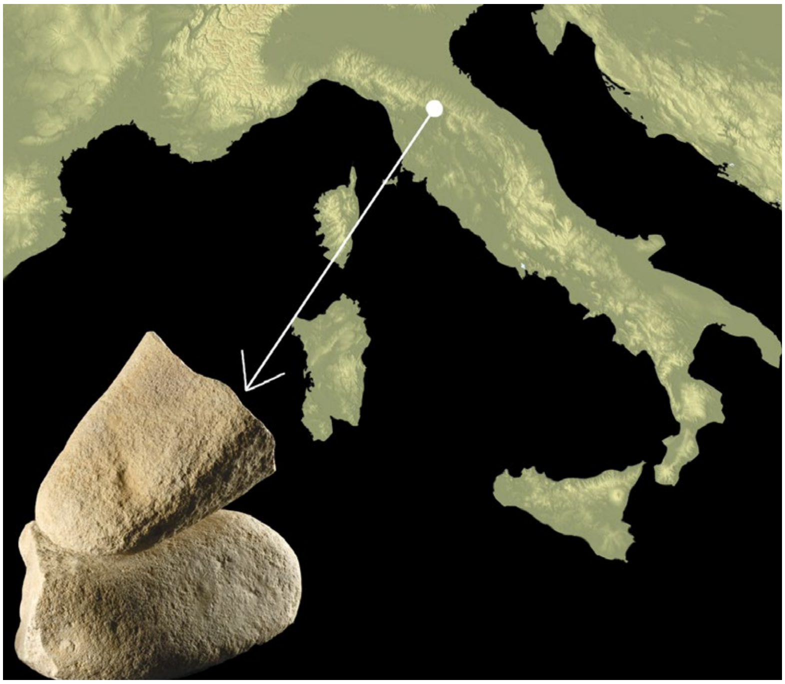

Figure 1: The grindstone and the pestle-grinder from Bilancino (Tuscany, Central Italy).

The project PLUS_P - Plant use in the Palaeolithic

The first discovery of tools used for grinding plant material dating to the Gravettian was made at Bilancino in Tuscany (Aranguren *et al.* 2007; Aranguren and Revedin, 2008). A grindstone and pestle-grinder were found, which conserved on their surfaces numerous starch grains largely referable to cattail (*Typha* sp.) rhizomes and to caryopses of grasses (Poaceae), representing the first documentation in Europe of the production of flour from wild plants datable to the Gravettian.

These discoveries stimulated the systematic search for vegetal remains in Palaeolithic sites, in particular on artefacts that could have been used in the processing of plant material, such as tools made of bone and flint, grindstones, hearthstones etc. (Revedin *et al.* 2009, in press).

The experimental archaeology activities carried out to produce different kinds of flour allowed to reconstruct the processing phases, define new sampling methods, obtain flour samples to be used for morphological and chemical-nutritional analyses. The research is part of the project of the Italian Institute of Prehistory and Protohistory PLUS_P - Plant use in the Palaeolithic.

The project is based on the hypothesis that plant resources with high energy content, such as complex carbohydrates, were part of the diet of the hunter-gatherers of the Upper Palaeolithic and that processing plant food and production of flour were common activities in Europe for at least 30,000 years.

An interdisciplinary research team was thus formed, composed of specialists from different countries and different disciplines: archaeology, experimental archaeology, archaeobotany, use-wear analysis, food science.

Materials and Methods

The research activity was carried out through a series of successive phases, starting from the identification of the artefacts, the use-wear analysis, the detection and analysis of the plant remains, the identification of the starch grains, up to the experimental reproduction of the activity of grinding wild plants, and the chemical-nutritional characterization of the flours which were experimentally reproduced (Aranguren and Revedin 2011).

Identification of the artefacts

Focus was put on stone tools (mainly pebbles) without traces of lithic reduction, which displayed morphologies potentially reliable to plant processing activities, such as millstones, grinders, pestles, mortars, cutting boards, etc. Tools made from natural pebbles still do not receive the same attention paid to other categories of findings. This is probably due to the objective difficulty of identifying and, even more so, classifying artefacts consisting of natural stones that have been modified by use, compared to the much more recognizable chipped stone tools. In fact, only the detection of traces due to their intensive, not occasional use, allows us to identify them as artefacts (de Beaune 2000, 2004).

Over 50 artefacts on pebble were examined, different in terms of morphology, raw material, origin and chronology, most of which did not show starch remains, perhaps because they had been washed after the discovery.

The findings examined over the years come from the sites of Bilancino (Italy), Arene Candide (Italy), Arma delle Fate (Italy), Grotta della Cala (Italy), Grotta Paglicci (Italy), Kostenki, (Russia) , Pavlov VI, Dolni Vestonice, Milovice and Kolibki (Czech Republic) (Revedin *et al.* 2009, 2015), and others are under study.

Except for the pebble from Kostenki, they are more or less elongated and flattened, with a fracture at one end and rounded and tapered at the other end. The length varies from 10 to 12 cm and the weight from 500 gr to 1 kg. Only the Pavlov pestle-grinder is larger than 18 cm and heavier than 1 kg.

Regarding the chronology, all the aforementioned artefacts are attributed to the Gravettian, starting from the ancient Gravettian (Table 1).

Table 1: Radiocarbon dating of the Gravettian layers containing the ground stone tools object of the analysis.

Site	Layer	14C Radiocarbon date	Sample n.	Lab	Bibliography
Paglicci	23 A	32,318 ± 563 cal BC	1414	UtC	Palma di Cesnola 1993
Bilancino II	Hearth	28,298 ± 301 cal BC	106549	Beta	Aranguren, Revedin 2008
Pavlov VI		28,985 ± 337 cal BC	37627	GrA	Svoboda et al. 2009
		29,078 ± 339 cal BC	37628	GrA	
		29,078 ± 339 cal BC	18306	OxA	
Kostenki	16 (Uglyanka)	28,087 ± 253 cal BC	1431	LE	Sinitsyn, et al. 1997
		30,106 ± 953 cal BC	5270	LE	Revedin et al. 2010
		29,464 ± 562 cal BC	8033	GIN	
		30,786 ± 520 cal BC	8031	GIN	
		31,904 ± 698	74126	LE	
Dolni Vestonice I	Middle zone	25,820 ± 170	1286	GrN	Svoboda et al.1996

Use-wear analysis

After collection and before any cleaning treatment, the findings are analysed according to an integrated methodological approach (Longo and Lunardi 2008).

Macroscopic and microscopic analysis of the surfaces for the detection of traces:

a) Analysis of under dissection microscope LEIKA MZ6 at different magnifications (6x - 50x);

b) Metallographic optical microscope analysis (50x, 100x, 200x);

c) Comparisons between the traces of processing detected on the finding and the traces of processing on experimental instruments (Figure 2).

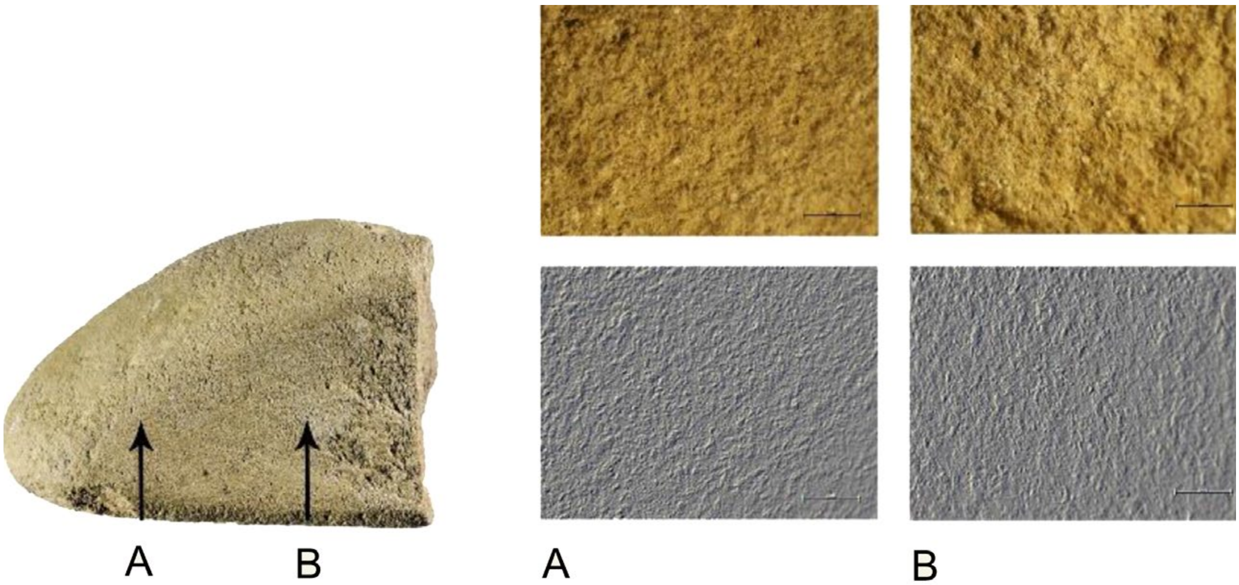

Figure 2: Stereomicroscope micro-photographs of the grinding surface of the Bilancino grindstone A, peripheral area. B, grinding area (from Revedin et al. 2018, revised).

Plant remains analysis

The sampling

The detection of the starch grains adherent to the surface of the Bilancino tools (grindstone and grinder) followed the protocol developed by Piperno *et al.* (2004). It consisted in the following steps: washing the surface with distilled water; collecting the washing water and subjecting it to centrifugation in order to obtain the sedimentation of the suspended particles, including starch grains.

Subsequently, a new sampling procedure was tested (Figure 3), which was developed on tools used for experimental grinding. According to this new procedure, the instruments are wrapped in a PVC plastic film which leaves a 4 cm square portion free on which the sampling is carried out. This procedure was developed to obtain a quantitative evaluation of the plant remains and to analyse their distribution on the surface of the tool; indeed, the distribution of the plant remains provides information on the dynamic of use during the grinding; furthermore, the presence of the plastic film preserves a good part of the surface, leaving it usable for subsequent analysis.

This new sampling procedure was applied for the first time on Paglicci's pestle-grinder as well as on experimental grinders (Mariotti Lippi *et al.* 2015; Revedin *et al.* 2018).

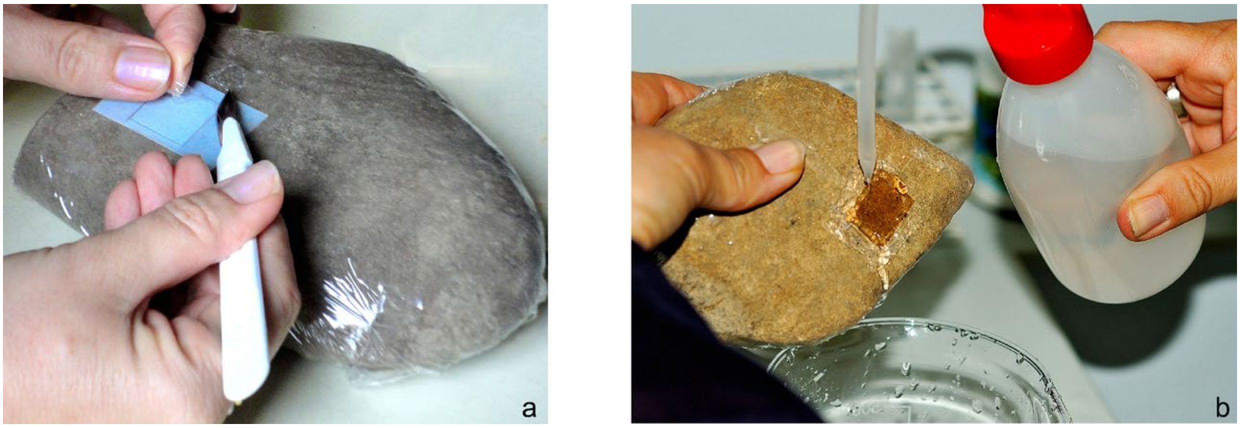

Figure 3: The sampling tests carried out on the experimental artefacts: (a) the tool is covered with high-adhesion, transparent cling film and a square with a side length of 2 cm was cut out of the film, (b) a water jet is directed onto the exposed surface and collected into the beaker.

Starch analysis

The recovery of starch grains on stone tools is in itself an important information as it demonstrates the use of the tool for obtaining flour and therefore for food purposes. Throughout the world, flour represents one of the main sources of carbohydrates in the human diet and is obtained from different plant portions, in particular from seeds and fruits, such as caryopses, and from underground storage organs.

For the identification of the starch grains, the existing atlases (for example Seidemann 1966) were not sufficient, because they do not include the starch of most part of the wild species. For this reason, a specially prepared reference collection was set up by grinding fresh material or herbarium exsiccata. The selection of the plants to be ground was made on the basis of the past pollen spectra of the site from which the tool came or of the surrounding area.

The identification of the plant used for the flour represents one of the major difficulties of this type of research. In fact, the starch grains display a low number of morphometrical features and consequently many of the starch grains can be attributed to a large number of species. In other words, based on the morphometrical features, many starch grains may be attributed to a group of plants rather than to a species, making it difficult to identify the precise source plant.

It is always very important to have a sufficiently high number of starch grains to be observed, since the analysis of morphometrical variability is a good information for a better identification of plant species.

Ethnographic research and experimental activity

Once the plants used on Palaeolithic artefacts have been identified, an ethnographic study is carried out to confirm the uses of specific parts of the plants and the different technologies used for the exploitation of plant resources (Gott, 1999; Humphrey *et al.* 2014; Liu *et al.* 2011; Pinna 2013; Schroth 1996.). The role of ethnography in studying and addressing archaeological research questions is undeniable, since it allows to look at the relationship between human behaviours, the '*material culture and the physical environment in a functioning observable setting*' (Ingersall *et al.* 1977). A crucial stage of the research is the experimentation of the processes for the production of food starting from the plant material. An attempt was made to reconstruct the entire production chain, using the species identified during the research and through the use of instruments that have similar lithological and morphological characteristics to archaeological findings.

Nutritional characteristics of Palaeolithic flours

Evidences of processing/employment of *Typha* rhizomes were discovered both in Bilancino and Pavlov VI, while starch grains belonging to oak acorn and wild oats were found on Paglicci's pestle.

To improve knowledge of Gravettian diets, chemical-nutritional characteristics of whole flours similar to Palaeolithic samples (cattail rhizomes, oak acorns and wild oat grains) were compared with emmer wheat (*Triticum dicoccon* Schrank). The hulled wheat (emmer) is among the most ancient *Triticeae* cultivated in the world and have long represented a staple food with interesting nutritional properties (Nesbitt and Samuel 1996; Marconi and Cubadda 2005; Cubadda and Marconi 1996).

Quantitative and qualitative evaluation of protein, lipids and starch fractions was reported.

Results and Discussion

In the first phase of the research, a large number of artefacts on pebble were examined and subjected to starch analysis. They varied in the raw material, origin, and chronology. Most of them did not preserve starch grains on the surface. The lack of plant remains on the surface could be related to 1) non-use of the pebble, 2) the pebble was used for grind/pound non vegetal material, 3) post-depositional events, 4) the washing procedure after the discovery. To date, we have identified six tools for plant grinding: two from Bilancino, one from Kostienki 16, one from Pavlov VI, one from Dolni Vestonice I, one from Paglicci 23A (Figure 4); other pebbles are under investigation. The second phase of the study was devoted to defining the recurrent morphotechnical elements useful for identifying plant processing tools.

The kind of settlements vary from a cave, as "*grotta*" Paglicci, to an open-air settlement as Kostenki 16, to the hunting sites of Pavlov VI and the seasonal camp of Bilancino. The last one is the site where both the active and the passive artefact were found: a millstone and a pestle grinder obtained by breaking a single pebble. All the other tools are active instruments. According to the morphometric data, the tools are easy to handle. On the basis of the morphology and use-wear traces, the tools of Dolni Vestonice and Kostenki are multifunctional instruments, also used as pestles.

The study of the lithological characteristics is still in progress. However, although they are sandstone pebbles, they are quite different, which is tied to the different geological contexts of places very distant from each other. The differences concern the texture of the grains, their size and hardness, the resistance of the matrix and the abrasive capacity. The variability of these artefacts might be related to their use for the treatment of different materials (roots, caryopses, etc.) depending on local resources (Revedin *et al.* 2018).

Figure 4: The european findings of gravettian grinding tools: 1,6, Bilancino; 2, Paglicci str.23a; 3, Dolni Vestonice I; 4, Pavlov VI; 5, Kostienki 16.

Numerous starch grains recovered on the Bilancino tools, grindstone, and pestle-grinder, have been identified as belonging to *Typha* (Figure 5). In particular, the grain morphometry suggested the processing of rhizomes of *Typha angustifolia*. Other grains found on the same tools were referable to grasses, displaying a morphology very similar to those of *Brachypodium*. On the pestle-grinder, other grains were similar to those of *Sparganium*. The majority of the grains belonged to plants which are common in wet environment and were spread not far from the site (Aranguren *et al.* 2003; Aranguren and Revedin 2008).

Despite the small number of grains preserved after the instrument was washed, various morphologies of starch grains were also found on the Kostienki grinder; the only identifiable grains can be referred to *Botrychium* (moonworts) (Figure 6), a fern that was widespread in the area surrounding the site, as attested by pollen analysis (Holliday *et al.* 2007). The root of moonworts are very rich in starch and easy to grind (Revedin *et al.* 2010).

A large variety of starch grains was also recovered from the Pavlov pestle-grinder, some of them attributable to *Typha* and *Botrychium* (Revedin *et al.* 2010).

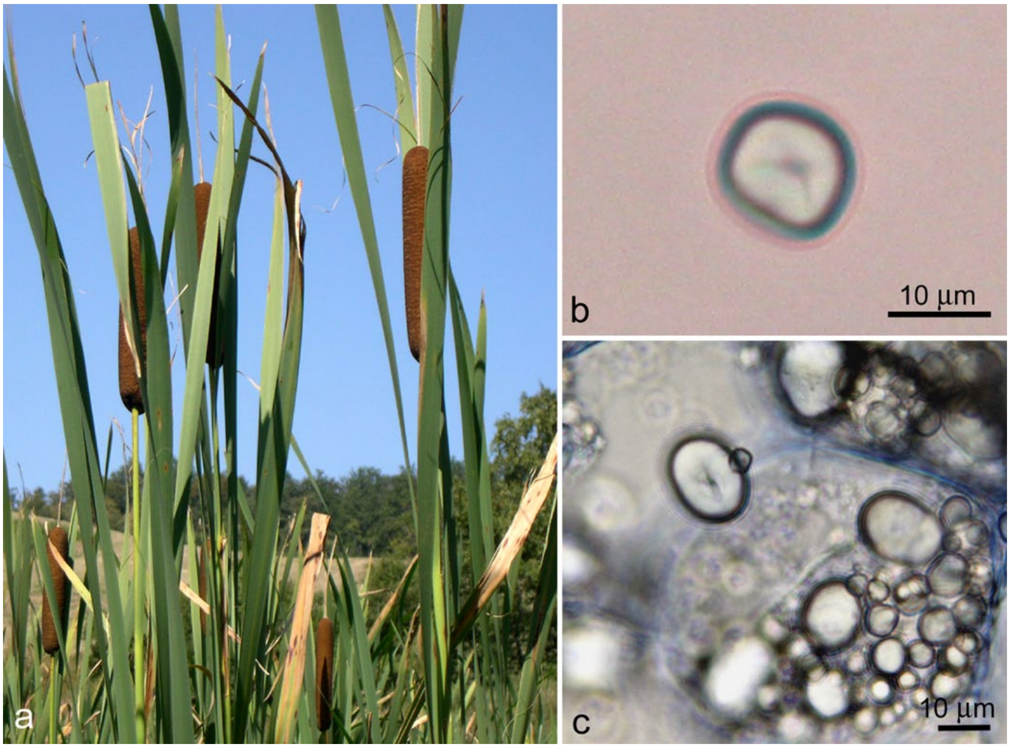

Figure 5: a) Typha latifolia*. b) a starch grain from the Bilancino grindstone. c) starch grains in the* Typha rizome*.*

Figure 6: Botrychium lunaria*: a) the plant b) starch grains from the starch-rich root.*

At Dolni Vestonice, the instrument was washed, and the sampling provided a small number of starch grains, some of which were possibly modern, due to contamination (Aranguren *et al.* 2011)

On the Paglicci artefact, as already said, most part of the starch grains was attributable to wild oats, more specifically the morphology pointed to *Avena barbata* (Figure 7); a few grains were referable to other grasses, acorns or unidentifiable. A challenging result in studying the Paglicci grinding tool was the record of swollen or partially swollen, gelatinised starch grains. The swollen starch grains presented the physicochemical changes that normally occur after heat treatments. This evidence suggests that a heat treatment was performed on the plant material before grinding (Mariotti Lippi *et al.* 2015) (Figure 8).

Large amount of starch grains of a specific plant on an artefact is not necessarily the direct consequence of the preference for that plant rather than another (Table 2). It could instead reflect the last material ground with that instrument or could be connected to the size/granulometry of pounded/grinded starch flour, connected to the dimensional relationship between the starch grain size and the granulometry of the tool, more specifically the spaces between the surface clasts of the stone.

Table 2: Possible origin of the starch grains found on the tools.

	Bilancino II	Kostienki 16	Pavlov VI	Dolni Vestonice I	Paglicci 23A
***Avena* (caryopsis)**					+
"Millet" (caryopsis)					+
Poaceae unident. (caryopsis)	+				
***Typha* (rhizome)**	+		+?		
cf. *Sparganium* (rhizome)	+				
***Botrychium* (root)**		+	+?		
cf. *Quercus* (acorn)					+
Unidentified	+	+	+	+	+

To understand if and how it was possible to produce *Typha* flour, an experimental activity has been set up. The rhizomes of *Typha*, i.e. the underground stems of this plant, were harvested at the end of the summer, when they are rich in starch. The rhizomes, once dried, were ground with tools analogous to the ones found at Bilancino. The flour obtained was kneaded with water and spread to make cakes. The cakes were cooked on a hearth that was rebuilt on the basis of the one found in Bilancino (Aranguren and Revedin 2008, 2011; Aranguren *et al.* 2015; Revedin *et al.* 2018) (Figure 9).

The processing of wild oat caryopses documented in Paglicci is very different from that of *Typha* in Bilancino and includes an additional heat treatment. The experimentation made it possible to confirm certain hypotheses previously made in relation to the discovery of grains of oat starch on the Paglicci pestle (Figure 10). The heat treatment of the starch grains discovered on the Paglicci pestle could be a further step aimed to accelerate the drying of oat, the process of threshing and dehusking, to make grinding easier and/or to improve the nutritional properties and the preservation of the caryopses/flour.

The chemical and nutritional composition of meals of different botanical origin is shown in Table 3. All the analysed samples showed a starch content higher than 50%, revealing that Palaeolithic diet provided a significant amount of complex carbohydrates. Regarding proteins, wild oat had the highest

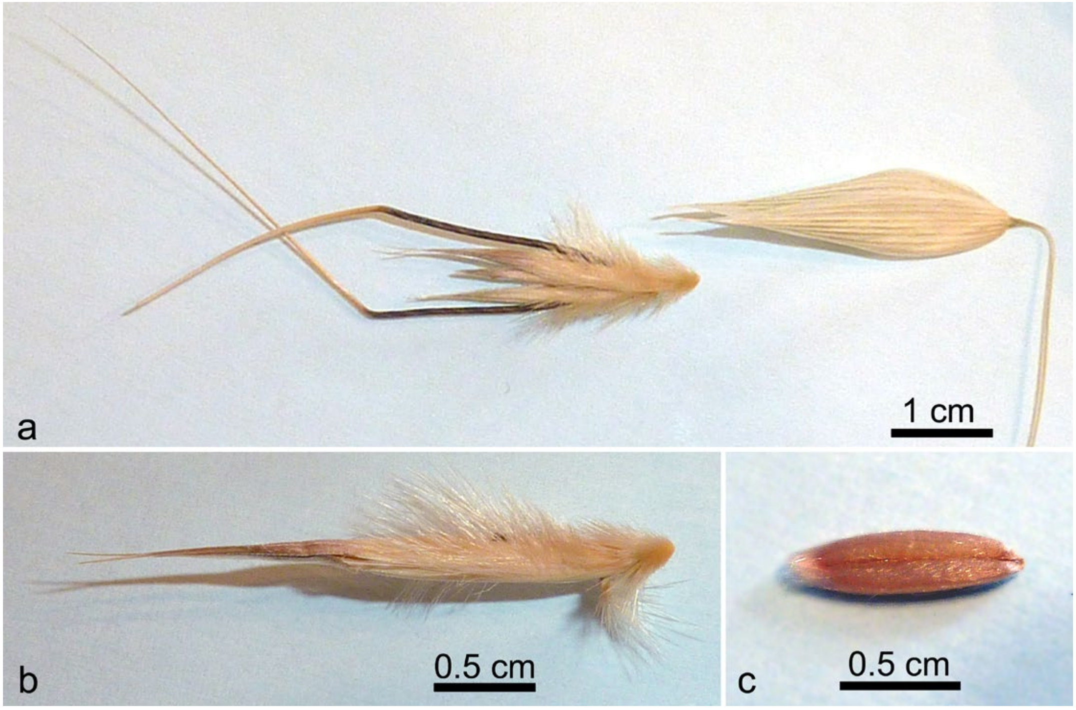

Figure 7: Avena barbata *spikelet: a) florets (each surrounded by lemma and palea) and the empty glumes; note the long awn arising from the lemma. b) a floret. c) caryopsis, ventral view.*

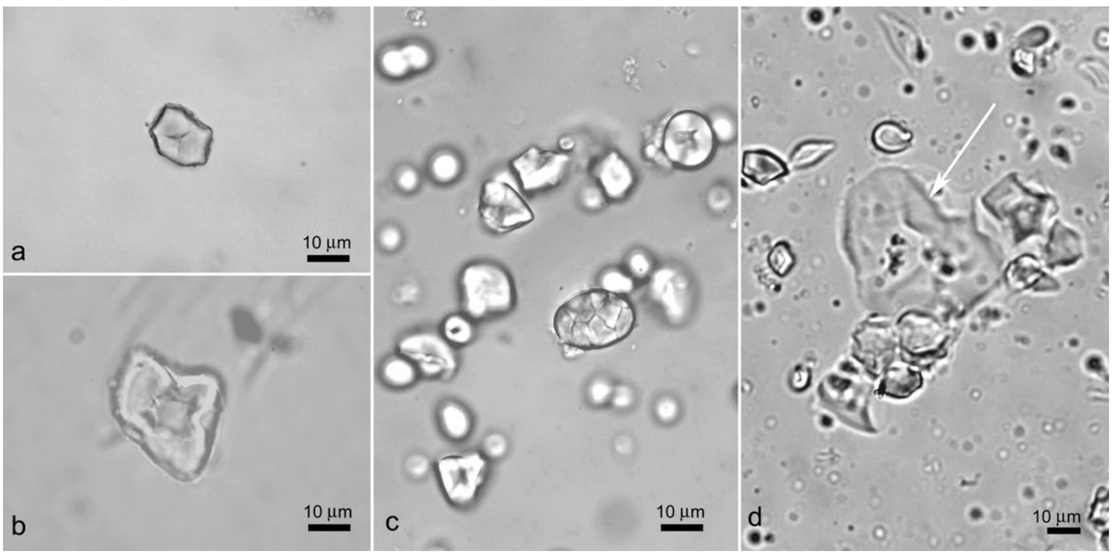

Figure 8: Starch grains: a) a starch grain from the Paglicci pestle-grinder. b) a "gelatinized", swollen starch grain from the Paglicci pestle-grinder. c) starch grains of Avena barbata *caryopses (fresh plant). d)* Avena *starch grains after popping. Note the presence of a gelatinized, swollen grain (arrow).*

Figure 9: The experimental production of Typha *flour: a) Cattail plants (*Thypha*); b) The collection of the rhizomes; c) Dried rhizomes of cattail; d) The grinding of the rhizomes into flour; e) The cooking of the* Typha *cakes.*

Figure 10: The processing of oats: experimenting the heat treatment on stone heated up on embers.

content (about 20%), while in emmer wheat it was 12% and in cattail 9%. Acorn flour reported the lowest values (3-5%) balanced by a higher amount of fats.

The high fat content, both in the acorns (8-13%) and in wild oats (8%), nutritionally interesting, was probably the reason why these products underwent a preliminary heat treatment (parching/heating/toasting/roasting/cooking). In fact, it resulted useful both for dehulling/shelling of caryopses/fruits and to reduce the enthomatic, microbiological and enzymatic infestations/alterations (Forni 2002; Nesbitt and Samuel 1996).

As for the fatty acid composition of the lipidic fraction, it is pointed out that the oak and oat (*A. sativa* and *A. barbata*) meals have a high content of monounsaturated fatty acids (oleic acid) (>60% and 40%, respectively), and therefore a composition balanced from the nutritional point of view and stability to storage, especially in the presence of high amount of natural antioxidants (polyphenols and tocols). On the other hand, cattail flours showed a high content of polyunsaturated fatty acids (>40%) (Revedin *et al.* in press).

Although the acorn cannot be considered an oil-bearing seed, the oil content was in the range of other vegetable materials that are used because of their health components or their industrial or pharmaceutical applications, such as wheat germ (8-14% fat content) or amaranth (6.5%).

Regarding protein biological values, calculated as chemical score, that is the balanced composition of essential amino-acids, wild oat reported the best value (chemical score= 67) followed by cattail (58) and emmer wheat (48) (Revedin *et al.* in press). Despite these levels were insufficient to provide optimum amount (chemical score=100), higher intake of proteins was still ensured by the consumption of fishery and meat products.

Qualitative evaluation of proteins, starch, and lipids fractions and of functional compounds (dietary fiber, vitamins, antioxidants-polyphenols) demonstrated the importance and the equilibrated nutritional value of foods derived from these plants (rhizomes, fruits, caryopses).

Table 3: Chemical and nutritional composition of oak, cattail, emmer and oat meals (g/100g fw)*.

Proximate composition	Oak acorn	Cattail rhizome	Emmer		Oat**	
			whole meal	flour	cultivated	wild
Energy (kcal)	314	266	307	329	345	338
Protein	3.3-5.0	9.1	11.9	11.0	12,7.4	17.7
Lipid	7.8-12.7	2.2	2.8	1.7	7.1	7.7
Dietary fiber	nd	17.3	10.4	4.7	8,7.3	11.0
Starch/available carbohydrates	49.6-55.6	52.5	58.7	67.3	57.7	49.6

* adapted from Revedin *et al.* in press

** adapted from Sosulski and Sosulski 1985

Conclusions

Our research on artefacts used for plant grinding was aimed at gathering information not only on the ancient diet, but also on the preparation of food and, therefore, at understanding the complex subsistence strategies that constituted an important part of the population's "cultural baggage" during the Palaeolithic.

The production of flour requires various technological steps to manipulate the plant before cooking, depending on the different plant portion used: selection and collection of the specific portions of wild plants containing starch, dehusking/dehulling, soaking/boiling, parching/roasting/charring, drying/heating, pounding/grinding, rehydration, cooking to remove glumes and antinutritional factors and to gelatinize starch (digestible starch) (Forni 2002; Nesbitt and Samuel 1996).

As demonstrated by the results of the IIPP research project, the technology for the production of flour was a common skill spread across the entire chronology of the Gravettian period and in a large part of Europe, from southern Italy to the plain of the Don, in Russia (Figure 4).

All the instruments were used for the treatment of different parts of wild plants (seeds, acorn, roots, etc.), depending on what the surrounding environment offered.

The variability of the artefacts is the result of the adaptation of a technique that had to be rather common and spread to different economic and environmental contexts.

In any case, the tools, pestle, and pestle/grinder, were handling and active instruments, with the sole exception of the Bilancino grindstone which was a passive tool.

The common absence of passive instruments can be variously interpreted, but it must always be kept in mind that these technologies were used by nomadic populations. The use of grindstones may have been only occasional and therefore difficult to identify in the archaeological record. We have considered the possibility that also some cavity in the bedrock could have been used as passive instrument (Rosenberg and Nadel 2017 and cited references). The research to support this hypothesis, firstly tested in Castelcivita cave in Southern Italy (Gambassini 1997), was unsuccessful so far.

Another hypothesis is that pestles were used in combination with mortars. In this case, it could be assumed that the mortars were made of wood (Murray 2014), making them easier to manufacture and transport and therefore more suitable for use by nomads than stone tools. However wooden artefacts are perishable, and they are difficult to find in the Palaeolithic sites.

The importance of starch-rich meals for Palaeolithic hunter-gatherer populations consists in having an energetic foodstuff for an equilibrated and integrated diet (animal and vegetable protein, complex carbohydrates, minerals and bioactive compounds).

Palaeolithic flours, obtained from wild plants, have revealed to have optimal characteristics for the human diet, even higher than the cultivated species, although obviously with a lower yield.

The multistep technology to produce flour from wild plants has important implications in Upper Palaeolithic communities. The high caloric intake of flour combined with its ease of transportation and preservation, made this product an important food resource, allowing hunter-gatherers great mobility and autonomy.

The whole process of making flour, from harvesting different plant portions to cooking, it is also a time-consuming activity. Therefore, it must be highlighted that the important energy investment in the gathering, documented for the Gravettian *sapiens*, could be explained as a reliable calories income integrating the less reliable hunting activity, especially in harsh conditions.

The widespread knowledge of these technologies may have represented a real advantage for Early Upper Palaeolithic AMHs in Eurasia, especially in the use of different environmental resources.

Our hypothesis, supported by these findings, is that the technological knowledge related to the production of flour from wild plants was a part of human cultural heritage and that this skill has evolved continuously starting from at least the ancient Gravettian up to its full development that has become clearly evident in the Natufian, creating the conditions for the dawn of the agricultural economy.

Starting from the Neolithic, starch-rich plant species were selected and transformed on the basis of procedures, known since the Gravettian age, necessary of making complex carbohydrates digestible.

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2. The Groundstone Assemblages of Shubayqa 1 and 6, Eastern Jordan - Technological choices, Gestures and Processing Strategies of Late Hunter-Gatherers in the Qa' Shubayqa

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Introduction

Since the early 2000s, there has been an increasing interest in groundstone tools and technology in prehistoric archaeology of Southwest Asia (henceforth SWA). Publications have addressed varied topics related to the use of groundstone tools from food production and their relationship with pre and early agricultural societies (e.g. Dubreuil 2004; Dubreuil and Plisson 2010; Dubreuil and Nadel 2015; Hayden *et al.* 2016; Hodder 2018; Rosenberg 2008; Rosenberg and Gopher 2010; Wright 2000, 2014), their social significance; exploring their role in burials (Dubreuil and Grosman 2009; Dubreuil *et al.* 2019; Liu *et al.* 2018; Richter *et al.* 2019; Rosenberg and Nadel 2014), social inequality (Wright 2014; Molleson 1994) and using a range of methods like microscopic use-wear (e.g. Dubreuil 2004; Dubreuil and Grosman 2013; Dubreuil and Plisson 2010) and residues (e.g. Liu *et al.* 2018; Terradas *et al.* 2013). However, I believe further issues remain: the view of how this technology develops is tied to a linear *standard view* of technological development and tool use, in for example food processing, is not always fully recognized as representations of technological choices and consciously selected *processing strategies* by individuals and communities. These issues, I tentatively address here. The focus in this paper is on the influence of movements, or *gestures,* on tool morphology and tools as representations of processing strategies; a material reflection of choices that change over time. Using the groundstone tool assemblages of two prehistoric sites located eastern Jordan: Shubayqa 1 and 6, dated to the late Epipaleolithic-early Neolithic respectively and concentrating on groundstone tools used in food processing tasks, I elucidate local scale changes in technological practices and consequently processing strategies during the Natufian and Pre-Pottery Neolithic of SWA by introducing a way of analysing assemblages based on the interplay between movements, gestures and tool morphology.

The Natufian and the early Neolithic of Southwest Asia

The Natufian period is part of the late Levantine Epipalaeolithic and lasts approximately 3500 years from around 15,000 to 11,500 cal. BP (Grosman 2013; Richter *et al.* 2017; Weinstein-Evron *et al.* 2012). The period is divided into the early Natufian (*c.* 15.000-13.600 cal. BP) and the late Natufian (13.100-11.500 cal. BP) (Grosman 2013). Climaticly it coincides with the Bølling-Allerød interstadial and resulting wet and warm climatic conditions *c.* 14.700-12.900 cal. BP (Blockley and Pinhasi 2011; Jones *et al.* 2019; Rosen and Rivera-Collazo 2012). In the late Natufian, sites seem to become smaller and more dispersed indicating less sedentism in this period (Belfer-Cohen 1991; Grosman 2013). This shift in the late Natufian has often been seen as a response to environmental stress climatic changes caused during the Younger Dryas *c.* 12.900-11.700 cal. BP (Goring-Morris and Belfer-Cohen 1997). This event supposedly caused colder, drier weather and featured increased seasonal variability (Blockley and Pinhasi 2011; Goring-Morris and Belfer-Cohen 1997; Moore and Hillman 1992; Stutz *et al.* 2009). However, mounting evidence seems to suggest that climatic impact of this event was less severe, or perhaps at least more locally variable, than previously thought (Grosman 2013; Richter *et al.* 2017; Rosen and Rivera-Collazo 2012;

Yeomans *et al.* 2017; Yeomans 2018). Subsistence during the Natufian was based on hunting principally gazelle, but also smaller game especially in the late period, and gathering of wild plants (Arranz-Otaegui *et al.* 2018; Munro 2004; Olszewski 2004; Rosen and Rivera-Collazo 2012; Stutz *et al.* 2009; Willcox 2012; Yeomans *et al.* 2017). Plant resources seems an important component of a varied diet (Arranz-Otaegui *et al.* 2018; Rosen and Rivera-Collazo 2012; Willcox 2012). The early Neolithic of SWA, the so-called 'Pre-Pottery Neolithic' is characterized by several Neolithic features such as, increased sedentism, population density, cultivation and incipient domestication of plants and animals but without ceramics (Bar-Yosef *et al.* 1991; Bar-Yosef and Belfer-Cohen 1989; Finlayson 2009; Kuijt 2002, 2011; Kuijt and Goring-Morris 2002). The PPNA is the earliest phase this period featuring most of the above characteristics but with no definite evidence for the domestication of plants and animals (Asouti and Fuller 2013; Horwitz *et al.* 1999; Kuijt and Goring-Morris 2002; Mason and Nesbitt 2009; Willcox 2012; Willcox *et al.* 2008; Willcox and Stordeur 2012). In this paper the period will mostly referred to as the Early Pre-Pottery Neolithic (Henceforth EPPN), encompasing both the PPNA, but also parts of the late PPNA and subsequent early PPNB and for our purposes dates to *c.* 11,600-10,600 Cal. BP (see below). EPPN subsistence also relied on hunting and increasingly plant resources, climatic conditions improved in this period with wetter, warmer conditions in comparison with the end of the Natufian (Rosen and Rivera-Collazo 2012; Willcox 2012).

Food Processing Groundstone Technology

The tools I examine in this paper are groundstone tool pairs used to significantly reduce the particle size of an intermediate edible matter between two stones through abrasion, crushing or a combination of both (Adams 2002). I use the generic term: food processing or processing tools here. These groundstone tools consist of an upper mobile and lower stationary tool and may be further subdivided into two subgroups: grinding tool pairs, handstones and grinding slabs or querns (Wright 1992a), and pounding tool pairs, pestles and mortars (Wright 1992a).

Epipaleolithic-Neolithic Food Processing Groundstone in SWA in the standard view

To contextualize the Shubayqa groundstone assemblages within more general technological trends during the period covered I establish the standard view of the emergence of food processing groundstone in SWA. Groundstone tools first appear in the Upper Palaeolithic and during the subsequent Epipaleolithic vessel-style mortars and pestles appear (de Beaune 2004; Dubreuil and Nadel 2015; Kraybill 1977; Wright 1991). These types become even more common during the late Epipaleolithic Natufian, where groundstone tools in general are more widespread and numerous (Kraybill 1977; Wright 1991, 1992b, 1994). In this period both pounding and grinding tools become major tool groups within the inventory of Natufian foragers, but pounding tool pairs are most abundant (Dubreuil 2004; Dubreuil and Plisson 2010; Kraybill 1977; Wright 1991). In the late Natufian, vessel-mortars were superseded by boulder and bedrock mortars (Rosenberg and Nadel 2011, 2014; Power *et al.* 2014; Terradas *et al.* 2013). Pounding tools evidently give way to grinding tools over time (see Dubreuil 2004; Wright 1994) and by the EPPN, grinding tools are the most common, this seen as a result of increasing reliance on cereals grains (Wright 1994), while pounding tools continue to be found less frequently. This trend continues into the later Neolithic (Wright 1992b, 1993).

What was presented above, follows a somewhat linear and direct path of technological development from elaborate pounding tools in the late Epipalaeolithic to grinding tools in the EPPN. This is an example of what Pfaffenberger (1992) criticized as being a *standard view of technology*, i.e. a history of technological development that is linear and singular with the development of inevitably 'correct'/'commonsense' technologies. What will be argued here, is that by applying a different approach to these technological developments, one based on the relationship between movements (or *gestures*), tool pairs and wear, we may refine this linear and singular standard view.

The setting and the sites

The sites are located in the *harra* desert of eastern Jordan. The *harra* is a basalt desert spreading from Syria and the Jebel Druze to the north across the *badya* region of eastern Jordan continuing into the Arabian peninsula to the south (Betts 1998). This basalt desert is the result of volcanic activity in the late Tertiary to Quaternary, from approximately 8.9 to 0.1 mya (Allison *et al.* 2000). It is defined by Saharo-Arabian type steppe vegetation and currently receives less than 200 mm of mean annual rainfall (Zohary 1973). The Shubayqa sites are located in the *Qa'* Shubayqa (see Fig. 1), a twelve square-kilometre large mudflat basin (Richter *et al.* 2012; Richter 2014; Richter *et al.* 2016).

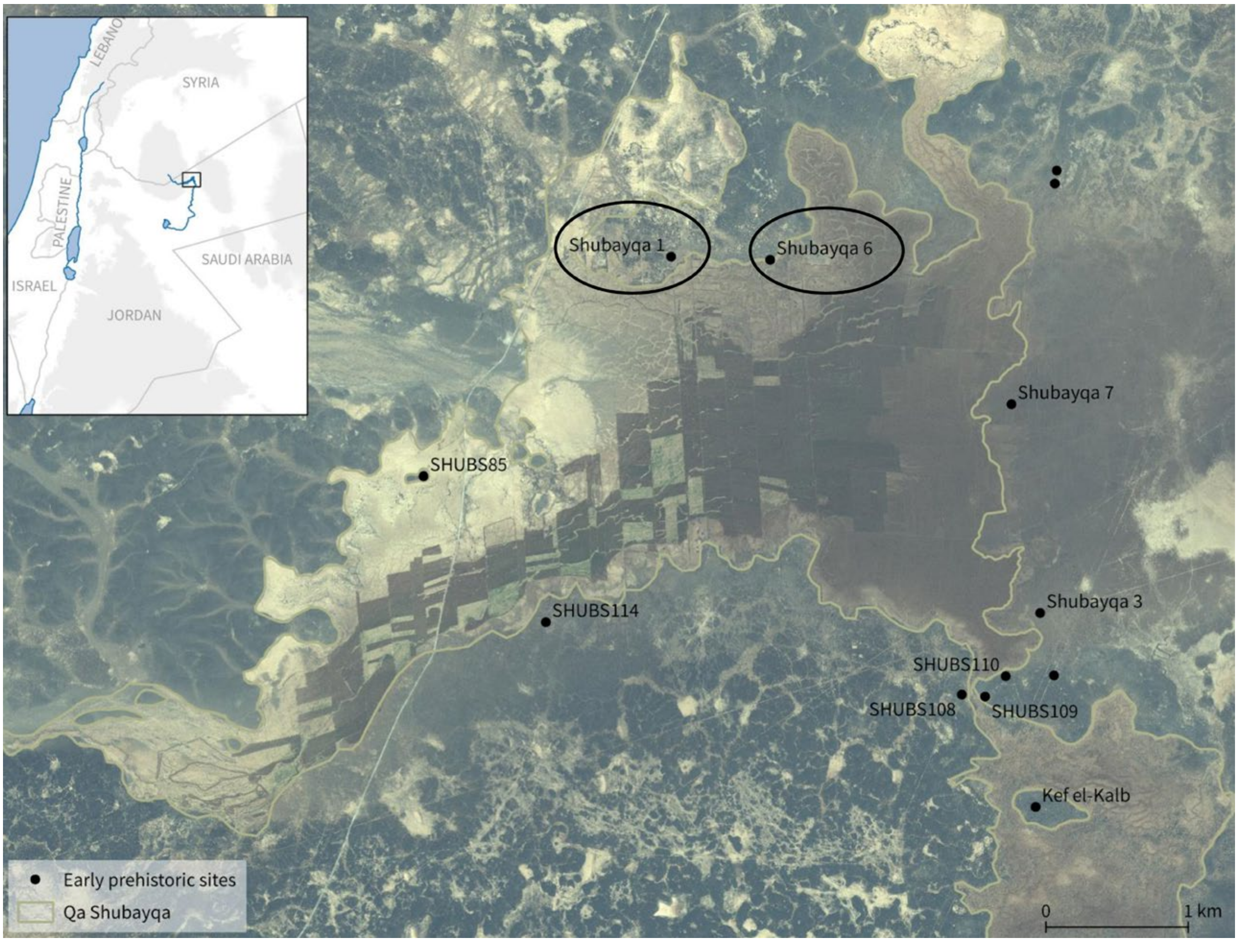


Figure 1: Shubayqa 1 and 6 location.

Shubayqa 1

Is located on a two to three meter mound, on the northern edge of the *Qa'* near the abandoned Islamic period village of Khirbet Shubayqa (Richter *et al.* 2012, 2014, 2017; Richter 2017). Alison Betts first discovered Shubayqa 1 during survey in 1993 (Richter *et al.* 2012). Between 2012-2015 the site was excavated by a team from University of Copenhagen.

Table 1: Shubayqa 1 dating, for detailed overview see (Richter *et al.* 2017).

Phase	Period	Date range cal. BP at 68% probability
1	Final Natufian	~12.083-11.807
2-3	Late Natufian	~13.300-13.100
4-7	Early Natufian	~14.400-14.100

Initial occupation of the site is dated to the early Natufian (Table 1: Phases 4-7) and relates to the construction and use of Structure 1, a large roughly oval-shaped stone built structure of upright basalt boulders with a flagstone floor and a central hearth (Richter *et al.* 2017) (Fig. 2). The hearth held substantial amounts of charred plants, especially club-rush tubers, faunal remains and lithics (Richter *et al.* 2017; Yeomans *et al.* 2017). Food remains were also retrieved including fragments of flatbread (Arranz-Otaegui *et al.* 2018). Another paved area featuring a hearth (Phase 5), included the remains of at least nine individuals (perinates, infants and adults) interred beneath the paving (Richter *et al.* 2019). Late Natufian occupation at Shubayqa begins with the construction and use of Structure 2 (Phase 3). This structure is also stone-build with a flagstone floor and a hearth (Fig. 2), but significantly less well-preserved. Also features several burials beneath the pavement (Richter *et al.* 2019).

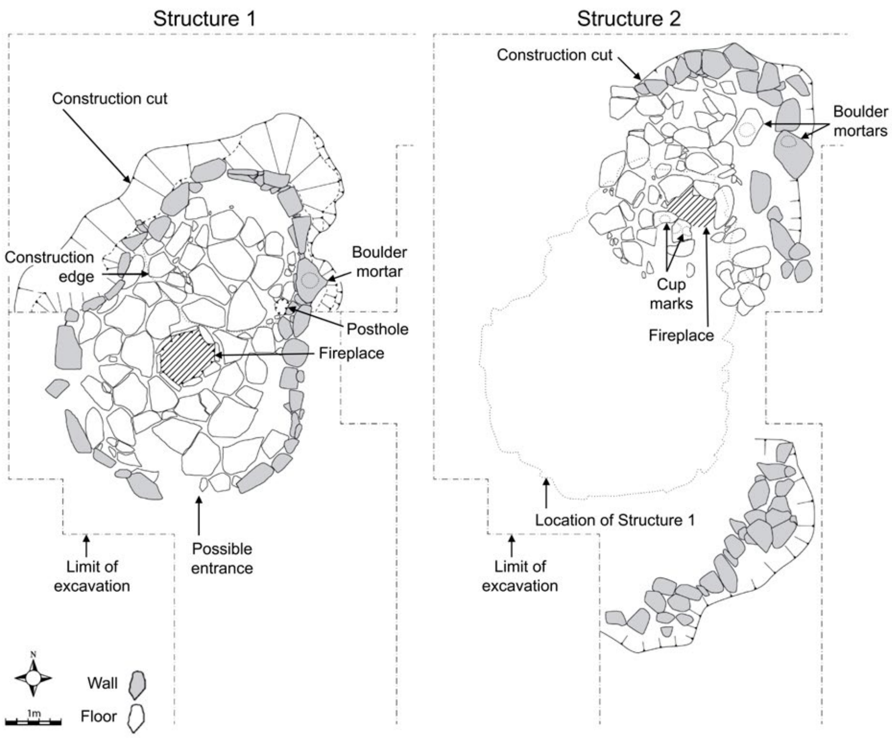


Figure 2: Shubayqa 1.

Shubayqa 6

Two to three meter high mound, located some 700 m east of Shubayqa 1, discovered in 2012. Excavations started in 2014 (Richter *et al.* 2016) and are ongoing. The site consists of a Neolithic settlement with several circular to sub-circular dry-stone buildings two to six meters across (see Fig. 3) (Richter *et al.* 2016). The exact stratigraphic relationships and phasing of the site is still being examined, so for the purpose of this study, it is tentatively divided into two occupational phases (see Table 2).

Table 2: Shubayqa 6 Dating (based on (Yeomans *et al.* 2019).

Space (Phase)	Period	Date range cal. BP at 68% probability
Space 4 (upper infill) + Space 3	LPPNA-EPPNB	~10,729-10,588 (Poz-76085)
Space 4 (lower infill)	PPNA	~ 11,595-11,267 (RTD-9342)

The first phase is contemporary with PPNA (Richter *et al.* 2016). The second phase encompasses late PPNA to early PPNB. Collectively these two phases are referred to as 'EPPN'. The archaeobotanical material from Shubayqa 6 is currently being examined. However, the archaeobotanical evidence from Shubayqa 1 would substantiate that tubers, alongside wild cereals, must have been important resources. Evidence suggests that dogs were present at EPPN Shubayqa 6 (Yeomans *et al.* 2019).

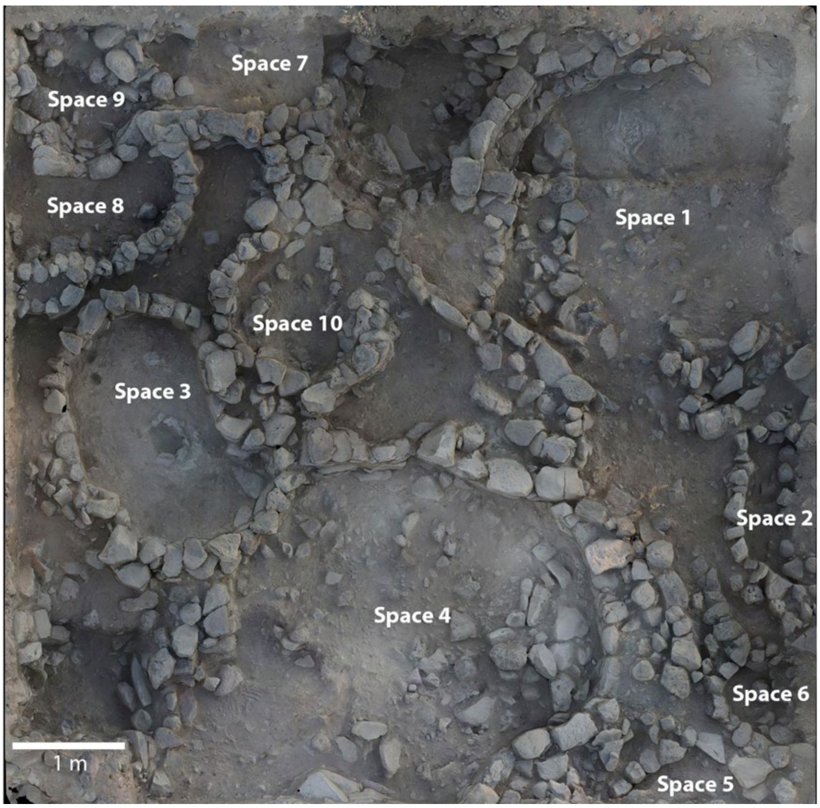


Figure 3: Shubayqa 6.

The Shubayqa 1 and 6 groundstone assemblages

Raw material

Located in a basalt desert, the assemblage consists almost exclusively of basalt implements. Chemically the basalt is defined as mafic alkali to sub-alkali basalt (Al-Malabah *et al.* 2002; Ibrahim and Al-Malabeh 2006; Krienitz *et al.* 2007; Shaw *et al.* 2003). It often features vesicles and generally has a fine to medium grained porphyritic texture, holocrystalline with phenocrysts primirally of olivine, plagioclase and clinopyroxene (Al-Malabah *et al.* 2002; Odat 2015; Shaw *et al.* 2003).

Assemblages

Table 3 provides an overview of the assemblage. Classifications and definitions generally follow Wright (1992a).

Table 3: Assemblage overview.

Tool type	Early Natufian	Late Natufian	PPNA	LPPNA-EPPNB	Total
Axe/adze	3	-	1	1	**5**
Cupmark	3	2	1	1	**7**
Groovedstone	3	2	1	1	**7**
Hammerstone	2	1	2	3	**8**
Handstone	149	346	62	36	**593**
Slab/Quern	13	34	19	15	**81**
Mortar	29	11	5	2	**47**
Pestle	40	28	11	10	**89**
Polisher	2	5	-	-	**7**
Pounder	5	2	3	1	**11**
Vessel	4	12	-	3	**19**
Multiple tool	14	27	3	4	**48**
Varia	2	3	1	1	**7**
Debitage	39	-	8	9	**56**
Unidentified	81	63	13	25	**182**
Total	**388**	**535**	**129**	**112**	**1164**

The Shubayqa Groundstone

The Shubayqa assemblages conform, from a typological standpoint, with other levantine assemblages and seem to follow developments elsewhere; thus, on the surface, it more or less confirms the *standard view* of technological development. E.g. vessel-mortars are the most common in the early Natufian phase at Shubayqa 1 making up 70% (see example Fig. 4.1), then boulder mortars (Fig. 4.3) become prominent in the late Natufian phase making up 45% of mortars, similar to trends elsewhere in SWA (e.g. Edwards and Webb 2013; Rosenberg *et al.* 2012; Rosenberg and Nadel 2014; Wright 1991). Both early and late Natufian also feature grinding tools (see Fig. 4.2 + 4.4). The proliferation of basin type grinding slabs and ovate handstones (see Fig. 4.5-6) at Shubayqa 6, also conforms to what is observed at other EPPN sites (e.g. Harpelund 2011; Kadowaki 2014; Nierle 2008; Rosenberg and Gopher 2010; Wright 1992b, 1993).

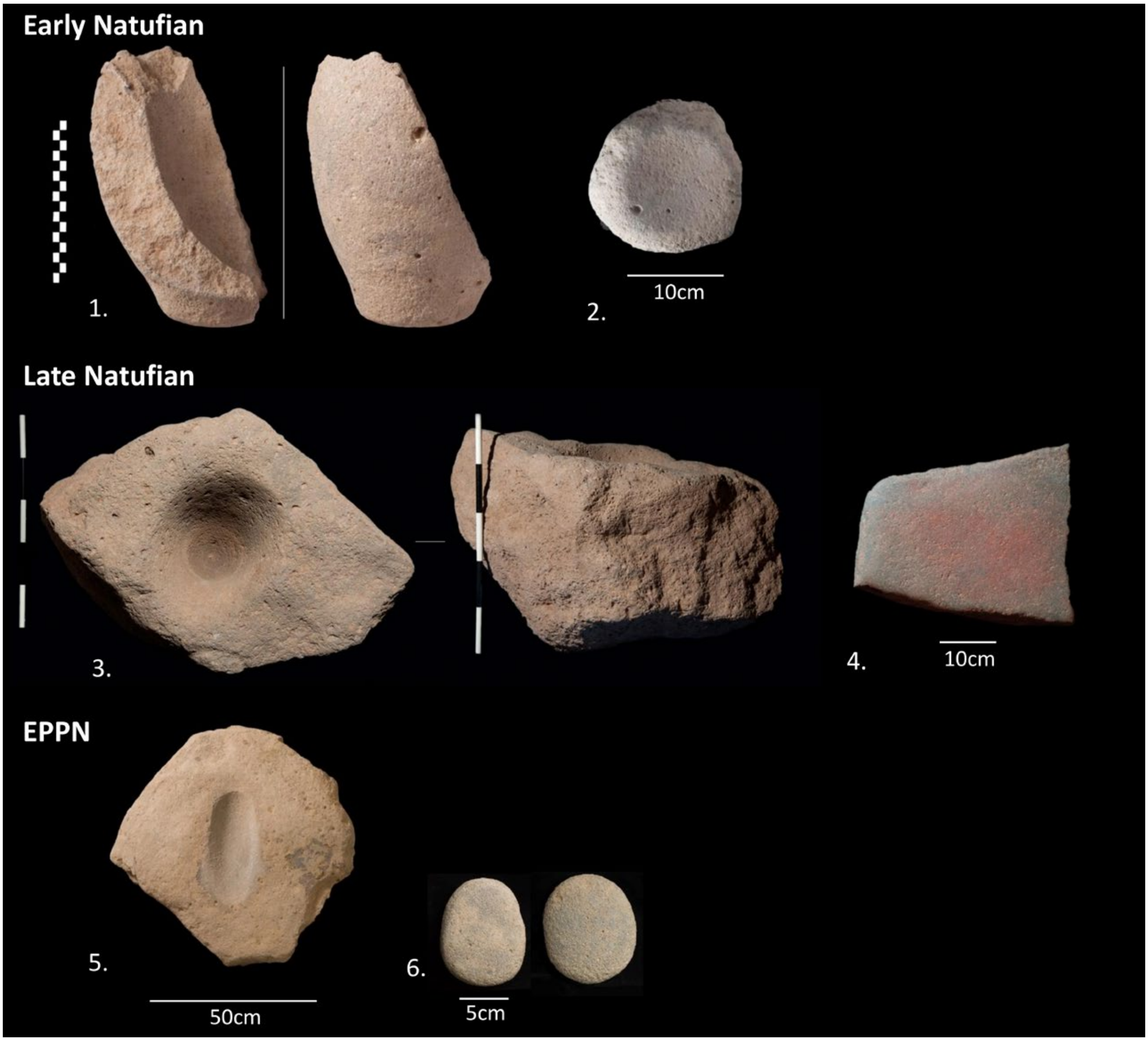


Figure 4: Selected examples from the Shubayqa assemblages, early and late Natufian from Shubayqa 1 and EPPN from Shubayqa 6 (photos by Alexis Pantos).

Towards a socio-technical approach to groundstone, technological choices and food processing strategies

The *food processing strategies* categories applied here are a synthesis of operational movements (*gestures*) and the use and wear expressed materially in archaeological tools. A more detailed presentation of the approach than given here is underway (see Pedersen *forthcoming*). The use of the term technology and *gestures* further rely on additional concepts, most importantly: the sociotechnical system and technological choice. The sociotechnical systems approach sees technology, not only as relating to making and using objects, but also involving the social relations and dynamics engaged in technological activities and actions (Pfaffenberger 1992, 513). Further these actions imply agency; the agency of individuals and groups of individuals engaged in solving technical problems (Dobres and Hoffman 1994). Technological change, as I examine here, happens within such a system through external borrowing or internal innovation, or the result of external stresses that may cause mutations of the system (Leroi-Gourhan 1993). Changes within a system further entail social aspects that may promote or impede the adaptation of certain techniques (Pfaffenberger 1992). Technological choice is the choice of an individual or individuals, to do specific things during the performance technical actions, whether this is overtly conscious action or not (see Lemonnier 1992). Choices are ultimately what changes the system. Technological choices also require the performance of specific bodily actions, i.e. *gestures,* often in conjunction with artefacts. The term *gesture* coined by André Leroi-Gourhan (1993) are the bodily movements with which humans interact with the material world and are necessary in operating tools, making them technically effective. Thus, gestures are specific technological choices, influencing and influenced by the system, i.e. the technological traditions and norms within the community (Hegmon 1998; Leroi-Gourhan 1993; Mauss 1979) and by using particular gestures instead of others, people interact with tools through gestures according to, and modifying, traditional ways of overcoming problems (Dobres and Hoffman 1994; Wobst 2000). Tools are then the '*objectified result of techniques*' (Dietler and Herbich 1998, 235) and gestures (as technological choices) are 'trapped' materially in the tool through use and observable to us in tool shape and surface morphology.

Food processing strategies

Based on the synthesis of these elements: gestures, use and wear progression and resulting tool shape and surface morphology, I have devised the scheme below for the Shubayqa groundstone. Gestures are identified from my own observations of the morphology of the tools in the assemblages, along with some exploratory experimentation in making and using these tools (articles are forthcoming) and from published ethnographic observations (Ertug 2002; L. A. Nixon-Darcus 2014; L. Nixon-Darcus and D'Andrea 2017; Hamon and Le Gall 2013; Robitaille 2016; Searcy 2011; Schroth 1996). In addition I draw on work by others, whom have applied similar schemes for analysis in SWANA: Kadowaki (2014), Nierle (2008), Banks (1982) and Dubreuil (2001; Dubreuil and Plisson 2010), as well as in the Aegean (Stroulia *et al.* 2017) and from Iberia (Delgado-Raack and Risch 2009, 2016) (Delgado-Raack and Risch 2009, 2016). The gestures involved in operating food processing tool pairs follow Leroi-Gourhan's (1993) terminology as presented by Sophie de Beaune: *diffuse resting percussion*, i.e. grinding and *diffuse thrusting percussion*, i.e. pounding (de Beaune 2004). In my scheme I propose three processing strategies that are types of grinding and one pounding. These are, respectively: Confined Reciprocal Grinding (CRG), Open Reciprocal Grinding (ORG), Rotary Grinding (RGP) and Confined Pounding (CPR). See Figure 5-6 and Table 4 for illustrations, archaeological examples, detailed description, explanations of tool pairings and overview of strategies. I henceforth stick to the abbreviations CRG, ORG, RGP and CPR for the strategies.

Table 4: Strategies: Action, gestures and resulting tool shape and surface morphology based on observations of the Shubayqa material.

Strategy	Primary function	Overall movement	Gesture Description	Upper tool	Lower tool	Upper surface shape	Lower surface shape
Confined Reciprocal Grinding (CRG)	Diffuse resting percussion Grinding, abrading	Linear, Reciprocal. Movements within a depression, which constricts movements	Performed with one or two hands, pressure exerted from the shoulder(s)	Ovate handstone	Basin or trough blab	Planar: Oval/ovate/ rectilinear Transverse: Flat (>) to convex Longitudal: Flat (>) to convex	Planar: Elongated/ elliptical Transverse: Concave Longitudal: Concave or sloped
Open Reciprocal Grinding (ORG)	Diffuse resting percussion Grinding, abrading	Linear, Reciprocal. Movements on open surface. Movements relatively free across the surface of the lower	Action primarily performed using two hands. Pressure exerted from the shoulders, most of this created proximally; closest to the operator	Loaf handstone	Flat block slab or baddle slab	Planar: Elongated rectilinear Transverse: Flat Longitudal: Flat (>) to concave	Planar: Elongated rectilinear Transverse: Flat (>) to convex Longitudal: Flat (>) to concave

Table 4 continued: Strategies: Action, gestures and resulting tool shape and surface morphology based on observations of the Shubayqa material.

Strategy	Primary function	Overall movement	Gesture Description	Upper tool	Lower tool	Upper surface shape	Lower surface shape
Rotary Grinding (with some pounding) (RGP)	Diffuse resting percussion Grinding, abrading	Rotating or circular. Movements within a depression, but the upper stone is moved freely within	Action primarily performed using one hand. Pressure exerted by the arm, with less and less pressure the farther it moves from the operator.	Discoidal Handstone	Basin quern, Block quern, Boulder quern	Planar: Circular or oval Transverse: Convex (>) to flat Longitudal: Convex (>) to flat	Planar: Circular or oval Transverse: Concave (>) to shallow Longitudal: Concave (>) to shallow
Confined Pounding (with some rotary grinding) (CPR)	Diffuse thrusting percussion Pounding, crushing	Downward stroke or thrust. Movements within a depression, the upper stone is moved somewhat freely up and down. The base and sides of the hole allows for some grinding by twisting the upper stone within lower	Action, performed with one hand or two, force exerted using both elbow(s) and shoulder(s)	Pestle	Mortar	Overall: Cylindrical or conical Profile: Circular, sub-circular, oval, square, rectangular Terminus transverse: Convex (>), flat or concave	Planar: Circular, sub-circular, oval Transverse: Concave or conical

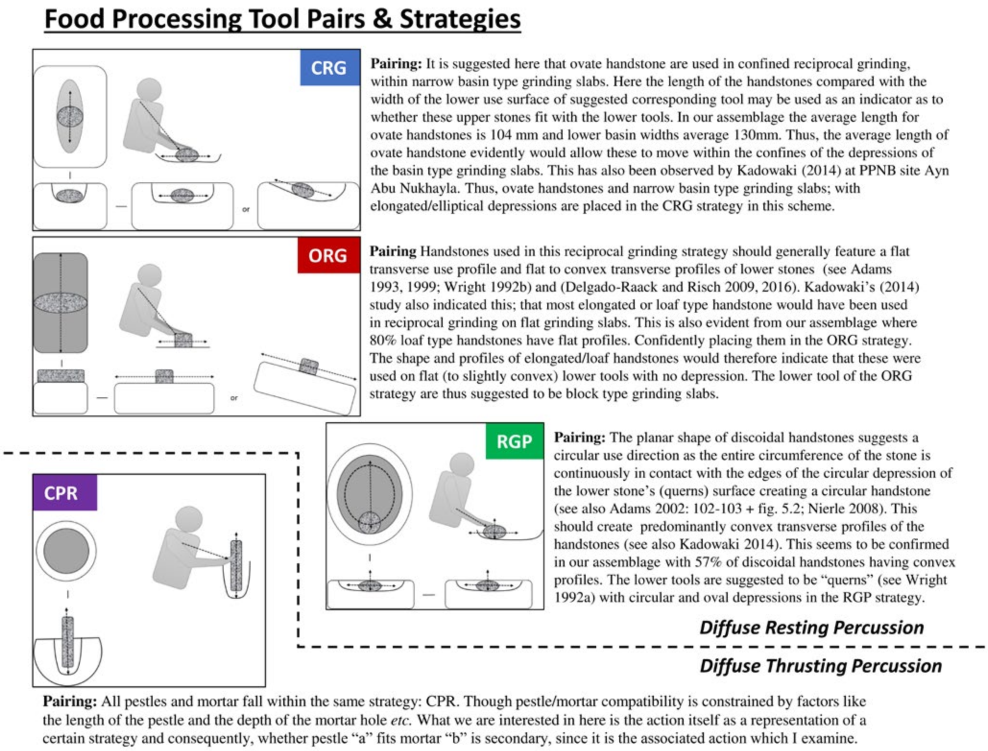


Figure 5: Food processing strategies.

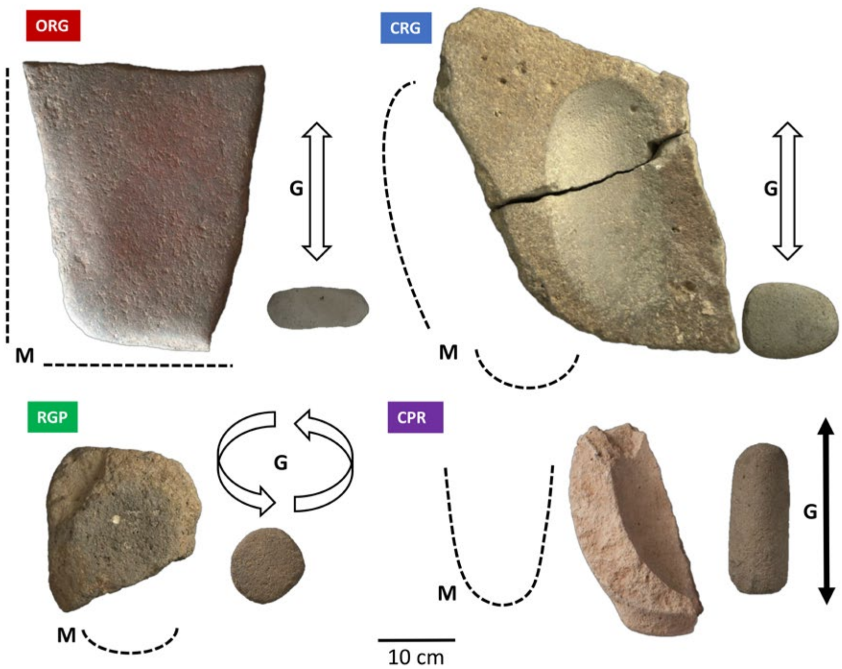
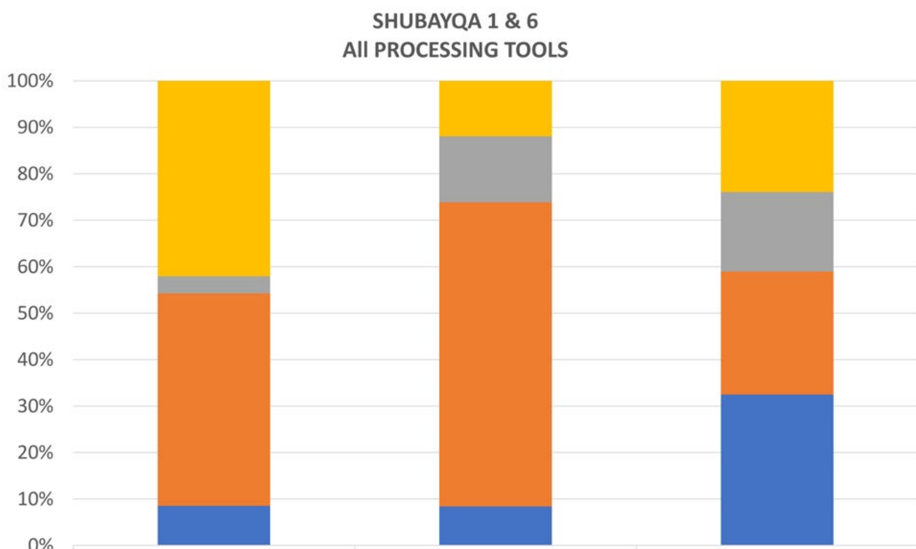


Figure 6: Archaeological examples of the different tool pairs and strategies from the Shubayqa assemblages with the transversal and longitudinal morphology of the used surfaces: M along with the related gestures: G.

Analysis

Initially, all implements count for one example (or expression) of a strategy. Meaning even small fragments count representative of a strategy.

Looking at all tools (including fragments) of processing strategies, divided into three larger periods, it appears that in early Natufian there are two main strategies (see Fig. 7). The first strategy, accounting for 42% of tools is pounding in mortars, or CPR. As was also explained above this is a strategy that has been observed at many early Natufian sites, and in the mediterranean zone this appears to be the most common processing strategy (Wright 1991, 1994). However, the most common strategy at early Natufian Shubayqa 1, seems to be reciprocal grinding on open slabs, ORG, accounting for 46% of the tools. This is an interesting contrast to the evidence just cited. In the late Natufian there seems to be a concentration on a single strategy, the aforementioned ORG strategy (see Fig. 4.4), which mirrors observations at late Natufian Abu Hureyra (Moore 2000). There is also an increased involvement of the confined rotary grinding, RGP. The pounding strategy (CPR) comes back at 24% in the EPPN and at 27% ORG, continues to be common. However, a previously less used strategy increases explosively in the EPPN, confined reciprocal grinding, CRG at 32%.

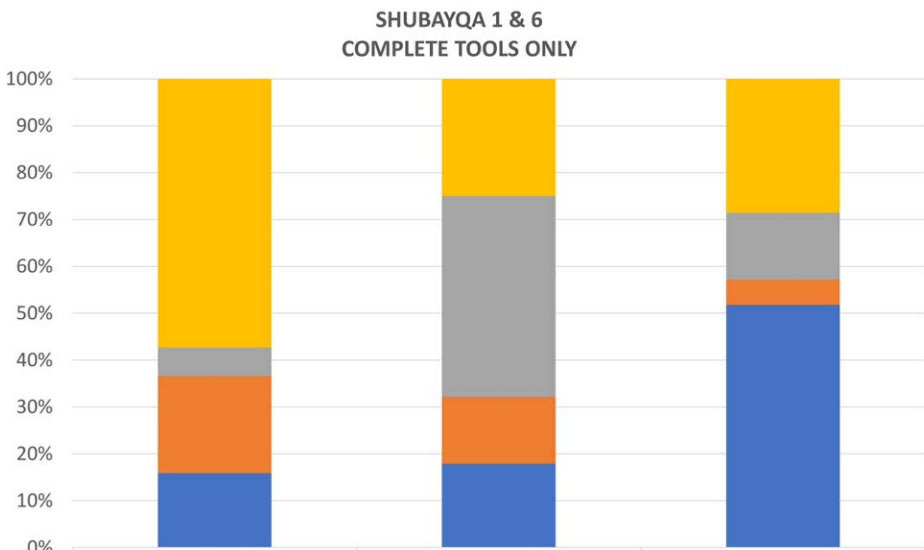


	Early Natufian	Late Natufian	Early Neolithic
CPR	69	27	28
RGP	6	32	20
ORG	75	148	31
CRG	14	19	38

Figure 7: Strategies with all tools.

An issue with the numbers above are however, the numerous small fragments of upper implements, especially handstone. These somewhat skew the numbers towards certain strategies. Often upper stones will be more numerous in analysed assemblages, as they expire faster (Delgado-Raack and Risch 2009) and, in my experience, are more easily identified than smaller fragments of larger lower tools. Especially common are fragments of elongated handstone, smaller one-handed loaf types that are associated with open reciprocal grinding (ORG). Whether these were exclusively used in this strategy is also contentious since some of them have evidence they might also have been used in pounding (see Pedersen *et al.* 2016). So to eliminate their skewing effect on the data, I opted to do a second analysis, using only complete tools. Of course, taphonomic factors and presence of intentional and unintentional breakage, plays a role here (Adams 2008; Dubreuil *et al.* 2019; Rosenberg *et al.* 2012), but this allowed me to more securely pair tools with individual processing strategies.

Little changes in the early Natufian (Fig. 8). However, it clearly shows that the most widespread strategy is pounding here confirming the standard view of early Natufian groundstone. Though at 40% grinding strategies seem more important here than what is usually assumed (e.g. (Wright 1991, 1994). In the late Natufian there is a marked increase in circular grinding, the RGP strategy. Multiple complete querns and discoidal handstones are present in that period (Fig. 8). Before a high number of small handstones fragments of the ORG strategy overshadowed this, we now observe that circular grinding is prominent in this period. At the same time pounding is proportionally more important than what the other graph showed, but is still less than in the early Natufian. In the EPPN, pounding strategy remains more or less the same (Fig. 7 + 8), but the most common strategy for processing is by far the CRG confined grinding strategy. There seem to be some similarities between proportions of the different strategies in relation to one another between certain phases; e.g. pounding drops after early Natufian and in the proceeding periods. Something that confirms previous studies and the standard view (Dubreuil and Plisson 2010; Wright 1992b, 1994). But, it is interesting that confined grinding in general becomes more common. First with a confined circular grinding RGP, which is then replaced with a confined reciprocal strategy CRG. Though CRG, along with the ORG strategy, appears to be the most common by the EPPN elsewhere in SWA (e.g. Harpelund 2011; Kadowaki 2014; Wright 1992b). This analysis reveals that technological choices and sociotechnical systems are geared towards more than simply more grinding and less pounding over time as has perhaps been the general assumption (e.g. de Beaune 2004; Dubreuil 2004; Dubreuil and Plisson 2010; Wright 1991, 1994). Perhaps not unrecognised by others, but perhaps underrepresented in the standard view. I.e. there is an expression in specific ways of grinding: from circular to linear gestures, choices by individuals materially expressed in the CRG strategy eclipsing the RGP, at least at the Shubayqa sites.



	Early Natufian	Late Natufian	Early Neolithic
CPR	47	14	16
RGP	5	24	8
ORG	17	8	3
CRG	13	10	29

Figure 8: Strategies with only complete tools.

Diversity

Technological choices by individuals and preferences for certain strategies within a sociotechnical system may also be expressed in the diversity of strategies within these periods. Here, I briefly examine different coexisting processing strategies and if they increase or decrease over time at the Shubayqa sites. If fewer strategies become dominant over time, meaning less diversity, it may suggest a specialization in processing, or a concentration of labour around specific tasks (Risch 2008). I here applied a Simpsons Diversity Index, which is usually used to examine the diversity of species at a specific location. Here, I apply it to the strategies at Shuabyqa, divided into three large periods. The Index follows the statistic formula: $D = (n / N)^2$. D equals the diversity of strategies in a value between 0 and 1, with 0 representing infinite diversity and 1 being no diversity.

First including all tools (Table 5), the period with most diversity seems to be the early Neolithic, followed by the early Natufian and the late Natufian the least. However, these are heavily influenced by the presence of fragments and again I have opted to put in a table where only complete tools feature.

Table 5: Diversity of strategies when including all tools, i.e. fragments etc.

			ALL TOOLS
Diversity	Early Natufian	Late Natufian	Early Neolithic
D =	0.39	0.47	0.26

Using the complete tools reverses the story (Table 6). While the early Natufian stays the same, with its reliance on the pounding strategy, the late Natufian and early Neolithic switch places, the most diverse being the late Natufian. It has been argued that in the late Natufian, we may observe a steady decline in the diversity of grinding implements and an increase in the frequency of grinding implements (e.g. Dubreuil 2004). This does not fit the data in our second table. That the late Natufian is actually the most diverse appears contrary to the standard view of a concentration of labour and tasks in that period (see Dubreuil 2004; Dubreuil and Plisson 2010; Wright 1991).

Table 6: Diversity of strategies when including only complete tools.

			COMPLETE TOOLS ONLY
Diversity	Early Natufian	Late Natufian	Early Neolithic
D =	0.39	0.29	0.36

Tools and surface size

Another change occurring is the change in size of used surfaces of upper and lower tools. Examining grinding tools only using the approximate surfaces in contact with the intermediate material with length and width as the variables.

Starting with the lower tools, early Natufian have the smallest average size, late Natufian the largest (most of them RGP), closely followed by the Neolithic lower tools (see Fig. 9). Again, as with the increased diversity of strategies in the late Natufian, there is great variety in the sizes for faces from this period. So diversity in strategies is also mirrored in a diversity of tool sizes it seems. The early Neolithic slabs are, barring one that clusters with the late Natufian ones, generally long and narrow depressions. This fits with the confined grinding strategy (CRG) that people of the period seem to have preferred.

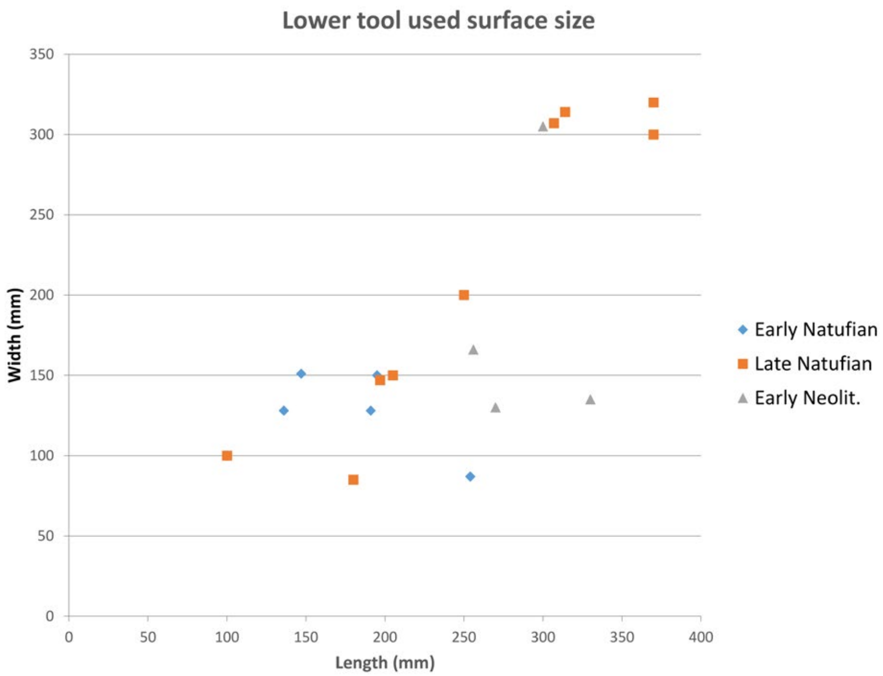


Figure 9: Lower tool active surface size.

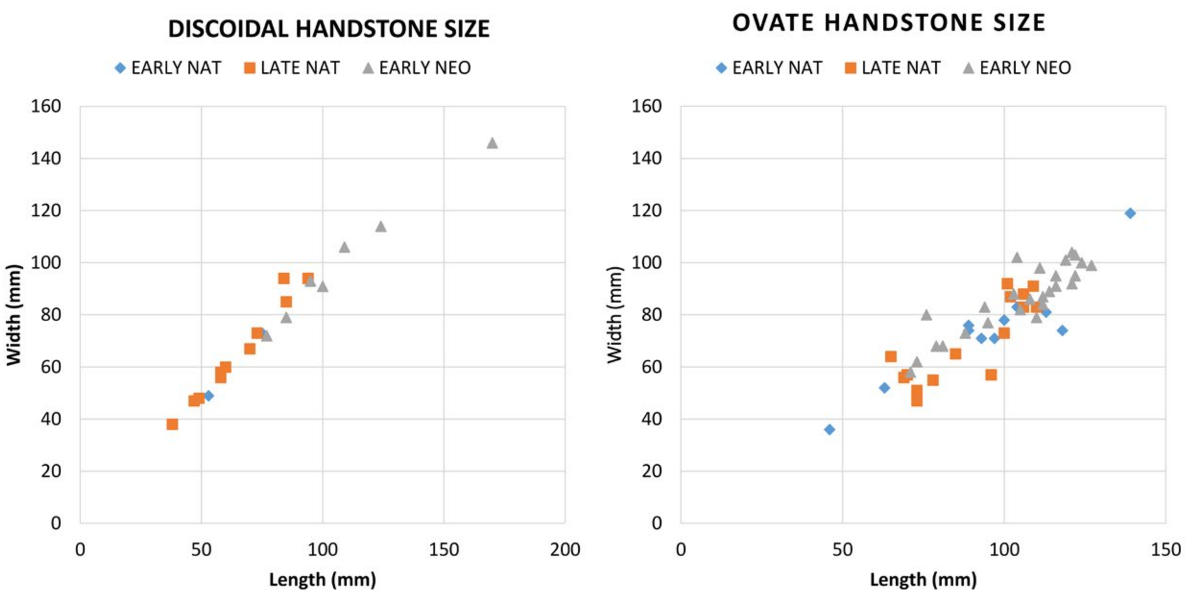


Figure 10: Handstone size.

It was only possible to compare sizes of the two most common handstone types: discoidal and ovate. Discoidal handstones from the Neolithic are generally larger than the Natufian examples (Fig. 10). There is again a great deal of variety in the sizes in the late Natufian, also for this handstone type. Ovate handstones have a less clear pattern. The early Natufian features both the smallest and the largest of this type. However, Neolithic examples generally cluster as the largest. It would appear that there is a general increase in handstone size of this type from the Natufian into early Neolithic. It has been noted that grinding tools in general seem to become larger in SWA from the Neolithic and onwards (Wright 1992b, 1993) and here in relation to handstone size our assemblage seems to confirm the standard view.

Discussion

The analysis shows that changes do not always happen in a linear or singular fashion, echoing Pfaffenberger (1992). Rather, multiple strategies of processing supplement each other, converge and diverge. Pounding (CPR) for example, seems to recede during the late Natufian, but increases by the Neolithic and confined grinding (CRG), suddenly increases drastically in the Neolithic, after being a marginal strategy in the Natufian (see Fig. 8). It may have been a modification of the previously prevalent RGP strategy; individuals consciously changing their gestures from circular to linear, from RGP to CRG. Furthermore, at late Natufian Shubayqa 1 we see a high diversity, contrary to the standard view (e.g. Dubreuil 2004). Perhaps this was a period with increased experimentation with the available resources? This may be attributed to local environmental factors, as well as social factors. In this period we see changes in the wetland resources of the *Qa'* Shubayqa area. Evidence from water fowl suggests that in the late Natufian, there was a less staple water resource in *Qa*' (Yeomans *et al.* 2017). Perhaps there was an incentive for people to explore, exploit and experiment with more diverse resources and techniques, which is then mirrored materially in the diversity of processing strategies at the site. The increase (and diversity) of sizes of lower surfaces in late Natufian (Fig. 9) may thus reflect intensive (or extensive) use of a wide range of resources, or perhaps a focus on exploiting specific resources in the face of a diminishing wetland (Yeomans *et al.* 2017). Thus, the local climatic conditions during the late Natufian may have been an external factor affecting the socio-technical system of the Shubayqa community, causing an internal adaptation; increasing the need to exploit different resources and thus diversifying strategies and enlarging tools, already present in the early Natufian. Hence, drawing on existing knowledge to increase end-product, through increased size of used surfaces of lower tools (see Fig. 9) as larger tools are also generally more 'productive' (Adams 1999; Buonasera 2015; Mauldin 1993), then combined with a diversification of strategies (see Table 6). By the EPPN people then opted to switch to narrow elongated lower surfaces, as this was deemed more useful in their eyes. These technological choices could thus be related to the amount of edible matter. Using larger surfaces and confined grinding strategies (RGP and CRG), and increasingly reciprocal confined grinding over time, from the Natufian into the EPPN, along with an increase in handstone sizes (Fig. 10) could be a way of maximising end-product. Jenny Adams (Adams 1999) has observed something similar happening in prehistoric Southwest USA. An issue with 'maximising' and 'effectiveness'' is however that it assumes that technological choices and strategies will be directed towards effectiveness and maximising this (Pfaffenberger 1988, 1992). Conversely, people having intimate knowledge of their environment and resources (Lemonnier 1992) acting as conscious agents (Wobst 2000) could have chosen certain strategies, potentially to maximise end-product. This does not necessarily entail that they become more 'effective' per se, but rather that they are deemed effective in the eyes of users and have a *'functionally satisfactory form'* (Leroi-Gourhan 1993, 301). I.e. choices are the result of agents interacting with and adapting to their physical reality (Wobst 2000) drawing on knowledge and traditions within their socio-technical system.

Work by Jenny Adams (1993, 1999) using experimental and ethnographic data, has suggested that adaptations towards reciprocal grinding strategies is also more 'efficient' in being less labour intensive, less straining on the body. This may be one of the reasons why reciprocal confined grinding CRG ends up dominating the EPPN (Fig. 8). Concurrently, linear grinding might also have been advantageous in terms of less complex movements. Fred Plog ((Plog 1974, 61) argues that: *'...simple repetitive acts are [generally] more productive than complex ones...'*. The preference for the linear confined grinding in the EPPN may have been to simplify gestures, i.e. a simplification of work (Risch 2008): It was seen as less straining and more 'effective' in people's eyes. This would, potentially, also allow for the production of more end-product or, less time and effort spent to produce the same amount of product (Adams 1993). Diversity drops in the Neolithic perhaps as there is a concentration on certain resources and tasks, the tool surfaces stay large and confined, but elongated. Again, I reiterate that these choices stem from the behavior of individuals within the sociotechnical system, perhaps affected by outside factors like the environment and available resources, or internal innovations: adjusting gestures. These adaptations and modifications were deemed useful and adopted in technological tradition (Dobres 2010; Dobres and Hoffman 1994; Hegmon 1998; Leroi-Gourhan 1993; Mauss 1979; Pfaffenberger 1988, 1992). Desired end-product could also have warranted adaptations. At early Natufian Shubayqa 1 we have evidence of bread-making (Arranz-Otaegui *et al.* 2018), which in turn implies flour production, and it seems a composite flour made of club-rush tubers and wild cereals was used to produce flatbread (Arranz-Otaegui *et al.* 2018). Tubers have been found in large quantities in the hearths of Shubayqa 1 and substantial ethnographic evidence exists of the consumption of such tubers (Fowler 1990; Hillman *et al.* 1989; Rivera *et al.* 2012). Though pulverizing is not a prerequisite of consumption, it has some advantages (Wollstonecroft *et al.* 2008, 2011) and it might have been deemed desirable to grind them into flour. It may be that some strategies at Shubayqa were aimed at recipes where tuber (and cereal) flour was the desired end-product. If the wetland of the *Qa*', where these types of tubers would have grown, diminished by the late Natufian, the intensification of confined grinding strategies (i.e. RGP) may have been a way to 'stretch' ressources and/or increase the component of wild cereals, a resource that might have become the more important by the early Holocene.

Conclusions

This paper presented a way of examining changes in groundstone technology from the early Natufian to early Neolithic at a local scale by analyzing material from the Shubayqa 1 and 6. It has examined changes in sociotechnical systems by focusing on technological choices expressed in the form of gestures involved in operating groundstone tools. Using a scheme of food processing strategies based on gestures and their dialectic relationship with tools and wear, I have attempted to illuminate how technology and technological choices changed. I suggest most of the changes we observe are the results of modifications and adaptations based on past knowledge and traditions within a sociotechnical system applied by individual agents choosing specific actions, in our case gestures and tools, to meet challenges and process food in ways they found satisfactory. To conclude:

1. The analysis showed that it was possible to refine the *standard view* of groundstone technological development by using the scheme of *processing strategies* and looking at local scale developments, showing developments are less linear and singular than often assumed

2. The diversity of strategies can change over time. The period with the most diversity is the late Natufian, possibly due to a changing local environment

3. Increases in size of used surfaces and a focus on confined grinding strategies, late Natufian (RGP) and in the EPPN (CRG), reflect conscious choices, using existing technology and knowledge to: a. increase the amount of edible end-product b. stretch resources *c.* shorten work time or d. may also reflect efforts towards producing specific end-products (flour). Or all of the above

4. Concurrently changes may also be influenced by the effect it has on the body, perhaps related to stress and fatigue and/or preference for less complex movements and/or decreasing work-time

Further work on these initial observations about changes in technological practices is needed. The evidence presented here is now being paired with microscopic use-wear analysis and residue analyses. This will help us assess whether we can further substantiate any of the above observations. In addition, future experimental studies will also be required to further establish the relationship between gestures, tool morphology and use, stress, strain and labour time.

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3. Starch Grain Analysis Of Early Neolithic (Linearbandkeramik And Blicquy/Villeneuve-Saint-Germain) Contexts: Experimental Grinding Tests Of Cereals And Legumes

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Introduction

The Neolithic was a significant period in human history where economic and social changes occurred, including the manner in which food was produced, in turn developing a range of processing and cooking techniques for the consumption of plants and cereals (Fuller and Gonzalez Carretero 2018). Various lines of data have allowed to shed some light on the range of plants consumed and how these were processed during the Early Neolithic period in Europe. Archaeobotanical data include those in macrobotanical form (e.g., Antolín and Jacomet 2015; Antolín *et al.* 2015; Bakels 1992; Klooss *et al.* 2016; Kubiak-Martens *et al.* 2015; Raemaekers *et al.* 2013), and microbotanical remains such as starch grains and phytoliths (Delhon *et al.* 2020; García-Granero *et al.* 2018; Pető *et al.* 2013; Saul *et al.* 2013). Furthermore, use-wear analysis in Early Neolithic European contexts has provided clues on the types and characteristics of the tools, gestures, and technologies used to process vegetal materials (Bofill *et al.* 2020; Hamon 2008; Verbaas and van Gijn 2007).

Our study focuses more specifically on plant processing and consumption in western Linearbandkeramik (LBK) regions, and specifically in the Paris Basin. The expansion of the LBK culture originating from central Europe occurred rapidly across Central Europe north of the Alps around 5500 BC (Salavert 2017). In a first wave, farmers colonized Northwestern Europe (east of the Rhine) around 5300 BC, and in a second wave, they reached the Paris Basin around 5100 BC. In the Paris Basin, the archaeobotanical record comes from the study of sites spread from the Aisne Valley in France to Hesbaye in central Belgium (Bakels 1999; Berrio 2011; Dietsch-Sellami 2004; Salavert 2010, 2011). Data indicate that cereals such as hulled wheats —einkorn (*Triticum monococcum*) and emmer (*T. dicoccum*) — were dominant in Early Neolithic LBK assemblages. However, it seems that the former dominates assemblages west of the Rhine, while the latter is mostly found east of the river (Kreuz 2007; Salavert 2011). The status (crop or weed) of barley is also unclear in LBK assemblages, although both hulled (*Hordeum vulgare* subsp. *vulgare*) and naked (*H. vulgare* subsp. *nudum*) varieties have been reported in archaeobotanical assemblages. Other cultivated plants include legumes such as peas (*Pisum sativum*) and lentils (*Lens culinaris*), as well as flax (*Linum usitatissimum*), a plant used for its oil but also for its fiber. The opium poppy (*Papaver somniferum*), used for its oil or psychoactive properties, probably appears in the Paris Basin between 5200 and 5000 BC (Salavert *et al.* 2020). Moreover, a range of wild and weedy plants have been identified in the archaeobotanical record of the LBK, including fat-hen (*Chenopodium album*), rye brome (*Bromus secalinus*), and green bristlegrass (*Setaria viridis*). For the subsequent period, known as the Blicquy/Villeneuve-Saint-Germain (BVSG), there seems to be an increased reliance on naked wheats (*T. turgidum/durum/aestivum*) and barley (*Hordeum vulgare* subsp. *nudum*) (Hamon *et al.* 2019).

Use-wear studies have provided significant information, made possible by the recovery of an important number of grinding tools either recovered in lateral refuse pits that flank the typical Neolithic longhouses or in special deposits (quern hoards) that can be found either in the lateral pits or in isolated configurations (Hamon 2020). Combined low and high-power observations conducted by several authors has led the following discriminant use-wear signatures, at least from an experimental point of view, to be proposed (Bofill *et al.* 2013; Cristiani and Zupancich 2020; Dubreuil 2004; Hamon 2008; Hayes *et al.* 2017). Cereal grinding is characterized by a strong surface levelling, a smoothing of the areas in relief and general grain rounding; the corresponding micropitted micropolish displays a certain roughness, with reticular morphology, a dull to moderate brightness, and fine striations. A different pattern characterizes dehusking operations, more impacted by the silica component of the cereal glumes; the roughness of the surface is higher and the abrasiveness of the silica (phytoliths) particles generate a strong micropitting of the micropolish. Legume and acorn (*Quercus* sp.) processing generates a strong levelling of the plateau, and a dull aspect. The hardness of legumes also generates microchipping, and in some cases microstriations. Due to the presence of natural lubricants, the processing of oil-rich nuts generates a protective film, which slows the mechanical levelling of the surface but accelerates the development of smoothing and the rounding of the grains. Hard seed grinding shows diverse intensity of surface levelling as well as grain rounding, while the micropolish appears reticular and relatively bright. Grass processing generally leaves very ephemeral traces on the surfaces and are difficult to identify. Use-wear studies (Hamon 2008, 2014) show that in 70% of the Early Neolithic contexts, grinding tools were used for processing cereals, either for dehusking, or for the grinding of clean grains. Others were used or reused for mineral (coloring, grog) and animal matter processing.

The fact that not only cereals were processed has also been brought to light by microbotanical analysis, namely through starch grains and phytoliths. One study considered starch grains and phytoliths from LBK grinding stones from the site of Remicourt 'En Bia Flo II' in Belgium (Chevalier and Bosquet 2013, 2017). These analyses made it possible to extract starch grains on six of the nine grinding stones studied, allowing the identification of different species such as wheat, barley, oats (*Avena* sp.), peas, and acorns. The phytolith study was less revealing, in fact, none of the grinding stones contained evidence to suggest these tools were used to process cereals, instead showing they were used to process a variety of plants, including dicotyledons. Other studies focused rather on phytolith analysis, despite the low rate of silica microfossils preserved in temperate climates (Hamon *et al.* 2011). Elongated, dendritic, pointed or short phytoliths from leaves and glumes clearly indicated the processing of Poaceae, especially cereals. Their low proportions suggest the grinding of partially cleaned grains rather than dehusking actions on the stone tools. The presence of circular cells belonging to dicotyledons also suggested the grinding of other types of plants.

To study what vegetal foods were processed and consumed by Early Neolithic populations, combining methodologies that include use-wear, as well as macro and microbotanical analyses, whereby each has its advantages and limitations, is essential. Prior to our extensive work (Hamon *et al.* 2021) there was a real lack of multidisciplinary studies for the Early Neolithic period in the Paris Basin. Our results indicate the rather multipurpose function of grinding stones, to obtain food but also possibly medicines and dyes. We found the rather ubiquitous presence of cereals on the grinding stones, along with evidence for the processing of legumes, wild plants, and underground storage organs, but also ferns, fibers, and wood tissues.

Similarly to phytoliths, where the absence of multicellular structures can indicate exposure to mechanical pressure (Albert and Portillo 2005; Portillo *et al.* 2013), starch grain analysis provides a major contribution to study food plant consumption in general, as it can not only indicate the presence of a particular plant species but the types of damage they present can provide clues on how they may have been processed (Ma *et al.* 2019). We also wanted to study whether we could detect any additional types of modifications on the grains after the tools were buried. Relying on the LBK archaeobotanical record and use-wear studies of the Paris Basin, we selected five different plant taxa to experimentally process via dehusking and/or grinding. Three types of cereals were chosen, wheats (emmer and einkorn) and hulled barley, along with two types of legumes, lentils and peas.

Our overall goal was to create a reference collection and comparative database not only for the species, but also to illustrate the mechanical damages resulting from their processing and subsequent taphonomic actions. Here, we present our experimental tests as well as the resulting starch grain reference collection, which should make it possible to propose the different plant transformation techniques implemented by past societies.

Starch Grains

Starch

Starch, the energy storage of plants, is composed of a mixture of two glucose polymers (chains): amylose and amylopectin. These polymers are arranged in grains as alternating semi-crystalline and amorphous layers that form growth rings (lamellae), departing from the center of growth known as the hilum (Copeland *et al.* 2009). Starch is synthesized in plastids during photosynthesis and then primarily stored in amyloplasts in underground storage organs (tubers and rhizomes), seeds, and fruits (Gott *et al.* 2006). Starch grains are microscopic, ranging from 1 to 100 µm (1 µm = 0.001 mm), and exhibit characteristics that permit their taxonomic identification, which include their size, shape, but also the presence of the highly diagnostic extinction cross (also known as the Maltese cross). This feature, visible only when viewed under cross-polarized light, is due to the orientation of the semi-crystalline molecules (Gott *et al.* 2006).

Native starch grains

Native, or unmodified cereal starch grains from the Triticeae tribe (e.g., *Triticum, Hordeum, Secale*) have a bimodal size distribution meaning there are two main size categories. Here we focus on the larger size class as the smaller ones are rarely diagnostic (Yang and Perry 2013). Einkorn (*Triticum monococcum*) starch grains are simple, with larger grains ranging between 13 and 36 µm (Aceituno Bocanegra and Lopez Saez 2012; Juhola *et al.* 2014) in width (Figure 1A-B). The grains are oval in plane view and lenticular in lateral view. Craters are visible on the grain’s surface and few lamellae are present, in particular closer to the center of the grain. Emmer (*T. dicoccum*) starch grains are simple (Figure 1C-D), with larger grains ranging between 8 and 34 µm in width (Aceituno Bocanegra and Lopez Saez 2012; Juhola *et al.* 2014; Yang and Perry 2013). The grains are oval to kidney-shaped in plane view and lenticular in lateral view. Craters/dimples are visible on their surface, as well as faint lamellae. The extinction cross of both einkorn and emmer are very similar in that it is radially symmetrical and often the arms widen towards the ends of the grains. Grains of hulled barley are simple, with the larger grains (8-25 µm) going from oval to reniform in plane view and lenticular in lateral view (Henry *et al.* 2009) (Figure 1E-F). Lamellae are typically absent, but sometimes observed on the larger starch grains. The extinction cross is usually bilaterally symmetrical (X-shaped). Some grains have surface craters/dimples or cupules. Lentil starch grains are simple, oval to reniform and range in size between 20 and 35 µm (Figure 1G-H). Lamellae are well defined and regularly spaced. A mesial longitudinal cleft fissure can be seen. The extinction cross is bilaterally symmetrical, often diffuse, especially in grains with deep fissures (Henry *et al.* 2009). Finally, pea starch grains measure between 15 and 45 µm in length, and are simple, large, and ovoid to elongate in shape (Figure 1I-J). The outline is often irregular. The larger grains tend to have distinct lamellae, which are especially visible on the outer edges of the grain. The central part of the grain seems slightly wrinkled. When the grains are viewed sideways, a fissure is visible. The extinction crosses are central, often elongated on the same axis as the fissure (Henry *et al.* 2009).

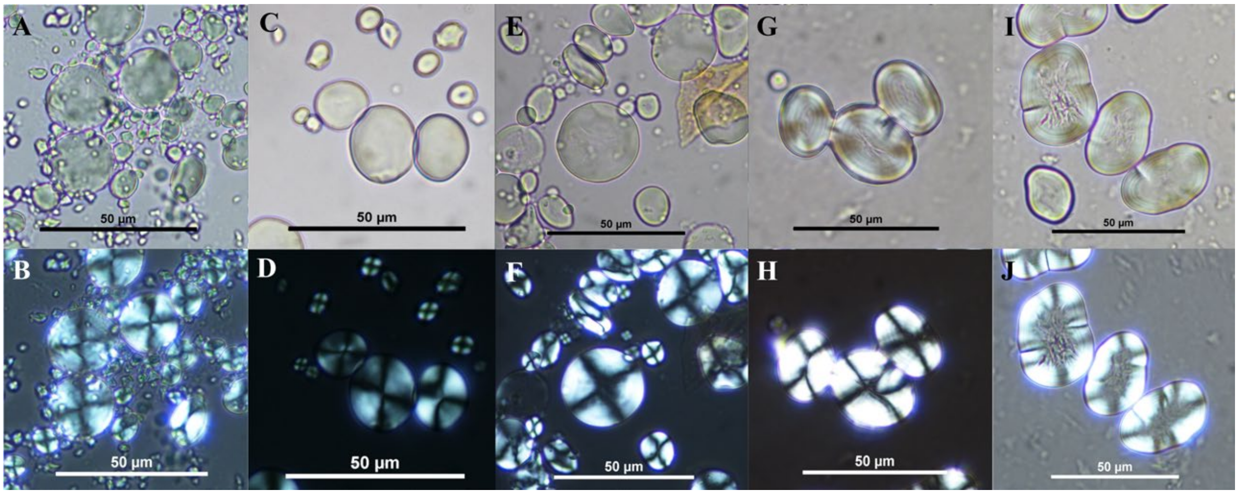

Figure 1: Native (unmodified) starch grains viewed under plane polarized and cross-polarized light (x 600). A-B: einkorn; C-D: emmer; E-F: barley; G-H: lentils, and I-J: peas (photos C. Cagnato).

Modification of starch grains

The physical and compositional characteristics of starch grains can be altered by cooking and charring, malting and fermenting, but also by mechanical forces such as grinding or pounding (Babot 2003; Cagnato 2019; Chantran and Cagnato 2021; Crowther 2012; Henry *et al.* 2009; Li *et al.* 2020; Ma *et al.* 2019; Pagan-Jimenez *et al.* 2017; Valamoti *et al.* 2008; Wang *et al.* 2016, 2017). These processes can in turn alter or destroy the morphological and optical properties that allow analysts to identify them. In particular, the complex internal organization of starch, damaged as a result of heat or mechanical forces, will result in alterations to the shape of the grains, but also to their birefringence properties. Grinding and milling will result in damage that includes fractures, changes in birefringence properties, but also in the increased susceptibility to gelatinization and digestion (Mishra *et al.* 2012). Full gelatinization, whereby the starch grain has irreversibly swollen and therefore structurally collapsed, occurs once a species-specific temperature and degree of moisture has been reached (Crowther 2012). The fact that starch grains are subject to changes depending on external factors can help to reconstruct past practices, however, solid reference collections are necessary. Experimental work has been carried out by various scholars. New World plant species include important crops such as maize (*Zea mays*), manioc (*Manihot esculenta*), potatoes (*Solanum tuberosum*), and sweet potatoes (*Ipomoea batatas*) (Babot 2006; Cagnato 2019; Chandler-Ezell *et al.* 2006; Mickleburgh and Pagán-Jiménez 2012; Pagan-Jimenez *et al.* 2017; Raviele 2011). Other studies have considered Old World plants— bread wheat (*Triticum aestivum*), barley, oats, broomcorn millet (*Panicum miliaceum*), sorghum (*Sorghum bicolor*), rice (*Oryza sativa*), lentils, peas, chickpeas (*Cicer arietinum*), and mung beans (*Vigna radiata*)— and the ways their starch grains were modified as a result of different cooking processes (Henry *et al.* 2009). Additional tests have been made on rice, bread wheat, barley, foxtail millet (*Setaria italica*) and broomcorn millet, Job's tears (*Coix lacryma-jobi*), and green bristlegrass (Ge *et al.* 2011; Li *et al.* 2020; Ma *et al.* 2019).

Experimental tests

Aims and principles

Our main aim was to determine how starch grains of different species were affected by extensive mechanical processes that include dehusking and grinding, processes observed through use-wear studies on Early Neolithic archaeological tools. Our experimental results could then be compiled to create a reference collection that could aid in interpreting the archaeological record, and in turn reconstructing past processing techniques.

Moreover, we wanted to test how the starch grains were affected by taphonomical processes. Several factors affect the degradation of starch, this includes soil properties (e.g., pH and moisture) and elements present in the soil (e.g., bacteria, fungi, and enzymes) (Haslam 2004). Early experimental work done by Lu (2003) indicated that starch grain preservation was reduced significantly when left in an open situation condition and survived better in a buried or sheltered situation condition. Barton (2009) and Langejans (2010) followed with their own taphonomic experiments. These results[1], therefore, prompted us to test how starch grains would preserve in similar environmental conditions to those where the Neolithic tools were recovered (in temperate conditions).

While some of the species we tested (barley, peas, and lentils) have previously been processed to observe changes in the starch grains (i.e., Henry *et al.* 2009), we chose to work with different wheat species and replicate as much as possible past conditions, notably by using raw materials present in the Paris Basin during the Neolithic and using typical forms of grinding stones recovered in the archaeological record.

Dehusking and grinding processes

Two series of tests were organized, respectively the grinding of cereals and legumes, and the dehusking of cereals. During the first series of tests, four types of plants were ground into small fractions with a different set of stone tools for 2 hours each (Table 1). Einkorn and barley were ground in a back-and-forth motion exclusively to obtain flour, while peas and lentils were crushed and then ground into smaller fractions (Figure 2A-D). Barley was soaked prior to grinding. All grinding tools were shaped out of quartzitic sandstone blocks and cobbles, to ensure adapted handling for crushing and/or grinding. The active surfaces of the lower and upper tools were superficially pecked to ensure a minimum of abrasiveness of the tool. The product was considered achieved when homogeneous flour or fractions were obtained. It should be noted that barley and einkorn were processed on opposite sides of the same tool, while peas and lentils were processed on two separate tools.

The second series of tests was dedicated to the dehusking of experimental einkorn and emmer (Table 2; Figure 2E-F). Two sets of querns and grinders were intentionally shaped out of quartzitic sandstone blocks from the Aisne River. This raw material was selected as it was commonly recovered at Early Neolithic sites in the Paris Basin. Their active surfaces were intensively pecked for several hours with different types of hammerstones to ensure a regular active surface and gesture. Both cereals were first dehusked dry, and then soaked for 20 minutes prior to processing. This ensured a rolling motion rather than the crushing of the grains which favored the separation of the hulls from the grains. This separation was made possible by the back-and-forth motion combined with a light pressure on the heavy grinder.

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1 Other taphonomic tests involving starch and a range of other residues on stone flakes have been carried out (see Croft *et al.* 2016; Wadley *et al.* 2004).

Table 1: Details of the grinding activities undertaken.

Plant type	Grinding Time	Preparation	Tools	Gesture	Quantity processed	Buried y/n
Einkorn	2h	Dry	Flat slab and one-hand circular handstone (Figure 3A)	Back-and-forth grinding	475 g	y
Barley	2h	Wet	Flat slab and one-hand circular handstone (Figure 3B)	Back-and-forth grinding	300 g	y
Peas	2h	Dry	Flat slab and one-hand circular handstone (Figure 3C)	Crushing and grinding	300 g	y
Lentils	2h	Dry	Flat slab and one-hand circular handstone (Figure 3D)	Crushing and grinding	200 g	y

Table 2: Details of the dehusking activities undertaken.

Plant type	Time	Preparation	Tools	Gesture	Quantity processed
Einkorn	2h	Dry	Flat quern and two hand bread-shaped grinder (Figure 3E)	Back-and-forth grinding	895 g
Einkorn	2h	Soaked 20 minutes	Flat quern and two hand bread-shaped grinder	Back-and-forth grinding	1080 g
Emmer	1h45	Dry	Flat quern and two hand bread-shaped grinder (Figure 3F)	Back-and-forth grinding	1050 g
Emmer	1h45	Soaked 20 minutes	Flat quern and two hand bread-shaped grinder	Back-and-forth grinding	1080 g

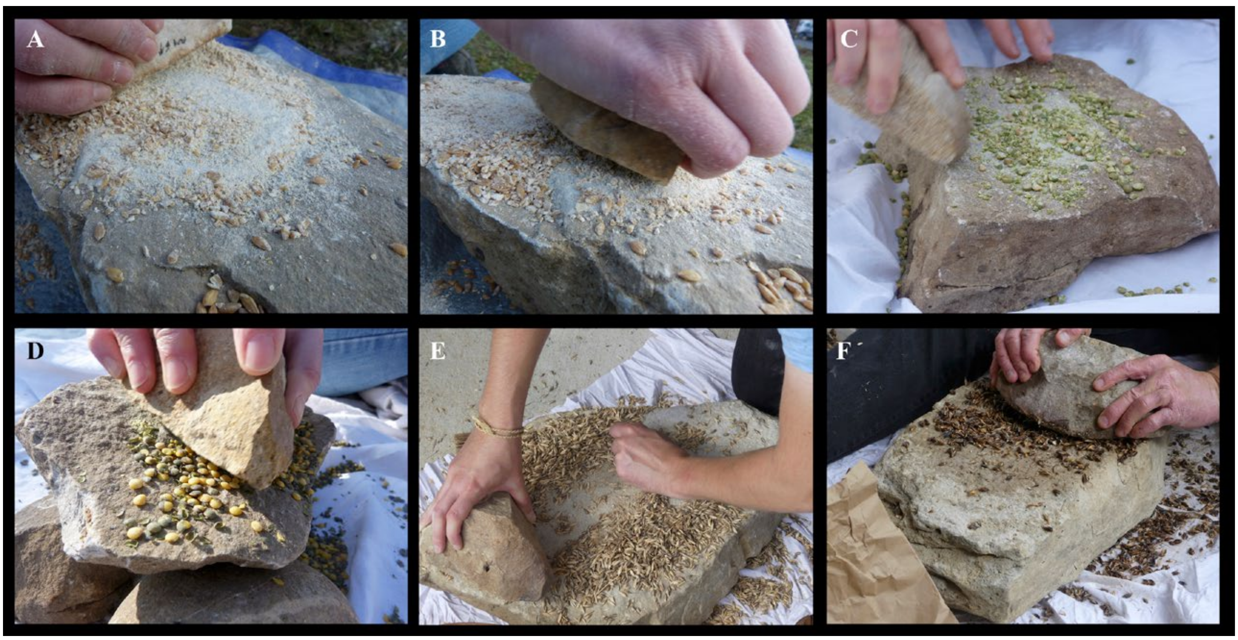

Figure 2: Grinding and dehusking activities. A: einkorn; B: barley; C: peas; D: lentils; E: dehusking einkorn and F: emmer (photos C. Hamon).

The starch grain extraction process

We collected samples from the various slabs and querns listed above. For the wheat and barley, we collected samples from both the center and the lateral parts of the slabs: the latter was done to test whether differences could be observed in the modifications of the starch grains when they are less in contact with the grinder. From the tools used to process the peas and lentils, we took samples only from the central part of the slabs as this is where the crushing and grinding action was focused (Figure 3A-D). For the tools that were used for cereals, dehusking samples were only taken from the central part of the querns (Figure 3E-F).

For all these tools we used the recovery protocol previously published by other scholars (Torrence and Barton 2006): droplets of distilled water were placed on the surface of the tool and with the micropipette tip, the droplets were gently agitated before being sucked up (Figure 4A-B). The samples were then placed in clean containers. For each sample, we prepared one slide. This was done by placing a couple of drops of each sample on a clean microscope slide, followed by a 1:1 distilled water: glycerin solution[2], then sealing the sample with a coverslip. The slides were viewed under plane polarized and cross-polarized light (100-600x). The starch grains were observed in three dimensions, and several variables were noted, including changes in size and shape, visibility of lamellae, surface modifications, and changes in the extinction cross. We also considered whether the original structure (single or compound) was retained but also whether amyloplasts and other structures were present. Whenever possible, we observed and measured 100 starch grains.

Some of the tools were selected to be buried to undergo the taphonomical experiments. Once the tools were photographed and the samples taken, to avoid contamination, we wrapped them in clingwrap for transport. After the removal of the clingwrap, three tools were placed in a pit of approximately 70 *cm* in diameter and 30 *cm* deep (Figure 5), in a sediment similar to the one expected at Early Neolithic sites of the Aisne Valley, France. The 3 lower grinding tools were placed with their active face upwards, except for the surface used to grind einkorn which was placed facing downwards[3]. They were completely covered by soil and left for 6 months underground between February and August 2019[4]. The tools were then unburied, and immediately transported to the laboratory where they were sampled for starch analysis. The surfaces were first photographed and then washed using a clean toothbrush and distilled water. The resulting sample was collected into a clean container. To view the starch grains (mixed with sediment and other organic materials found in the soil), we had to chemically isolate the grains. To do so, we followed the protocol outlined in Cagnato and Ponce (2017). Once the samples were clean, drops of each sample were placed on a clean microscope slide, a 1:1 distilled water: glycerin solution was added, and this was sealed with a coverslip. The slides were viewed under plane polarized and cross-polarized light (100-600x).

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2 Preparing a solution composed of 50% glycerin and 50% distilled water is a rather common practice (see Li *et al.* 2020 for additional references), although other specialists use a solution composed of 10% glycerin with 90% distilled water (e.g., Yang and Perry 2013).

3 As a result of using this same grinding stone to process both barley and einkorn, albeit on opposite sides.

4 Environmental conditions at Cuiry-les-Chaudardes during this period were obtained from the nearest meteorological station, Reims-Prunay, located about 30 km to the southeast. The lowest average temperature recorded was in February (0 degrees Celsius), while the highest average temperature was recorded in July (27.6 degrees Celsius). The lowest temperature on record was -3.9 degrees Celsius (in February) while the highest was 41.1 degrees Celsius (in July). For 2019, the maximum rainfall was recorded for the month of May (with 64 mm), for a total of 265.8 mm between February and August 2019 (Source: Météo-France). Pedological studies indicate that the site is located between colluvial deposits, podzols, and limestone-rich soils (Perrier *et al.* 2016). The soil pH ranges between 6.5 and 7.

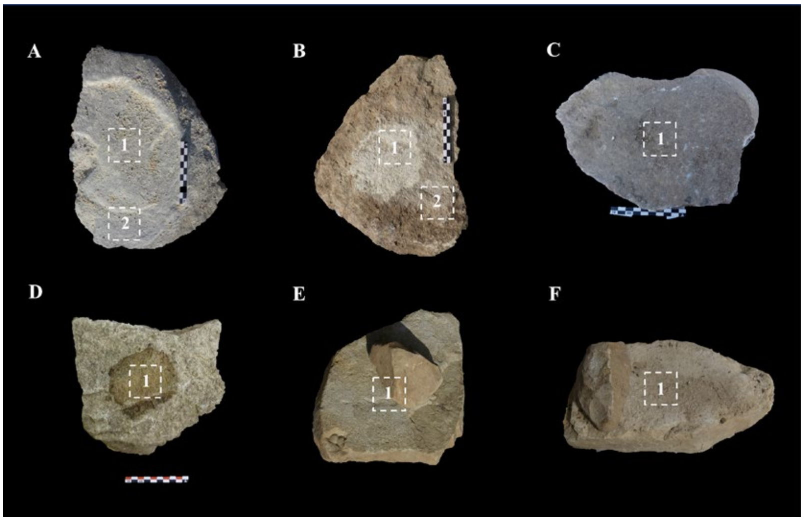

Figure 3: Location of where the samples were taken from after the experimental grinding: A: einkorn; B: barley; C: peas; D: lentils; and dehusking of E: einkorn, and F: emmer (photos C. Hamon and C. Cagnato).

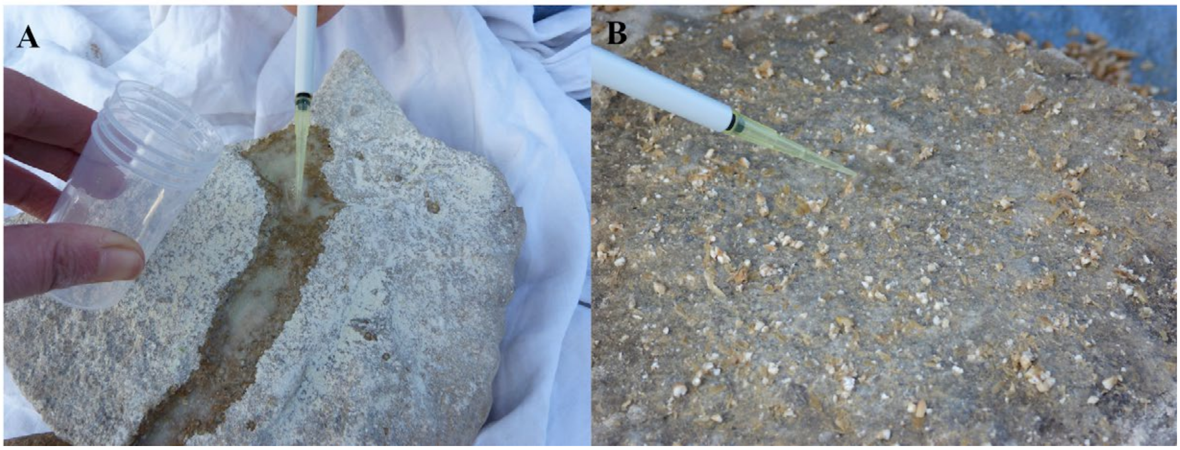

Figure 4: Taking samples from the tools after processing cereals and legumes through the use of a micropipette tip and distilled water (photos C. Hamon).

Figure 5: Grinding stones in the pit prior to being buried at Cuiry-les-Chaudardes, France (photo C. Hamon).

Results

Wheat

Our experimental dehusking tests on emmer or einkorn did not leave diagnostic starch grains on the tools. With regards to grinding, einkorn grains were generally found disjoined, although some clumps (aggregates of starch grains) were found: the largest one was identified in the sample taken from the lateral part of the tool (Figure 6A). Noticeable immediately was the deformation of the starch grain, observed when viewed from the top (plane view), or from the side, where a lateral protrusion formed (Figure 6B-E). Other types of damage include ripped (broken) grains or with fissured edges (Figure 6F-G). With regards to the extinction cross, these were most often deformed (thicker arms and darker centers), while others were fainter than unprocessed einkorn starch grains when viewed under polarized light, or even absent as the grain had been completely crushed (Figure 6H-I). In addition, cupules were still present on some of the grains (Figure 6J), albeit faintly visible, and lamellae were mostly absent. In terms of size, we found smaller grains in the center of the tool compared to the lateral sample: the former averaged 22.2 ± 4.93 µm (n=100), while the latter averaged 22.80 ± 4.13 µm (n=65). In both samples, the grains ranged between 12.5 and 31.25 µm in length.

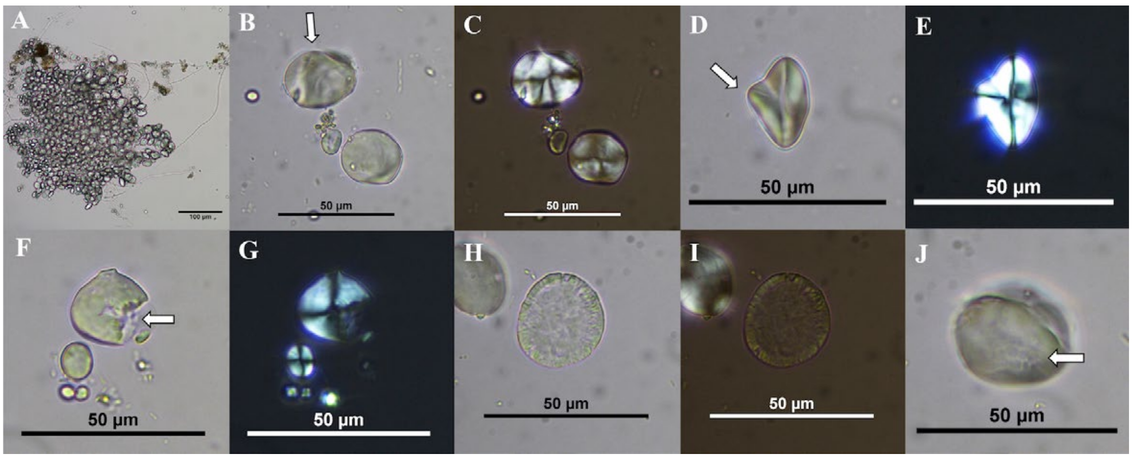

Figure 6: Modifications observed in einkorn starch grains, seen in plane polarized and cross-polarized light (photos C. Cagnato). Arrows point to specific damages observed: protrusion seen from different angles (B and D), broken edges (F), and presence of craters visible on the surface (J).

Barley

Barley grains were found mostly isolated, although a couple of clumps of grains were found (Figure 7A-B). Although ninety percent of the starch grains observed had some type of damage, they could be identified. Barley starch grains in rare cases were torn apart (not a clean break, Figure 7C-D), but more commonly the edges have fissures or have become uneven (Figure 7E-H). There is also damage on the surface (Figure 7K-L). While the barley starch grains were at times slightly indented (Figure I-J), their shape was less affected than when compared to einkorn. Moreover, unlike in einkorn starch grains, we did not observe the formation of protrusions in barley. The extinction crosses were affected by grinding: the arms are no longer symmetrical and in some cases are disjoined (see Figure 7H and J). In some cases, the cross was fainter than the one observed in unprocessed barley starch grains. Lamellae and surface craters, both sometimes observed on unmodified grains, remain visible on the experimentally ground barley. The former in some cases appear more distinct after grinding; they appear slightly deeper. The edges of the barley starch grains were for the most part affected by grinding. In terms of differences in grains between the central and lateral portions, we noticed about half the number of grains in the former compared to the latter. Size-wise, the grains ranged between 11.25 µm and 32 µm (n=100) and averaged 22.5 ± 5.51 µm for the central part, and 20.5 ± 5.49 µm (n=100) for the lateral samples.

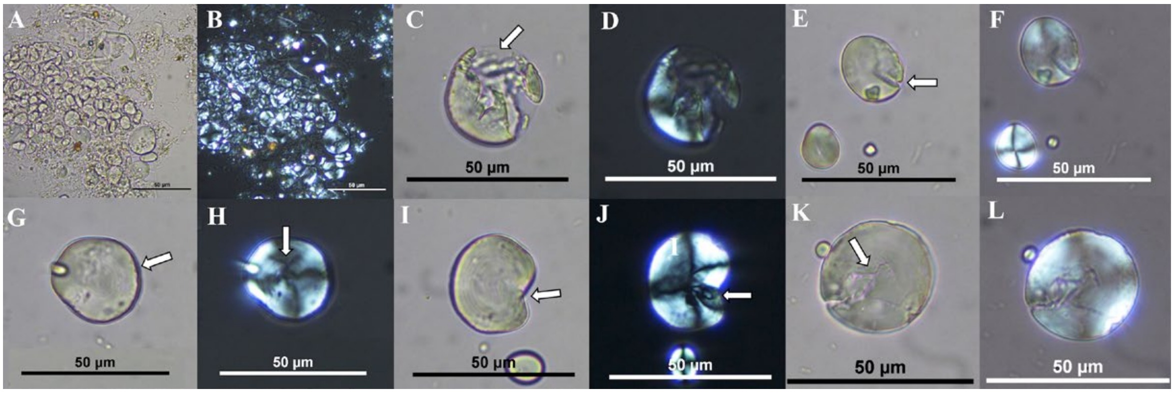

Figure 7: Modifications observed in barley starch grains, seen in plane polarized and cross-polarized light (photos C. Cagnato). Arrows point to specific damages observed: broken, fissured, uneven edges (C, E, G), modification to the shape of the grain (I), asymmetrical extinction crosses (H, J), and surface damage (K).

Peas

We found both isolated pea starch grains as well as some still intact inside the amyloplasts (Figure 8A-B). In terms of the isolated grains, we found an important number to have undergone modifications as a result of grinding. Notably, a number had deep fissures that almost broke the grain in half (Figure 8C-F). Moreover, the edges were affected, with some looking as if some parts had "melted" (Figure 8G-H). The lamellae, visible especially along the edges remain present in 90% of the time, however, we noticed small new fissures, perpendicular to the lamellae, appearing along the edges (Figure 8I-J). In some rare cases, although the grain retained its shape and size, the lamellae along the outer edges of the grain became more visible. Damaged extinction crosses were noticeable (Figure 8K-L). The original fissure, seen sideways, was now deeper and more pronounced. The shape of the grains was also affected, becoming even more irregular than it originally is. In terms of size, we found, similarly to the lentils (see below), starch grains on the larger end of the spectrum, averaging 36.4 ± 7.96 µm in length for a maximum length of 56 µm and a minimum of 22.5 µm (n=100).

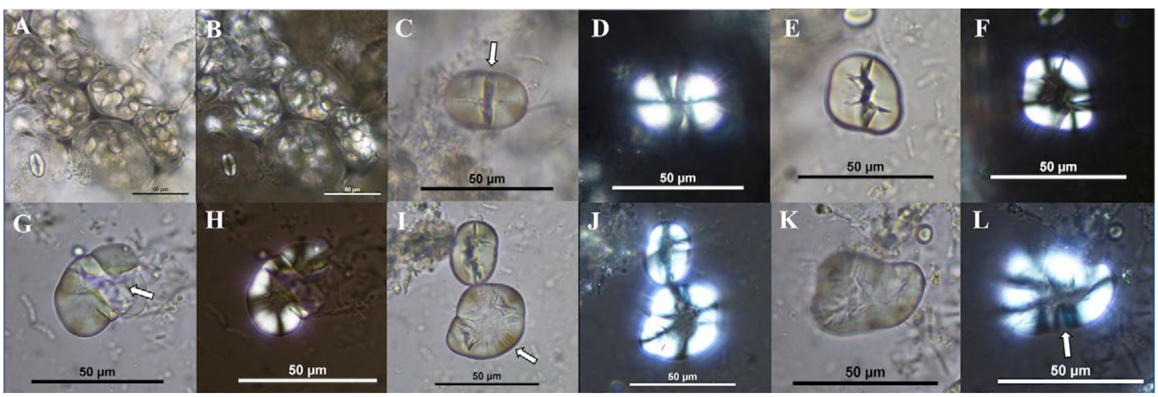

Figure 8: Modifications observed in pea starch grains, seen in plane polarized and cross-polarized light (photos C. Cagnato). Arrows point to specific damages observed: fissured grains (C), 'melted' edges (G), small fissures along the edge (I), and damages to the extinction cross (L).

Lentils

We found that about half of the lentil starch grains present in the experimental samples were rather intact. The other half were often fractured in half (Figure 9A-B) or with edges missing (Figure 9C-F). In the latter case, the lamellae were relatively intact, remaining well-defined and regularly spaced as in the native starch grains. Although rarely observed, we did notice central depressions (Figure 9G-H). The extinction cross was comparatively intact, although at times it did lose its symmetry and widened along the mesial longitudinal cleft. The shape of the grain was not altered much. In terms of size, we found starch grains averaging 28 ± 5.67 µm in length (n=100), including a few that were extremely large, up to 44 µm long, with a minimum size of 16.25 µm. The mesial longitudinal cleft was sometimes deeper and less regular than on the native grains. The grains were generally recovered in isolated form, although surrounded by other starchy material, found in the now ruptured amyloplasts.

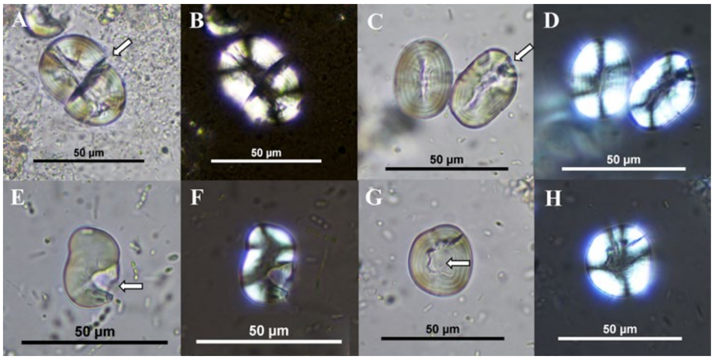

Figure 9: Modifications observed in lentil starch grains, seen in plane polarized and cross-polarized light (photos C. Cagnato). Arrows point to specific damages observed: fissured grains (A), damage to the edges (C, E), and central depression (G).

Taphonomy

With the exception of one, starch grains were not observed in any of the four buried samples extracted from the tools. The one starch grain that was recovered on the tool used to process the peas was extremely damaged, evidently enlarged and with the central part completely 'digested' or missing (Figure 10). Small canals or fissures can be seen along the edges of the grain: this type of damage was observed in pea starch grains having undergone grinding. However, the central damage is completely different from what we observed in the samples having undergone grinding activities. It is therefore likely that this grain was in the process of being digested by bacteria or fungi present in the soil (see also Hutschenreuther *et al.* 2017).

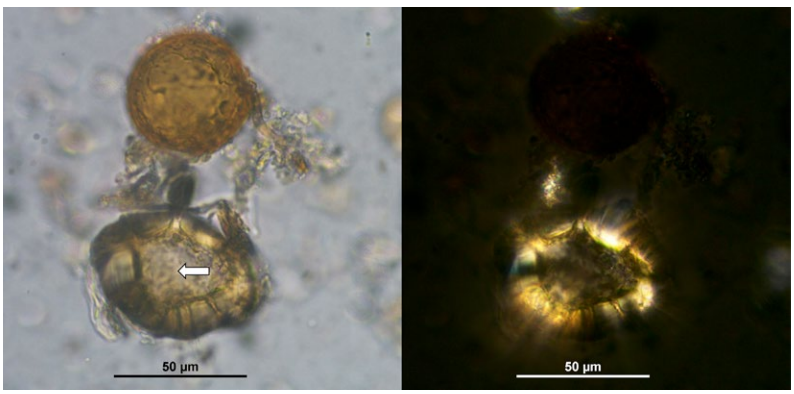

Figure 10: Damaged starch grain, seen in plane-polarized (left) and cross-polarized light (right). The arrow indicates the central part of the grain, which seems to have been digested (photos C. Cagnato).

Discussion

Mechanical modifications

Undoubtedly, as has already been shown by previous experimental works, starch grains are damaged by mechanical forces that include grinding and pounding (see Table 3). Dehusking, on the other hand, left little evidence in terms of starch grains; this stands in contrast to phytolith studies, which are better able to detect dehusking practices (Ma *et al.* 2019; Portillo *et al.* 2017). In fact, very small quantities of starch grains as a result of dehusking millets were recovered by Ma *et al.* (2019), who also note that these were nearly impossible to distinguish from native millet grains. This type of result is not surprising given that phytoliths come from the external part of the grains (the hull), contrary to the starch, which comes from the inner parts of the grain.

Similarly, with other studies (e.g., Li *et al.* 2020; Ma *et al.* 2019; Pagan-Jimenez *et al.* 2017), not all the starch grains had evidence of damage, in fact, an important number of grains (~25%-30%) were relatively intact after two hours of grinding (and grating for Pagan-Jimenez *et al.* 2017). Hand in hand with the presence of whole pea amyloplasts along with wheat and barley clusters, this explains why archaeologists can still find intact starch grains when studying ancient stone tools.

Table 3: Parameters of other experimental studies where grinding and/or dehusking was carried out with the aim to study starch grain modifications. Note: Pagan-Jimenez *et al.* (2017) was not included here as they grated manioc and sweet potatoes followed by cooking experiments.

Study	Tool type	Duration of processing (minutes)	Grinding technique(s)	Area sampled on tool	Plant species experimentally tested
Li et al. (2020)	Sandstones from Maas River (Netherlands)	60	Wet and dry grinding; back-and-forth motion	n/a	Rice, foxtail millet, Job's tears, barley
Ma et al. (2019)	Grinding stones and slabs made of sandstone/shale (China)	~17 m per lot (grinding); ~52/ lot (dehusking)	Rolling back and forth to dehusk and grind	n/a	Foxtail and broomcorn millet, bristlegrass
Mickleburgh and Pagán-Jiménez (2012)	Marble mortar and pestle	5	Grinding of kernels soaked 1 hour prior	n/a	Maize
Ge et al. (2011)	Mortar and pestle	20	Pounding	n/a	Foxtail and broomcorn millet
Babot (2003, 2006)	n/a	n/a	n/a	n/a	Dry maize, ripe corn, *chuño*, quinoa, bean, amaranth
Chandler-Ezell et al. (2006)	*Mano* and *metate* (grinding stones)	5 (pounding); 10 (grinding)	Pounding and grinding	n/a	Maize, manioc

Regarding barley, we obtained similar results to those noted by Li *et al.* (2020) after wet grinding, who reported minor changes in terms of their shape and with faint lamellae remaining visible. Size-wise we obtained similar results in the average size of the grains: 23.38 ± 5.21 µm for Li *et al.* (2020), compared to our 23 ± 5.51 µm for the grains in the central part of the grinding stone. The major difference concerns the extinction crosses, ours were clearly damaged, while Li *et al.* (2020) report a large number of intact crosses. Moreover, our lamellae tended to be deeper after having been ground. Overall, however, we can agree that soaking cereals might result in less damage to the starch grains (cf. Li *et al.* 2020). However, Li *et al.* (2020) also found that dry-grinding cereals led to the loss of birefringence. We did not find this on our wheat, and therefore this may be particular to other cereals they tested (rice, foxtail millet, and Job's tears). A difference between einkorn and barley, and perhaps as a result of being processed dry vs. wet, was the greater shape modification, and this latter point is especially evident in the development of protrusions, as seen on einkorn starch grains. With regards to wheat, we found similar damages to those reported by Ge *et al.* (2011): incomplete or broken grains, irregular outlines or edges, and wider arms on the extinction cross. When we consider the legumes, we found that similar types of mechanical forces (crushing and grinding) led to comparable modifications to the edges of the starch grains and the retaining of the very diagnostic lamellar structure. A major difference between the two set of legumes is the higher occurrence of torn grains in lentils and fissures along the edges in peas; damages documented by Babot (2003), albeit for other species. Moreover, we observed the central depression only on lentil starch grains, but this type of feature fits with general damages produced by milling (Babot 2003). Size-wise, it has been demonstrated that grinding alters the size of the grains, enlarging them (Li *et al.* 2020; Liu *et al.* 2011[5], Ma *et al.* 2019). Our results did not show major changes in the size of the grains, although we did observe some larger grains among the lentil and barley samples. When comparing the central vs. the lateral parts of the stone tools, we found smaller barley starch grains in the central part of the tool. While it is possible that the center of the tool is more effective for grinding, and that the larger grains were more easily damaged/destroyed, we would need to carry out more tests to determine if this is a pattern. Based on our experimental tests we would argue that even after grinding, peas and lentils may often still be identifiable in the archaeological record due to the presence of their lamellae and distinct extinction crosses. Regarding cereals, we believe that it will be trickier to differentiate between wheat and barley starch grains, especially once they have undergone additional deterioration due to aging and exposure to soil properties and organisms in the soil.

Taphonomy

Regarding our taphonomical experiment, how burying and exposure to climatic factors and enzymes/bacteria would have altered the starch grains further is not observable. Yet, our results, or lack of, obtained from our preliminary taphonomical experiment support Barton and Torrence's (2015) statement in that there is still a lot we do not know about starch taphonomy. Interestingly, it has been proposed that damaged starch grains, either as a result of mechanical or oxidative processes, are more susceptible to attack by enzymes (Crowther 2012; Haslam 2004). In our experiments, not all the starch grains were evenly damaged, and therefore we could expect that at least the undamaged grains could have survived while buried. Yet, this was clearly not the case. Other factors that have been put forward for the differential preservation concerns the size of the starch grains themselves (see Haslam 2004).

We propose that several reasons could explain the lack of starch grains. First is the fact that the crevices of the stone tools were not deep enough. In fact, it is argued that it is these crevices and pores in stone tools that permits the starch grains to survive extended periods of time (Piperno *et al.* 2000; but see Barton (2007) and Mercader *et al.* (2018) for arguments against this). The depth at which the tools were buried may also be a factor to consider, even if studies have shown that microbial and enzymatic activity (and to a lesser degree fungal activity) can be found even between 3 and 4 m below the surface, albeit at different degrees (see Haslam 2004:1721). Moreover, we wrapped the tools in clingwrap while the tools were still humid, and this perhaps did not allow for a hard plaque to form, and in turn prevent microbial attack (see Barton 2009; Loy 1990). Additionally, climatic and soil conditions could be considered.

5 But based on wet grinding. Soaking in water is known to slightly swell starch grains (Henry *et al.* 2009).

Haslam (2004:1725) suggested that mechanisms may exist in the soil that help protect against enzymatic attack; these include clays, heavy metals, and soil aggregates. Finally, the position of the tools (with the active surface upward or downward) could be another important factor; however, we did not find any difference between those that were buried upwards or downwards. Few other studies have considered this parameter, but those that did found that the samples facing downwards preserved residues better than those facing upwards (Langejans 2010). It is likely that a combination of some or all of these factors affects the preservation of the starch grains, and therefore additional tests will be necessary.

Conclusions

When grinding was carried out on rather clean cereal grains, but also on legumes, we found both damaged and undamaged starch grains present. The mechanical modifications we commonly identified include a clean fracture of the starch grains, especially visible on those belonging to peas. On cereals, the breaks were less clean, and looked more like the starch grains had been torn. Changes to the original shape of the starch grains were especially evident in wheat, where we observed the creation of protrusions. Due to the nature and end-goal of dehusking, which is to preserve the grains, this type of activity will seldom leave behind diagnostic data (in the form of starch grains) indicative of such mechanical processing.

There is a clear need for more experimental work in the Paris Basin, in light of the archaeobotanical data that have been recovered to date from Early Neolithic contexts, which include the processing of different types of underground storage organs, along with cooked cereals and legumes, and malted/germinated grains. We strongly believe that to accurately reconstruct past activities, we need to continue developing a reference collection that is based on replicating techniques and materials known to have been used in the past.

While our taphonomical experiment was preliminary, it clearly proves the need for additional tests, which may include modifying a range of factors that include the time the tools are left to dry before being buried as well as the depth at which the tools are buried, to name but a few examples. We also plan on collecting sediment adjacent to the tools to explore mechanisms of how starch moves in post-depositional contexts. We strongly believe that combining experimental data is essential if we are to make better sense of the archaeological record.

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4. Mapping Life-Cycles: Exploring Grinding Technologies And The Use Of Space At Late/Final Neolithic Kleitos, Northern Greece

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Introduction

Grinding tools constitute an indispensable part of the toolkit of agricultural communities, holding a key role in the survival of the household group and the community as a whole (Adams 2002; Wright 1994). Not surprisingly, ethnographic studies have shown a strong symbolic value ascribed to these implements, often incorporated in ritual acts (e.g. Fernández Souza 2008; Mobley-Tanaka 1997), treated as heirlooms and material property to be gifted, safeguarded and passed from one generation to the other (David 1998: 25; Hamon and Le Gall 2013: 116-117; Nixon-Darcus and D'Andrea 2017: 203-204; Searcy 2011: 74).

Browsing through ethnographic reports is sufficient to get an idea of the complex lives of these implements: tools wear out or accidentally break, thus becoming unsuitable for a specific task but potentially usable in another, they fall in disuse and are left behind to be scavenged by others and be used again in a similar or totally different way, context and activity. With the passage of time, the functions of these tools as well as their contexts succeed one another, the owners and users may change, the attributed meanings and values may alter, fade or be enhanced, and the same applies to the artifacts themselves which change through the constant wear and maintenance. It is therefore clear that in order to gain an insight into their entanglements with the organization of daily life and their social significance, a contextualized analysis of grinding tools in relation to the various stages of their life-cycle is essential.

The present paper offers a short overview of aspects related to the grinding technology and its spatial dimension in two Late/Final Neolithic settlements in Northern Greece. An attempt is made to understand how grinding tools are manipulated in different spatial and social scales and through that to gain a glimpse at the traditions and practices that synthesize the cultural milieu in which these tools were made and used. To this end, contextual analysis is combined with a special emphasis on aspects of the tools' life-cycles, their state of preservation and taphonomic factors.

The site

The site of Kleitos is located in north-western Greece (Figure 1) and more specifically in the densely populated during prehistoric times alluvial Kitrini Limni Basin (Andreou *et al.* 1996: 568–569, 575; Fotiadis and Hondroyianni-Metoki 1997: 21). The excavations brought to light two neighbouring, partially overlapping in terms of chronology, Late and Final Neolithic settlements which were almost fully excavated. In this respect, Kleitos stands out as one of the very few Neolithic settlements excavated almost in their entirety in the whole of Greece.

Kleitos I is a flat, 'extended' settlement of circa 2ha dated in the early phase of the Late Neolithic, i.e. late 6th - early 5th millennium BC (Ziota 2011: 215, 227). It has a center-periphery structure bounded by

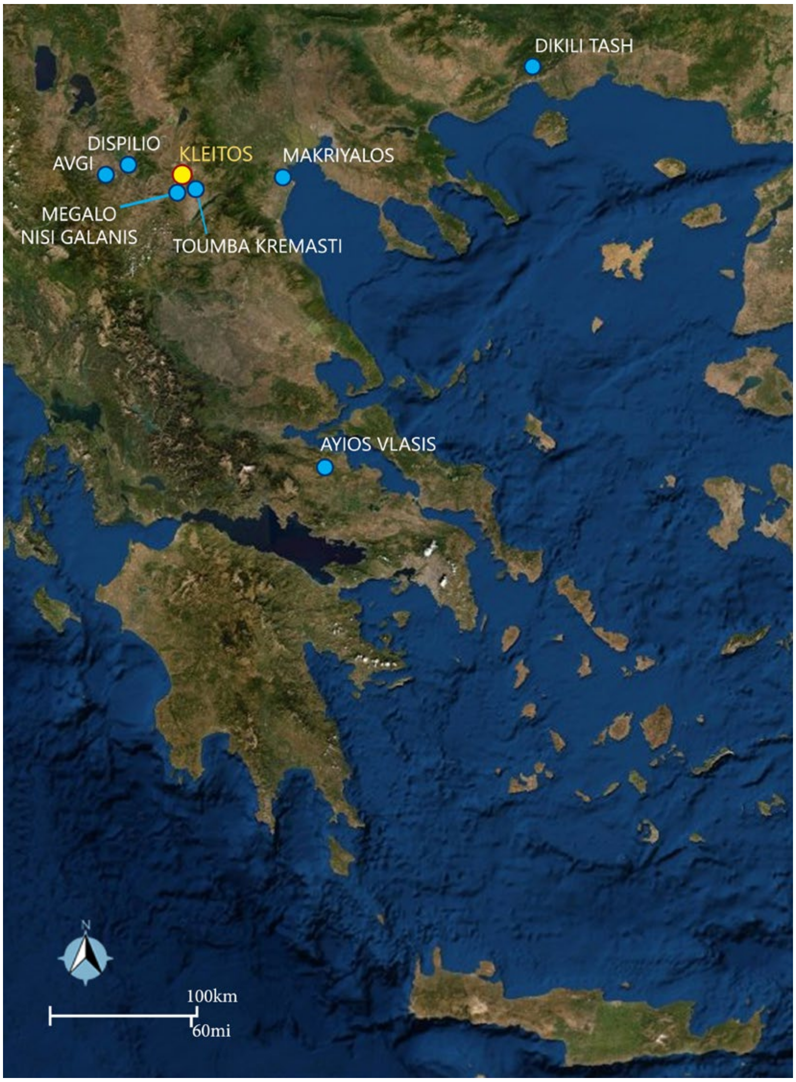

Figure 1: Map of Greece and prehistoric sites mentioned in the text.

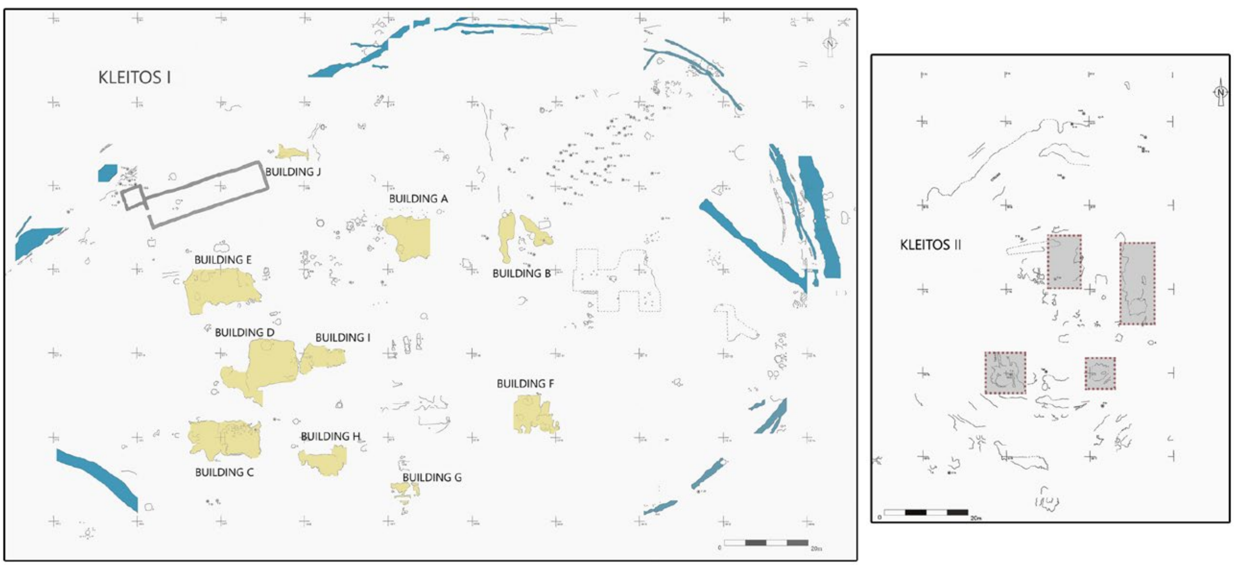

Figure 2: Plan of Kleitos I (left) and Kleitos II (right) with building remains and peripheral ditches highlighted.

a system of ditches and fences, which marked the boundaries of the community, literally and possibly ideologically as well (Figure 2). Ten sparsely distributed quadrilateral, above-ground dwellings have been found, each of them with one to three separate building phases. The remains of the best preserved examples cover an area of 100-120m2 each, with the possibility of an upper storey at least for some of them (Ziota *et al.* 2013: 59, 64). Numerous thermal and storage clay structures have been detected in built interiors and outdoor areas (Ziota 2011: 216-222).

The second settlement (Figure 2) lies to the north-east of Kleitos I at a distance of less than 100m. Kleitos II is significantly smaller compared to its neighbouring site, covering an area of just 0,25ha and is more densely structured, with limited open spaces between the five preserved dwellings (Hondroyianni-Metoki 2011: 238-240; Ziota *et al.* 2013: 79). Peripheral ditches are absent and the settlement is demarcated exclusively by natural streams (Ziota 2014a: 327). The buildings have one to three building phases each. Two have a curvilinear plan and rather small dimensions (4-6m diameter), while the rest are elongated rectangular and more spacious, e.g. Building 4 covers an area of ca 90m2 (Ziota *et al.* 2013: 71, 73). Storage and thermal structures are mostly located in interior spaces (Ziota *et al.* 2013: 79).

No radiocarbon dates are available yet, but according to the ceramic finds the earliest phase of Kleitos II is partially contemporary to the first settlement, with the habitation extending to the late phase of the 4th millennium BC (Ziota *et al.* 2013: 73; Ziota 2014a: 326-327). This means that the two settlement areas were at some point inhabited simultaneously. Yet, despite their proximity and partial contemporaneity, they differed greatly in terms of size and spatial organization, as noted above. The detected differences could be function-related, i.e. the second site could have been an extension of the pre-existing settlement aimed at hosting different activities (Hondroyianni-Metoki 2011: 240; Ziota 2014a: 332), or they could be the result of sociocultural factors (Ziota 2011: 228). Ground stone tool analysis may, among other things, shed some light on such questions regarding the relation of the two nearby sites. Unfortunately, due to the lack of C14 dates, a more comprehensive analysis by habitation phase was not possible. Hence, when the two sites are compared, the temporal dimension of the differences observed cannot be examined in detail.

The grinding tool assemblage

The Kleitos ground stone tool assemblage consists of more than 7000 implements, from which almost 4000 have been analytically examined (Chondrou 2018). The applied sampling strategy prioritized the findings originating from sections of the excavation with undisturbed layers of secure dating. The selected sectors cover most of the excavated space and represent a range of different spatial units (i.e. residential core, marginal zone, surrounding ditches, pits, space between the two sites etc.). The study included macroscopic and low-magnification analysis of the artifacts, along with raw material identification and thin section analysis of selected samples. A refitting process was also conducted aiming at the identification of conjoining parts of the same artifact as imposed by the high fragmentation rates in the assemblage under study. The resulting data provide evidence for anthropogenic activities related to the management and disposal of the ground stone technology, as well as for different processes that shaped the archaeological image. Spatial data regarding the recovery location of each find (based on the excavation calendars, the illustration and photographic records, and additional data from the available publications) were also examined in order to shed light on the tool use and depositional contexts. The excavation of Kleitos was carried out on the basis of a grid, with squares of 25m2 and, in the case of destruction layers, a micro-grid of 1m2.This permitted the triangulation of the findspots of small objects and consequently the detailed and accurate depiction of their distribution.

The 3767 finds examined have been classified into 11 main categories (edge tools, grinding tools, abrasive and percussive tools, multifunctional tools, perforating tools, pieces of ochre with traces of use, maceheads, raw material pieces and production debris, indeterminate) and several subgroups. The category the present paper is dealing with, i.e. grinding tools, comprises 602 specimens recovered from the Neolithic strata. The analysis applied focused on the combined examination of morphometric (overall shape, special features, longitudinal and transverse sections, size, length, width and weight), technological (type, distribution, density, intensity and sequence of manufacturing traces per tool surface) and functional attributes of the artifacts (number of use-surfaces, type, intensity and sequence of use-wear traces) and the identification of the various stages of the artifacts' life-cycle: from the design stage, raw material procurement and manufacture, use, 'secondary use(s)' or recycling of the artifact, to its final deposition, disposal and/or abandonment.

The classification system applied classifies each artifact based on its final use, at the same time mentioning any evidence of it being a) reused (i.e. used again, e.g. after a breakage, for the same function for which it was originally designed and used; for a different use of the term see Adams 2002); b) secondarily used (i.e. secondarily employed for a function different from its initial use with no reshaping of its original design); c) redesigned (i.e. reshaped prior to its new utilization); d) recycled (i.e. utilized in a totally different context compared to its original function). The above presuppose the identification of the temporal sequence of the different uses of an object. For example, multifunctional tools with different surfaces used for different functions imply concurrency, whereas single-use tools with different episodes of use, where the new activity often inhibits the previous one, imply sequentiality. It should be noted, however, that this distinction may not always be possible (see also Dubreuil and Grosman 2013: 528). Worn-out or exhausted grinding implements have reached a minimum thickness due to their prolonged use and extensive wear and are no longer usable in the context of the activity for which they have been initially designed for. Of course, there may be cases, such as those of heavily fragmented implements, where the level of wear cannot be assessed. Finally, regarding the state of preservation, the intact or fragmented state of the artifacts, the degree and pattern of fragmentation and the part of the initial tool represented -based on the restoration, whenever possible, of the position of a fragment in the original (i.e. intact) body of the tool-, as well as signs of erosion and fire exposure are documented. Breakage, spalling, microfracturing, pitting, discoloration, adhesions, and weight loss are some of the reported fire effects on artifacts made of stone (Deal 2012: 98). Their presence, location on the body of the tool and intensity are recorded; the same is applied for the evidence of erosion.

The grinding activity requires the pairing of a stationary implement (*passive tool, i.e. quern*) and a mobile one (*active tool, i.e. handstone*) for matter between their surfaces to be ground. In terms of typology, the vast majority of Kleitos grinding implements belongs to the 'overhanging' type, that is handstones operated with both hands in a back and forth reciprocal motion, whose length exceeds the width of their passive counterparts (Figure 3.1, 3.A-C). The other two types, i.e. querns paired with short handstones used in a back and forth rectilinear motion and querns with small handstones used in a 'free', curvilinear motion (Figure 3.2-3, 3.D-E), constitute a minority in our sample (i.e. around 22% without counting indeterminate specimens), with type 3 tools being the least represented. Regarding their metrical characteristics, evidence suggest the coexistence of both small and large tools i.e. querns ≤30cm and >30cm in length (see also Chondrou 2020), yet the relative proportions of implements per tool type is not possible due to high fragmentation rates.

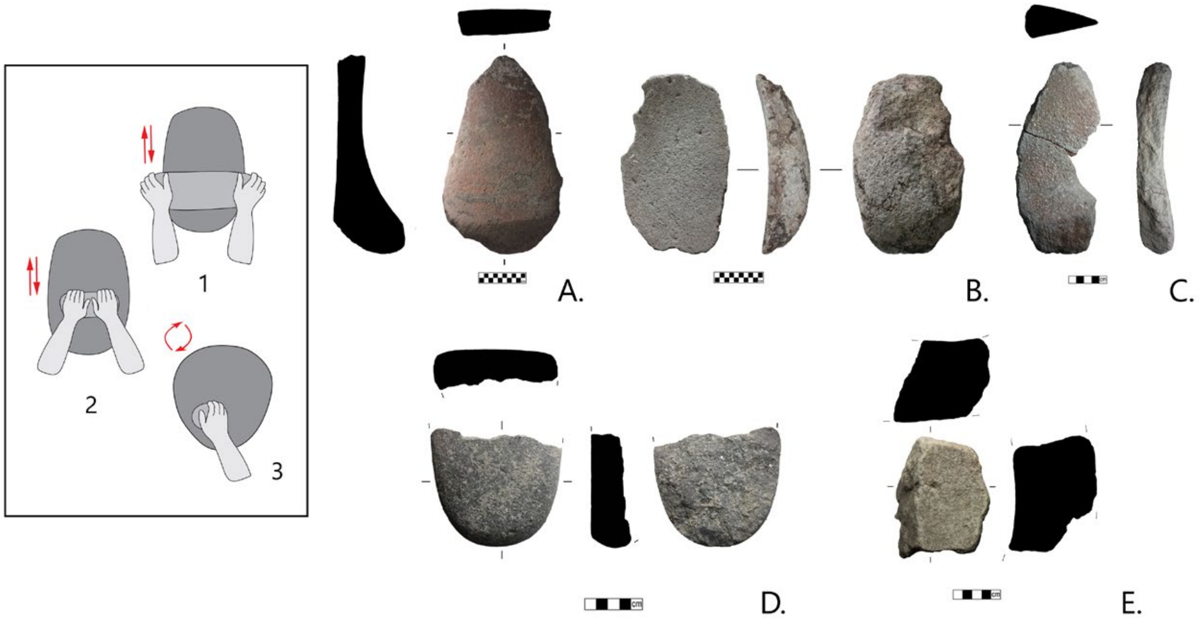

Figure 3: Three main grinding tool types (drawing by the author). Type 1 querns and handstone (A-C.), a type 2 handstone (D.) and a type 3 highly fragmented and a type 3 highly fragmented quern (E.).

Tool manufacture and maintenance

The alluvial plain of Kitrini Limni, where Kleitos is situated, is devoid of appropriate lithic sources (Fotiadis 1988: 45, 49), same as its neighbouring streams. Therefore, the material needed would have been obtained from beyond the borders of the plain on a radius larger than 10km. Based on the naturally smoothened surfaces that remain visible in most of the artifacts, it is safe to suggest that the basic procurement strategy was the exploitation of secondary deposits such as stream and river beds or surface concentrations of rolled material, whereas there are no signs at all of quarrying (i.e. samples with completely fresh surfaces are absent, as are furrows or other traces that would indicate extraction from the mother rock).

A limited range of rock types -sandstone, microconglomerate, gneiss, pyroxenite and schist- was selected for the manufacture of grinding tools, querns and handstones, in both Kleitos settlements suggesting a targeted procurement of raw materials. However, when comparing the two sites, a significant divergence of the rates of different rock types is detected: microconglomerate, from representing 37% of the total assemblage of grinding tools in Kleitos I and the second most preferred choice for the manufacture of this type of implements, is reduced to 16% in Kleitos II, whereas gneiss, from 5% and an obviously rare choice in Kleitos I, increases sharply to 34% in Kleitos II (Chondrou *et al.* 2018: 30, fig. 8 and 9). There is also a more pronounced diversity within distinct lithological groups selected for the manufacture of grinding tools in Kleitos I, i.e. presence of different varieties of the basic raw materials (see also Chondrou 2018: 152-154, Annex B, tables B.2.1-2, Fig. B.1.2-1.5, 1.8; Chondrou *et al.* 2018: 30). These two observations could indicate diversified strategies of exploitation of the surrounding landscape that apply different emphasis on or have differential access to the various sources. Moreover, various ethnographic studies highlight the relation between the raw material of the grinding tool, in particular its texture and durability, and the implement's function (e.g. David 1998: 23; Horsfall 1987: 340-341; Shoemaker *et al.* 2017: 423-424). Therefore, a shift of emphasis to a different lithic material for the manufacture of grinding tools detected between Kleitos I and Kleitos II could be related to changes in cooking practices and more precisely to a preference for finer ground ingredients. It has been proven experimentally that the microconglomerate variety found in Kleitos is ineffective in terms of controlled fine-grinding, but ideal for more coarse derivatives (see Chondrou *et al.* 2018).

A very limited number of boulders and rough-outs were found on-site, in Kleitos I exclusively, but no manufacturing debris at all. It appears therefore that the tools, as a rule, were manufactured off-site and brought to the settlements fully formed or as semi-finished products. The same does not apply to the subsequent maintenance activities, which were performed on-site as clearly attested by a unique example of a handstone with incomplete re-pecking of its use-surface. Flaking and pecking were the basic techniques applied in the manufacture of grinding implements in both Kleitos settlements, targeting mainly the shaping of the use-surface of the tool and its periphery. A third technique, abrasion, is encountered in a few cases only. There are, nevertheless, also tools bearing more extensive manufacturing traces which reveal varied ways and sequences of technique application (Figure 4). The absence of homogeneity in the manufacturing process (i.e. manufacturing techniques applied in different ways, in diverse combinations and on varied extent over the tools' bodies) along with the wide variation in morphometric attributes point towards a non-standardized production of grinding tools, with a possible opportunistic exploitation of the available boulders, by many manufacturers with varied level of technical skills (see also Chondrou 2020).

Intensive/extensive curation would be anticipated for the grinding implements of both Kleitos settlements since they are made of non-readily available raw materials and are potentially long-lasting tools. On the contrary, however, the rates of worn-out, redesigned or recycled implements are very low and intact specimens are often detected in non-functional contexts such as pits and ditches, suggesting their non-exhaustive use by Kleitos inhabitants. This is intriguing since it contrasts the image from other settlements (e.g. Early Neolithic Ayios Vlasis and Neolithic Dikili Tash, both exhibiting very high rates of tool exhaustion in domestic contexts and, in the latter case, also in pits). The low degree of use of grinding implements and their status of preservation in relation to their contexts of retrieval permit the hypothesis of consumption patterns driven by other than practical motivations.

Figure 4: Three examples of grinding tools: a rare case of a quern with complete formation of its passive surfaces with pecking and two handstones with peripheral flaking, one coarser and one finer.

Spatial analysis

The overwhelming majority of the finds derives from the two settlements, primarily Kleitos I (554 specimens against 38 from Kleitos II). The difference in the volume of the two assemblages can be primarily associated with the difference in the size of the two settlements. The analyzed samples originate from an area of circa 1.55ha in Kleitos I, whose total extent is 2ha, and 0.25 ha in Kleitos II, i.e. its entire extent. The fragmentation rate is also an influencing factor. At Kleitos I small fragments that represent 1/8th of the original grinding implement or even a smaller portion are twice as many as in its neighbouring site. The material from the area outside the settlement boundaries is minimal. It comprises mostly highly fragmented implements with signs of erosion due to long exposure to environmental conditions resembling, therefore, refuse deposits.

In both settlements no special patterning (i.e. repeated association with specific contexts) is discernible in the intra-site distribution of implements based on the different tool-types or the degree of invested work in the tool manufacture. The same applies to the relatively few exhausted implements: they are located in open-air spaces (23 samples in Kleitos I), ditches (one sample in Kleitos I) and pits (two samples in Kleitos I), as well as building interiors (three cases in Kleitos I and two in Kleitos II). These few exhausted or nearly exhausted tools, almost 5% of the total grinding assemblage of each settlement, represent exceptions to the rule since prolonging to the maximum the use-lives of these implements was, as aforementioned, not a primary concern at Kleitos.

It is noteworthy that only a small fraction of the total assemblage was found to be associated with the interior of dwellings (Figure 5): 55 grinding implements, 47 in Kleitos I (i.e. 8.5% of the site assemblage) and 8 in Kleitos II (i.e. 21%). Their distribution in separate building phases is not homogeneous at both the intra- and inter-settlement level. Kleitos I dwellings (17 building phases) contain zero to 10 grinding implements, whereas Kleitos II buildings (9 building phases) zero to three. A comparison between the two settlements clearly highlights the more limited presence of grinding tools in Kleitos II buildings. Excluding those with no grinding implements at all, the rest seem to contain one quern accompanied by one or two handstones, whereas Kleitos I dwellings tend to have at least two grinding pairs in their interiors (Chondrou 2020, table 2; Chondrou and Ziota in prep.). Although depositional and post-depositional factors may have distorted the original distribution, the recurrent numerical deviation between the two sites, in terms of absolute numbers, and the fact that Kleitos II buildings are generally smaller in dimensions could be indicative of social factors in play (e.g. different composition or type of family group, see David 1998: 23; Horsfall 1987: 358-359, table 7.7).

The tools found in building interiors, although very fragmented, offer evidence of diversity in both terms of size and typology at the household level. The two handstones originating from Building 4 in Kleitos II, for example, both belong to type 1 but present different metrical traits, one exceeding 30cm in length and the other being much smaller (≥20cm). In Kleitos I, one of the very few securely identified type 3 querns was found in the second phase of Building D alongside numerous type 1 implements, among which a wedge-shaped handstone and a loaf-shaped one. The detection of diverse morphometric types in the same context, on the one hand, may reflect differences in the initial form of the exploited raw materials; on the other, it suggests technological diversification at the household level aimed perhaps towards the processing of different substances. The tool-type 2 and 3 minority is spatially correlated with specimens of the dominant type 1, which could indicate that these implements were reserved for special functions of a complementary nature (for ethnographic examples see Arthur 2014; Horsfall 1987). Lastly, it is worth noting that almost all querns from building interiors are quite thick with an average thickness of 7.25cm, therefore having long remaining use-lives.

	QUERNS	HANDSTONES	INDETERMINATE
KLEITOS I	121	207	226
KLEITOS II	18	10	10
AREA BETWEEN THE SETTLEMENTS	1	9	0

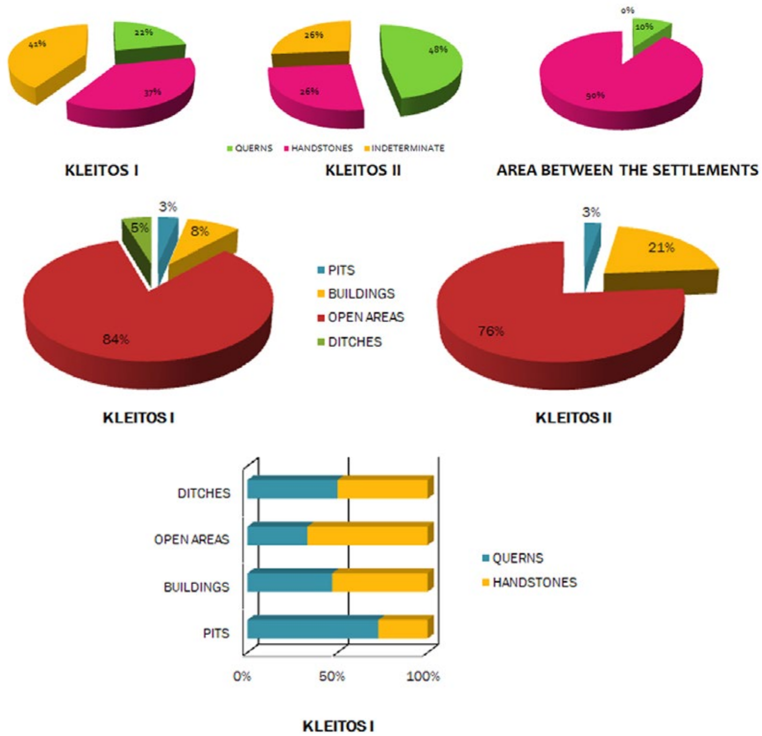

Figure 5: Distribution of grinding tools per type, main spatial unit and various recovery contexts. Synthesis of the grinding tool assemblage per main spatial unit. Relative percentages of querns and handstones between selected Kleitos I contexts.

Grinding tools from building interiors were sometimes found alongside vessels with stored grains (Figure 6), but they rarely shared an intimate spatial connection with clay thermal structures (only 7% of the tools found indoors), which highly contrasts what has been reported from numerous other settlements in Greece and the Balkans (e.g. Bailey 2000; Kalchev 2013; Souvatzi 2013: 55; Todorova 1978: 52; Tringham *et al.* 1985: 431). Zones of the built domestic space with high concentration of clay structures are in most cases empty of grinding implements. The same applies to external spaces: less than 4% of the tools located in open-air areas present spatial connection with thermal structures (Chondrou and Ziota in prep.).

One could oppose to this observed phenomenon the fact that no fixed grinding equipment was identified in Kleitos and that all implements, even the bulkiest ones, were portable, thus allowing changes in the context of the grinding activity if needed, e.g. on a seasonal basis. However, grinding implements are repeatedly found far from thermal structures both indoors and outdoors and the scale of repetitiveness of this pattern does not permit an underestimation of its importance. This is unlikely to be the result of factors influencing the position of the tools after having fallen out of use. Instead, it seems more probable to be a reflection of the choreography of the everyday activity of food preparation, different from what we have seen elsewhere, with the stage of edible substance processing being spatially, maybe also temporally, separated from the cooking process.

Structures identified as milling areas, such as rimmed clay features, have been found in various settlements in Eastern Europe (e.g. Burdo *et al.* 2013: 101, 103; Kalchev 2013). Some very limited indications of the possible existence of such features associated with grinding are found in Kleitos as well. In two cases, one in each settlement and both in relation to open areas, grinding tools were reported to have been found associated with clay structures in such a way that it permits the hypothesis that they were initially inside or on top of them. It is worth noting that they, too, were situated at a distance from thermal structures.

The majority of the grinding implements originate from external areas. Correlating the distribution analysis of the artifacts and their state of preservation, reveals that, with very few exceptions, the grinding implements found in relation to open-air spaces not associated with particular buildings are eroded, sometimes burnt and highly fragmented, most probably representing accumulation of discarded material. Grinding tools are also found outside dwellings, in their immediate periphery, in a few cases in areas with special formation, such as fence-partitions and plastered floors (Figure 7). This external zone seems to have functioned as an extension of the structured space of the household (Chondrou and Ziota in prep.). In the limited cases of well-preserved or even intact implements found in building exteriors, these were located either to the west (e.g. Building H, Kleitos I) or to the north of the building (e.g. Building 3, Kleitos II). If this special positioning reflects indeed functional contexts and, by extension, the organization of the related activities, then it demonstrates spatial preference possibly linked to specific architectural features (e.g. yards connected with the entrance or other openings of the dwellings) or even natural elements (e.g. the direction of wind or the course of the sun and the creation of shade). This idea gains merit if we take into account the fact that the built domestic spaces -at least in the case of Kleitos I- present a similar interior arrangement with the various clay features systematically found along the north wall, rarely along part of the west wall as well. Summed together these repetitive aspects of organization indicate the existence of certain regulatory norms regarding the structuring of domestic space (see also Chondrou and Ziota in prep.).

Depositional practices

Grinding tools, among other types of artifacts, can be detected all over the settlement grounds. Some have been exposed to fire (exhibiting different degrees of exposure) and others not, some are heavily fragmented -with or without signs of deliberate breakage-, eroded or patinated, while others are unaffected by such processes.

As far as the artifacts with signs of fire are concerned, the impression is that they are present everywhere. Their distribution covers both settlements, whereas few are also found in the area beyond their margins. In the case of Kleitos I however, where the assemblage is bigger, the spatial analysis revealed a much higher density in the southwest part of the settlement: 42.9% of the grinding implements with traces of fire originating from open-air areas came from this part of the site. Artifacts have been variously affected by fire, exhibiting a number of alterations. The presence of fragments -with or without traces of deliberate fragmentation- that are evenly burnt on all sides compared to pieces with traces of fire on their external sides but not on their fractured surfaces suggests that in many cases breakage has preceded the exposure to fire.

The distribution of artifacts with signs of erosion shows high frequencies in marginal areas of the settlement grounds revealing long exposure to natural processes, as well as non-peripheral concentrations that can be associated with the burnt remains of buildings (Figure 8). The latter can be attributed to alterations following fire episodes. For example, in Kleitos I the concentration of eroded artifacts in the area of Building F shows also very extensive damage due to combustion, clearly related to the fire episode that destroyed the building; in fact, it stands out for this since it possibly indicates exposure to much higher temperatures than the group of finds from other dwellings.

Figure 6: Grinding implement found in the interior of Building 3 next to a vessel with stored grains. On its dorsal side a small quantity of building debris is preserved along with the imprints of a few grains spilled from the vessel.

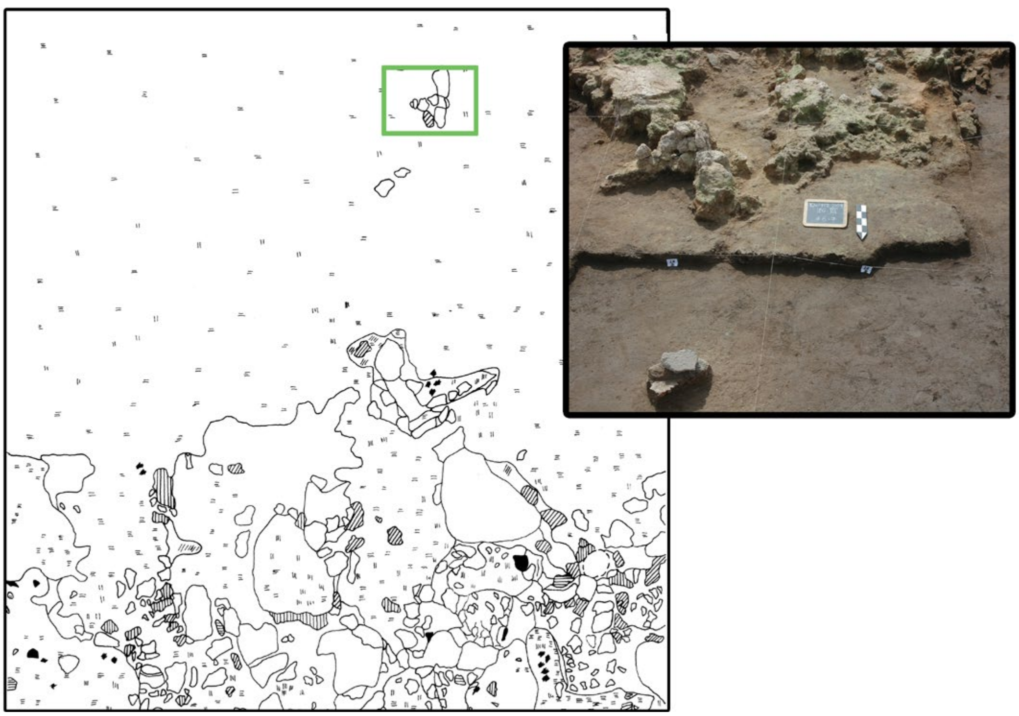

Figure 7: Area immediately outside Building E and the findspot of a fragmented grinding tool on a partially preserved plastered floor (drawing and photograph from the excavation archive of Kleitos).

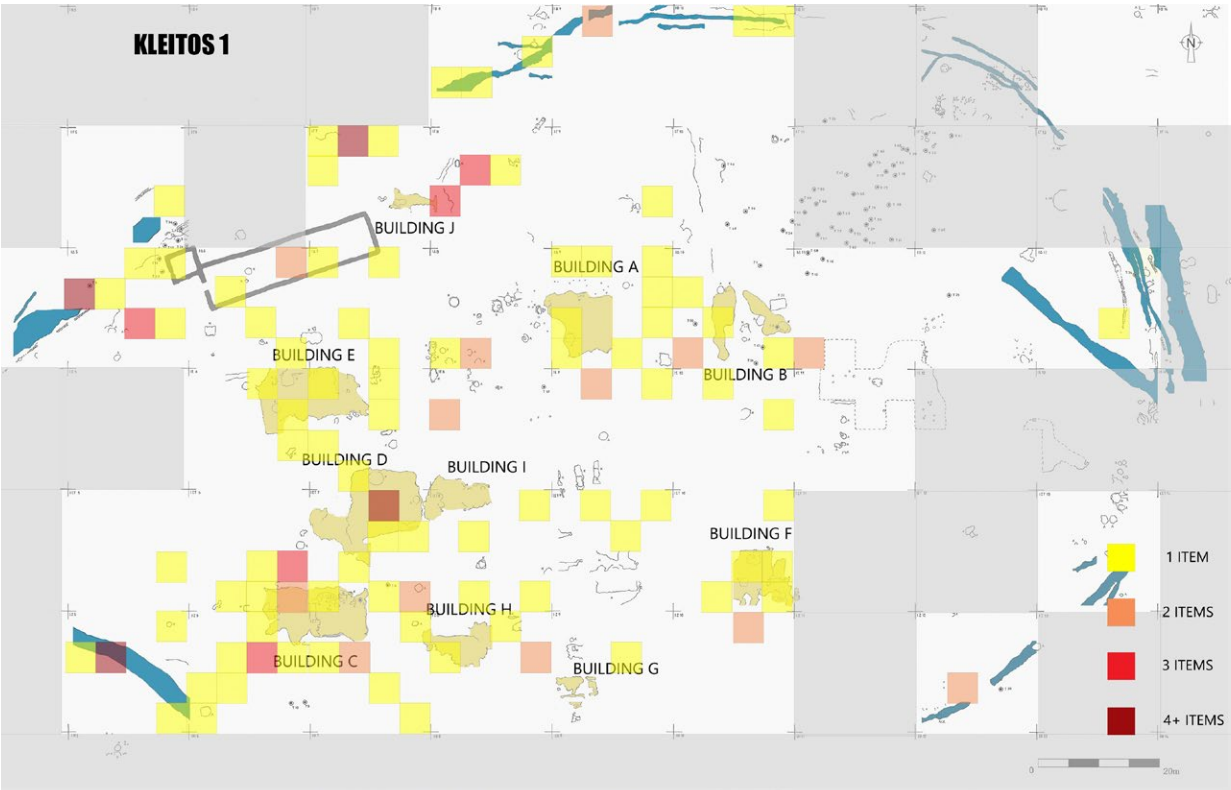

Figure 8: Quantitative spatial distribution of grinding stones with signs of erosion in Kleitos I settlement. The sums of the implements are shown per excavation squarein order for items that have no certain contextual origin to be also included.

The accumulation of discarded material in the open, marginal or not, areas of the settlement seems to be the norm. The concentrations of fragmented, eroded and/or burnt grinding tools -among other ground stone artifacts and material categories- are in some cases thin, indicating possible 'transient' uses of space, but in few other cases, they are continuous in depth indicating successive episodes and long-term spatially focused activities. The practice of retaining disposed of material within residential limits has as a direct effect the proximity of the residents to the objects they have discarded and the creation of more or less dense and visible concentrations. This picture is consistent with observations made in other Neolithic settlements in south-eastern Europe, where the absence of a clear separation of everyday activity areas and special refuse sites is repeatedly noted (Chapman 2000a: 356). These accumulations of fragmented grinding tools alongside other artifacts, outside dwellings, in open-air communal spaces, or in other more remote areas, still visible from various parts of the settlement, should not have been considered 'unpleasant' or dangerous (e.g. to stumble and injure one's feet etc.) by the residents of the site, at least not to the extent that it would require their off-site disposal. In fact, according to the evidence (i.e. signs of erosion and patination), these items were discarded and/ or deposited and gradually accumulated in open-air spaces, where they lay for some time before they were fully covered by sediments. While there is no doubt that these specimens have been discarded, it is equally certain that they did not have a common origin. They have been affected by various, physical and anthropogenic factors, in different spatial contexts and possibly at different periods of time, and have eventually found their way to these peripheral or not areas, most likely through different processes (e.g. site clearance, levelling activities, pit-digging) forming 'cumulative (and temporal) palimpsest' assemblages (Bailey 2006). This means that these accumulations of varied synthesis (i.e. fragments of grinding implements alongside other types of ground stone and flake tools, pot sherds or clay and bone finds) represent a mixing of materials from different episodes of activities (the complete range of which is impossible to clarify), possibly further mixed and displaced through the re-use of specific areas, animal and human traffic or natural processes.

Evidence for the disposal of grinding implements as well as other ground stone artifacts in the ditch system around Kleitos I or for their concealment in or beyond settlement grounds (i.e. interment in pits) is very limited. Contrary to other contemporary cases such as the Neolithic site of Makriyalos with ditches and borrow pits filled with huge quantities of finds accumulated through different processes, such as communal events of conspicuous consumption (feasting) and long-term activities (Halstead 2007; Pappa *et al.* 2004; Tsoraki 2008), or the Neolithic site of Toumba Kremasti where an overwhelming total of 462 pits in the periphery of the settlement were found filled with anthropogenic material (Chondrou 2011; Hondroyianni-Metoki 2009; Stroulia and Chondrou 2013; Stroulia *et al.* 2017: 2-3), similar features in Kleitos do not exhibit such massive contents. Yet, although they represent something else in the sheer scale of volume, they do not seem to serve a primary refuse role either. In both the ditches surrounding the settlement of Kleitos I and the pits inside and outside the two settlements, grinding implements constitute a limited but recurrent component of their infill. The majority has been deposited in a fragmented state. Some implements present irregular breakage patterns or visible percussion marks unrelated to maintenance or reshaping episodes suggesting their deliberate destruction. When examining the tool types in terms of their contexts, it appears that while querns and handstones are equally represented in ditches, in pits querns are the predominant type (Figure 5). Also, the few finds preserved intact in such contexts are all querns but one. Noteworthily, the single exception was found in a pit beyond the margins of the two settlements, an area where few other pit contents were also deemed 'unusual', regarding their typological uniqueness or rarity, compared to the image we have from the residential space (see Chondrou in prep.). Overall, what the data seem to illustrate is a patterned behaviour behind the formation of ditch and pit infills and a distinct symbolic connotation ascribed in the tools synthesizing the grinding pair (see also Chondrou 2020).

From the analysis of the material, their context of retrieval and co-findings it is clear that artifacts ending up in pits and ditches have been exposed to different processes, similar to implements found in open-air areas. Among these processes, burning and possibly to some extent erosion would have occurred prior to their disposal. However, the systematic presence of erosion and its differentiated intensity between different parts of the ditch system seems to reflect the effects of post-depositional processes as well. The evidence suggests the long exposure of discarded materials to natural erosion and therefore the slow infilling of the ditches (not necessarily in the same rate throughout their extent). On the other hand, in contrast to the ditches, the very low presence of eroded finds in pits illustrates their relatively fast infilling. In the case of pits with multiple filling episodes, this could mean either short intervals between successive episodes of use or temporary coverage of the pits in some way. The few finds with signs of erosion originate exclusively from the upper layer of pit infills supporting the aforementioned hypothesis.

Depositional practices - the case of dwellings

Kleitos dwellings have been severely affected by fire. All but one separate building phases in Kleitos I and several in Kleitos II were burnt, yet no signs of a generalized fire have been found to account for the partial or complete destruction of the settlement (Ziota 2014a: 326). Such an explanation would have been insufficient anyway since the buildings were not all contemporary with each other and their destruction must be attributed instead to separate events. Contrary to the edge-tools (i.e. axes, adzes and chisels) retrieved from domestic contexts which are in their majority preserved intact, the grinding tools from the same contexts are completely fragmented, often showing signs of multiple breakages -some not compatible with random or use-related accidents- and repeatedly missing their conjoining parts (see also Chondrou 2020). There is not a single case, among all the building phases that have been excavated in both settlements, where all the fragments of a single grinding tool have been found. This is highly unexpected, even if we take into account the complete destruction of the buildings through exposure to fire and posterior activities in the areas of building debris, such as levelling, the opening of pits or the re-building on top of the remains. In the Neolithic site of Dikili Tash dwellings have also been destroyed by fire and have undergone in some cases post-fire disturbances (Darcque and Tsirtsoni 2010), yet conjoining fragments of grinding implements are systematically found in close association with each other (Chondrou, pers. obs.).

The observed patterns seem to suggest the deliberate destruction of the dwellings and a process of selective decommissioning and removal of their contents. If this is indeed true, then we are dealing with a series of social practices that focus on the house and the intentional ‘closure’ of its life-cycle, applied in many, but not all of the building phases of the two Kleitos settlements. A very interesting exception is the first phase of Building 3 which unlike many of its counterparts preserved a rich inventory of artifacts, among which grinding implements(Figure 9), and impressive quantities of stored products, suggesting that its inhabitants were unable to remove the building’s contents prior to its accidental, as it seems, destruction (Ziota 2014b: 59–60).

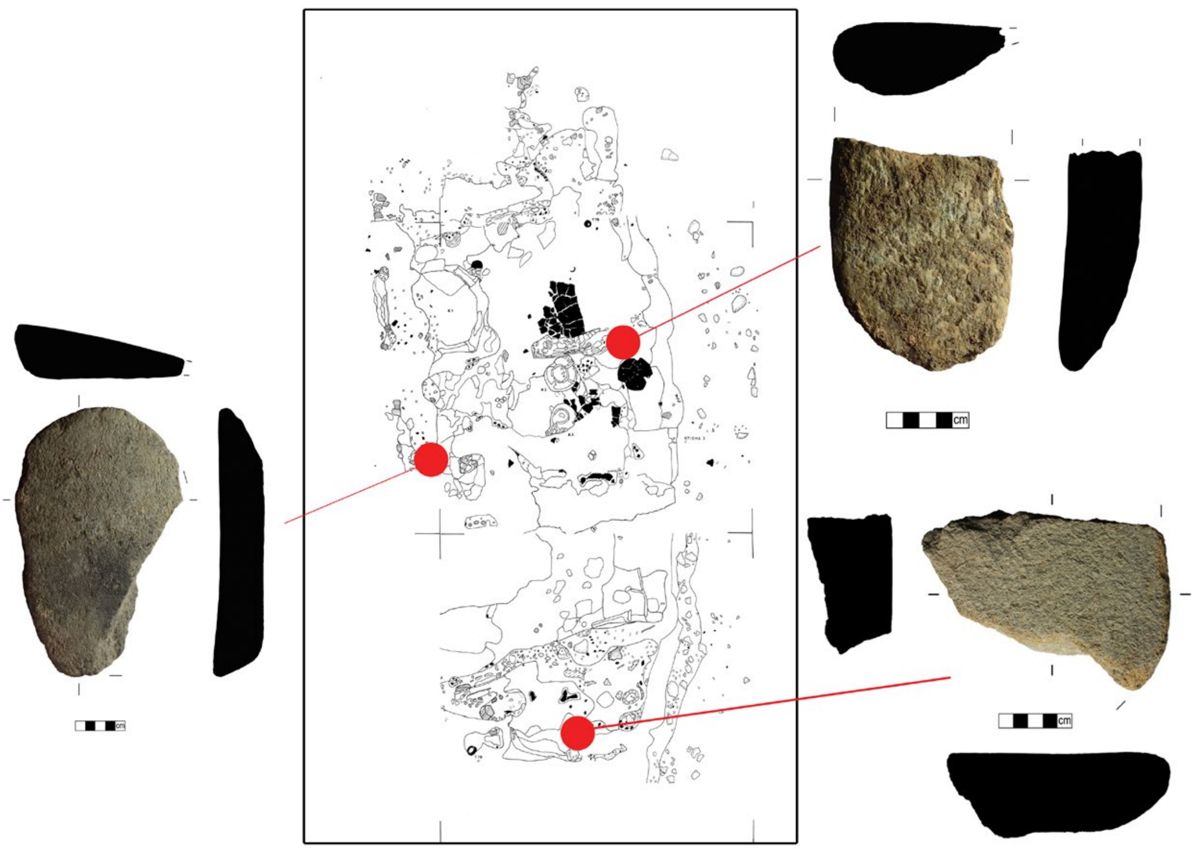

Figure 9: Plan of the first building phase of Building 3 (Kleitos II) and the grinding tools found in its interior. The dots mark the findspots of the implements.

The idea of deliberate house destruction is not new (e.g. Bailey 2000; Chapman 1999; Stevanović 1997; Stevanović and Tringham 1997; Tringham 1991; 2013), the same as the intentional destruction of stone tools. The latter has been supported in numerous cases around Europe (see, for example, Hamon 2006: 143-144; Verbaas and van Gijn 2007: 196-197; Pokutta 2014: 139-140) among which for several assemblages in north-western Greece where it is perhaps not unwarranted to say that there seems to be a shared tradition of (ritualized?) social practices regarding the special treatment of material culture in the context of the house or beyond: two neighbouring settlements within the margins of the Kitrini Limni Basin, Late Neolithic Toumba Kremasti (Chondrou 2011; Stroulia and Chondrou 2013; Stroulia 2014) and the Late Neolithic site of Megalo Nisi Galanis (Stroulia 2005: 576); Late Neolithic Makriyalos (Tsoraki2008), Middle/Late Neolithic Avgi (Bekiaris 2020) and Late Neolithic Dispilio (Ninou 2006: 106). Also, the contrasting pattern in the manipulation of edge tools and grinding tools has been reported elsewhere as well, in Late Neolithic Makriyalos (Tsoraki 2008: 106-108, 122-125, 129) and in numerous cases from the Balkans (Chapman 2000b: 93–94).

One question that arises in the case of the grinding implements of Kleitos dwellings is where their missing conjoining fragments are. Heavily fractured items are literally everywhere in Kleitos, a site where the fragmentation rate of the grinding tools reaches an extraordinary 97%, with no more than 18 complete implements (6 querns and 12 handstones). Many of the fragmented items bear also traces of fire. It is possible that some of them represent the missing parts of the specimens found in the building interiors. However, no refitting between fragments found outside the dwellings and fragments found in house interiors has been made possible so far, except for one case, a multifunctional abrasive-percussive implement broken in two halves, which were found at a distance greater than 5m from each other, one having been affected by fire, the other not (Chondrou in prep.).

Overall, dwellings appear to have been deliberately abandoned and their grinding equipment decommissioned, before they are left to the devastating effects of the fire. The grinding tools are systematically located broken without their conjoining fragments. They represent different biographical stages, some having long remaining lifespans and others (a few) not, having been extensively used. The presence of exhausted tools in houses, although limited, could indicate their vertical cycling, i.e. their transfer from one building phase to another, and from one generation to the next (see also Wright 2014). However, only in two cases were exhausted tools found in the final phases of buildings, with previous phases of the same buildings also containing abandoned implements. This is not what one would expect in a society that is based on cross-generational wealth transmission. As Wright (2014: 26) notes, absence of abandoned implements would be anticipated for the earlier phases of a building and extensively used implements for the last one. As aforementioned, these implements of very prolonged use constitute an exception in Kleitos where the general practice was that of intentional decommissioning of still usable tools. Grinding implements, both fragmented and burnt, present an extensive dispersion all over the residential area. Some of these may very well be the remains of the destructive practices focused on the dwellings.

Discussion

According to this short overview, Kleitos grinding tools were incorporated in particular spatial and social spheres at various stages of their life-cycles following specific norms. Made from raw materials not locally available, they were brought ready-made to the settlement but were regularly maintained on-site. They formed a stable, inextricable part of the household toolkit, functioning in strong spatial association with the household domain (interior and exterior spaces included), yet rarely to the point of exhaustion. Instead, it seems that various culturally-driven practices often dictated their abrupt end, mostly through breakage and burning, possibly in connection with the life-cycles of the dwellings of which they were a part of, or the life-stages of individuals, or even episodes regarding the community as a whole (for ethnographic references to varied occasions of 'ending' an artifact's life, such as disease, death or special events of conspicuous consumption, see Adams 2008; Chapman 2000b; LaMotta and Schiffer 1999). In some cases a change in the artifacts' context is also evident with their deposition in ditches and pits or their disposal in open-air settlement areas. Of course, not all burnt and fragmented items are the product of 'ritualistic' behavior. What is important in the case of Kleitos is the striking tendency for non-exhaustive use of the grinding implements and the clear evidence of their varied manipulation. Fragmented specimens with irregular breakage patterns and/or clear percussion marks, results of neither an accident nor extensive wear, enhance the likelihood of intentionality. Similar phenomena can also be detected to other ground stone tool categories e.g. maceheads, although not in the same frequency (Chondrou 2018). The fact that such 'specially' treated implements end up side by side with others that have not been similarly manipulated, in contexts that more often than not do not resemble 'special' deposits enhance the idea of no clear boundary between secular and ritual.

Overall, although the grinding implements are present all over the excavated area, very few of them seem to be in the contexts of their primary use, having instead been moved, with or without having been previously subjected to a series of transformative actions. This performative manipulation seems inextricably linked to the intrinsic power of these tools, which lies in the symbolic references they incorporate throughout their life-cycles and their involvement into various daily-life processes and special social events and in all the memories they can evoke in relation to these events and their participants, their owners and users, alongside other possible links to their manufacturers or the sources of their raw material (see also Hodder 2005: 183-185).

These practices of material culture manipulation are not unprecedented in the area of Kitrini Limni. In the neighbouring site of Toumba Kremasti, tools end up deposited -complete or parts of them- in pits in the periphery of the community or maybe even further away (Chondrou 2011: 169-170, Stroulia and Chondrou 2013), after having been used and diversely manipulated (burning, fragmenting). In Kleitos, instead, when tools are finally decommissioned, their fragments often remain visible for a long period of time at various parts of the settlement. For the residents of the site, these tools may have served as reference points to previous contexts and practices in which they were used before finally being incorporated into the anthropogenic layers that literally formed the foundation of the community. To conclude, it can be hardly supported that the importance of grinding tools in Kleitos is illustrated through their longevity as functional implements used for the daily grind. Instead, their significance is clearly highlighted through their implementation in various practices that stretch beyond the tools' primary use, linking them with the entity of the household and the community as a whole.

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5. Macro-Lithic Tools And The Late Neolithic Economy In The Middle Morava Valley, Serbia

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Introduction

Information on macro-lithic tools from the Central Balkans is still limited, although they represent a major source of paleo-economic information (Antonović 1992, 1997, 2000, 2003: 59; Живанић 2010). Observations show that a wide variety of raw materials were of raw materials used to manufacture macro-lithic tools during the Late Neolithic of the Central Balkans (5400/5300- 4650/4600 BC). During the last years geo-archaeological as well as ethnographic research has confirmed that riverbeds in the vicinity of settlements were the main source of raw material (Prinz 1988: 256; Risch 1995; Hampton 1999: 224; Stout 2002; Antonović *et al.* 2005: 66; Antonović 2003: 18). Some results show that the quality of certain rocks was recognized and appreciated over distances of hundreds of kilometres (Risch 2011; Szakmánz *et al.* 2009). However, the long-distance exchange could involve complex mechanisms of social needs and relationships (Pétrequin *et al.* 2017; Risch 2011: 114).

Despite recent evidence that metallurgy was present from its beginning, the Vinča culture at the Central Balkans is labelled traditionally as a Late Neolithic culture (cf. Porčić 2012: 23). The sedentarism caused a new socioeconomic organization, as the need to supply a growing population consequently impacted food production, accessory items of technology, and non-subsistence goods. This led to greater investments of labour and restructuring of activities, resulting in an economic intensification (Kaiser and Voytek 1983: 329). The recent analysis of rocks, presented in Vučković's (2019) thesis on the Neolithic economy and macro-lithic items in the Central Balkans, has allowed the identification of three geo-economic regions. The term geo-economic region represents characteristics of the economy based on features of the raw material of macro-lithic tools involved in the different activities of a studied area. These regions have been identified primarily by rocks used in grinding technology. In addition to their intensive implementation in the whole of the Central Balkans, sedimentary rocks were also the most important rock type to the economies of the north-western part of the Central Balkans and the southern part of the Pannonian Plain. The second area is defined by the importance of igneous rocks in grinding technology in the south and south-west of the Central Balkans. The third geo-economic region is located in the Middle Morava Valley, where igneous, metamorphic, and sedimentary rocks were used likewise for tools with abrasive surfaces.

This paper focuses on the economy of the latter geo-economic region identified in the Middle Morava Valley, based on the evidence of the Late Neolithic settlements of Slatina - Turska česma, and Motel Slatina (Figure 1, 2).

Aims and objectives

A geo-archaeological analysis was employed in order to elucidate the economic characteristics of Middle Morava Valley during the Late Neolithic. This approach has enabled the identification of the social value of rocks and their procurement strategy, which informs about the time invested in transport as

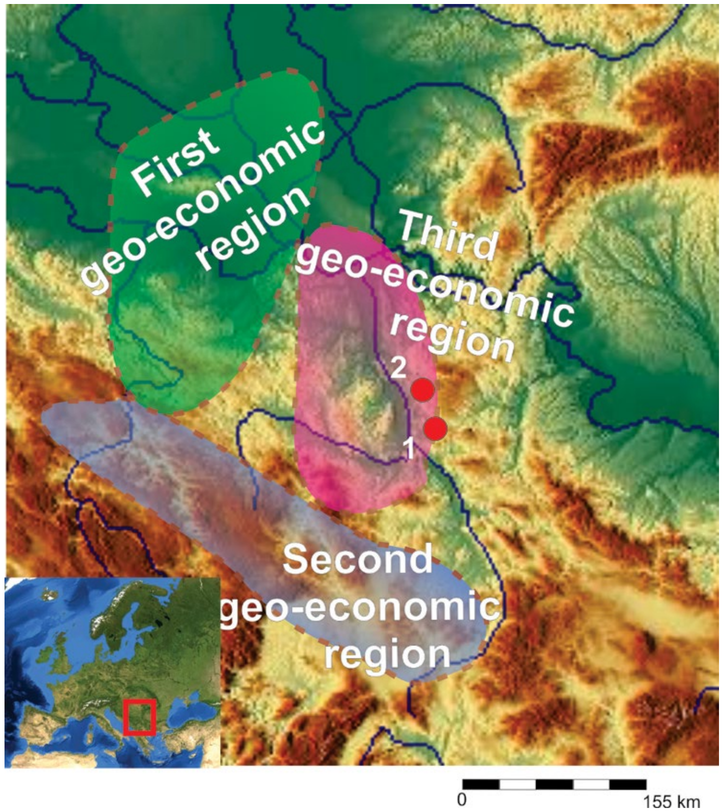

Figure 1: Geo-economic regions and position of Late Neolithic settlements from which macro-lithic tools have been studied: 1. Slatina - Turska česma; 2. Motel Slatina. R 1: 310 000.

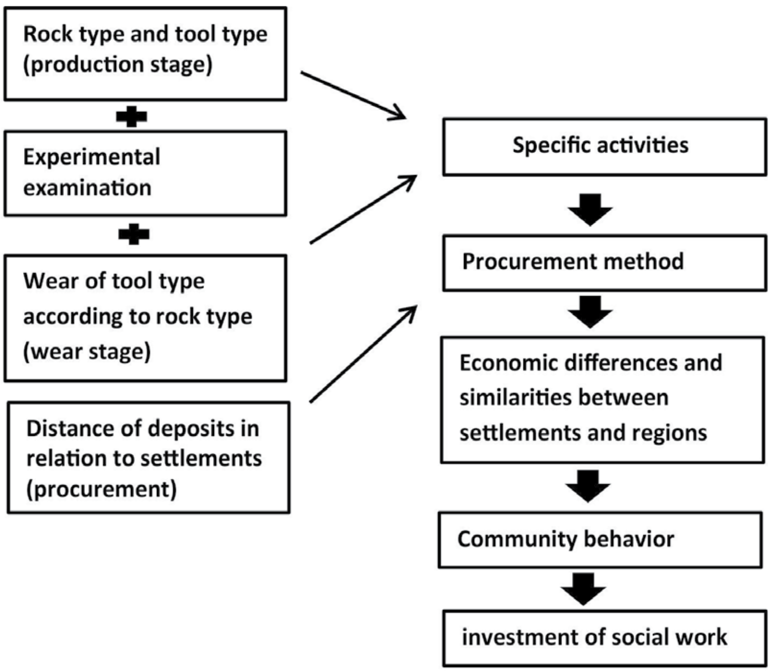

Figure 2: Analytical steps of geo-archaeology analysis.

well as availability, quality, behaviour, and mechanical properties. The evaluation of Motel Slatina as a distribution centre has been also part of this observation. Ultimately this information provides the avenue for discussion of the socio-economic organization of the communities in this area, territorial borders, the *community behaviour* concerning other communities, and lastly the remote exchange of raw materials.

Table 1: Middle Morava valley: number of rock types according to the settlements.

	type of tool	**Slatina - Turska česma/N**	**Motel Slatina/N**
1.	grinding slab, grinding slab?	24	4
2.	handstone, handstone?	8	6
3.	mortar ?	1	
4.	abrasive slab, abrasive slab?	49	8
5.	abrader, abrader?	150	48
6.	abrader with groves		6
7.	axe, axe?	10	11
8.	celt	7	14
9.	adze	1	3
10.	chisel	1	2
11.	percussive tools	39	16
12.	perforated axe	10	
13.	perforated mattock		2
14.	hammer, hammer?	10	10
15.	pestle	12	8
16.	re-used polished edge tool	1	4
17.	figurine, figurine?		2
18.	braclet	1	
19.	discoidal object	1	
20.	mace, mace?	1	2
21.	anvil	3	1
22.	flakes knocked of the tools with polished edge tool	29	2
23.	raw material, raw material	8	8
24.	semi-finished product	2	2
25.	weight for fishing net	30	
26.	unidientified tool type	18	28
	In total	**416**	**187**

Table 2: Middle Morava valley: number of tool types according to the settlements.

	rock type	Slatina - Turska česma/N	Motel Slatina/N
1.	alevrolite, alevrolite?	77	77
2.	amphibolite	9	14
3.	andesite	1	4
4.	basalt	1	3
5.	claystone	2	5
6.	diabase	2	1
7.	diorite		6
8.	flint		2
9.	gabbro	8	6
10.	gabbro-diorite	5	
11.	gneiss	2	1
12.	gneiss-granite	2	
13.	granite	3	1
14.	light white stone	5	
15.	limestone	3	2
16.	marble		2
17.	marl	1	1
18.	micro-conglomerate	2	
19.	peridotite (serpentinite)	3	
20.	phylite	1	2
21.	quartzite	33	11
22.	sandstone	232	46
23.	schist	19	2
24.	schist?	1	
25.	skarn	2	
26.	unknown	2	1
	In total	**416**	**187**

Materials and methods

The analysis of 603 artefacts classified in 25 tool types and 25 rock types consists of three stages including the results of an experimental examination (Figure 2; Table 1 - 2). All the raw materials analysed in this study have been classified macroscopically with a hand loupe (10x)[1]. Microscopic analysis of petrographic thin section has been carried out on four selected samples from, Slatina - Turska česma[2] (Vučković 2019: chapter 5.1).

The initial stage of the analysis is the correlation between rock and tool type which allows for the separation of specific activities such as grinding, cutting, polishing etc., based on the importance of certain rocks in the manufacture of different tools. The second stage of the analysis is the *correlation between rock type and tool wear.* This provides insight into the intensity of the use, quality of raw material, and the correlation between rocks and mechanical stress of specific activities. Here, tests to address the mechanical behaviour of the raw materials are performed. The final stage *is the study of procurement strategies.* It is based on the distance between the raw material deposits and settlements. This approach reveals patterns of raw material exploitation according to the sites and regions and includes possible contacts and exchanges with other communities.

Paleoecology, geology, and geomorphology of the Middle Morava Valley

The Late Neolithic settlements of Motel Slatina and Slatina - Turska česma cover areas of more than 40 ha on gentle slopes at the Middle Morava valley or Paraćin – Jagodina basin, which lays in the northern part of the Balkan Peninsula (Figure 3).

The Middle Morava valley is bordered to the south by mountains consisting mainly of gneiss and phyllite mica shist formed during the Paleozoic. The eastern and the northern boundaries are represented by the Paleozoic orogen formations and consist of limestone ranges, schist, red sandstone, and breccia. The Paleozoic volcanic activity in the eastern area created a gabbro formation 3.5 km long and 1.5 km wide. The western part of the central region provides granite, mica-schist gneiss, and amphibolite. Vast blocks of quartz are visible on the same side, under the lacustrine deposits (Milojević 1951: 1, 2; Marković 1954: 23, 25; Geological map of Kragujevac - Zaječar). The Triassic is represented by limestone and dolomite rocks. Volcanic activity in the eastern part of the valley formed andesite, rhyolite, and volcanic tuff (Marković 1954: 25; Andjelković *et al.* 1992b: 10, 32, 33, 58) (Figure 3). The mountain's lacustrine depression was developed during the Oligo-Miocene. The Oligocene lacustrine deposits consist of sandstones, marls, and schists which covers a wider area, reaching an altitude between 225 m to 500 m. Miocene formations consisted of limestone, sand, and marl. During the Pliocene appeared the Pontic lake, represented by deposits of sandstone and clays, reaching an altitude up to 540 m (Marković 1954: 25; Andjelković *et al.* 1992a: 75, 78, 97, 155). These geological conditions provide a great variety of type sources for the communities of the Late Neolithic. Moreover, we can observe the importance of secondary deposits, as the settlement of Motel Slatina reaches a bank of the Crnica river and, at the eastern part of the site of Slatina - Turska česma (Figure 3), lays a dried riverbed of the Drenovac stream, oriented in the east-west direction with two springs in its vicinity.

1 The raw material was analysed macroscopically by Dušica Petrašinović, petrographer of the High School of Geology and Hydrogeology, Belgrade. She offered a short general macroscopic description of the rocks.

2 Microscopic analysis of petrographic thin section has been carried out on four selected samples at the Autonomus University of Barcelona. These analyses were undertaken by Francisco J. Fernández, David Gómez-Grass (Geology Department) and Roberto Risch (Prehistory Department), all from the Autonomous University of Barcelona.

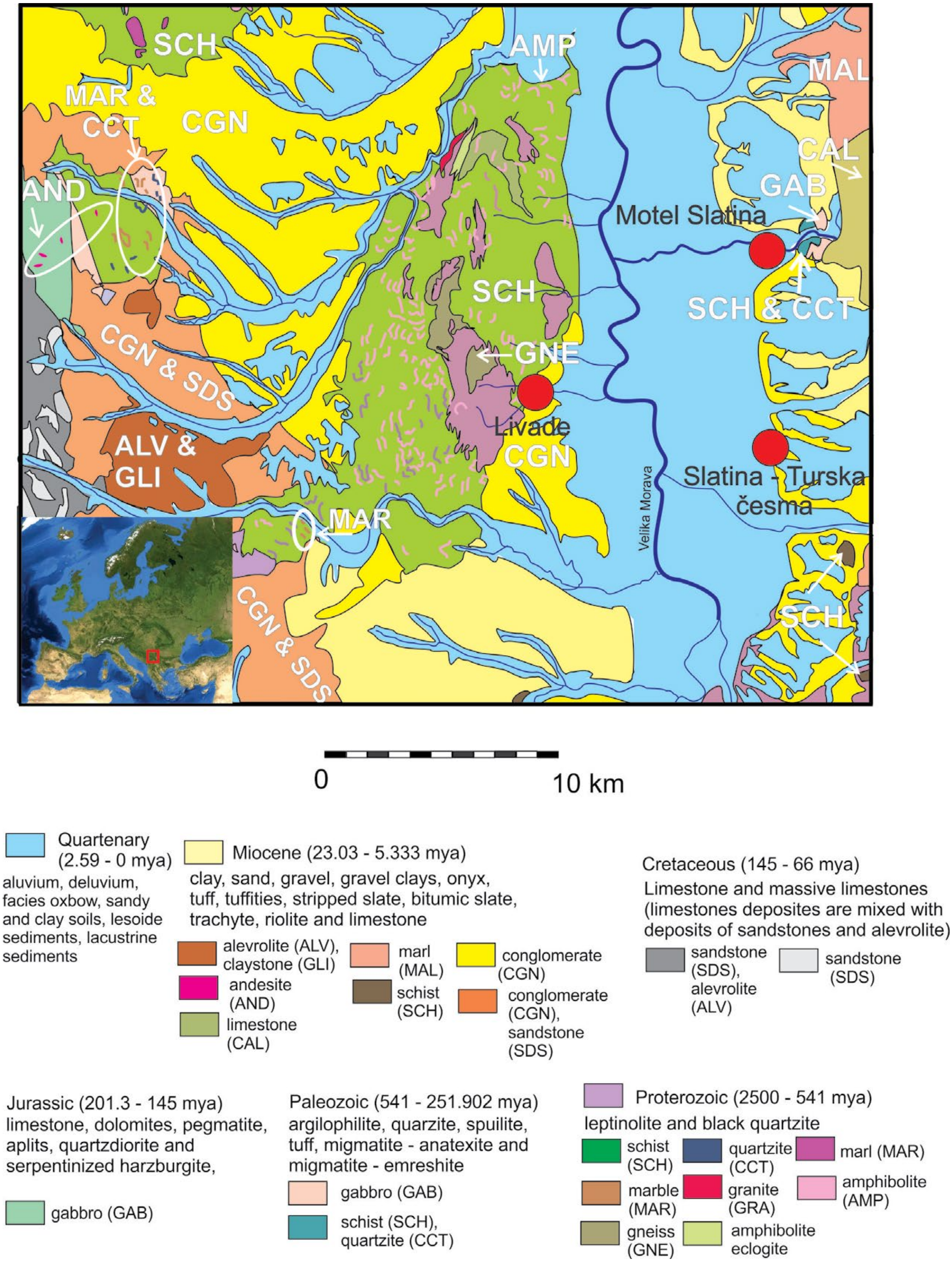

Figure 3: Geological map and position of settlements of Motel Slatina, Slatina - Turska česma and Livade; adopted after: geology map L 34 – 7 Paraćin 1: 100 000.

Results: a. Motel Slatina

The result of the analysis suggest that *c.*70% of the artefacts of the settlement of Motel Slatina are made of sedimentary rocks such as (meta)alevrolite, sandstone, flint, light white stone[3] and limestone (Figure 4a). They were used mainly for manufacturing small abrasive tools[4], polished edge tools[5] percussive tools[6] and a grinding slab (Vučković 2019: fig. A 1.9).

Around 18% are tools made of metamorphic rocks such as amphibolite, quartzite, schist, gneiss, marble, and marl. These rocks were employed mainly to manufacture abraders, grinding slabs, handstones and percussion tools[7] (Figure 4b; Vučković 2019: fig. A 1.9).

Igneous rocks such as diorite, basalt, diabase, gabbro, peridotite, and granite represent c.11% of the artefacts (Figure 4c) which include objects such as abrasive slabs, axes, pestles, and a mace (Vučković 2019: fig. A 1.9).

A correlation between rock type and tool type indicates a connection between coarse-grained sandstone, and a grinding tool, hammers and an object that might be a part of a figurine. (Meta)alevrolite was suitable for manufacturing polished edge tools[8], re-used polished edge tools, tools with traces of secondary modification, a fine-grained abrader[9], and a multi-functional utensil, used as an anvil and retouching tool. This rock type has been identified among the flake negatives knocked off the polished edge tools as well. Finally, marble was implemented in manufacturing a figurine, while schist was used for a probable grinding tool and gabbro for mazes. A pressure-retouching tool was made of basalt and a semi-finished product of amphibolite (Table 3; Vučković 2019: fig. A1.9).

Most of the tools are poorly preserved regardless of rock type. It can only be remarked that light white stone items are mainly preserved. However, this conclusion should be considered carefully due to the small number of items (n=5). The results indicate that items made of sandstone, amphibolite, and igneous rocks show the greatest level of wear (Table 3; Vučković 2019: fig. A 1.10; Table A 1.2).

The results suggest that 19% of the implemented geology such as quartzite, schist, gabbro, and limestone come from the immediate vicinity or *c.* 800 m to the east (Figure 3, 5). Amphibolite, marl, granite, gneiss, diabase, basalt, sandstone, diorite, and andesite pebbles were available in secondary deposits of the Velika Morava river. The geological cartography of this area shows that marl deposits have been documented *c.* 6 km to the northeast, an amphibolite deposit has been detected *c.* 7 km in a direct line to the west and deposits of gneiss and granite are 12 and 14 km to the west. Unlike this, more than 45% of raw material comes from a distance further than 20 km. (Meta) alevrolite and sandstone compose the largest portion of this group, and their deposits have been identified between 23 and 26 km to the

3 Light white stone is a term used in Serbian archaeological literature, established by Antonović D., due to the lack of more precise petrological determinations of a group of macroscopically similar rocks. This group includes rocks such as magnesite, altered and metamorphosed tuffs, *white ash-tuffs,* porcelanite or *cherty shale* and *diatomaceous earth*. In some cases, the petrographic analysis could not provide a precise determination. These rocks are light, porous and relatively soft, showing different shades of dirty white and yellow-white colour. They are mostly fine-grained, compact and tough displaying a conchoidal fracturing pattern and various hardness –from 4 to 6 according to Mohs' scale (cf.Antonović 2003: 137).

4 coarse-grained abraders and fine-grained abraders.

5 axes, celts, adzes, and chisels.

6 re-used polished edge tools, hammers, pestles, retouching tools, and perforated mattocks.

7 Pestles, percussive tools, and a hammer.

8 Adzes, a chisel, and celts.

9 As the petrographic composition of the rocks affects their abrasive capacity and function of abraders (Delgado-Raack *et al.* 2009), not only the rock type, but also the grain size has been taken into account.

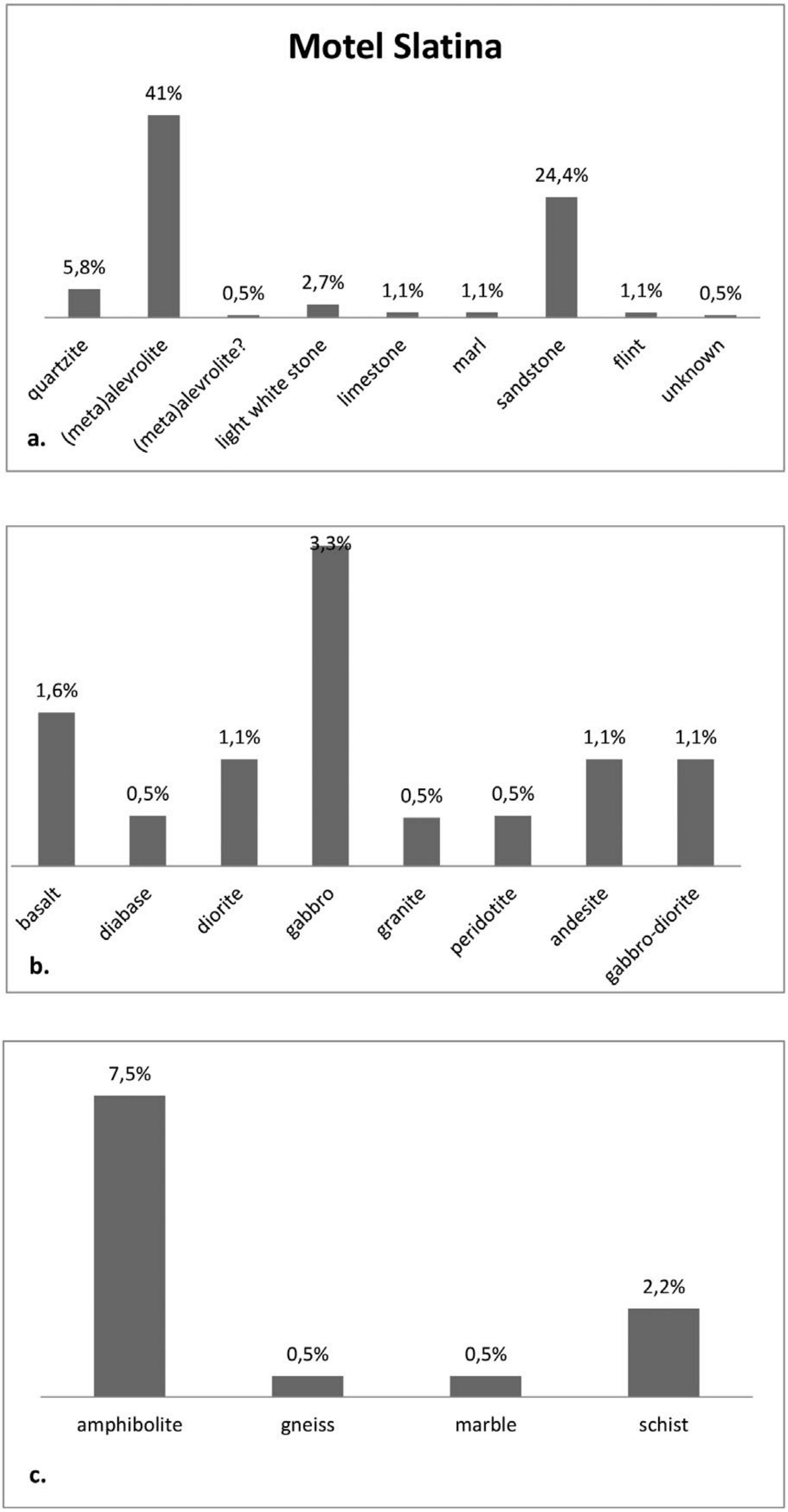

Figure 4: Motel Slatina: Raw materials and source distance.

Southwest. Towards the same direction, at a distance around 24 km, claystone and marble deposits have been detected. Furthermore, geological exploration suggests that a different claystone source has been detected *c.* 14 km to the south of the site (Dolić *et al.* 1981: 27). Diabase deposits are present only in the eastern part of the Gledićke mountain, which is located *c.* 30 km to the west of the settlement[10] (Dolić and Kalenić 1981: 21; Figure 3, 5). An andesite layer is found *c.* 28 km to the northwest of Motel Slatina (Figure 3, 5). The specific origin of gabbro-diorite and flint is still unknown.

Table 3: Middle Morava Valley: Results of the first and second analytical steps according to settlements.

site	The first analytical step: correlation between rock type and tool type		The second analytical step: rocks with the greatest level of wear
Motel Slatina	coarse-grained sandstone	grinding tool, hammers and figurine?	
	(meta)alevrolite	polished edge tools, re-used polished edge tools, tools with traces of secondary modification, a fine-grained abrader, and a multi-functional utensil, used as an anvil and retouching tool, flake negatives knocked off the polished edge tools	sandstone, amphibolite, and igneous rocks
	marble	figurine	
	schist	grinding tool ?	
	gabbro	mazes	
Slatina - Turska česma	sandstone	small abrasive tools, percussion tools and a mortar?	
	(meta)alevrolite	a chisel, celts and axes, a pendant, the tools with traces of secondary modifications and flake negatives knocked off the polished edge tools	schist and igneous rock
	Light white stone	an adze	
	claystone	a bracelet and a maze?	
	quartzite	an anvil-retouching tool and fine-grained abrader-percussion tools.	

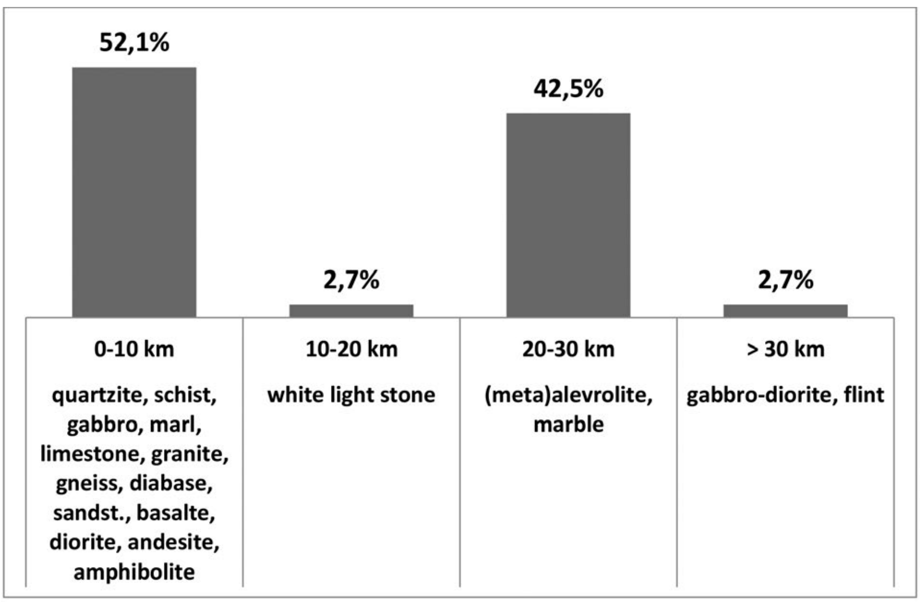

Figure 5: Slatina - Turska česma: Raw materials and source distance.

10 See: geology sheet L 34 – 7 Paraćin 1: 100 000, http://geoliss.mre.gov.rs/OGK/Raster Serbia/OGKWebOrig/listovi.php?karta=Paracin

b. Slatina - Turska česma

Around 77% of the objects from the Late Neolithic settlements of *Slatina - Turska* česma (Figure 3) are of sedimentary rocks such as sandstone, (meta)alevrolite, limestone, claystone, light white stone, and micro-conglomerate (Figure 6a). These rocks were used for manufacturing small abrasive tools[11], percussion tools[12], polished edge tools[13], and grinding tools[14] (Vučković 2019: fig. A.1.11).

Around 17 % of all studied tools from the Late Neolithic horizons are of metamorphic rocks such as amphibolite, quartzite, schist, gneiss, and marl (Figure 6c). For example, these rocks were implemented in manufacturing small abrasive tools[15] percussion tools, an axe, and a handstone (Vučković 2019: fig. A1.11).

Around 4% of the tools are of igneous rocks such as gabbro, basalt, diabase, skarn, granite, peridotite, and gneiss-granite (Figure 6b). They were employed in manufacturing percussion tools[16], and grinding tools[17](Table 3; Vučković 2019: fig. A.1.11).

A correlation between rock type and tool type indicates a link between sandstone and small abrasive tools[18], percussion tools[19] and an object that probably was used as mortar. (Meta) alevrolite was linked with a chisel, celts and axes, and a pendant as well as with the tools with traces of secondary modifications. This rock type was detected mainly among the flake negatives knocked off the polished edge tools. Light white stone is connected with an adze and claystone with a bracelet and an object that could represent a maze. Quartzite is linked with an anvil-retouching tool and fine-grained abrader-percussion tools (Table 3).

The results indicate that around 74% of material came from an area, which can be found locally, at a distance below than 10 km to the west of the settlement. This large group includes pebbles of granite, micro-conglomerate, quartzite, limestone, basalt, etc, which have been detected during our geo-archaeological survey along the Velika Morava river (Vučković 2019). Primary deposits of sandstone, gneiss, and amphibolite are located between *c.* 12 to 18 km to the West. Granite sources are found *c.* 18 km to the Northwest. Probably, gneiss-granite came from the contact zone in the same area where gneiss and granite appeared, although our geoarchaeological surveys have confirmed that these rocks can be found in the fluvial deposits of the Velika Morava river.

Around 21% of the studied objects are made of rocks whose deposits have been documented in distant areas. This group consists of marl with a source located 20 km to the west of Slatina - Turska česma as the crow flies. (Meta)alevrolite and clay are found also 21 km to the west and diabase sources exist *c.* 30 km in the same direction. Gabbro, limestone, and schist appear *c.* 8 km to the north. Quartzite probably came from the Pliocene lake cobble deposits of quartzite and igneous rocks, visible on the terraces of the Morava river. Such a terrace was identified in the vicinity of the Drenovac village which is *c.* 4 km to the west of the site of Slatina - Turska česma (Milojević 1951: 6). Geological research has also identified

11 Coarse-grained abraders - ALS, fine-grained abraders, a fine-grained abrader – retouching tool, and a coarse-grained abrader-anvil.

12 Hammers, percussive tools, pestles.

13 Axes, celts, a chisel, and an adze.

14 Grinding slabs and handstones.

15 Coarse-grained abraders, fine-grained abrader, a fine-grained abrader – percussive tool;

16 Pestles, retouching tools, a percussive tool– anvil;

17 Grinding slabs and handstones;

18 Coarse-grained abraders, fine-grained abraders.

19 Hammers, and an anvil, a retouching tool.

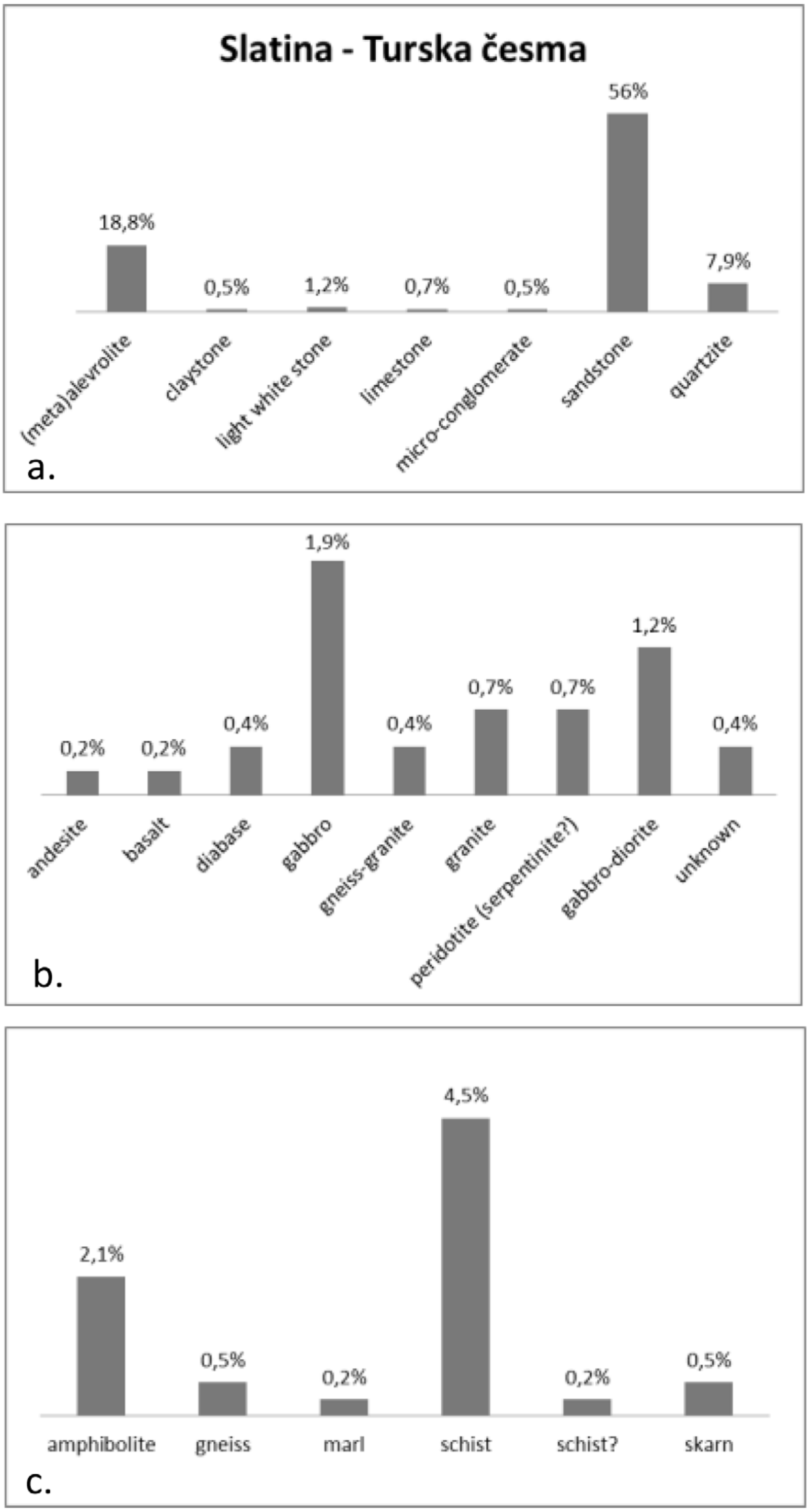

Figure 6: a) Slatina - Turska česma: sedimentary rocks and unknown rock type; b) igneous rocks; c) metamorphic rocks; N=416.

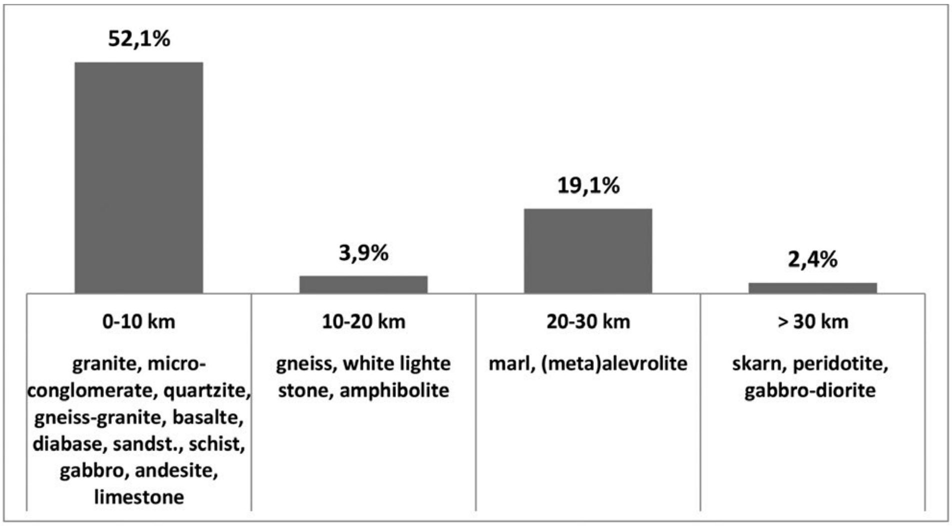

Figure 7: Slatina - Turska česma: Raw materials and source distance.

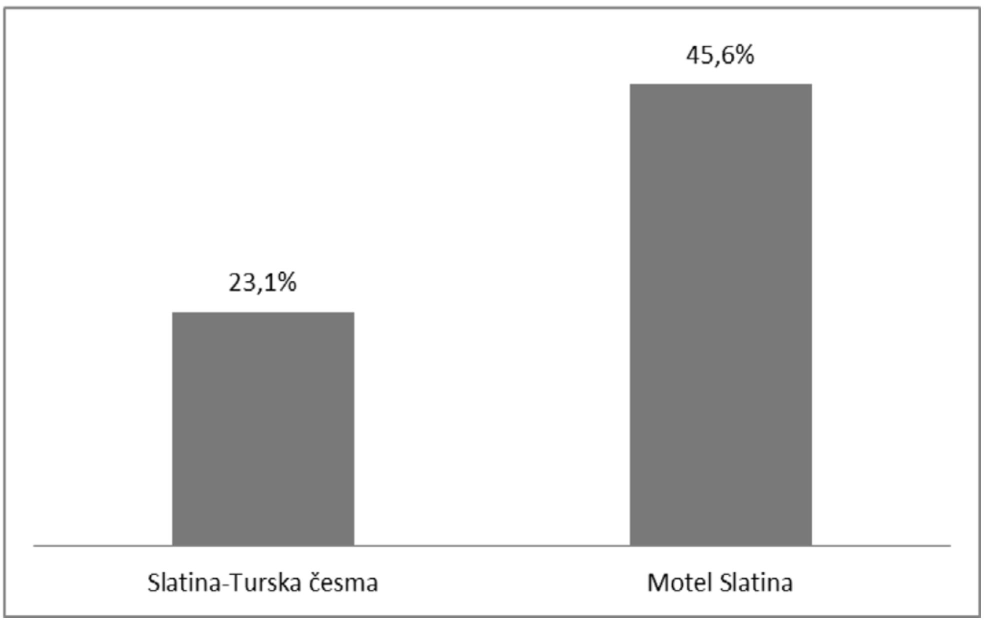

Figure 8: Motel, Slatina and Slatina - Turska česma: proportion of dependency on raw material from the western part of the Central region; N=222.

a claystone source *c.* 4 km to the south of the settlement (Dolić *et al.* 1981: 27) (Figure 3, 7). However, the origin of peridotite, gabbro-diorite, skarn, as well as sandstone used for large tools with an abrasive surface in the settlement remains unknown (Figure 3,7). However, we believe that skarn could be found in the riverbeds, while rocks for large tools with abrasive surfaces might be preferentially collected in primary deposits, which offered a better choice in the size of required raw materials.

The objects from this settlement show a very poor level of conservation, indicating the intensive use or poor raw material quality, such as the tools made of schist and igneous rock (Table 3; Vučković 2019: fig. A 1.12; table A 1.2).

Geological investigations confirm that amphibolite deposits exist in the southwest and northwest of the region (Figure 3) (Vučković 2019). An archaeological surface survey detected the Late Neolithic site of Livade in the vicinity of this southwest amphibolite source (Documentation by Hometown Museum, Paraćin, Serbia) (Figure 3). In this sense, it can be expected that an amphibolite distribution centre with skilled workers was established, from where products were distributed to both of the Late Neolithic settlements present in this region (Figure 3, 5, 7; Vučković 2019: fig. A 1.9, 11). Furthermore, the results indicate economic and social connections with the western part of the region (Figure 3). This is particularly evident for communities near Motel Slatina, where around 45,6% of raw material originated (Figure 3, 5, 7, 8). It should also be mentioned that diabase detected in both Late Neolithic settlements of the Central region probably derived from diabase-chert. This formation is presented only in the Gledićke Mountain, in the western part of the Central region (Dolić and Kalenić 1981: 21).[20]To understand the meaning of a selection of raw materials, experimental tests were conducted to examine the working efficiency of five different rock types (sandstone-variety a, with silicified cement, sandstone-variety b, with carbonated cement, gabbro-diorite, gabbro, and amphibolite), used as grinding and abrasive tools during the Neolithic at this area. During the working of stone against stone, water was used to remove stone dust from the active surface. Thus, the examination was conducted on a moist working surface. These tests classified gabbro-diorite and sandstone-variety a (with silicified cement) as very efficient for grinding, while amphibolite and gabbro are not defined as preferable for work (Vučković 2019)[21].

Discussion

The geo-archaeological analysis of the Late Neolithic macro-lithic artefacts from of the Middle Morava Valley leads us to define economic specifies including the various values of rocks and procurement methods of the studied area. These procurement strategies inform about the time invested in transport and finally, about the social-economic organization of the communities.

The first step in the analysis focuses on the correlation between rock type and tool type. It shows that (meta)alevrolite and sandstone were the most favourable for the manufacturing of macro-lithic tools in the studied area, followed by gabbro, marble, gabbro-diorite, amphibolite, quartzite, claystone, light white stone, and basalt. The use of (meta)alevrolite was related mainly to the manufacture, use, and re-shaping of polished edge tools. Sandstone, gabbro, gabbro-diorite, and amphibolite were more suitable

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http://geoliss.mre.gov.rs/OGK/Raster Serbia/OGKWebOrig/listovi.php?karta=Paracin

21 The results were presented at “Ground Stone & Society” - An international workshop, the Association for Ground Stone Research (AGSR), Haifa, 2015 and at Session Experimental Archaeology in the Balkans: Summa Summarum, XLII Annual meeting of Serbian Archaeological Society, Negotin, May 2019.

for abrasive tools, while quartzite was implemented for percussive tools (Table 3; Vučković 2019: fig. A1.9, 11; table A 1.1). The social value of these rocks can be explained in terms of their availability, quality, behaviour, and mechanical properties.

The second step in analysis relates the breakage pattern of the tools to their respective rock type. The results depend on the intensity of the activity carried out with the tools and quality of raw material. These artefacts were used in grinding, abrasion, and percussion (Vučković 2019: fig. A1.10,12; table A1.2). This has been observed among the items made of sandstone, amphibolite, schist, and igneous rocks, suggesting their high use value (defined by Risch 2011) or low quality.

Observations indicate the importance of the tools with an abrasive surface in the economy of these communities. Unlike most of the Vinča culture, where a mainly uniform choice of raw material has been detected, igneous, sedimentary, as well as metamorphic rocks, were used to manufacture these artefacts from the settlements of the Middle Morava Valley (Vučković 2019: subchapter 5.3, fig. A 1.9,11). This has been explained by experimental examinations, conducted to show the use of rocks with different working efficiency. It varies from very high efficiency, in the case of gabbro-diorite and silicified sandstone, to low efficiency, in the case of sandstone with carbonated cement, amphibolite, and gabbro (Vučković 2019: chapter 2.3.1). Mechanical analyses have also shown that igneous and metamorphic rocks are much more resistant than sedimentary rocks. (Delgado-Raack *et al.* 2009).

The local economy of the Middle Morava Valley during the Late Neolithic period was dependent upon both the accessibility of raw resources, and by extension, the distributive trade network by which these materials could be acquired; ultimately these two factors define the production value of raw materials (Risch 2011). The results show that the two local Late Neolithic distribution centres were involved in a local exchange network. Deposits of igneous rocks towards the west and the presence of amphibolite layers in the immediate vicinity of the settlement of Livade might label this site as a regional distribution centre although this is only known based on the surface survey (Figure 3, 4 a-c, 5, 6 a-c, 7) (Vučković 2019: fig. A1. 8, 10, 12). The second distribution centre is the settlement of Motel Slatina, which was located neighbouring a gabbro outcrop (Figure 3). The direct engagement in the exploitation, processing, and probable exchange of raw material or products at these two sites could be confirmed by the presence of gabbro and amphibolite in abrasive and grinding tools, and in unmodified gabbro rocks or gabbro semi-finished products among the studied material from the Late Neolithic settlements in the Central region (Vučković 2019: fig. A.1.9, 11). Moreover, a selection of similar rocks can suggest territorial unity of this region as well (Figure 4 a-c, 6 a-c).

Observations also suggest that the exploitation of local raw materials is stressed at Slatina -Turska česma, where *c.* 71% of all rocks were collected at a distance not further than 10 km. This proportion of tool-making material is demonstrably lower at the Motel Slatina settlement, where *c.* 49% of all used raw material came from the same distance. We can also expect that raw material for large tools such as grinding slabs and abrasive slabs would be selected from primary deposits than from river courses due to the small size of raw materials detected in the Morava river and other serving streams. Despite this, there is a possibility that rocks such as andesite and flint, whose origin is unknown, were either brought from the riverbeds or were part of a distribution network. The difference in locally sourced tools thusly indicates a fundamentally different social organisation between these two settlements. It seems that communities from Motel Slatina invested more time and energy in the procurement of raw materials through exchange than Slatina -Turska česma and developed stronger contacts with other communities, particularly those in the west (Figure 8). This implies that the inhabitants of these settlements invested more time and energy in a social network than Slatina - Turska česma. This allowed for the transport of raw material, especially for tool types such as polished edge tools and grinding equipment, indicating that the production value of these macro-lithic objects was high. Although the economy relied mostly on local raw material, the production of tools in this area needed to compensate for the lack of certain rock material via exchange networks. This also indicates that these communities did not depend on only one source of raw material as a reliable supply. Moreover, it demonstrates the substitution of low-quality rocks by more suitable, higher quality resources, aiming to improve productivity, such in the case of tools with an abrasive surface which were manufactured out of rocks with various abrasive capacities, as the experimental examinations show (Vučković 2019).

Conclusion

Grassy areas, steppe fields, mixed forests, and fertile lands formed primarily along the Velika Morava river characterised the Middle Morava valley during the Neolithic. The inhabitants of the Late Neolithic settlements of Motel Slatina and Slatina - Turska česma occupied the undulating terrains along alluvial zones covered mainly by vertisol (Benac, Garašanin and Srejović, 1979: 17; Janković, 1984: 68, 72, fig. 9). The Velika Morava and South Morava rivers linked this area to the Pannonian Basin in the north and to the southern part of the Balkan Peninsula. Such environmental conditions enabled the development of various economic activities of the Late Neolithic communities in this area. Observations suggest the importance of grinding, abrasion, percussion, cutting, and fine work on materials such as wood or bone, and work on stone. These tools were made of specific rocks with different different valuable characteristics, such as availability, quality, behaviour and mechanical properties. These values sandstone, gabbro, marble, gabbro-diorite, amphibolite, quartzite, claystone, light white stone, and basalt as rocks with social value. Rocks such as sandstone, amphibolite, schist, and igneous rocks have been determined as rocks with high use value (use value defined by Risch 2011) or low quality.

The difference in accessibility and variability of rocks used as a raw material in the studied area affected the organisation of two procurement systems. One is a local exchange network with two local distribution centres. The first centre might be the site of Livade, due to deposits of igneous rocks towards the west and the presence of amphibolite layers in the immediate vicinity of the site. The direct proximity to gabbro layers defines Motel Slatina as the second distributive centre. The second system is a distant supply network. This relates particularly to (meta)alevrolite and partially to raw material for the creation of tools with an abrasive surface due to demand in the procurement, indicating their high production value. Furthermore, the development of a long-distance exchange network reveals that these communities did not depend on only one source as a reliable supply of raw material. The use of various raw materials, such in the case of the grinding tools, enabled an increase in productivity and the production of a surplus gain which could indicate the availability of a sufficient labour force for grinding and/or low economic importance of cereal processing and specific dietary (Delagado-Rasck *et al.* 2009).

The results also show differences in organization of the inhabitants of Motel Slatina and Slatina - Turska česma. The percent of raw material from distance larger than 10 km at Motel Slatina is lower than at Slatina - Turska česma suggesting differing social organization in the procurement strategies of these settlements. It also indicates that the inhabitants of Motel Slatina invested more time and energy in the procurement of raw material, exchange and had stronger contacts with communities settled towards the west than population at Slatina - Turska česma. In addition, a selection of raw material within the Middle Morava valley is mainly uniform regardless of the source distance, suggesting territorial unity.

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6. The Ecological Significance of Ground-stone axes in the Later Stone Age (LSA) of West-Central Africa

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Introduction

The Later Stone Age (LSA) in West-Central Africa is the latest of the Stone Ages before the advent of agriculture and iron (and/or other metals); it is characterised by the appearance of microliths (scrapers, chisels, segments, points, and backed blades), pottery and ground-stone axes (Alabi 2005; Daniels 1975). The LSA succeeded the Middle Stone Age (MSA) and preceded the Iron Age (IA) in West-Central Africa (Andah 1983; Lavachery 2001). The term 'Late Stone Age' (Andah and Anozie 1980; Lavachery 2001; Phillipson 2005; Alabi 2005) is preferred in West-Central Africa while 'Later Stone Age' is commonly used in North (Garcea, 2010), East (Ambrose 1998) and Southern Africa (Cochrane 2008; Villa *et al.* 2012). Both terms, however, refer to the same period. The oldest LSA sequence in the region is in the Shum Laka rock shelter in Cameroon; it was dated to 30,300 - 31,700 BP (Cornelissen 1996) while the youngest was noted in Kariya Wuro rock shelter, Nigeria, which is dated to as late as 910-800 cal BP (Allsworth-Jones 2015). This late date indicates that the timing of the transition from LSA to IA, which was earlier put at *c.* 2000 BP (Daniels 1975), differs across the region. For instance, the transition took place *c.* 2300 BP in Tse Dura, central Nigeria (Andah 1983), and between 2150-900 BP in Shum Laka, Cameroon (Lavachery 2001). In some other instances, artefacts characteristic of the LSA (microliths) and IA (iron and iron slags) occur together such that there are no well-defined distinctions between both periods (Lavachery 2001; Seidentricker 2016; Orijemie 2018), suggesting continuity and similarity or some form of adaptation. Our understanding as to how particular technological traits associated with the LSA relate to changing tropical environmental settings in West-Central Africa remains poor.

The development of ground-stone axes has been regarded as a major technological and behavioural change within the lithic package of the Later Stone Age (LSA), and in some cases, the Iron Age, in this part of the world (Daniels 1975; Phillipson 2005). Kolář (2019: 41) stated that the ''introduction of the axe as landscape technology represents a significant transformation of the human-environment relationship and its importance was symbolized in many spheres of human life''. Leakey (1943) provided a summary of the different kinds of ground-stone and polished axes in East Africa; the types and number in her summary largely apply to the West-Central African region. It is the ground-stone axe that is the main focus of this paper. Ground-stone axes (Figure 2) are usually made from hard rock types such as granite, dolerite and hematite; although some have also been found that were made from soft rock such as sandstone. They are characterised by ground edges, which are broader and sharper than the opposite blunt end (butt). To produce ground-stone axes, cores are first hammered to flesh out the crude shape; then, they are ground and polished using a hammer and/or core stones (Daniels, 1975).,

In wester Asia, it has been argued that the appearance of ground-stone axes might have coincided with a shift in house construction from small circular/roundhouses to large rectilinear structures thus reflecting the establishment of larger settled communities (Barkai and Yerkes 2008). In other words, axes would have been used to fell trees needed for building large houses. Others have suggested that the development of the ground-stone axe was associated with forest clearance and farming, which in several cases was a response to demographic pressure to increase food production (Bostrom 2014) and that they reflect the socio-economic changes that occurred during that period. It was as a result of these ideas that they were once defined as being a characteristic feature of the 'Neolithic' i.e. food producing period (Shaw 1944). However, this phenomenon does not seem to be the case in other localities where ground-stone axes were recovered. For example, it has been stated that there are many instances worldwide where ground-stone axes occur among peoples who do not farm (Casey 2013).

Figure 1: Map of West-Central Africa and the sites mentioned in the text (Google Earth).

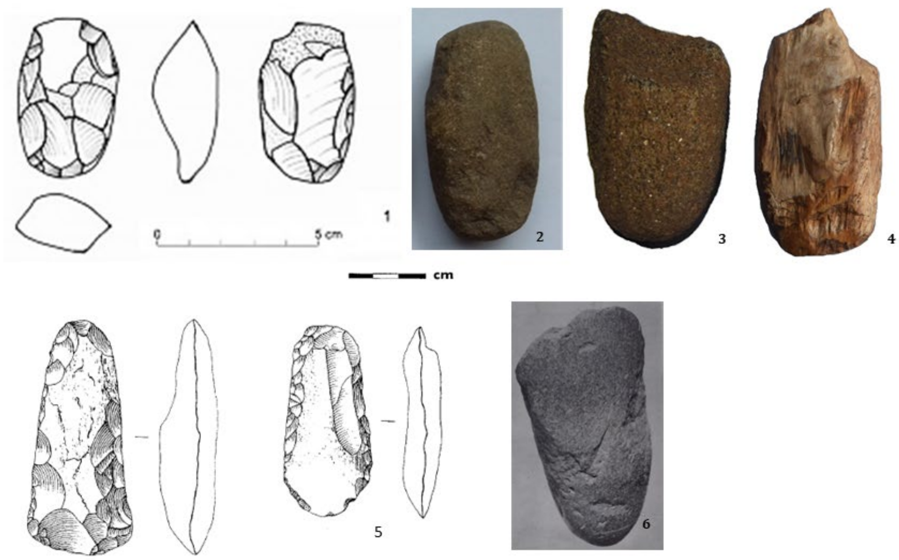

Figure 2: Ground-stone axes recovered from surface collection and archaeological contexts in West-Central Africa. 1. Itaakpa; 2. Batalimo; 3-6. Tse Dura, 3. Adze; 4-6 ground-stone axes; 3-5, surface collections; 6, unfinished; 7-8. Ajaye, Iresi; 9. Dutsen Kongba.

The shape of ground-stone axes, being similar to modern-day metal axes, coupled with the results from actualistic experiments in Denmark (Coles 1974) has bolstered the interpretation of their use as tools for the felling of trees and woodcutting in some archaeological contexts (Noble 2017). The view that they were used for felling wood presupposes that the area in which they appear was forested in the past or at least consisted of a substantial amount of trees that required felling. Iversen (1956) demonstrated that during Neolithic times, humans had already started clearing the forest in Denmark. Furthermore, Tipping *et al.* (1993) and Magyari *et al.* (2012) showed that the marked reduction in tree pollen in Neolithic sites in Scotland and Hungary respectively was a result of human clearance with the aid of ground-stone axes. It is believed that these activities were accompanied by farming in Neolithic Europe from 7500-5350 BP. Microwear on some of the axes recovered from the Levant indicated that they were used for tree-felling and wood cutting activities (Yerkes *et al.* 2012). In the tropics it remains hotly debated as to whether the appearance of these technologies is necessarily associated with either deforestation or farming activities. In New Guinea, for example, ground axe/adze pre-forms have been found in 'Neolithic' contexts ~5,000 years ago, but also before 6,000 years ago (Shaw *et al.*, 2020), though they seem to be linked to forest clearance and the exploitation of starch-rich plants. In West-Central Africa, it has been presumed that the recovery of ground-stone axes from archaeological or other contexts indicated felling of trees (Alabi *et al.* 2009; Allsworth-Jones *et al.* 2012), an action which is often preparatory to farming. However, direct, context-specific evaluation of this hypothesis has remained limited.

The appearance of ground-stone axes in archaeological sites in West-Central Africa is presumed to have accompanied pottery production and farming (Shaw and Daniels, 1984). Farming and/or food production, based on direct botanical and archaeobotanical evidence, occurred *c.* 4500 BP in Mali (Manning *et al.* 2011); 3980 – 3470 cal BP in Ghana (D'Andrea *et al.* 2001), *c.* 2800–2450 BP in Nigeria (Sowunmi 1985; Kahlheber *et al.* 2009) and 2490 – 2160 cal BP in Cameroon (Kahlheber *et al.* 2014). However, in some instances in Nigeria, ground-stone axes appear in contexts that have pottery making this interpretation even more complex (Andah and Anozie 1980). The question that arises is this: does the occurrence of ground-stone axes in archaeological sites in West-Central Africa indicate tree felling and related activities, or were there other uses to which ground-stone axes were put which are not easily recognised in the archaeological record? This paper aims to ascertain the significance of ground-stone axes in West-Central Africa from the perspective of palaeoecology and archaeobotany. To achieve this goal, it investigates the interpretations given to ground-stone axes primarily from West-Central Africa (Figure 1), and tests the narratives of ground-stone axes against a set of palaeoecological and archaeobotanical data obtained from Later Stone Age (LSA) sites in the region (Table 1).

Table 1: A chronological overview of the archaeological phases and environmental conditions of the sites discussed in the text.

	Site	Country	Archaeological Phase	Environmental Conditions	Chronology (Ground-stone axe)	Reference
1	Bosumpra cave	Ghana	LSA	Humid	12430-11830 cal BP	Oas *et al.* 2015
2	Iwo Eleru	Nigeria,	LSA	Wet-Dry	7000-5500 BP	Shaw and Daniels 1984
3	Ajaye rock shelter, Iresi	Nigeria	LSA	Wet-Dry	5653-5581 cal. BP	Opadeji, 2020
4	Shum Laka rock shelter	Cameroon	LSA	Humid	*c.* 5000-4000 BP	Lavachery 1996, 2001
5	Oursi	Burkina Faso	LSA	Dry	*c.* 4000-3000 BP	Ballouche and Neumann 1995

	Site	Country	Archaeological Phase	Environmental Conditions	Chronology (Ground-stone axe)	Reference
6	Ounjougou	Mali	LSA	Seasonality and deterioration of climate	3820–2971 BP	Ozainne *et al.* 2009
7	Dutsen Kongba, rock shelter	Nigeria	LSA	Dry	4510-3830 cal BP; 3470-3250 cal BP	York 1978
8	Ogooué valley	Gabon	LSA	Dry-Wet	*c.* 3200 BP	Oslisly *et al.* 2013
9	Gajiganna	Nigeria	LSA	Dry	c. 3200 BP	Breunig and Neumann 2002
10	Afikpo rock shelter	Nigeria	LSA	Dry-Wet	3000-2500 BP	Andah and Anozie 1980
11	Apa, near Badagry	Nigeria	LSA	Dry	2920-2720 cal BP	Alabi 2002
12	KA4 RS1 rock shelter (Tse Dura)	Nigeria	LSA	Wet	2490 – 2180 cal BP; 2680-2180 cal BP	Andah 1983
			LSA-IA	Dry	725-690 cal BP	Orijemie 2018
13	Itaakpa rock shelter	Nigeria	LSA	Dry	2330 – 2130 cal BP	Allsworth-Jones et al. 2012
14	Kariya Wuro rock shelter	Nigeria	LSA-IA	Dry	912 – 800 cal BP	Allsworth-Jones 2015
15	Ita-Ogbolu rock shelter	Nigeria	LSA	Dry-Wet	Not dated yet	Olajide 2018

A temporal and geographical overview of ground-stone axes in West-Central Africa (Holocene-Present)

In West-Central Africa, the Holocene is characterised by the prevalence of wet and warm conditions, rejuvenation of rivers, and the re-establishment of the tropical rainforest. The Holocene period succeeded the Last Arid Maximum (Maley 1991), a period of great aridity that is synonymous with the Last Glacial Maximum in Europe and America. It must however be stated that the timing of these 'marker' events is not synchronous globally, or even regionally (Dupont *et al.* 2000; Miller and Gosling 2014).

For West-Central Africa, the beginning of the Holocene has been placed at 13,600 BP based on the marked increase in freshwater discharge and high sedimentation rates in the Niger Delta, Nigeria (Pastouret *et al.* 1978). Other evidence include: the 'occurrence of thick successions of turbidite silts' which were interpreted as evidence of 'a shift to deep, stable, stratified lake after *c.* 12,800-11,800 cal. BP in Lake Bosumtwi, Ghana (Talbot and Delibrias, 1980); the marked increase in rainfall and rejuvenation of the Senegal River *c.* 12,500 BP (Rossignol-Strick and Duzer 1979); the re-establishment of rainforest at *c.* 14,000 BP in Lake Barombi Mbo, Cameroon (Maley 1991) and in Lagos, Nigeria at 12,500 – 5,000 cal BP (Adeonipekun *et al.*, 2017), and the prevalence of wet conditions in West Africa from *c.* 13,000 BP (Zabel *et al.*, 2001). Miller and Gosling (2014: 22) provided a summary of the ''transition from the Late glacial to the Holocene'' from marine and terrestrial records from West Africa demonstrating that current dates range from *c.* 15,000 BP to *c.* 13.000-10.000 BP.

It was during an early phase of the Holocene of environmental stability (deMenocal *et al.* 2000), that hunter-gatherer LSA populations initially occupied Bosumpra, a cave site in Ghana. The archaeological sequence of the site yielded axe- or adze-like bladed ground-stone implements dated to ca. 12,430 – 11,830 cal BP (Oas *et al.* 2015). These implements occurred alongside simple pottery until *c.* 3500 BP (Shaw 1944). Andah (1978) reported the occurrence of ground-stone, polished and flaked axes from Rim, Upper Volta in Ghana. The archaeological sequence (Phases II and III) from which the axes were recovered was dated to 4150 – 3730 cal BP (N-1264) and 1170 – 725 cal BP (N-1204). Andah (1978: 137) stated that since the axes occurred in association with bored stones, pickaxes, and grinding stones, which represent a change from the underlying Phase I, the recoveries were ''more likely to be associated with cultivation than with pastoral activities''. However, Andah (1978) admitted that his excavations did not provide any direct evidence of food production in Rim. Similarly, in Nigeria, according to Shaw and Daniels (1984), ground-stone axes appeared at Iwo Eleru shortly before pottery during the period *c.* 7000-5500 BP. There were some environmental fluctuations in the forest zone of southern Nigeria between *c.* 7000 and *c.* 6000 BP which resulted in a slight decrease in the rainforest but they subsequently became extensive and diverse between *c.* 6000 and 5000 BP (Sowunmi 1981, 2004). Hence, unlike the situation in Ghana (Oas *et al.* 2015), ground stone axes first occurred in the Iwo Eleru sequence during a period of brief environmental instability; but again without direct evidence for association with cultivation.

In Ounjougou, Mali, ground-stone axes emerged between 3820–3640 BP and 3182-2971 BP in units HR2Aa and HR2Ab (Ozainne *et al.* 2009); approximately 5000 years after pottery was first produced at the site (Huysecom *et al.* 2009). The ground-stone axes occurred along with domesticated pearl millet (Pennisetum glaucum). Ozainne *et al.* (2009: 467) stated that the "appearance of stone structure settlements and the presence of grinding stones, polished axes, and polishing tools" at Ounjougou, Mali was evidence of food production but not forest clearance. This process is believed to have taken place during a period of marked seasonality and deterioration of climate. In northern Burkina Faso and north-eastern Nigeria (Gajiganna), ground-stone axes also occurred from *c.* 4000-3000 BP and *c.* 3200 BP respectively (Breunig and Neumann 2002; Ballouche and Neumann 1995.). In Dutsen Kongba, York (1978) established that there were at least three occupation phases at the site namely A, B and C. It was the latest phase, C, that yielded pottery, microliths and three ground-stone axes. The ground-stone axes emerged between 4510 – 3830 cal BP (I-7501) and 3470 – 3240 cal BP (I-7402). Although direct palaeoenvironmental investigations were not conducted there, data from Lake Tila near Biu, located *c.* 360 km to the east of Dutsen Kongba, revealed that conditions were dry from as early as 6800 BP and onwards (Salzmann 2000; Salzmann *et al.* 2002).

Andah and Anozie (1980) recovered ground-stone axes, ceramics, hoes, adze-like tools and microliths from the median occupation phase (phase B) of Afikpo rock shelter in Nigeria. This median phase was dated to 3000-2500 BP. Andah and Anozie (1980) opined that this phase succeeded the aceramic phase, and contained thin, fairly coarse red decorated ceramic wares, and that these were evidence of farming. This is yet to be validated considering that no archaeobotanical studies were carried out at the site. Andah (1983) recovered polished axes in association with some pottery from deposits dated to between 2480 – 2180 cal BP and 2680 – 2180 cal BP in KA4RS1 rock shelter located on Tse Dura hills. Based on sedimentological and geochemical analyses of sediments from KA4RS1 and KA4RS2 sites (Tubosun 1981; Tubosun and Andah 1983), and from Rivers Katsina Ala, Tete and Ojapo (Cross River basin) (Tubosun 1995), it was shown that the occurrence of the axes coincided with wet conditions in the region.

At Apa, near Badagry in coastal south-western Nigeria, a ground-stone axe was recovered from deposits which also contained charcoal, charred palm kernel and simple undecorated pottery, and was dated to 2920 – 2720 cal BP (Alabi 2002). Here, it was linked with forest clearance and the exploitation of oil palm (*Elaeis guineensis*). From palynological studies in the Badagry area, it has been shown that during this time, conditions were drier and sea levels were low, and the rainforest degenerated to secondary forests and coastal savannas (Sowunmi 2004; Orijemie and Sowunmi 2014).

In Itaakpa rock shelter in Kogi State, north-central Nigeria, a ground-stone axe, the remains of a human mandible and maxilla as well as pottery were recovered from deposits dated to 2330 – 2130 cal BP (Allsworth-Jones *et al.* 2012). Furthermore, there was an abundance of oil palm kernels at the level that yielded the ground-stone axe (Allsworth-Jones *et al.* 2012) which indicated that the environment at that time was an open or secondary forest, based on the natural ecological requirements of oil palm trees (Sowunmi 1999). Interestingly in Kariya Wuro rock shelter, Bauchi, north-central Nigeria, a ground-stone axe was recovered from a level dated to 910 – 800 cal BP (Switsur *et al.* 1994; Allsworth-Jones 2015). Pollen samples from sediments within the same and over- and under-lying contexts revealed a dominance of *Zizyphus* cf. *spina-christi* and Poaceae; both plants are natural to the savanna (Sowunmi and Awosina 1991) perhaps suggesting a use of these tools away from more densely forested regions in this case.

At Shum Laka rock shelter, Cameroon what is referred to as "waisted axes" (Lavachery 1996: 267 figure 1: 1, 2) were recovered from deposits dated to *c.* 5000-4000 BP (Lavachery, 2001). These "waisted axes" resemble ground-stone axes in morphology except that they have grooves around the 'waist' to enhance hafting. In Mbi crater rock-shelter in the grass fields of Cameroon, ground-stone axes along with distinct pottery (comb-stamping motif which is associated with the emergence of farming in the area) were recovered from deposits dated to 3060 – 2750 cal BP (BM-2426) (de Maret 1985). Pollen data from Lakes Mbalang and Tizong in central Cameroon revealed the gradual disappearance of the montane forest elements with a concomitant increase in grasses from 3000 BP onwards (Vincens *et al.* 2010; Lebamba *et al.* 2016). Furthermore, palynological evidence from Lake Nyabessan in southern Cameroon reveal marked reduction in rainforest taxa and widespread increase in pioneer species between *c.* 2800 and 2400 BP (Ngomanda *et al.* 2009). These vegetation changes have been linked to human impact (Brncic *et al.* 2009; Maley *et al.* 2012; Oslisly *et al.* 2013; Lézine *et al.* 2013).

In the Ogooué valley of Gabon, a ground-stone hoe, an implement not morphologically dissimilar to a ground-stone axe, appears during a time of unstable climatic conditions from about *c.* 3200 BP (Oslisly *et al.* 2013). There were no archaeobotanical remains directly associated with the stone tools despite the extensive use of oil palm kernels that is known from the area. However, it is argued that the occurrence of the ground-stone hoe along with pottery and polished stones were indicators of the arrival of a farming population (Oslisly *et al.* 2013). This period in Central Africa was equally climatically unstable (Bostoen *et al.* 2015). In the Central African Republic (CAR), ground-stone axes, dated to the fourth century AD, were recovered from Batalimo, CAR (Phillipson 2005). Palaeoenvironmental data from sediment cores obtained from around the Lobaye River in the CAR revealed that the area did not witness significant deforestation and no savanna vegetation replaced the rainforest in the last 2000 BP (Kiahtipes 2016). Overall, this regional review highlights that ground-stone axes have been found in a variety of temporal and environmental contexts in West-Central Africa, suggesting that a more context-specific approach to their use and significance is required.

New data from Nigeria

In Nigeria, recent excavations from three rock shelters yielded ground-stone axes. In addition, palynological and sedimentological analyses were conducted on these sites to shed light on the palaeoecological conditions during the time of occupation. The combination of 'on-site' palaeoecological data in direct association with ground-stone axes enables more detailed insights into the adaptive contexts of these tools.

At Ita-Ogbolu rock shelter, Ondo State, Olajide (2018) recovered sixteen ground-stone axes from a 2 m by 1 m unit sunk inside the rock shelter; the pit reached a depth of 1.2 m. The ground-stone axes occurred at 80-90 cm (N=1), 40-20 cm (N=4) and 0-10 cm (N=11). No palynomorphs were recovered from below 90 cm until a depth of 120 cm where the excavation ended. The inferred vegetation at 80-90 cm was characterised by a complex of dry forest and Guinea savanna; in the subsequent levels (40-20 cm and 0-10 cm) where ground-stone axe occurred, Guinea savanna and grasses (Poaceae) increased significantly while the rainforest, though present, greatly decreased.

At Ajaye rock shelter, in Igbo Egbekun area of Iresi, Osun State, south-western Nigeria, a 2 m by 1m test pit was dug within the rock shelter and ground-stone axes were recovered from levels 60-40 cm (N=3), 40-20 cm (N-4) and 0-20 cm (N=1) (Anyanwu 2019). The palaeoenvironment at 70-60 cm was characterised by a complex of open forest and palms; subsequently, at 60-40 cm, dated to 5653-5581 cal. BP (4860± 30 BP; Opadeji 2020) Guinea savanna elements increased significantly while forest taxa decreased. From then onwards i.e. from a depth of 0-20 cm, forest taxa continued to decrease with a concomitant increase in Guinea savanna taxa. Therefore, the pollen evidence indicated the prevalence of open and dry conditions during the period of the occurrence of ground-stone axes.

Orijemie (2018) re-excavated KA4RS1 rock shelter located on Tse Dura hill. Based on the archaeological materials from a 2 m by 2.5 m excavated trench, three occupation phases I-III were identified. The occupational Phases lasted from before cal AD 888-1015 BP to the 18th century AD (Orijemie *et al.* 2021). The archaeological materials included pottery, microliths (side scrapers, burins, backed pieces and points), as well as one broken and one unfinished ground-stone axe. The occurrence of the lithics and their associated dates suggest that the LSA culture there lasted well into the latest millennium AD. The phase from which the ground-stone axes were recovered was dated to 725-690 cal BP; it had an abundance of Guinea savanna and secondary forest elements. Bulliform and elongate phytoliths which belonged to the Panicoideae, as well as the caryopses of *Pennisetum glaucum* were also recovered. These archaeobotanical materials indicate the existence of an open landscape. However, the reconstructed vegetation was not significantly different from what occurred at the preceding and upper levels of the unit.

Therefore, these recent archaeological finds indicate that the presence of ground-stone axes in Ita Ogbolu and Ajaye, both located in the rain forest zone, coincided with marked reductions in forest vegetation with a concomitant increase in Guinea savanna and grasses. However, it is important to note that common contrasts between ‘savannah’ and ‘forest’ in tropical Africa can miss a variety of environmental complexity in both environmental categories (Lawson, 1986). Indeed, Guinea savanna biomes still consist of woody species that would also require felling. Furthermore, in the Guinea savanna zone, where Tse Dura hill is located, the ground-stone axes showed no correlation with the reduction of woody species, hence, there is no evidence it had any impact on the vegetation. The majority of ground-stone axes recovered from archaeological contexts in West Africa are small; their sizes are 5-8 cm (width), and rarely reach 10-12 cm (length); they also weigh just around 1-1.5 kg or less. Ground-stone axes are usually dull hence a combination of more energy and axe weight is required for efficiency (Mathieu and Meyer 1997). Small ground-stone axes usually lack the weight required to produce a great impact on trees; hence, they do not fit into the status of objects that could have been used to effectively cut down trees. These are in contrast to many of those from Neolithic Europe of sizes which range between 10 cm and 20 cm or more, and weigh over 1.5-2 kg (Mathieu and Meyer 1997). While it is evident that the ecological associations of these tools is diverse in West-Central Africa, further use-wear and microbotanical analyses, that have yielded insights into the ecological function of these tools elsewhere in the tropics (Shaw *et al.*, 2020), are needed on a site by site basis to further elucidate their function and human-environment associations. In addition, no use-wear analyses have so far been conducted on the ground-stone axes to ascertain their function. Hence, the ground-stone axes in West-Central Africa do not completely fit into the tree-cutting model as we know it from Europe.

Ground-stone axes in rituals

In Europe, stone axes were recovered as part of grave assemblages particularly from the graves of men considered to be of significance in the society, as well as in farms and bogs (Larsson 2011; Kolář 2019). This association dated to 5500-4800 BP in Denmark, revealed their ritual, as well as economic, significance. A distinction has been made between smaller and larger axes based on use-wear analysis. Smaller axes found in megalithic graves are thought to be real tools while the larger ones deposited individually or in hoards in wetland areas were likely for ceremonial purposes only (Kolář 2019). Unlike in Europe there is currently no direct archaeological evidence for the ritual significance of ground-stone axe in West-Central Africa. What is currently known is that the ritual interpretation of ground-stone axe is rooted in ethnography. In several West African societies, ground-stone axes are thought to be magical stones (Bafour 1912). For instance, Connah (1975) observed the presence of large ground-stone axes (called *Ughavan,* i.e. thunder-axe in Bini) deliberately placed on family altars of past *Obas* (Kings) in Benin City, southern Nigeria. There, ground-stone axes constitute part of the materials, along with other sacred objects namely *Ukhurhe* (rattle staffs), *Uhumwun* (memorial heads) and *Eroro* (altar bells), that are dedicated to deities (Basu 2020; Ben-Amos 1997). In Benin, traditions state that the ground-stone axes are not artefacts but are thunderbolts created by the gods (Connah 1964) whom they call upon as a witness during oath taking, and to lay curses on an accused or offender either by the Oba (Figure 3) or designated elders. Balfour (1903) described a unique ground-stone axe with a bronze ''head'' and dried blood on it. Balfour (1903) describes it as a ritual object, which is believed to possess some magical powers to bring to effect the punishment of an offender. However, the Benin region has no rock formations from which raw material could have been procured for the production of the ground-stone axes. It has been suggested that the axes belonged to an early Later Stone Age (LSA) group, referred to as *Efa* (Bondarenko and Roese 1998), who came from the northern parts of present-day Edo State where granite rock formations and outcrops, matching the raw material of the Benin axes, are abundant (Oloto and Anyanwu, 2013). Several of the Benin axes reach 40.6 cm in length and 12.7 cm in width and have sharp tips, while the smaller ones are mostly less than 10 cm in length and 5cm in width. The large ones, the sizes of which are comparable to those used in cutting wood in Europe (Mathieu and Meyer 1997), appear well suited for the same purpose although this is yet to be confirmed. Often, ground-stone axes are deposited in farms and seldom in the houses of individuals during thunderstorms and/or lightning (Balfour, 1929a). Consequently, rituals are usually required and performed by male figures to remove them from such sites.

Ground-stone axe-related ritual performances are also common practice among the Yoruba of southwestern Nigeria who call the ground-stone axe *Edun ara* (Table 1) and associate it with *Sango*. *Sango* was a famous Yoruba King of the Oyo Empire, who was deified as the god of fire, lightning and thunder (Isola 1991). In Ghana, Balfour (1912) reported the recovery of 150 ground-stone axes during a road construction from Kumassi to Ejura. Native people in the area refer to them as ''thunderbolts''; the axes were recovered from the sub-surface rainforest soils, usually from a depth of 0.5 m–1.2 m. In addition, Balfour (1912) also reported the recovery of ground-stone axes from several localities across the West African region with very similar or ''identical interpretations of the qualities and potentialities of the ground-stone axes'' (Balfour 1929 a: 48). The association of ground-stone axes with thunder and/or lightning (Table 2) among several peoples in West Africa (Balfour 1903, 1912, 1929 a, 1929 b; Connah 1964) who are geographically and culturally distinct (Table 2) hints that an origin of this association in prehistory is likely.

Figure 3: Oba Ewuakpe (1701-1712) left; Oba Akenzua I (1713-1740) right, both depicted holding thunder-axes (ground stone axes) in their left hands (Courtesy Berlin Museum). Reproduced from Benin Kings and Rituals exhibition catalogue, ed. Barbara Plankensteiner.

Table 2: The names of ground-stone axes in some cultures in West Africa.

	Ethnic group	Country	Name	English equivalent
1	Accra	Ghana	*Jongman limbe*	god axes
2	Axim	Ghana	*Osraman-bo*	lightning stones
3	Bini	Nigeria	*Ughavan*	Thunderbolt
4	Central Asanti	Ghana	*Nyame Akuma*	god axes
5	Ewe	Ghana	*So-kpe*	fire stones
6	Hausa	Nigeria	*Gaterin haderi*	thunder axes
7	Tiv	Nigeria	*Aôndo*	Thunderbolt
8	Togo	Togo	*Eso da bure*	god-stone
9	Togo	Togo	*Eso da pabei*	god-thunder
10	Togo	Togo	*Teu bure*	rain stone
11	Yoruba	Nigeria	*Edun ara*	Thunderbolt

Ground-stone axes in Food production

Among the Tiv in central Nigeria, ground-stone axes, colloquially referred to as *Aôndo* (thunderbolt), are associated with agriculture partly because they are often recovered from farmlands (Andah, 1983), although whether this is a product of recent farming activity uncovering archaeological sites or a real association between these axes and past farming remains to be determined. There are, however, clear instances where ground-stone axes have been found in contexts associated with 'farming' cultures in the archaeological record. For instance, ground-stone axes were recovered from archaeological deposits of the Mbi crater rock-shelter, Cameroon, which contained, the comb-stamping motif pottery decoration, regarded as a key cultural marker of early farming populations in that area. The site was dated to 3060–

2750 cal BP (BM-2426) (de Maret 1985). The recovery of ground-stone axes in association with pottery, was once considered part of the food production (or the so-called Neolithic) package (Leakey 1943; Shaw, 1944). However, this idea has been reviewed given that ground-stone axes, in several cases, were not accompanied by pottery or any evidence of farming (Shaw and Daniels, 1984), and also given that global studies are showing pottery need not necessarily be associated with agriculture (Mazurkevich and Dolbunova 2015).

Significantly, ground-stone axes (Figure 2) have been found in association with plant remains particularly cultivated and/or managed plants as was found in Nok (Rupp *et al.* 2005). Alabi (2002) recovered a ground-stone axe in association with charcoal and charred kernels of the oil palm (*Elaeis guineensis*) from a sequence in Apa near Badagry dated to 2920-2720 cal BP. Although, oil palms (*Elaeis guineensis*) are often not directly cultivated, they are protected during slash and burn activities that are carried out preparatory to farming in West-Central Africa (Sowunmi, 1999). In Ounjougou (Mali), and Gajiganna and Nok, both in Nigeria (Rupp *et al.* 2005), the recovery of ground-stone axes was accompanied by domesticated pearl millet (*Pennisetum glaucum*). In KA4RS1 rock shelter on Tse Dura hill, Benue State, central Nigeria, ground-stone axes were also recovered along with grind stones, caryopses of domesticated pearl millet (*Pennisetum glaucum*) and pollen grains of yams (*Dioscorea* spp.) from a deposit dated to 725-690 cal BP (Orijemie *et al.* 2021).

Discussion and Conclusions

There are therefore powerful hints that ground-stone axes did indeed play a potentially important role in food production and human adaptations to diverse forest settings more widely. These axes could have been used in digging up tubers. While perhaps not used for direct deforestation, they may have been used to de-bark trees, making them catch fire more easily. This latter action would kill the trees and provide more arable land on which crops could be planted. Based on the evidence available, and reviewed above, it has been demonstrated that the use of ground-stone axes in West-Central Africa, from archaeological contexts, started in the early Holocene (Oas *et al.* 2015) and lasted until about 700-800 yrs BP (Orijemie *et al.* 2021). They are found in environments ranging from tropical rainforest through to open 'savannah' settings, though woody vegetation elements appear to be constant throughout their ecological range. While they may also appear in pre-agricultural contexts, perhaps suggesting a broader use in tropical vegetation management (Oas *et al.*, 2015), they have been found in clear agricultural contexts, associated with plant food remains and other material manifestation of food production (Alabi, 2002). Furthermore, ethnographic and oral accounts demonstrate that ground-stone axes serve as symbolic objects representing lightning and as ritual objects used in oath taking and placing of curses across West-Central Africa. Further context-specific micro-wear, use-wear, and organic residue analyses is required to provide more direct insights into the function of these artefacts at different sites (Adams 2014; Dubreuil *et al.* 2015; Shaw *et al.*, 2020).

Nevertheless, the occurrence of ground-stone axes in similar contexts across such a wide area as West-Central Africa with similarities in the morphology, overall size, as well as their interpretation as 'Thunderbolt' or ''god axe'' suggest that it is likely that there is a deep cultural and economic significance of these tools in the region. Balfour (1929a) has even suggested that ground-stone axes ''had their origin in one centre and gradually spread by culture-diffusion'', although tracking a 'centre' of origin seems challenging at best. What is significant is that (i) LSA peoples engaged in regional interactions, which were made possible through (ii) an efficient transportation or network system. The recovery of ground-stone axes from farmlands, usually after heavy rainfall, accompanied by lightning, suggests that they had hitherto been deposited there, perhaps as a symbol of supernatural significance or they eroded out or farming techniques revealed them. Those who subsequently recovered them, probably farmers, were familiar with the belief of them being potent and/or having magical powers and continued to spread that narrative, which has been sustained for the better part of the latest Holocene, and into the present times.

Ground-stone axes are regarded as an important technological innovation in West-Central Africa during the Holocene. Although they may have been used for cutting down trees in other parts of the world, Europe for instance, this paper argues that the evidence in support of this narrative in West-Central Africa is not very convincing. A review of their appearance in the region from the early Holocene to present times has made it quite apparent that they were not restricted to specific environments. However, the appearance of ground-stone axes during the Late Holocene Dry Phase, when most parts of the rainforests and wetter savannas became more open with sparse trees coincided in part, in some areas, with the management of certain plant food types (e.g. yams and pearl millet), grinding stones and pottery. As a result, while in some cases use in deforestation remains possible, it is clear that ground-stone axes played an important, and diverse, role beyond tree felling. Ground-stone axes have also been linked to lightning or the ''god of thunder'' and associated rituals. This tradition is widespread in the region and ethnographic in nature; however, its origin is likely situated in prehistory, although, there is yet no archaeological data to support this suggestion. The similarities in the form and interpretation of ground-stone axes as ''thunderbolts'' across West-Central Africa is a reflection of the interactive and network systems and social transformation of LSA populations.

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7. The New Oasis: Potential of Use-Wear for Studying Plant Exploitation in the Gobi Desert Neolithic

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Introduction

Global shifts in diet and land-use occurred throughout the terminal Pleistocene and early Holocene (Bird *et al.* 2016; Gamble 1986; Hayden 1981, 1990; Janz 2016; Keeley 1995; Popov *et al.* 2014; Redding 1988; Zeder 2012). These occurred at different times and had very different outcomes depending on the region. At a broad scale, human adaptation to northern climates is distinct and often characterized by prolonged hunting and gathering, and a very specific range of organizational changes progressing along a continuum of early and extended declines in residential mobility, intensified use of aquatic species, and more active management of natural resources. These shifts did not always lead to either long-term sedentism or domestication. Depending on the region, they preceded a wide range of other organizational shifts, including return to greater mobility, the adoption of exotic domesticates, and increasingly specialized hunting strategies (Basgall 1987; Beck and Jones 1997; Bousman and Okasnen 2012; Chatters *et al.* 2012; Fisher 2002; Habu 2004; Popov *et al.* 2014; Rosenthal and Fitzgerald 2012; Weber and Bettinger 2010; Wolff 2008).

The Gobi Desert is a compelling case study for organizational change among northern hunter-gatherers during the Holocene as the long cold winters combine with low vegetative biomass to create distinct adaptive challenges. During the early to middle Holocene there was a massive shift in ecological conditions with strong evidence of unprecedented humidification related to both the large-scale melting of glaciers following the Last Glacial Maximum (LGM) and the strengthening of the East Asian Summer Monsoon system, which carries summer precipitation across the Gobi Desert and the far eastern steppes (Herzschuh 2006; Lee *et al.* 2013; Winkler and Wang 1993). Rising groundwater levels and precipitation led to the massive expansion of freshwater lakes, rivers, and marshes (Hartmann and Wünnemann 2009; Holguín and Sternberg 2018), while stabilizing aeolian sands with vegetative groundcover (Felauer *et al.* 2012; Shi and Song, 2003; Wang *et al.* 2010; Xiao *et al.* 2004; Yang and Williams 2003; Yang *et al.* 2013). Recent research has shown that hunter-gatherers in the Gobi Desert responded to these ecological changes with a shift towards the specialized use of wetland environments (Janz 2012, 2016; Janz *et al.* 2017).

Janz (2016) has argued that the mid-Holocene Climatic Optimum (Hypsithermal/Altithermal), which coincides with the onset of the Neolithic period (c. 8.0-3.0 k cal BP), allowed hunter-gatherers to reduce residential mobility and exploit a wider range of small prey and vegetal resources newly abundant around stabilized freshwater marshes and wetlands. In this case, the shift towards Broad Spectrum Foraging was driven not by resource depression, as traditionally theorized (Binford 1968; Christensen 1980; Flannery 1969; Stiner *et al.* 2000; Stiner 2001), but rather by environmental conditions which favoured the complimentary use of both big game hunting and the exploitation of resilient, high density resources such as small, fast prey and plant foods (Janz 2016). Under this framework, we see oases as a place of ecological abundance rather than a refugium for hunter-gatherers clinging to dwindling resources under threat of aridification.

This "new oasis" theory therefore proposes that climatic amelioration can, just as environmental degradation, serve as a catalyst for diet breadth expansion and technological innovation. The theory rests on the idea that hunter-gatherers were not only camping around wetlands, but were engaged in the active use of wetland resources, as suggested by the adoption of new processing technologies, particularly grinding stone technology. The lack of direct evidence for plant exploitation, however, has led some researchers to suggest that milling technology in East Asia was adopted as an intensification strategy aimed at processing meat or bone (Elston *et al.* 2011), an idea that would counter evidence for diet breadth expansion. Ultimately, our broader program of use-wear research aims to better understand the adoption of ground stone tools (GST) among Holocene hunter-gatherers in the Gobi Desert as it potentially relates to plant use, particularly grinding and pounding tools. Here we present our preliminary results, which illustrate the potential for a more systematic approach to use-wear analysis on GST in East Asia, including as a way to understand functional morphology, mechanics of use and to identify taphonomic processes as they relate to surface preservation.

In this paper, we employ detailed analysis of 30 GST from four Neolithic sites (Baron Shabaka Well [BSW] and Chilian Hotoga Well [CHW], Jira Galuntu/Site 18 [JG] and Shabarakh-usu [SU], Subsite 2) in the Inner Mongolia Autonomous Region, People's Republic of China (PRC) (Figure 1). These sites are mostly known through surveys and collections of material undertaken during early 20th century scientific expeditions. These materials are currently housed at the American Museum of Natural History (AMNH, New York, USA). The integration of such legacy collections has been instrumental in accomplishing large-scale synthesis as well as in assessing the chronology and changes in adaptation in the Gobi Desert (Janz 2012; Frieman and Janz 2018). Our approach to GST analysis integrates morphological, technological and use-wear analysis with the aim of better understanding variability in GST types and their connection with food practices and plant processing. The analysis of surface finds from a desertic context imposes specific challenges to functional analysis. This paper therefore integrates a detailed taphonomical approach to evaluate use-wear preservation. Despite the limitation imposed by post-depositional alterations, our integrated multiple scale approach allows us to test the hypothesis that grinding systems used in the Gobi Desert following the LGM were connected with plant exploitation.

Background

The Gobi Desert spans the southernmost region of Mongolia and a large portion of the Inner Mongolia Autonomous Region of the People's Republic of China (PRC). Three biogeographic sub-regions can be distinguished (Figure 1): the East Gobi, the Gobi-Altai and the Alashan Gobi (Janz 2012: 22-26). The sites analyzed in this paper are located in the East Gobi (a desert-steppe environment of basins, small lakes, plains, and mesas dissected by numerous drainage channels, riverbeds, and dry gullies) and the Gobi-Altai (a desert to desert-steppe environment characterized mostly by sparsely vegetated gravel pavements interspersed with dune-field accumulations). The AMNH collections, along with comparable collections from the Museum of Far Eastern Antiquities/Östasiatiska museet were inventoried, analyzed and photographed by Janz as part of a larger research program to develop the first date-based chronology for the Gobi Desert region following the LGM (Janz 2012; Janz *et al.* 2015, 2017). Extensive site descriptions for the above assemblages are included in Fairservis (1993) and Janz (2012), while site dates and chronology are summarized in Janz *et al.* 2015, 2017.

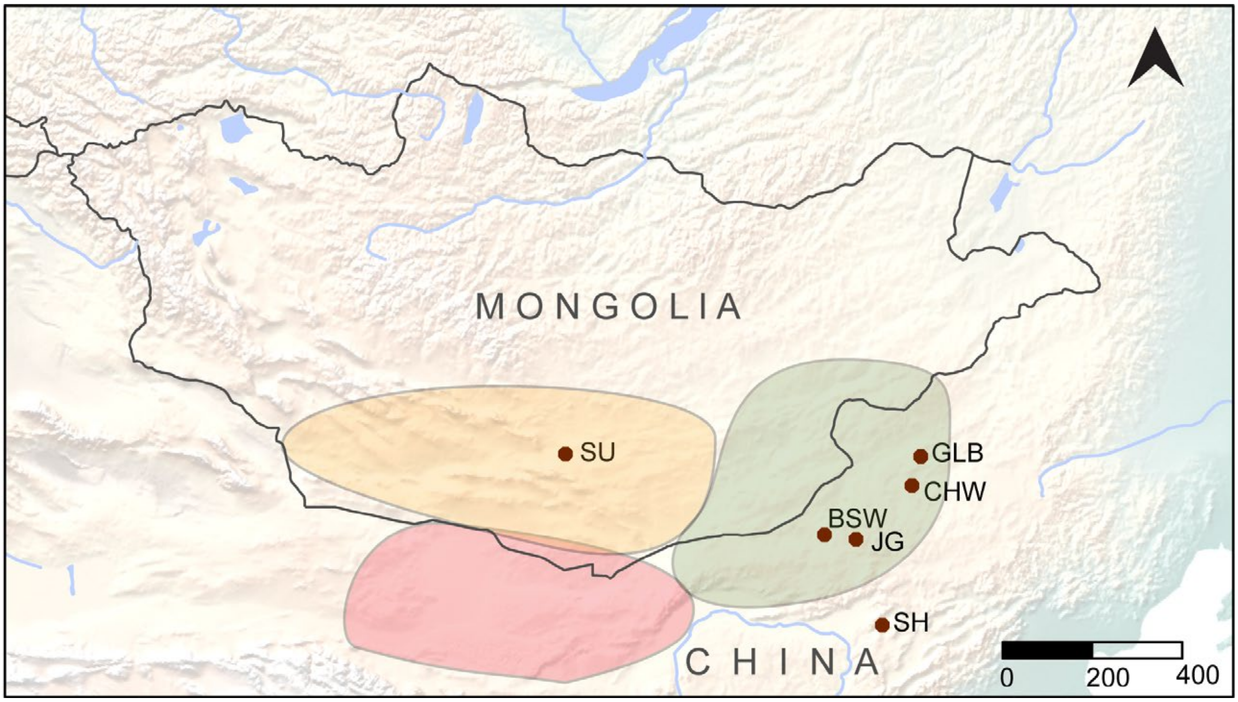

Figure 1: Presentation of the studied area and location of the sites discussed in this paper. Gobi-Altai region is roughly delineated in orange, Alashan Gobi in red, and East Gobi in green.

Based on this research, three stages of adaptation to post-LGM environments were proposed (Janz 2012, 2016; Janz *et al.* 2017). During Oasis 1 (Mesolithic), beginning by at least 13.5 k cal BP, local hunter-gatherers were exploiting a wide range of ecozones, including upland plateaus, wetlands and rivers within low-laying basins. Tool kits were characterized by microblade core reduction strategies and retouched microlithic tools. Pottery may have been adopted towards the end of this phase, with the earliest vessels dating to 9.6 k cal BP (Janz *et al.* 2015). Oasis 2 (Early Neolithic), beginning by at least 8.0 k cal BP, represents a period of substantial changes in the organization of land-use and technology. Residential sites were consistently located around low elevation wetlands, often situated at the juncture of multiple ecozones, particularly dune-fields, upland ranges or plateaux, and open plains. Hunters would have been in a position to exploit prey across the full range of neighbouring ecozones, while on-site wetland oases provided a much broader range of small prey and edible plant foods. Microblade core reduction strategies remained important, but pottery, grinding stones, and chipped and/or polished adzes and axes were also ubiquitous. Oasis 3 (Late Neolithic/Eneolithic/Bronze Age), estimated to have begun around 5.0 k cal BP, represents another period of substantial change, during which pastoralism spread across and beyond the Gobi Desert, primarily between 4.0-3.5 k cal BP. This period marks the widespread adoption of stone monumental architecture and burial cairns, both of which incorporated domestic herd animals, especially caprines (Honeychurch 2015; Wright 2015; Wright *et al.* 2019). By 3.5 k cal BP there is direct evidence of dairying (Janz *et al.* 2020).

The sample of GST discussed in this paper originates mainly from two dune-field/wetland sites dated to Oasis 2. Baron Shabaka Well/Site 19 (BSW) is located in a narrow dune-filled valley with wind eroded hollows, extending over an area of about 0.4 x 1.2 km (Fairservis 1993; Pond 1928). The locality consists of many small sites characterized by what appear to have been temporally coherent scatters, several associated with hearths. Almost 7000 artifacts were recovered and curated from the BSW locality, including 160 individual GST. These encompass grinding slabs of different shapes and sizes, pestles or knobbed/ball-headed rollers, handstones, stone vessels/mortars (Janz 2012). Radiocarbon dates on potsherds collected from these scatters and the surrounding dunes span 6984-6773 cal BP, with one sherd dating to the Medieval period (Janz *et al.* 2015). Sixteen artifacts from BSW are included in this study (Cat. #73/2080a to 73/2092b). Fourteen GST (Cat. #73/2745c to 73/2748g) come from Chilian Hotoga Well/Site 35 (CHW), a locality described by Pond (1928) as consisting of multiple habitation sites, located on the side of an escarpment in a large wind hollow in the sand. The site was excavated to reveal a hearth site about 2.5 m in diameter, containing burned stones, bone fragments, charcoal, and one 'roller' for grinding. Excavation revealed a rich assemblage of artifacts including a fragment of ochre, ostrich eggshell fragments, drilled bivalve shells, pierced carnivore teeth, pottery, a total of 47 GST, and numerous other lithics (Pond 1928). Luminescence and radiocarbon dates on potsherds from the assemblage bracket occupation at 7740-4720 years, with emphasis on the earliest part of that range (Janz *et al.* 2015). Additionally, there are GST from two other East Gobi localities: from Jira Galuntu/Site 18 (JG) (Cat. #73/2426a, b) and Great Lake Basin/Site 31 (GLB) (Cat. #73/2710a, b) (Figure 1). There is one artifact (Cat. #73/715a) from Shabarakh-usu (Bayanzak), Subsite 2 (SU) (Gobi-Altai region) (Figure 1). There are no definitive dates for this particular subsite. Current luminescence and radiocarbon dates from Shabarakh-usu ceramics date between 6.5 and 2.5 k cal BP, indicating occupation during Oasis 2/3 and into the Bronze Age (Janz *et al.* 2015).

Methodology

Sampling strategy

The artifacts discussed here were analyzed by LD at Trent University under a study loan from the AMNH. The main objective was to determine tool function for a full range of GST types, using low and high magnification microscopes well-suited for the analysis of GSTs. As the tools analyzed mostly correspond to surface finds, assessing post-depositional damages through comparison of the various surfaces was established as a pivotal first step in our analysis.

The selection of the GST sample for this study was done by LD and LJ based on photographs and aimed at documenting the diversity of shape and raw material present in the collection. We selected implements whose surface appeared well preserved (less fragmented, with no conspicuous evidence of surface attrition or patina), presenting good potential for use-wear analysis.

Method of analysis

Our method of analysis combined morphological with technological and functional approaches. Tool shape variability is first assessed based on the most complete artifacts, taking into account their morphology in plane, longitudinal and transversal profiles, and the presence of specific features. The best-preserved artifacts were used as a reference to evaluate which type of tool a fragment might come from. Tool types are defined based on the presence of recurrent shape characteristics while the building of a typology, especially the terminology used, draws on comparison with other GST assemblages (e.g., Liu *et al.* 2014, 2016; Schneider *et al.* 2016).

The technological approach aims at differentiating between ad-hoc (pebbles, cobbles and blocks used without prior manufacture) and 'formal' tools and at reconstructing the methods and techniques employed in tool manufacture. In this study, we distinguished within the 'formal' tools, those for which evidence of manufacture is found on active and non-active surfaces (generalized) versus those for which the manufacture is more limited (generally the working surface, classified as partial manufacture). This distinction is aimed at gauging variation in investment in tool production. Examination at various magnifications is frequently required for better understanding the manufacturing process, therefore the technological approach is intricately related to use-wear analysis.

Use-wear analysis in this study is based on the examination of the surfaces of the tools at various magnifications. For the low and high magnification observations, we used a Nikon SMZ 1000 stereomicroscope with 8 to 80× magnifications range and a Nikon eclipse LV- 150 compound metallographic microscope with long distance objectives offering magnification from 50× to 500×. The metallographic microscope is equipped with DIC. Photographic documentation was acquired with a DSLR Canon EOS T2i camera and we also used Helicon Focus stacking program. Our framework for use-wear analysis has been presented in other papers (Dubreuil 2004; Dubreuil and Savage 2014; Dubreuil *et al.* 2015). Naked eye and low magnification observations focus on the configuration of the relief (especially the presence of flat levelled area called plateaux), the presence of impact marks, sheen and linear features. Specific attention is given to describing grain modifications including grain removals, microfracture, leveling and edge rounding (Adams *et al.* 2009). Table 1 provides the main lines of the system used to describe and record variation in micropolish morphology at high magnifications (for more details, see Dubreuil *et al.* 2015).

Table 1: Descriptive framework for the micropolish observed at high magnifications.

Criteria	Categories of variation		
Distribution (on the surface)	Sparse	Covering	Concentrated
Density (within the polish)	Separated	Adjacent	Connected
Microtopographic context	High topography only	Penetrating in low topography	High and low
Morphology in cross section	Domed	Sinuous	Flat
Texture	Rough	Fluid	Smooth
Contours (or limits)	Sharp	Diffuse	
Opacity	Translucent	Opaque	Trans/Opaque
Brightness	High	Medium	Low
Special features	Abraded area	Pits	Striations

An important aspect in use-wear analysis of GST, which is unfortunately often overlooked, is its usefulness for assessing the tool kinetics, especially in differentiating between tools used in pairs (combining a lower passive and an upper active implement) from those used alone as the abrader and polisher. Distinction between the two categories is not always feasible based on morphological characteristics of the tools alone. A classic example of this is the use of handstone 'look-a-like' tools in hide processing activities (Adams 1988; Dubreuil and Grosman 2009). Therefore, one of the main goals of this study is to solidly anchor our tool classification by incorporating use-wear analysis to differentiate grinding implements and abraders/polishers.

Differentiation between the tools used in pairs or alone as abraders is partly based on the configuration of the active surface, the distribution of use-wear across this surface and within the low and high topography. Grinding with a pair of stone tools tends to create regularized surfaces, with plateaus, on which the high topography is leveled, and found at a similar range of elevation across the active surface. On abraders and polishers, the use-wear is generally more randomly distributed on the high and low topography and the leveling of the surface, if present, less generalized on the surface (depending on the type of contact with matter processed). The differences described above should be not regarded as absolute criteria, as other parameters affecting the configuration of the use surface and use-wear distribution need to be considered. For instance, for similar grinding tasks, if the active area has not been manufactured but corresponds to the natural surface of a block, cobble or pebble, the plateaux may be less regular and more randomly distributed (Dubreuil 2002). Variation is also expected if the grinding system combines stone and wooden tools (Delgado Raack and Risch 2009). Assessing the techniques of manufacture and the types of raw material used for the upper and lower implements is therefore important. In addition, assessment of the relative hardness and abrasiveness of the matter processed (based for instance on grain modification and the presence of striation or flat/striated polish) should also be taken into account as these appear as chief parameters affecting the configuration of the use surface and use-wear distribution. For instance, abrasion of mineral matter can lead to the formation of plateaux and extensive and generalized levelling of the tool active surface.

Ultimately, our goal is to contribute to defining the grinding system prevailing during Oasis 2, i.e. the various tools used, associated kinematics and processed matter(s), the arrangement of grinding workspaces including systems to retrieve the ground matter, among other aspects. As shown in ethnography, grinding implements can be used to reduce a variety of substances into fine particles, including non-food products such as mineral matters (see for a discussion Dubreuil and Goring-Morris, in press). We are currently in the process of building an experimental reference collection for Mongolian use-wear analysis as this is critical for the definitive identification of food types processed. Here, our interpretation of use-wear characteristics focuses on distinguishing between grinding mineral versus non-mineral matters, greasy versus non-greasy and suggestions about whether use-wear characteristics appear to indicate processing of plant or animal matters. These interpretations will be revisited upon the completion and publication of our experimental program. Moreover, if conclusive, results from micro-botanical residue analysis will be integrated in future publications. To achieve our goals, an important first step in the analysis, which will be discussed in the following section, has been to assess and characterize post-depositional damages in order to evaluate the feasibility of a functional analysis through use-wear study.

Taphonomic approach

Assessment of surface preservation is of primary importance in use-wear studies and especially crucial here with our sample of surface finds, exposed for a long period to weathering in a desert environment and potentially greatly impacted by post-depositional alterations (see Evoy 2019 for Gobi Desert collections).

Post-depositional alterations are defined here as surface modifications visible to the naked eye and at various magnifications, which occurred as a result of mechanical and chemical processes after the artifact was discarded (Asryan *et al.* 2014; Keeley 1980). Such alterations can greatly impact the preservation of use-wear (Evoy 2019; Keeley 1980; Levi-Sala 1996; Michel *et al.* 2019; Plisson and Mauger 1988; Werner 2018). On stone tools in general, post-depositional alterations commonly result in chipping, fracture breakage, rounding, pitting, striations, the development of patina, and polish, as well as the formation of a layer of compacted dirt and calcium carbonate ($CaCO_3$) sometime called 'concretion' (Asryan *et al.* 2014; Caux *et al.* 2018; Evoy 2019; Ugalde *et al.* 2015). Breakage and chipping can generally be identified by naked eye and/or macroscopic analyses and does not necessarily impact the entire artifact. More problematic is compacted dirt and $CaCO_3$ which cannot be easily removed (Evoy 2019; Pop *et al.* 2018). Even more problematic, because of potential overlap with use-related wear, are pitting, rounding of the high relief or grain edge, and polish formation which are all especially relevant for this study. Indeed, these last three processes are quite common on stone tools from surface contexts in desert environments (Evoy 2019; Ugalde *et al.* 2015). In such environments, tumbling in sand dunes and abrasion from windblown sediments can round the high relief, remove grains and create pitting, leave striations across the surface, and cause the formation of highly reflective surface (referred to here as 'desert polish') or the development of a dark and shiny coating called 'rock varnish' (Ugalde *et al.* 2015).

In this study, we started our observation on fracture plan(s) that appear to have been post-depositional and compared grain alteration and polish formation found on these surfaces with those present on the other parts of the tool. Post-depositional wear was expected to be distributed more widely and randomly on the tool, as opposed to wear related to use or manufacture. Comparison between various implements were carried out to characterize the 'desert polish'. In general, assessment of tool surface preservation was based on the presence, intensity and distribution of post-depositional chipping, fracture breakage, rounding, pitting, striations, and polish as well as compacted dirt and $CaCO_3$. Several states of tool surface preservation were defined, ranging from highly to mildly impacted, and interpretation of use-wear features in terms of human behavior was adjusted accordingly.

Results: Assessing grinding/pounding tool kits variability

Our sample encompasses 30 tools made of various raw materials including coarse, medium and fine-grained sandstone (n=24, 80%), as well as basalt (n=2, 6.7%), granite (n=2, 6.7%), schist (n=1, 3.3%) and quartz/quartzite (n=1, 3.3%). Five of the tools are complete (Table 2). An assessment of artifact preservation is first provided in the next section, before detailing the repartition of our sample between abraders and grinding/pounding implements and appraising the different tool kits employed for reducing matters into smaller particles.

Artifact preservation

The Table 2 (next page) presents the distribution of the most common type of post-depositional alterations observed in our sample.

These include concretion (dirt/$CaCO_3$), smoothing of the grain's edges (rounding) and enhanced surface reflectivity ('desert polish') associated with smoothing. The post-depositional polish observed in the sample is associated with rounding of the grain's edges and can be described as translucent/opaque and very bright. Locally it can present a rough 'grainy' texture and striations. Its distribution into the micro-relief is of high amplitude but the polish is generally more conspicuous on arises and prominences (Figure 2). Randomly oriented fine and isolated striations were also often observed on the tool surfaces. These may be related either to matter processed or to post-depositional alteration. These hypotheses will be explored in the future through experiments.

The tools are affected by post-depositional damages in various ways, more or less extensively (Table 2). For 6 artifacts (20%), the impact is high (extensive on the object and combining multiple types of damages), for 6 (20%) it is evaluated between moderate/high, moderate for 12 (40%), and low for 6 (20%). Even in the cases of a high impact of post-depositional processes, it is generally possible to identify the active surface and to differentiate between utilization as an abrader or as grinding/pounding implement. For these highly impacted implements however it is more problematic to rely on some of the criteria commonly used to assess the type of matter processed (e.g., rounding of the grains, distribution of use-wear within the micro-topography, sheen). Interpretation regarding the properties of the processed matter(s) were attempted when the active surface appeared moderately to mildly affected.

TABLE 2: MOST COMMON TYPE OF POST-DEPOSITIONAL ALTERATIONS OBSERVED AND ASSESSMENT OF TOOL SURFACE ALTERATION (X=PRESENT).

Cat. #73/	Frag/Comp	Dirt/CaCO3	Round.	Desert polish	Other	Assessment
715 a	Frag		x	x		High
2745c	Frag	Locally	x	x	Micro-chipping	High
2710 b	Frag			x		High
2091 b	Comp	Locally	x	x	Pitting	High
2085 b	Comp			Extensive		High
2081	Comp	Extensive on 1 face		Extensive on 1 face	Scraping	High on face / Low on the other
2748c	Frag		x	Affect differently the various faces		Moderate/high
2748a	Frag		x	Affect differently the various faces	Removal, crushing and micro-fracture	Moderate/high
2710a	Frag		x	Affect differently the various faces		Moderate/high
2426a	Frag	Extensive	x		Grain removals probable	Moderate/high
2080a	Frag	Extensive on 1 face	Mild	Mild generalized		Moderate/high
2748b	Frag		Mild	Affect differently the various faces		Moderate/high
2748g	Frag			Mild very light		Moderate
2748d	Frag			Possible		Moderate
2745k	Frag		x	x		Moderate
2745f	Frag			Mild very light		Moderate
2092a	Comp?	Extensive on 1 face				Moderate
2091a	Comp				Possibly grain removals	Moderate
2089b	Frag		x			Moderate
2088b	Frag		x	Mild very light		Moderate
2088a	Frag	Locally				Moderate
2087a	Frag	Extensive on 1 face				Moderate
2085a	Comp	Locally				Moderate
2083b	Frag	Locally			Flake removals	Moderate
2426b	Frag					Low
2092b	Frag					Low
2089a	Frag	Locally				Low
2083a	Frag	Locally				Low
2082b	Comp					Low
2082a	Comp	Locally				Low

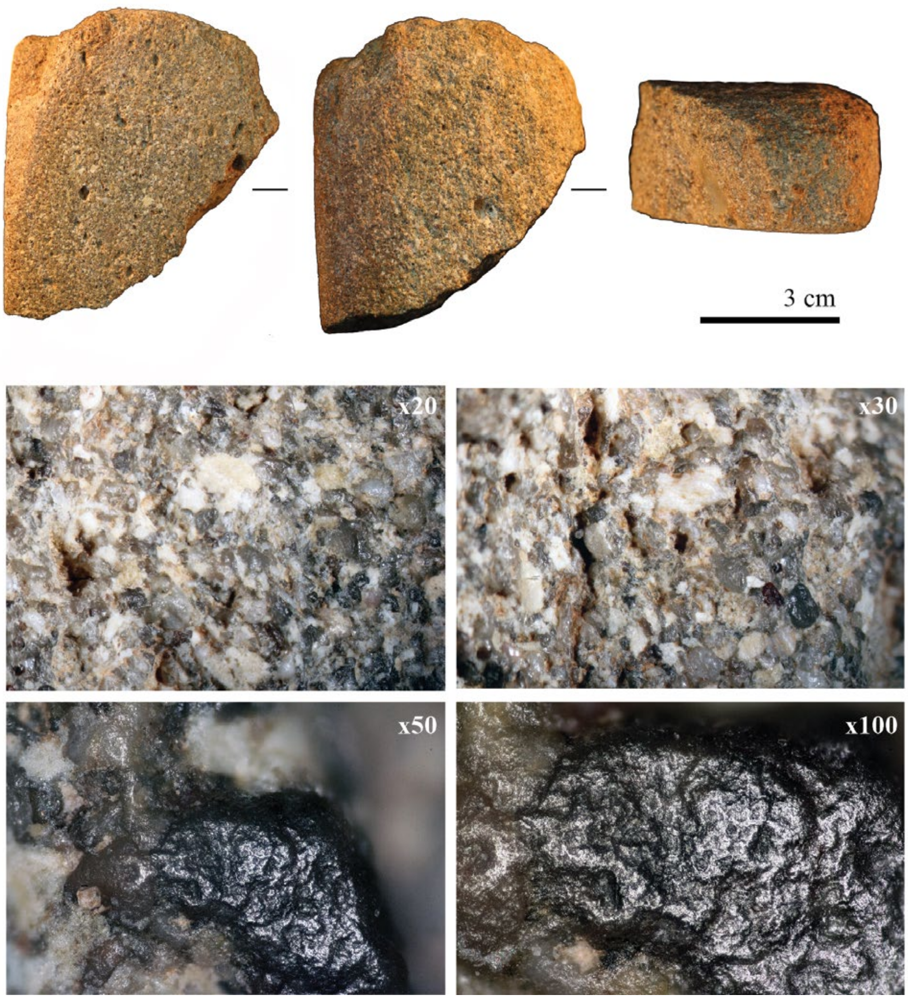

Figure 2: Post-depositional damage observed on #73/2748a. Grain rounding and reflectivity on the fracture plan at low magnifications (here shown ×20 and ×30); desert polish at high magnification (here ×50 and ×100).

Various types of grinding/pounding implements

Our analysis indicates that ten artifacts can be classified as abraders and 20 as grinding/pounding implements. Among the ten abraders, four of them will need to be reassessed after the completion of the experimental program to confirm our interpretation. There are several cases for which differentiating between abrader and grinding/pounding tools based on the shape is specifically problematic. In general, as mentioned earlier, combining morphology and use-wear observations provides stronger argument to sort between the two broad categories.

The sample of 20 grinding/pounding implements can be separated between six lower tools, 12 upper tools and two semilunar 'indeterminates'. The differentiation between lower and upper implements was made based on the overall shape of the tool and the configuration of the active surface (especially longitudinal and transversal profiles).

The lower implements

The lower implements are made of basalt (n=1) and various sorts of sandstone (n=5). All are fragmented yet thickness measurements can be provided: they range between 36 and 11 mm. Evidence of manufacture of the entire tool, including the non-active parts, is observed on all but one artefact (Cat. #73/2710b).

From the best-preserved artefacts in our sample and the complete tools present in the collection it can be said that morphologies in plan are either rectangular/elongate or oval (Figure 3). All the lower implements correspond to grinding slabs with no borders. The use surface is therefore open, suggesting that a specific system was used to collect the ground matter falling from the edges (e.g., basket, mat or piece of hide placed underneath the tool). The morphological variability in this sample is seen in the profile of the active surface which can be flat or show various degrees of concavity (see for an example of flat profile Figure 4). This variability may relate to different degrees of use or to the presence of distinct tool types and grinding systems (e.g., Stroulia *et al.* 2017). The analysis of upper grinding implements will provide additional data to discuss these hypotheses. Evidence of the chipping and flaking on the edges of the grinding slab post-dating use-wear is found on two implements and this may indicate the use of maintenance strategy for controlling the profile of the active surface.

Figure 3: Example of complete grinding slab found at Baron Shabaka Well. Note the deeper concavity in the middle and raised platforms at both ends. Photo L. Janz.

Comparable grinding slabs with open grinding surface (called milling platforms) are described by Schneider *et al.* (2016) for sites attributed to the Neolithic (Oasis2/3) period located further west. The range of thickness is similar to what is observed in our sample (Schneider *et al.* 2016: Tab. 1). The most complete grinding slab is rectangular in plan and has elevated platforms on either end of the active surface which is concave in its middle (Schneider *et al.* 2016: Fig. 8). A very similar grinding slab, yet narrower with a less concave working surface and less pronounced platforms, was also collected at Baron Shabaka Well but was not included in our use-wear sample (Figure 3). Liu *et al.* (2014, 2016), analyzing GST from later nearby sites, have described oval-shaped 'open' grinding slabs between 55 and 8 mm thick, also with less marked platforms. The platform may correspond to an area where the matter to be ground is regrouped before being pushed onto and ground on the rest of the active surface.

In our sample, for two grinding slabs, extensive post-depositional damages preclude further use-wear analysis (Cat. # 73/2745c and #73/2710b). For the rest of the lower implements, observations suggest that the matters processed are not abrasive and mineral (Table 3).

TABLE 3: TYPES OF USE-WEAR OBSERVED ON THE ACTIVE SURFACE OF THE LOWER IMPLEMENTS (LI).

Type of use-wear and distribution in the sample	Low magnifications	High magnifications (polish)
(LI-1) 73/2745k, 73/2710a and 73-2426b	Plateau of various sizes, microfractures, grain removals and leveling, occasionally smoothing	Penetrating a bit in the low topography, mildly reflective, sinuous, fluid/rough (granulated aspect) with parallel striations indicating the same main direction, as well as short isolated striations randomly oriented.
(LI-2) 73/2080a	Idem with isolated striations and generalized sheen	More restricted to the high topography and also more dense; Polish often oriented, i.e. giving the impression of a direction; with long and fine randomly oriented striations.

Figure 4: Example of lower implement (Cat. #73/2710a), working surface with a flat longitudinal profile. Opposite surface manufactured by pecking and smoothing. Use-wear on the centre of the working surface at low and high magnifications (type LI-1 described in Table 3).

It is possible that both types of use-wear are associated with plant processing, the second type with a rather 'dry' matter (LI-2) and the first type (LI-1) with a matter that contains some lubricant, however less than nuts, which are quite oily. These preliminary interpretations are currently being explored in our experimental program. Because of the prevalence of grouped parallel striations on all the tools, and despite the presence of randomly oriented short striations, it is suggested that the upper implements were mainly used according to a back-and-forth kinematic.

The upper implements

Two types of upper grinding implements can be distinguished in our sample. These encompass: 1) elongated or pestle-like (n=5); and 2) rectangular handstone/pounder (n=7). Type 1 is found on coarse sandstone, while the raw materials used for Type 2 are more diverse (coarse and medium grained sandstones, as well as quartz/quartzite and granite). All tools were entirely or partially manufactured.

1) The elongated and 'pestle-like' handstones (n=5)

These GSTs present an elongated body and, in general, thick ends. Two of them are pestle-like with spherical ends in which the diameter is larger than the body and seem to correspond to knobs or handles (Cat. #73/2088a and #73/2088b; Figure 5). The transversal section of the body is rounded (yet with a facet) for one, bi-convex and asymmetric for the other. A third implement is interpreted as a section of the body and presents bi-convex asymmetric transversal profile (Cat. #73/2089b). On the two most complete specimens, use-wear associated with grinding are mainly found on the body and striations indicate a main direction parallel to the width. We do not observe evidence of use of the very end in pounding activities, mainly the use-wear observed on this part of the tool can be associated with manufacture (Figure 5). The use-wear can, however, be intensive in some parts of the 'knob', for instance on the 'gorge' that forms the transition between the body and the larger rounded end. This suggests a friction with the lower implement in this part of the tool. Some polish probably related to prehension is also found on the knob. The distribution of use-wear suggests an overhanging handstone (length superior to the width of the lower implement) used according to a back-and-forth motion, the implement being regularly turned while the tool is operated. These tools were sometimes called rollers (Janz 2012; Pond 1928) and such 'rollers' are also described in the Neolithic of North and Central China, associated in some regions with footed grinding stones (Cohen 2003; Liu 2004; Liu *et al.* 2010; Liu and Chen 2012). In our sample, bi-convex profile or presence of facet on the rounded transversal profile suggest that the tool was not actually 'rolled' over the surface, but used with a back-and-forth movement. Descriptions of assemblages from Inner Mongolia dated from later periods do not mention the presence of such implements (Liu *et al.* 2014, 2016).

The grain modifications and polish observed in our sample are presented in Table 4 (UI-1) and Figure 5.

Two items classified as elongated handstones do not have knobs and present a plano-convex, transversal section. One is complete (Cat. #73/2085a) and one is a fragment with part of the body and one end (Cat. #73/2087a). On both implements, no indication of the use of the end in pounding or grinding activities is found. On the most complete item (Cat. #73/2085a), use-wear related to grinding is found on the flattest face, the opposite surface being mostly used for prehension. On the fragmented specimen (Cat. #73/2087a), both faces show evidence of use in grinding. Low and high magnifications observations for both tools are provided in Table 4 (UI-1).

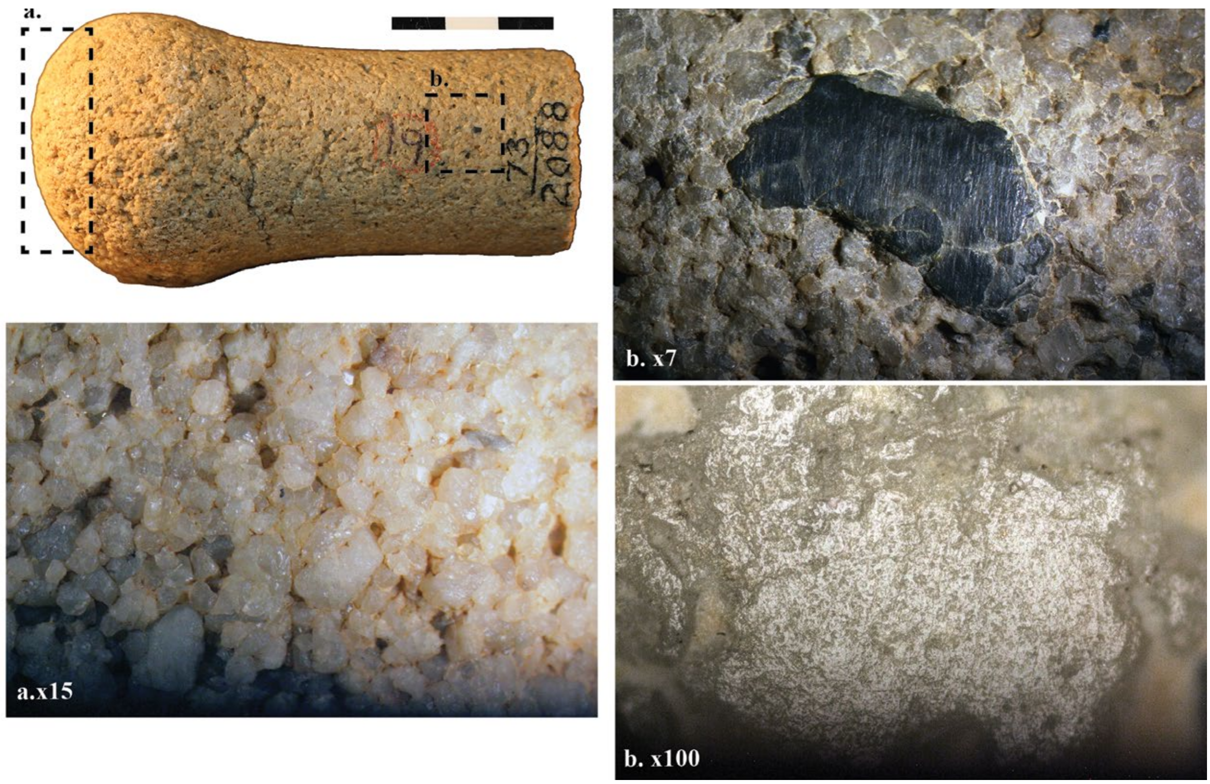

Figure 5: Pestle-like handstone with knob (Cat. #73/2088a) and associated use-wear observed on the end (a) and on the body (b) at low and high magnifications.

Table 4: Use-wear observed on the active surface of the sample of upper implements (UI).

Types of use-wear and distribution in the sample	Low magnifications	High magnifications (polish)
(UI-1) Pestle-like with knobs and elongated handstone	Plateau of various sizes, grain removals, microfractures and levelling, striations	Separated/adjacent polish, mainly on the top of levelled grains, yet penetrating a bit in the low topography. Sinuous morphology, rough texture, diffuse limits and mild reflectivity oriented or with fine grouped parallel striations, also with long or short fine striations isolated and randomly oriented; low polish development on 73/2087a.
(UI-2a and b) Rectangular handstone/pounder	Grain removals, microfractures, and levelling; more microfracture on the ends, more levelling on the long side	Observed on 4 tools UI-2a (on sandstone, 73/2748a, 73/2082a, 73/2748g): low amplitude, separated density, sinuous/flat, fluid/smooth with fine parallel striations and occasionally short striations randomly oriented. UI-2b (on granite, 73/2082b): mainly on the asperity, sinuous and rough (granulated) with patches of flat/wavy and very smooth polish. Fine, isolated, randomly orientated striations, and grouped and parallel striations.

2) The rectangular handstone/pounders

This category of upper implements consists of rectangular and thick handstone/pounders (n=7). Measurements are provided in Table 5.

Table 5: Use-wear observed on the active surface of the sample of upper implements (UI).

Ref	Preservation	Length/width/thickness in mm
73/2083 b	Frag	92/67/32
73/2748 c	Frag	66/58/33
73/2748 a	Frag	63/59/35
73/2082 a	**Complete**	**110/76/35**
73/2748 g	Frag	6/57/16
73/2083 a	Frag	82/77/26
73/2082b	**Complete**	**105/77/34**

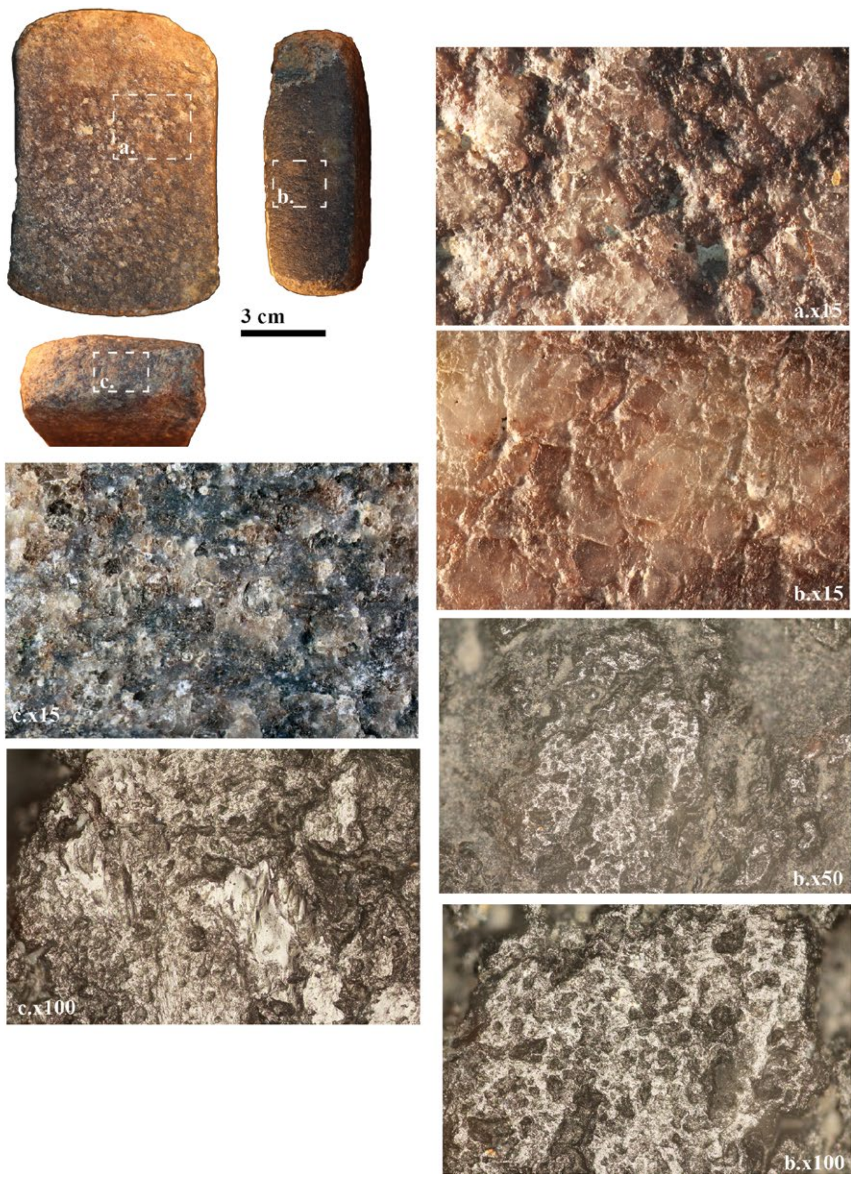

Figure 6: Example of handstone/pounder (Cat, #70/2082b) with use-wear at high and low magnifications.

They show evidence of use in grinding and pounding activities. In general, grinding is more prominent on the faces and longer sides while pounding is more prevalent on the ends of the tools (Figure 6). Well-developed striations are found on the long side of various specimens indicating a dominant back-and-forth motion. Striations tend to be less developed on the faces. While use-wear at low magnifications is very comparable in our sample, two types of polish have been observed (Table 4 UI2 a and b, Figure 4).

3) Comparative analysis of the upper implements

Results from both morphological and use-wear analysis suggest the presence of two types of upper implements, one more specially associated with grinding (elongated and pestle-like handstone), the other with a combination of grinding and pounding kinematics (rectangular handstone/pounder). In general, none of the upper implements appear to be associated with the transformation of mineral matter and the hypothesis of plant processing is favored at this stage of our analysis. The matters processed with the upper implements seem to contain some lubricant, however less than nuts or other oily plant matter. The use-wear on the rectangular handstone/pounders suggest the processing of resources that require a combination of intensive pounding and grinding. These may include for instance underground storage organ (USO) reduction or fiber processing (e.g., hemp or nettle). Alternatively, the pounding/grinding combination may also fit well with the reduction of dry meat into flour. While use-wear appears more in line with plant processing, it will be important to explore meat processing through experiments.

The semilunar GST

Our sample encompasses one complete tool (Cat. #73/2081) and one possible fragment (Cat. #73/2748b) of semilunar GST. The complete specimen (182/94/32 mm) presents a half-moon morphology in plan, a pecked border, while each face shows respectively a flat/slightly concave and a slightly convex transversal profile (Figure 7). The use-wear appears to be mainly localized on the slightly concave surface yet, because of extensive concretion, the opposite surface can only be analyzed on small areas. The overall shape of the tool seems to best fit into a handstone; however, no convex active surface has been found among the grinding slabs and so the concave active surface may indicate use as a lower implement. The fragment Cat. #73/2748b has a plano-convex transversal section, wear related to use is also mainly found on the flattest surface.

The use-wear characteristics observed on the semilunar GST are presented in Table 6 and Figure 7. The characteristics indicate the processing of non-mineral matters, most likely plants containing some lubricant (yet again not as much as nuts or other oily plants). The importance of grain microfracture in the wear formation and the moderate development of plateau may suggest combination of pounding/grinding, if the tool corresponds to a lower implement.

Table 6: Use-wear observed on the active surface of semilunar GST (indeterminate lower of upper implement, U/L).

Type of use-wear and distribution in the sample	Low magnifications	High magnifications (polish)
(U/L-1) Semilunar handstones (73/2081; 73/2748b)	No extensive plateau, wavy microtopography with grain removals, microfracture and levelling.	On 73/2081, mildly reflective polish penetrating in low topography, separated to adjacent density, sinuous/rough (granulated) to domed/smooth; Polish associated with fine, parallel and grouped striations. Also fine, long and isolated scratches, randomly oriented. 72/2748b with desert polish

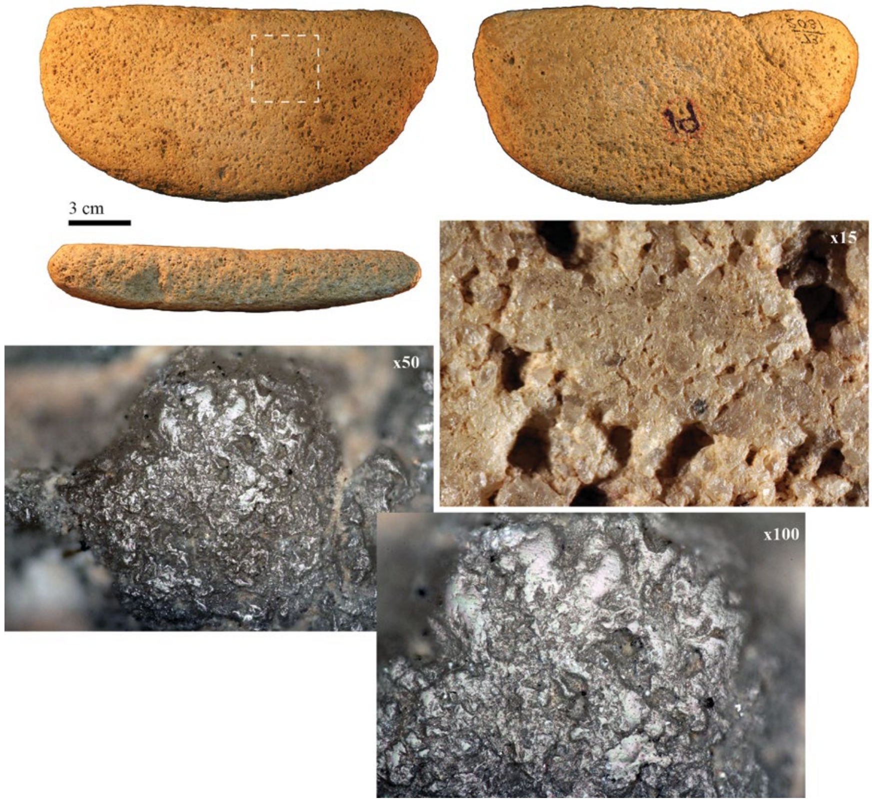

Figure 7: Example of semi-lunar handstone (Cat. #73/2081) and associated use-wear observed on the slightly concave active surface at low and high magnifications.

Conclusion and discussion: Toward a better understanding of the grinding and pounding tool kit of Gobi Desert Oasis 2 period

One of the main goals of this study is to explore, through morphological, technological and use-wear analysis, the relationship between GST technology and plant processing in the Gobi Desert during the Neolithic period (Oasis 2). Another goal is to contribute to better characterizing the grinding and pounding systems used. While our sample derives from surface finds, an important initial step in the analysis has been to assess post-depositional damages and especially its impact on use-wear preservation. Identification and effects of post-depositional damage should be carefully considered with regard to its impact on use-wear analysis.

Our observations suggest that the tools are diversely affected. On highly impacted artifacts, use-wear formation could still be employed to determine whether the tools were used in abrading or in grinding/pounding activities, and helped in developing a better understanding of the typology. Indeed, making such a distinction is not always possible solely on the basis of the tool morphology. The use of multiple lines of evidence hence offers more secure identification and allow better characterization of the tools used in grinding and pounding activities, potentially associated with the processing of plants for their consumption. In this study, various types of grinding/pounding tools have been characterized; interestingly, they all show substantial investment in manufacture (see also Janz 2012: table 3.6 p.202).

The lower implements in general present many similarities, including an 'open' grinding surface, undelimited by a border and a dominant use according to a back-and-forth motion. Some of the grinding slabs are very thin, showing exhaustive use of the tool. Main differences are found in the configuration of the grinding surface which can be flat to concave in profile. In addition, the most complete artefacts in the collections illustrate the use of elongated rectangular as well as oval grinding slabs in plan, some implements displaying raised 'resting' platforms at both extremities. The semilunar GST may represent an additional distinct type of lower implement (smaller with a half-moon morphology in plan), however at this stage of the analysis their use as lower or upper implements (or in combination) still remain to be established.

In contrast, there is a more distinct range of tool types among the upper implements. The elongated and knobbed pestle-like handstones present evidence of use on their body according to back-and-forth motion along their width, while the knob may correspond to a prehensive feature. This last interpretation should be tested on a larger sample. These tools appear suited for use with the elongated 'open' grinding-slabs previously described. It is interesting to note that at BSW, a 'grinding bar with knob' was found associated with such a grinding slab (Pond 1928; Fairservis 1993: 124).

The second type of upper implements identified in our sample, the rectangular handstone/pounders, combine intensive pounding and grinding. At least some of the grinding slabs in our sample appear too thin to withstand such pounding activities. In addition, the use-wear on the grinding-slabs is clearly dominated by grinding. The semilunar GST, on the other hand, exhibit more grain microfractures and limited formation of plateau and could have been used as a lower implement for pounding/grinding operations. We need to expand our sample to test this hypothesis.

At this stage of the analysis, the use-wear types on the grinding and pounding tools examined suggest the processing of vegetable matter(s), some more 'dry' (some of the grinding slabs) but more often rather 'soft' or 'wet' i.e., containing some lubricant, yet not in the range of nuts or other oily plants. The ongoing constitution of an experimental database will provide more data to inform the interpretation of the use-wear patterns observed in our sample. Future research should also focus on enlarging the sample of tools analyzed.

The preliminary results of residues analysis carried out by Schneider *et al.* (2016) on GST implements from the Neolithic in the Gobi Desert similarly suggest an association with plant processing. Liu and colleagues (2014, 2016), using starch grain analysis on GST from Inner Mongolia, have found possible evidence for the use of USO (*Lilium* sp., *Dioscorea polystachya*, *Trichosanthes kirilowii*, and *Typha* sp.), grains (Paniceae and Triticeae grasses, *Coix lacryma-jobi*), legumes, and nuts (*Quercus* sp.) in the somewhat younger Neolithic sites of Shihushan I and II (SHI is dated to 6530–6440 cal BP and thought to post date SHII) (Figure 1). In relation to our sample, non-native species were unlikely to have been exploited during the earlier phase represented in this study and there is no evidence for the establishment of nut-bearing trees in the Gobi Desert during this time.

However, many edible species of Liliaceae, Poaceae, and Fabaceae species are present in Mongolia. There is an overall lack of knowledge about potential dietary importance to hunter-gatherers as imported domestic species have overwhelmed the use of indigenous ones. Several native species do continue to be used, including: *Lilium pumilum* (bulbs), *Allium* spp. (bulbs and greens), *Rheum nanum* (roots used for flour, stalks as a fruit), *Chenopodium* spp. (seeds for flour), and Rumex spp. (greens) (Jigjidsuren and Johnson 2003). Within the Triticeae tribe, there are seven species of *Hordeum* (barley) in Mongolia (Jigjidsuren and Johnson 2003). *Caragana* spp. (peashrub) is also very common in the Gobi Desert and has been widely used as a food source in other regions. Fibre plants include *Urtica* spp. (nettle) and *Cannabis* sp. (hemp). Future research will focus on distinguishing grinding of three plant types: grass seeds, legumes, and root/bulb/tubers. It is likewise critical to all microbotanical research in arid East Asia that we continue to build reference collections for edible native USO and seeds, in particular for Liliaceae species, *Rheum nanum*, *Chenopodium* spp., *Hordeum* spp., and *Caragana* spp. Future research will also focus on exploring which type of activities and resources required the use of a combined pounding and grinding kinematic, as observed in some of the GST. Toward this aim, experimentations with fibres processing and reduction of dry meat into flour will contribute testing further the connection suggested here between Oasis 2 GST technology and plant exploitation in the Gobi Desert.

Overall, this analysis supports the hypothesis that Oasis 2 represents a temporary shift towards broad spectrum foraging during the Neolithic. The ubiquity of GST in Oasis 2 sites across arid Mongolia and China (Janz 2012; Liu and Chen 2012; Zhao *et al.* 2021) highlights a reorganization in subsistence that included high investment in processing plant foods, including the manufacture of elaborate and specialized tools. Plant foods were clearly a critical resource during this time. This represents an emphasis on efficiently processing seeds or USOs for carbohydrates. Although we do not yet have a clear understanding of early to middle Holocene palaeoecology, the emphasis on technology designed to exploit plant resources suggests that they were both reliably available and abundant enough to drive changes in technological, and perhaps logistical, organization. Continuing research is critical to understanding both human diet and Holocene palaeoecology in arid East Asia and will continue to test the "new oasis" hypothesis with a focus on confirming plant use and the types of plants targeted.

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8. Above And Below: The Late Chalcolithic Ground Stone Tool Assemblage Of Tsomet Shoket

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Introduction

Ground stone tools in general, and specific components within these assemblages such as vessels and maceheads, are one of the hallmarks of the Late Chalcolithic period in the southern Levant, serving as one of the main indicators for the changes experienced within the realms of technology and socio-economy during this period (Rosenberg *et al.* 2016a; Rowan and Golden 2009). Among the richest areas in sites bearing ground stone tools during the Late Chalcolithic period is the northern Negev (e.g. Gilead 1995; Rowan *et al.* 2006), making it a favorable region for testing the role of ground stone tools in the Late Chalcolithic economy and exploring various ground stone tools related topics such as intra-site variability, typological, morphological and technological variations, and raw material selection and discard patters.

The Late Chalcolithic ground stone tool repertoire is usually centered around food processing tools, with items such as vessels, mortars and grinding stones making noticeable appearances in most assemblages (Gilead 1995: 309–330; Ilan *et al.* 2015: 86–87; Rowan 1998: 103; Rowan and Golden 2009:39). The so-called V-shaped basalt bowls (flat-based, open vessels) and fenestrated vessels (frequently V-shaped bowls on a fenestrated stand) dominate Late Chalcolithic assemblages, appearing in sites throughout the southern Levant and are often decorated with incised motifs (Chasan *et al.* 2019; Chasan and Rosenberg 2018, 2019; Rosenberg *et al.* 2016a; Rowan 1998). These are found both in Late Chalcolithic villages and in burial caves (Chasan and Rosenberg 2018). Vessels made of limestone are also part of the Late Chalcolithic repertoire (Abadi-Reiss 2016; Gilead 1995: 321–326; Scheftelowitz and Oren 2004: 59).

Grinding stones also play an important role within the Late Chalcolithic assemblage; they serve as an indicator for various techniques and traditions of food production, highlighting subsistence changes typical of the Late Chalcolithic (Rowan and Golden 2009). Spindle whorls, maceheads and various types of perforated items are also found in the Late Chalcolithic assemblage. Similarly to the lower and upper grinding stones, the small tools mentioned above (with the exception of maceheads) also tend to be made of locally available resources, yet instances in which these tools were made of non-local stones are not particularly uncommon (Rowan and Golden 2009: 39).

While most Late Chalcolithic ground stone tool assemblages in general and in the northern Negev in particular are found in domestic architectural units, in a few sites ground stone tools were found in underground complexes, that are one of the hallmarks of this period, noted in sites such as Abu Matar (Perrot 1955), Bir-a Safadi (Perrot 1955; Rowan and Ilan 2013), Horvat Beter (Dothan 1958), Shiqmim (Levy and Alon 1985), Nahal Patish (Nahshoni 2010), Giv'at Ha-Oranim (Scheftelowitz and Oren 2004) and Holyland Park (Milevski *et al.* 2015). The function of the subterranean complexes at these sites is often elusive and debated by various scholars, ranging from burial and/or ritualistic contexts to storage facilities and daily activity areas (e.g. Perot 1955; Rowan and Ilan 2013). Moreover, the research surrounding ground stone tools taken from these underground spaces is lacking – only limited information regarding this topic has been published. This paper presents the ground stone tools assemblage from the site of Tsomet Shoket, where underground features were excavated recently. We will discuss the site's characteristics and significance, and explore its ground stone tools typo-morphological variations, discard patterns and raw material selection, as well as tool production.

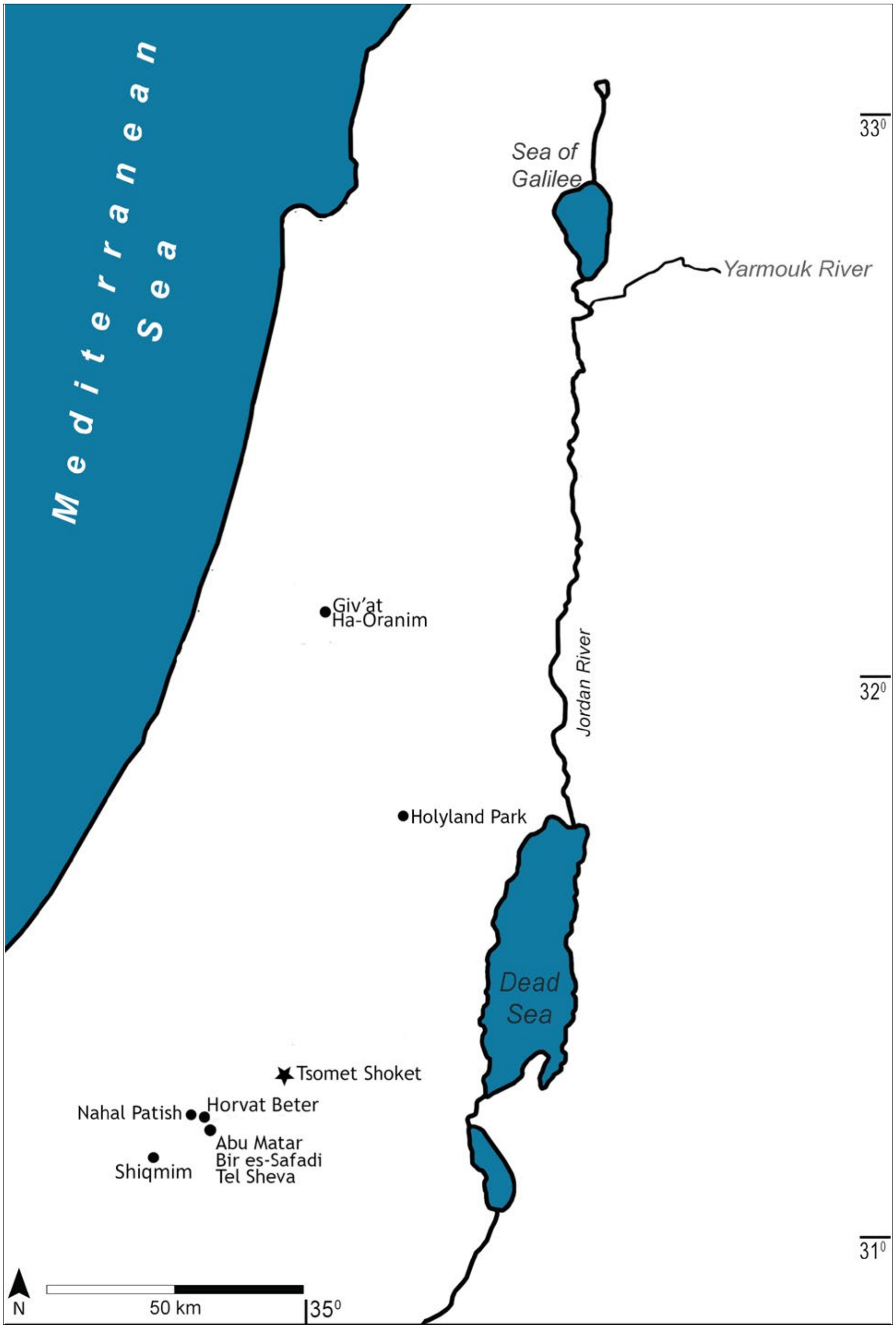

Figure 1: Map of Late Chalcolithic sites with artificial underground complexes.

Figure 2: Site of Tsomet Shoket: 1. General overview: 2. Some of the underground complexes at Site 3. Courtesy of Dr. Ron Be'eri.

Tsomet Shoket

The site of Tsomet Shoket was excavated as part of a salvage excavation, and is divided into five secondary sites (i.e. smaller sub-sites. Figure 2:1) located on the banks of Nahal Hevron (Wadi el-Khulil) in the Be'er Shevaʿ Valley (Be'eri *et al.* 2017). Surveys and excavations in the Be'er Shevaʿ Valley have led to the discovery of dozens of sites with a rich material culture from the late fifth millennium BCE. Most of the sites are found along the main streams that drain the valley, including Nahal Hevron, Nahal Be'er Shevaʿ and Nahal Gerar (Baumgarten and Eldar 1984; Be'eri *et al.* 2017; Dothan 1958; Gilead *et al.* 1991; Gilead 1995; Levy 1986; Levy *et al.* 1991; Nahshoni 2010; Paz *et al.* 2014; Perrot 1955; Perrot 1993; Rowan and Golden 2009). The secondary sites of Nahal Hevron are spread along a loess plain on the banks of the stream, where fields of dryland farming were in use until fairly recently; the five secondary sites are delimited by the horseshoe-shaped meanders of the streambed. The sites, comprising remains of buildings and installations, were separated by areas devoid of archaeological remains, extending over dozens and even hundreds of meters (Be'eri *et al.* 2017). The excavation was conducted only in Secondary Sites 3 and 4, where settlement remains from the Late Chalcolithic period including buildings, pits and four subterranean complexes, were unearthed (Figure 2:2).

The two excavated secondary-sites, 3 and 4, differ from each other in the duration of activity that was conducted in them: Site 3 had four stratigraphic phases, indicating a long period of activity, whereas only one phase was revealed at Site 4. However, the similarity between the two sites—evident in the multitude of ceramic V-shaped bowls, churns and perforated pebbles along with the custom of marking the pits with river pebbles—indicates that they both should be dated to the Late Chalcolithic period.

The subterranean complexes in Area A (Site 3, Figure 2:2), created a mild and satble temperature, unlike the arid climate prevailing in the Be'er Shevaʿ Valley, whichmade them suitable for storage and some day-to-day activities. Pits, installations and tools exposed around the building in Area B (Site 3) allude to daily household activities that took place there: processing food, churning milk, food storage, weaving and spinning. The multitude of finds discovered on the floors of the buildings; grains, legumes and animal bones, alongside spinning implements, churns, sickle blades, and pounding and grinding artifacts, indicate that the inhabitants of the site practiced a mixed agro-pastoral economy. The olive pits indicate that either olive trees grew in the area or olives were brought in from the Hebron hill country (Be'eri *et al.* 2017).

Methodology

The assemblage was sorted according to find contexts of the artefacts (above/underground) and classified according to the common typological classification frequently used for ground stone tools assemblages' analyses in the southern Levant (Rosenberg and Garfinkel 2014). The items were then examined and morphological characteristics, raw material preferences, technology, preservation and other traits were recorded in order to identify contextual characteristics. The assemblage is presented below in typological order. When weighing and measuring items, only complete items were examined, along with some of the broken items whose dimensions could be accurately predicted.

The assemblage

The assemblage consists of 144 items (Table 1). Of these, only four were found in underground chambers. Many items were retrieved from pits (30%). Eight general contexts were defined (Table 2). The "Other" category includes contexts that retain few items (1–3 items). Contexts (and number of items) that were included under the "Other" category are: soil above pit (n=2); soil above underground room (n=2); ash layer above pebbles (n=3); balk (n=2); bellow surface (n=3); collapse (n=3); floor (n=1); installation (n=1); installation inside shallow pit (n=2); context not specified (n=1); under infrastructure of road 31 (n=1).

Table 1: Breakdown of the assemblage for types and raw materials.

Types/Raw materials	Limestone	Flint	Basalt	Sandstone	Unidentified material	Total	Total %
Lower grinding stones	15	4				**19**	**13**
Upper grinding stones	15				5	**20**	**15**
Vessels	21		7			**28**	**19**
Perforated Items	25		6	2	7	**40**	**28**
Grooved stone objects	2	1				**3**	**2**
Hammerstones	5	8				**13**	**9**
Various tool fragments	4				2	**6**	**4**
Varia	9				6	**15**	**10**
Total	**96**	**13**	**13**	**2**	**20**	**144**	**100**
Total %	**67**	**9**	**9**	**1**	**14**		**100**

Table 2: Breakdown of the ground stone tools contexts.

Context	N	%
Accumulation of soil (non-anthropogenic)	28	19
Entrance shaft to underground room	2	1
Inside underground room	4	3
Underground Chambers fill	8	5
Layer of activity (anthropogenic)	21	15
Pit	43	30
Surface	17	12
Other	21	15
Total	**144**	**100**

Lower grinding stones

A total of 19 lower grinding stones were found. These were morphologically divided and classified into five types: oval slabs with a characteristic plano-convex cross-section (n=9); oval slabs with a characteristic bi-plano cross-section (n=5); oval palettes (n=1) (a lower grinding stone with a bi-plano cross-section with the thickness <3.0 cm); anvils (n=3); unidentified slab fragments (n=1). Over 50% of the lower grinding stones were found inside or near pits.

All the lower grinding stones are made of limestone, with the exception of four flint grinding stones (Figure 3:1-2), of which three are oval, plano-convex slabs and one is an oval, bi-plano slab. The active surface of the flint lower grinding stones is coarse, with sporadically smoothed spots, as opposed to the active surfaces of the limestone lower grinding stones in the assemblage, which are much smoother. The preference for locally available raw material such as limestone for grinding tools production aligns well with a general observation regarding Late Chalcolithic sites, in which these tools were commonly made from local raw materials (e.g. Gilead 1995: 326–330; Rowan *et al.* 2006).

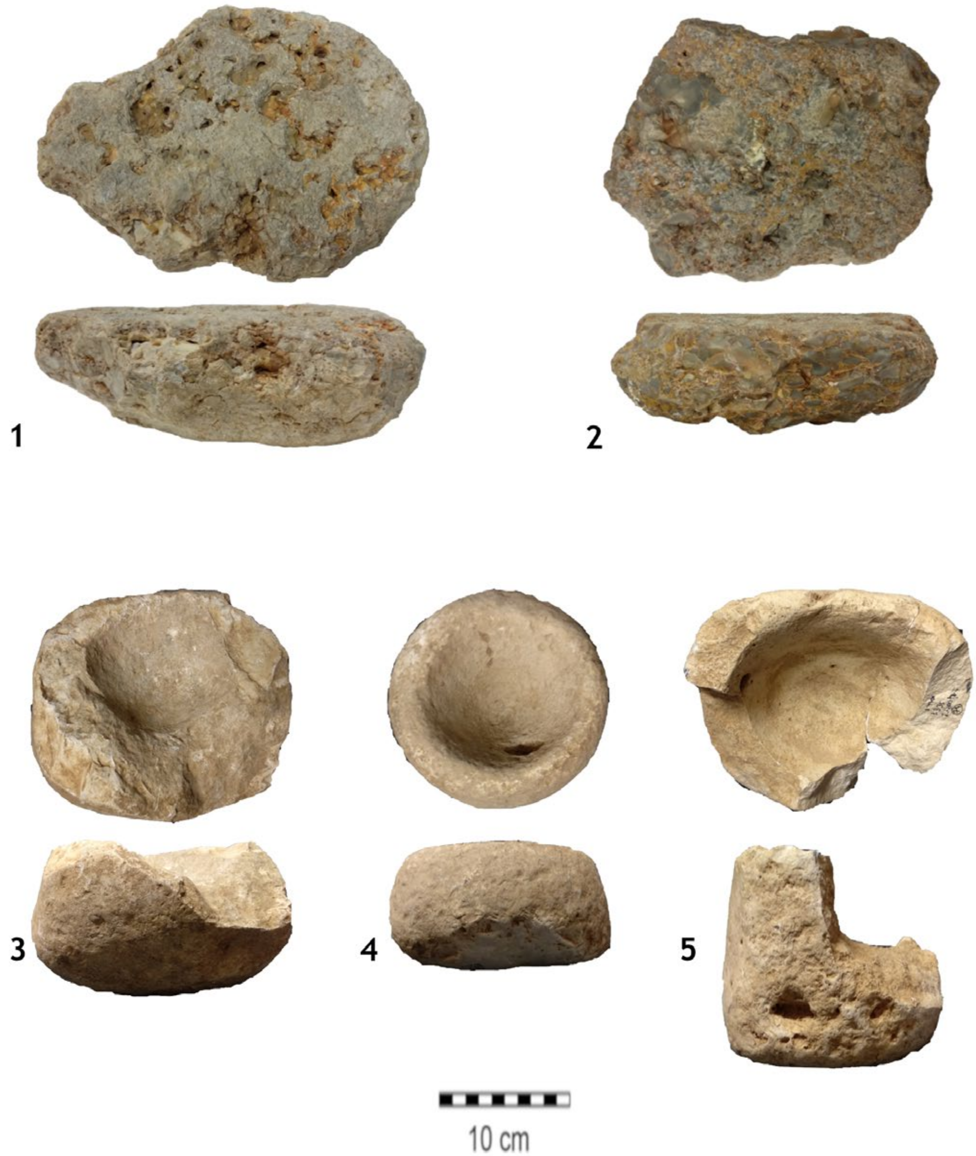

Figure 3: Lower grinding stones made of flint: 1-2. Large vessels 3-5.

Most (58%) of the lower grinding stones were found whole. Three of these are large (37.0–50.0 cm in length), weighing over 20.0 kg and categorized as multipurpose-anvil type stones (large boulders that were used for both grinding and battering). The average weight of the rest of the complete stones is 6.3 kg, the heaviest weighing 12.8 kg and the lightest weighing 0.6 kg.

Upper grinding stones

A total of 20 upper grinding stones were found. The upper grinding stones were classified into 11 types based on their morphology: oval, plano-convex (n=5); oval, plano-convex large (>20.0 cm) (n=2); oval, bi-plano (n=1); elongated convex-convex (n=1); round, plano-irregular (n=1); round, bi-plano (n=1); rectangular, plano-convex (n=1); amorphous, plano-convex (n=1); thick (>5.0 cm) cobble/pebble (n=3); thin (>5.0 cm) cobble/pebble (n=3); plano-convex fragments (n=1).

Similar to the lower grinding stones, the predominant raw material used for upper grinding stone production is limestone, constituting about 75% of the assemblage. The rest are made of an undetermined, greyish rock. 50% of the upper grinding stones are whole. The average weight for all the complete upper grinding stones is 0.7 kg. Most of the stones (85%) have a characteristic flat active face, while for the rest it is convex. Most upper grinding stones possess only a single active face (70%), some have two (25%), and a single item – a thick pebble, had four active faces, all moderately smoothed. All upper grinding stones show clear signs of smoothing in various degrees, and some exhibit polish as well. Some (40%) of the upper grinding stones were found either inside or nearby pits.

Vessels

A total of 28 vessels are included in the assemblage. These were classified into 10 types: upright bowl (n=4); V-shaped (flat based-, straight-walled) bowl (n=6); globular bowl (n=7) bowl, unidentified base fragments (n=1); unidentified rim fragments (n=2); globular/bowl-like mortar (n=2); cup on a pestle (n=1. Figure 7:1); shallow bowlet (n=1); bowlet, with deep depression (n=1); double-sided bowlet (n=3). The most common vessels in the assemblage are bowls of various types (upright, V-shaped and globular), all of which are broken excluding two complete globular bowls made of limestone weighing 3.0 kg and 5.0 kg, respectively. Most of the vessels are smoothed externally, some are smoothed both externally and internally, and some exhibit polish, mostly externally.

The most common raw material for vessel production is limestone, comprising 75% of the vessels (Figure 3:3-5). The rest of the vessels are made of basalt (25%), of which most are made of compact basalt (71%) and only one of porous basalt. All of the basalt vessels are fragments of V-shaped bowls; two base fragments (Figure 6:6) and five rim fragments (Figure 6:5), smoothed both on the inside and the outside walls. One of the basalt V-shaped bowl rim fragment bears a decoration of two incised horizontal lines along the rim (Figure 6:8), while another is decorated with triangle incisions along its rim. Another basalt rim fragment (with no visible, incised decorations) exhibits faded red-colored spots on the inside. The average rim diameter of the V-shaped bowls is 12.5 cm, the smallest bowl being around 8.0 cm and the largest 16.0 cm.

Of the limestone vessels, 38% are complete. The largest limestone bowl from this assemblage is a broken globular bowl, measuring 20.0 cm in rim diameter. Globular bowls (Figure 3:4; Figure 6:3–4) in general seem to be the most popular limestone vessel in this assemblage (33%), followed by upright bowls (19%) (Figure 3:5; Figure 6:1–2). The largest, complete limestone vessel is a mortar weighing 10.4 kg (Figure 3:3). Another limestone mortar, also complete and slightly smaller than the previously discussed item, weighs 8.8 kg (Figure 6:7). The average weight of the rest of the complete limestone vessels is 3.1 kg. There is a total of five bowlets (for definitions see Gopher and Orrelle 1995; Rosenberg and Garfinkel 2014:90–112) in the assemblage, the most dominant type being the double-sided bowlet (n=3. Figure 7:2), of which there are two complete items. Of the other two bowlets, only one is a shaped, vessel-like item (i.e. an item with clear signs of heavy modification. Figure 7:4) while the other was shaped on a dented limestone pebble with existing, natural perforations that have been further modified. The vessels were found in various types of locations throughout the excavation with no clear discard pattern.

Perforated items

The perforated items category (Figure 4) consists of 40 items, divided into several sub-categories: maceheads; spindle whorls; round weights; irregular weights; amorphous perforated pebbles and stones; perforated items preforms. The dominant raw material for these items is limestone (63%), basalt (15%), sandstone (5%) and undetermined rocks (17%). All weights (round, irregular and preforms), including spindle whorls, have clear striation and drilling marks. Most items were bidirectionally drilled (from two sides) except for two items which were unidirectional drilled.

Figure 4: Perforated items: Maceheads: 1-2. Spindle whorls: 3-5. Round weights: 6. Irregular weights: 7.

Maceheads (n=6, Figure 4:1-2): Include five complete specimens and a broken one along the length, with both halves present (found together). The maceheads include piriform, globular and onion-shaped sub-types. Two of the complete items are clearly macehead preforms: one is globular with two depressions on both far poles of the item (parallel to each other), while the other is piriform, exhibiting the same parallel depressions. Most of the maceheads are made of limestone, with two exceptions: one is made of basalt (Figure 4:1), and the other of an unidentified rock. The two halves of the basalt macehead are smoothed inside-out and polished on the outside. One is grey and the other is darkreddish, possibly due to sedimentary differences of the sediment matrix they were found in. All of the items were drilled from both poles, except for one, which showed signs of a conical drilling process. The heaviest and largest macehead is a globular, limestone macehead measuring 5.3 cm in height, 5.7 cm in diameter and weighing around 0.24 kg. The rest of the maceheads are relatively similar in dimensions, with an average height of 4.3 cm, an average rim diameter of 4.4 cm and an average weight of 0.1 kg. The majority of maceheads (n=5) were found in pits and pit fills, with the exception of one item that was found in an activity layer.

Spindle whorls (n=5, Figure 4:3-5): all spindle whorls are made of basalt; some are smoothed and polished (Figure 4:3, 4:5). Two of the items are broken in half (only one halve present). The average thickness of these items is 2.3 cm and the average item diameter is 4.8 cm, with the largest item measuring 5.5 cm (Figure 4:4) and the smallest item 4.0 cm. It should be noted that spindle whorls made exclusively from basalt are not a phenomenon typical of the Late Chalcolithic. They do however, become a standard trend in the Early Bronze Age period (Rosenberg and Golani 2012; Shamir 2003:210).

Round weights (n=8, Figure 4:6): these include five complete items and three broken ones, all broken in half (only one halve present). All items are somewhat homogenous in size, measuring between 5.0 cm to 5.7 cm in item diameter, with the exception of one large item measuring at 12.5 cm. While most (75%) items are fairly thick (thickness greater than 2.0 cm) with a round profile, two exhibit a flat profile, measuring less than 2.0 cm in thickness. All items were bi-conically drilled. This is especially apparent in the thicker items, as their perforations bear a clear, conical depression on both sides of the item.

Irregular weights (n=2): of these, one bears a rough, blocky shape; the second is smoothed and shaped into a triangle with rounded edges (Figure 4:7).

Amorphous perforated pebbles (n=16): of these, seven are naturally perforated limestone pebbles that may have been collected due to the existence of the perforation. Three of these are fairly heavy (>1.5 kg). The rest exhibit artificial perforations (with clear striation marks on the perforations) and varying degrees of smoothing. A single small pebble appears to be a reused upper grinding stones, to which a smoothed and polished depression was added. Of the naturally perforated items (n=7) four have two perforations.

Preforms of perforated items (n=3): these are stones which exhibit intentional modification which was not completed. Two of these are rough, circularly-shaped stones with an unfinished, bi-directional perforation (resembling a round weight), and one irregularly shaped, smooth pebble with an unfinished perforation.

Grooved stone tools

The grooved stone tools are elongated objects bearing grooves along their central longitudinal axis. These may be small hammers or mallets (Breglia *et al.* 2016; de Amico 2015; de Pascale 2004), weights or net sinkers, although they differ from the common morphology of net sinkers, known mainly from northern Israel (Rosenberg *et al.* 2016b: Figure 20:1-2). Three of these items are noted in the assemblage, all about the same length (8.3–9.5 cm) and width (4.0–5.3 cm). Two items (Figure 5:1-2) exhibit rounder features while one seems to have pointier, more defined edges (Figure 5:3). All of the items are consistently smoothed and weigh between 0.1 kg and 0.3 kg. One object is made of flint (Figure 5:1), while the other two are made of limestone and the grooves seem to have been made by pecking, though it is hard to tell due to the levels of smoothing. Two of them (Figure 5:1-2) bear pecking and battering marks on both edges, supporting their classification as small mallets.

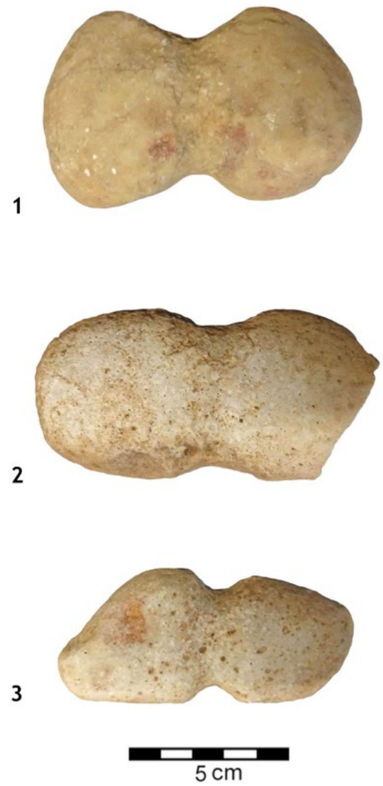

Figure 5: Grooved stone tools.

Hammerstones

There are 13 hammerstones in the assemblage. Most are made of flint (61%), followed by limestone (39%). Two were found inside knapping pits, surrounded by flint debitage. Seven of the hammerstones are oval, while the remaining six are of a rounded, irregular shape. All hammerstone exhibit flaking, battering and pecking marks, and one stone also shows signs of abrading (Figure 7:5). Eight have at least two active faces.

Various tool fragments

Six unidentified tool fragments were recorded. These include: a fragment of what seems to be a pestle with convex profiles; a limestone bi-facial preform; a fragment of (possibly) a grinding stone; a smoothed rim preform made of limestone; a smoothed and polished fragment, possibly of a lower grinding stone; and a square, smoothed, modified stone piece that might be a lower grinding stone fragment.

Varia

15 items were classified as 'varia'. Of these, four will be described here. The first item is a flat, almost rectangular (broken) pallet, smoothed and polished on all sides. Two of the pallets' edges are clearly shaped into a pointed, rectangular edge. The second item is an elongated and smoothed triangle-shaped pebble that resembles an axe. This odd pebble retains its "axe form" also from a profile point of view (the 'axe' is tapered towards its 'working edge'). The third and fourth items are elongated, rectangle-shaped pebbles with incision marks going down along the items' longitudinal axis. The rest of the items included here are flat, rounded pebbles, flat irregularly shaped pebbles, oval stones and rectangular stones which were intentionally modified.

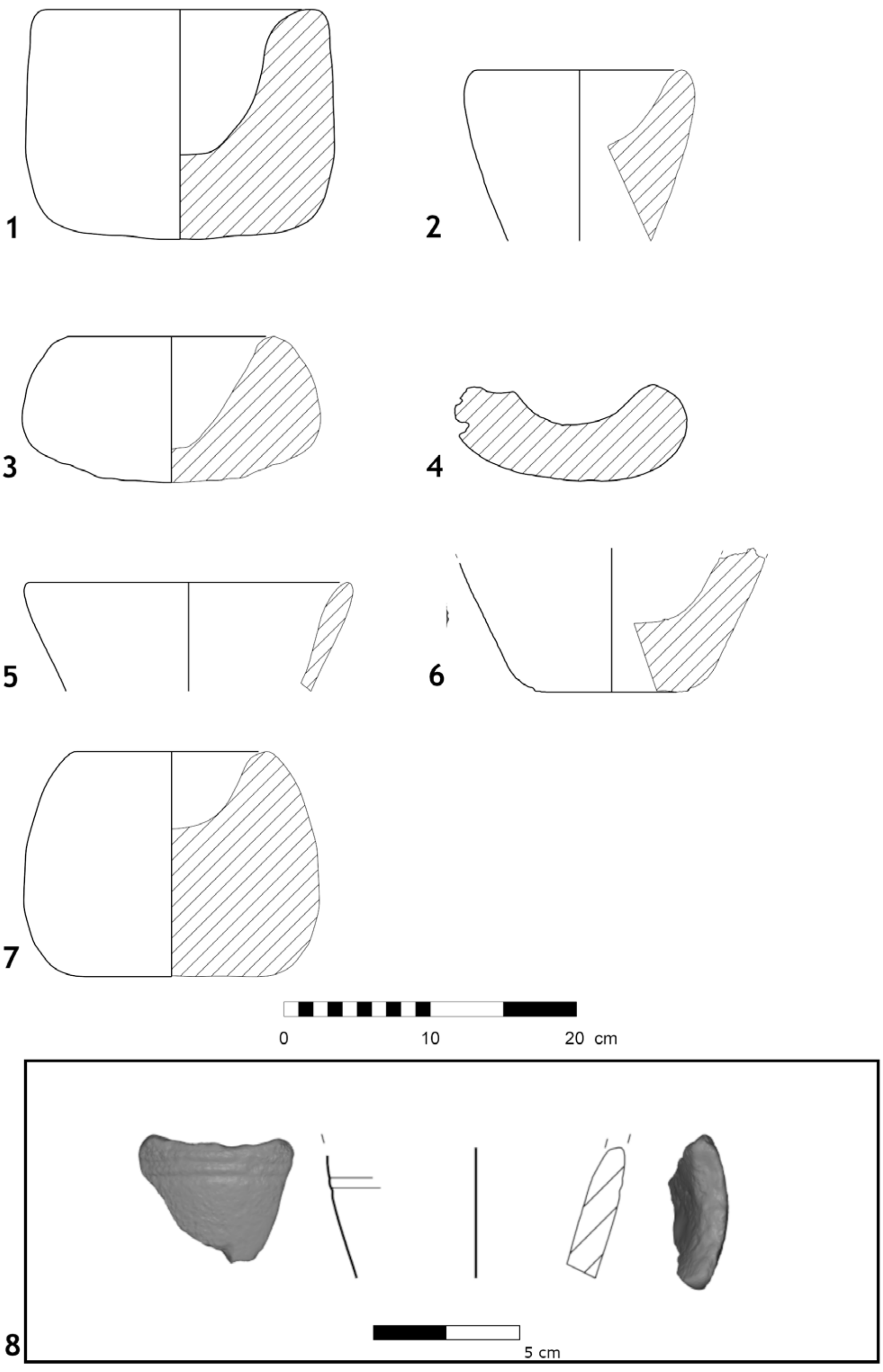

Figure 6: Cross-sections of multiple bowl-types and a decorated basalt rim: 1-2) Upright bowls; 3-4) Globular bowls; 5-6) V-shaped bowls; 7) Large mortar; 8) Decorated V-shaped bowl rim fragment.

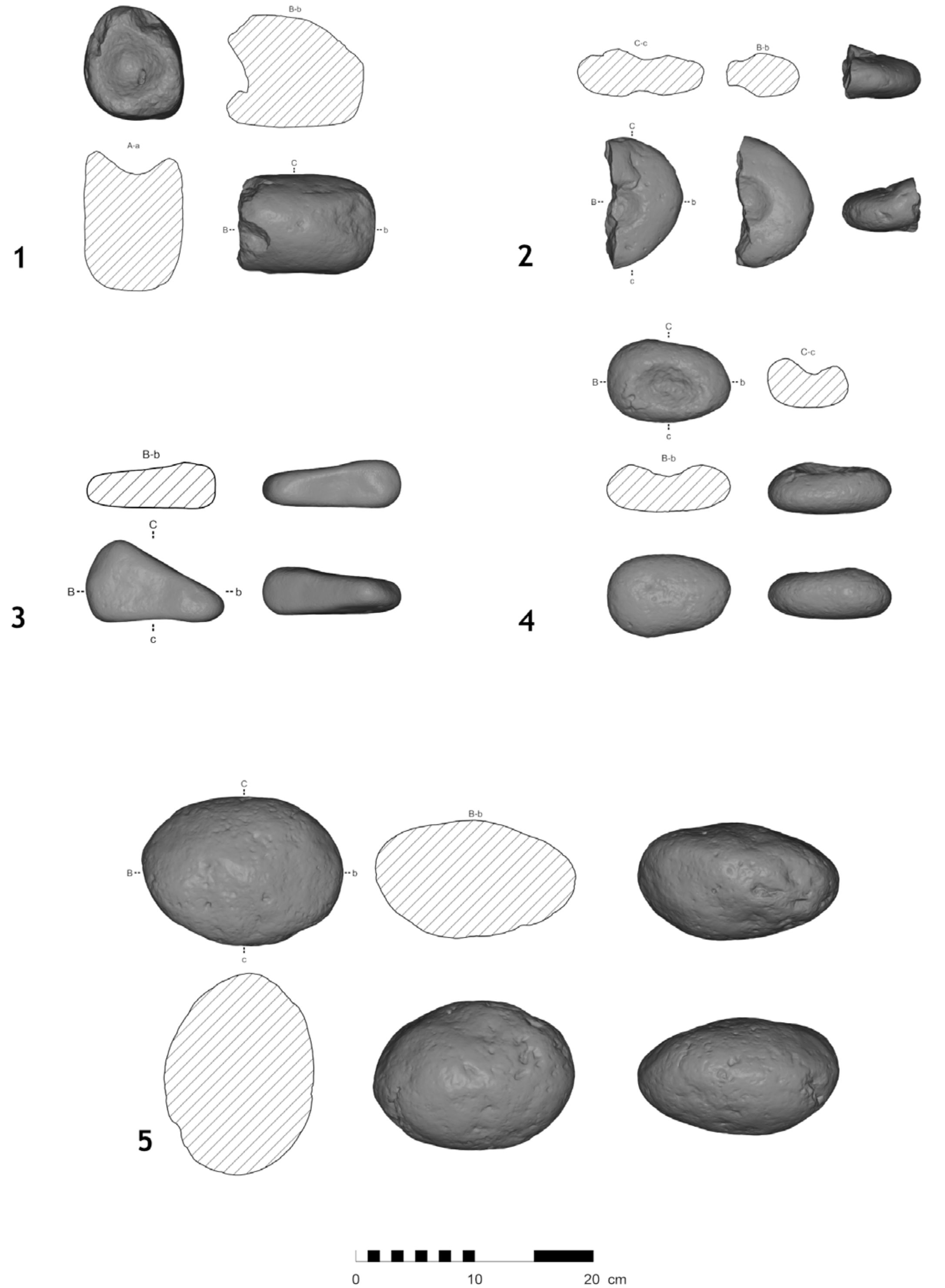

Figure 7: Upper grinding stones, bowlets, varia and hammerstones: 1) Cup on a pestle (recycled upper grinding stone); 2) Double-sided bowlet; 3) "Axe-shaped" stone (varia); 4) Shallow bowlet; 5) Large hammerstone.

Discussion

In recent years an increasing number of Late Chalcolithic ground stone assemblages have been studied and published, some targeting specific assemblages and others focusing on specific objects, mainly basalt vessels (e.g. Chasan *et al.* 2019; Chasan and Rosenberg 2018; Cohen-Klonymus and Bar 2016; Gilead 1995; Gopher and Eisenberg 2001: 139–140; Milevski *et al.* 2018; Rosenberg *et al.* 2016a; Rowan *et al.* 2006: 211–250; Rowan 2019), though a comprehensive comparison of whole assemblages or specific tool/vessel categories is not always easy. Furthermore, understanding and discerning contextual data is also problematic in many cases, especially when dealing with underground complexes, as so far, no reports from such contexts were published.

This is especially true to the Tsomet Shoket assemblage, that at least in part was retrieved from such underground chambers. The difficulty in understanding the connection between the underground chambers and the tools within them stems from the fact that all underground chambers at the site were filled up with sediment, thus, most tools retrieved from these chambers belong to the fill, rather than the chambers themselves. The only exceptions are four tools: one large grinding stone that was placed at the entrance of an underground chamber (see Be'eri *et al.* 2017: Figure 16), along with two smaller grinding stones, and one sinker that were retrieved from the floors/bottom of several underground chambers. Thus, only four tools contextually belong to the underground chambers at the site, constituting only 2.7% of the assemblage.

The most common tool types in the assemblage are the vessels, followed by lower and upper grinding stones and perforated pebbles. There is a considerable amount of unmodified perforated pebbles that seem to have been used. Judging by their amorphous shape, perforations and average weight (1.30 kg) they could have functioned as weights on nets, traps or various other devices. The most common raw material within the assemblage is limestone (67%), flint (9%), basalt (9%), sandstone (1%) and an unidentified type of rock (14%). In some cases, there seems to be a distinct selection of raw material per type of item; all V-shaped bowls and spindle whorls were made from basalt (see in this regards Rosenberg and Golani 2012), while upper and lower grinding stones were made mostly from limestone (excluding the four flint grinding stones), along with other types of vessels (globular bowls, mortars, bowlets, etc.). The common selection of limestone may relate to its availability, as the Hebron stream brings many boulders, cobbles and pebbles from the mountains with its annual floods.

Grinding is clearly the dominant food processing method practiced at the site as demonstrated by the upper and lower grinding stones, reflecting a trend known from previous periods (see Wright 1993 for the Pre-Pottery Neolithic period and Rosenberg 2011 for the Pottery Neolithic period). Of the lower grinding stones, the flint grinding stones are of special interest as this phenomenon is not common in most ground stone tools assemblages in the Near East (however, similar grinding stones were noted also in Abu Matar, see Perrot 1955: 189). The use of flint as raw material for grinding could indicate a variety of grinding methods, as the surface of the flint grinding stones is coarser than that of its limestone counterparts. The selection for materials of various textures for different types of food processing techniques was noted in the past – different types of cereals require different grinding methods and raw material texture (Dubreuil 2001; Nixon-Darcus 2014: 81–84, see also Nixon-Darcus this volume; Stroulia *et al.* 2017). This could stand true in the case of the flint grinding stones at this site as well. In terms of size, the lower grinding stones are typically larger than the upper grinding stones, some being exceptionally large (over 30.0 cm in length and over 20.0 kg in weight); others somewhat small (13.0–15.0 cm in length, weighing less than 1.0 kg). The upper grinding stones, in contrast to the lower grinding stones, measure between 4.0–18.0 cm in length and do not weigh over 2.5 kg at the most. It could be that some of the lower and upper grinding stones are compatible with each other; the lower grinding stones are larger than the upper grinding stones, and some the lower grinding stones somewhat align in size with the length of loaf-shaped upper grinding stones. Additionally, seven of lower grinding stones have a concave active face profile, and four of the upper grinding stones have a convex active face profile, all of which seem to fit each other well in terms of size.

The vessels in this assemblage are dominated by various types of bowls and bowlets, in particular – globular bowls and double-sided bowlets. The only vessels made of basalt are V-shaped bowls. Of the V-shaped bowls, one rim fragment bears incised triangle decorations internally, typical of the Late Chalcolithic period. Another fragment bears an external decoration of two incised, horizontal, parallel lines, which is also a typical decoration of the Late Chalcolithic (Chasan and Rosenberg 2019; Gilead 1995: Figure 7.1: 4, 6; Gopher and Tsuk 1996: Figure 4.14: 1, 3; Rosenberg *et al.* 2016a: Figure 7).

Perforated items make up a big portion of this assemblage (28%), interestingly, unlike other Late Chalcolithic sites, but in similar rates to some Early Bronze Age I sites (e.g. Mazar and Rotem 2012: table 9.1; Rosenberg and Greenberg 2014: table 5.1). The similarity to the EBI is also apparent in the exclusively-basalt spindle whorls in this assemblage, which are common during that period (Rosenberg and Golani 2012; Shamir 2003:210). In the Late Chalcolithic however, basalt spindle whorls are uncommon (e.g. van den Brink *et al.* 2016: table 11; Rosenberg and Golani 2012: table 2; Rowan 2003: table 6.1).

In general, the assemblage shares some similarities with other assemblages found in Late Chalcolithic Be'er Sheva' basin sites, such as Abu Matar and Bir es-Safadi. in the case of Abu Matar, both sites exhibit upper and lower grinding stones, including those made of flint; bowls and mortars; spindle whorls, weights and other types of perforated items and pebbles; maceheads, rectangular pallets; and the incorporation of locally available limestone (Perrot 1955: 189).

However, some differences are also of note between Tsomet Shoket and other assemblages in the northern Negev. For instance, while some of the Be'er Sheva' Valley sites seem to be rich in basalt vessels (see van den Brink *et al.* 1999; Gilead 1995; Perrot 1955), the Tsomet Shoket assemblage only has 13 basalt items (9% of the assemblage), of which only seven are vessel fragments (25% of the vessel assemblage). This is in contrast to the Grar assemblage, for example, where basalt is a popular raw material for ground stone tools production (49.3% of the assemblage, see Gilead 1995: 331–332). As in other Late Chalcolithic examples, it is clear that sites with a high ratio of vessels usually reflect a high ratio of basalt in the ground stone tool assemblage, due to the clear preference for basalt vessels during the Late Chalcolithic period, regardless of their geographic location and proximity to potential basalt sources (Rosenberg *et al.* 2016a). It is also interesting to note that unlike many other Late Chalcolithic sites in the northern Negev (e.g. van den Brink *et al.* 1999; Gilead 1995; Perrot 1955; Rowan 1998), and in other regions (e.g. Gilead 1995: 310–315; Ilan *et al.* 2015: 85–86; Lee 1973; Rosenberg *et al.* 2016a; Rowan 1998; Rowan *et al.* 2006: 597–601; Scheftelowitz 2004: 61–67) no fenestrated basalt pedestal vessels were found at the site so far. It could indicate that the Tsomet Shoket residents did not or could not fully participate in trade (specifically ground stone tools related trade), as 'exotic' non-local raw materials such as hematite are not present on site, and basalt is relatively scarce in comparison to other Late Chalcolithic sites in the region. The nearest possible sources of basaltic rocks to Tsomet Shoket are Transjordan, the Jordan Valley, the Galilee and the Golan, all of which are at least 50 km away.

The use of mostly local or readily available raw materials should also be noted. The low ratio of items demanding a high production investment like basalt vessels and maceheads probably made through specialized production and/or trade systems (Rosenberg *et al.* 2016a), compared to "simple" tools and vessels is apparent in this assemblage, though it may also be a result of partially excavated contexts (as most of the site remains unexcavated).

To sum up, the ground stone tools assemblage from Tsomet Shoket reflects domestic activities. The low frequency of basalt vessels which are common in many Late Chalcolithic sites could point towards a population that could not afford to trade such items. This could also explain the use of locally available raw materials to produce maceheads. Moreover, three of the four items retrieved from clear underground contexts are grinding stones, thus it is possible that some domestic activities (i.e. food preparation) took place both above-ground and underground.

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9. Grinding technologies in the Bronze Age of northern Greece: New data from the sites of Archontiko and Angelochori

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Introduction

Over the past decades, prehistoric macrolithic (or ground stone) artifacts have gained a rather prominent position within the discipline of archaeology. In northern Greece, recent, large-scale excavations on several prehistoric sites, especially in the region of Macedonia (cf., Kotsakis 2013, 2014), have yielded significant amounts of new macrolithic data, which became the focus of several studies (e.g., Alisøy 2002; Almasidou 2019; Bekiaris 2007, 2016, 2018, 2020; Chadou 2011; Chondrou 2011; Ninou 2006; Stroulia *et al.* 2017; Tsiolaki 2009; Tsoraki 2008). Rigorous analytical techniques (i.e., macroscopic examination, use-wear analysis, experiments, raw material provenance) and theoretical concepts (i.e., technology, chaine operatoire, object's biography) were employed to investigate the life-cycles of these technological products and explore their meaning for the prehistoric farming communities of the Aegean (e.g., Valamoti *et al.* 2020). Despite the unquestionable importance of these developments, there is a remarkable imbalance within this recent blast of the Aegean macrolithic studies: almost all of them concern assemblages dated to the Neolithic Period, while the Bronze Age material has yet to receive similar attention. Especially Bronze Age Macedonia, with the exception of few cases, such as Sitagroi (Elster 2003), Mesimeriani Toumba (Alisøy 2002) and Toumba Thessalonikis (Agatzioti 2000; Tsiolaki 2009), remains more or less a *terra incognita* regarding macrolithic technology. The vast majority of the relevant data derive from Bronze Age sites located in Southern Greece, particularly in Peloponnese, Cyclades and Crete (cf., Bekiaris *et al.* 2020).

Figure 1: Map of Northern Greece with the Bronze Age sites mentioned in the text.

In this paper, we take a step towards filling this research gap by presenting the grinding tools (grinding slabs and handstones)[1] from two Bronze Age tell-sites from Central Macedonia (Figure 1): Archontiko, in the region of Pella (Early/Middle and Late Bronze Age, *c.* 2135-1400 cal. BC), and Angelochori, in the region of Imathia (Late Bronze Age, *c.* 1630-1100 cal. BC). Through the comparison of selected technical and biographical attributes (i.e., raw materials, morphometrical features, manufacture and curation techniques, modes of use, recycling patterns, disuse and destruction), as well as through a brief investigation of their contexts of use and deposition, we investigate how grinding technology and the related food-preparation activities were manifested and practiced within these two Bronze Age communities of northern Greece. Furthermore, comparisons with other Bronze Age sites of northern Greece are made on several occasions (Figure 1).

The sites of Archontiko and Angelochori

Archontiko is situated in the northwestern part of the Thessaloniki-Yiannitsa plain and has the form of a large tell, extending over an area of *c.* 24 ha, with its height reaching up to 20 m. It is a long-lived site with traces of diverse human activities, dated both to prehistoric and historic periods (Papanthimou and Pilali 1992: 151; Pilali and Papanthimou 2002: 139; Chrysostomou and Chrysostomou 1992). Two major prehistoric occupation phases (B and A) have been identified in the site's stratigraphic sequence (cf., Papadopoulou 2010: 118; Papadopoulou *et al.* 2007: 77). Phase B, dates to the end of the 3rd and the beginning of the 2nd millennium, marking the transition from Early to Middle Bronze Age (c. 2135-1890 cal. BC). Its deposits consist of successive building horizons (II, III and IV), characterized by the presence of burnt post-framed buildings. Phase IV is the most thoroughly investigated and well-preserved habitation horizon. Based on several radiocarbon dates, it belongs to the Early Bronze Age period, *c.* 2135-1980 cal. BC (Pilali-Papasteriou *et al.* 2001; Papadopoulou 2010). Seven post-framed, rectangular houses (Houses A-Z) that were destroyed by fire are attributed to this habitation horizon. All houses follow the same orientation and are densely structured in individual clusters with shared walls. Between these clusters, extremely narrow, unroofed refuse areas occur (Papadopoulou *et al.* 2007; Papanthimou and Papadopoulou 2014). Each domestic unit was equipped with several clay structures, such as bins, hearths, ovens and platforms, indicating the strong association of the Early Bronze Age households with food preparation and storage practices (Papadopoulou 2010). Various mobile finds (e.g., clay vessels, macrolithics, lithics, bone tools, loom weights), but also animal bones (both terrestrial and aquatic), plant food remains (Valamoti 2002; Valamoti *et al.* 2008a; Valamoti *et al.* 2008b; Valamoti 2011) and burials (Pilali and Papanthimou 2002) derive from these units. The analysis of their contents points to self-sufficient, independent domestic groups, with no prominent social or hierarchical inequalities (cf., Papanthimou and Papadopoulou 2014). After 300 years of abandonment, the site was reoccupied during the Late Bronze Age (Phase A, *c.* 1510-1400 cal. BC). Occupation during Phase IV (Horizon I) is accompanied by distinct changes in building technology and pottery (Papadopoulou 2010; Deliopoulos 2006, 2014).

Angelochori is located in the western part of the Thessaloniki-Yiannitsa plain, in the region of Imathia. It is a tell-site that was inhabited during the Late Bronze Age (c. 1650-1000 cal. BC). The tell covers an area of *c.* 7 ha, while its height reaches 4.25 m. Archaeological research indicated that the tell was entirely man-made, created by the accumulation of sand and the creation of buttresses that enclosed the settlement (Stefani 2010). Three occupation phases (I-III), spanning the whole Late Bronze Age till

1 The technological analysis of the grinding tools from both sites was macroscopic and was conducted by Tasos Bekiaris. Selected grinding implements were sampled for plant micro-remains (e.g., phytoliths) by Dr. Danai Chondrou and Georgia Kassapidou. The same tools were subjected to use-wear analysis, also by Danai Chondrou (Chondrou *et al.* 2019).

the beginning of the Iron Age were identified. Their remains comprise the burnt superstructures and floors of wattle-and-daub and mudbrick buildings, but also several clay structures (e.g., hearths, ovens, platforms), rubbish pits and various organic and inorganic finds (cf., Stefani 2010).

The macrolithic assemblages

The macrolithic assemblage from Archontiko comprises 388 artifacts (Bekiaris forthcoming; Table 1). Most of them represent tools[2] that were employed in a wide range of tasks (e.g., grinding, abrading, polishing, cutting, chopping, digging and hammering), supporting various crafts and needs (e.g., food processing, object shaping, earth digging, tree felling, wood-working). Among them, were 123 grinding tools. Forty-five items were classified as grinding slabs or querns, 60 as handstones, while for 18 specimens it is unclear whether they have acted in a passive and/or an active manner. Sixty grinding tools derive from Early Bronze Age deposits (Horizons II-IV, cf., Table 2), while only five are so far attributed to the occupation of the Late Bronze Age (Horizon I). The date of the remaining items is for the time being uncertain since the chronostratigraphic study and contextual correlations of the finds at Archontiko is still in progress by the excavators, thus not allowing an in-depth examination of the grinding tools' contexts. Only for the grinding tools deriving from Phase IV has it yet been possible to proceed with a closer inspection of their contexts (see below). For the scope of this paper, the grinding tools from all occupation phases, including the uncertain cases, are discussed together unless stated otherwise.

Table 1: The macrolithic categories and types of Bronze Age Archontiko.

Macrolithic category	Macrolithic type	Count
Grinding, abrasive and polishing tools	Polishers/Pebbles	85
	Grinding tools (querns & handstones)	123
	Various handstones	42
	Abrader	15
	Total	265
Percussive tools	Globular hammers	22
	Hammers/pounders with ends	7
	Total	29
Edge tools	Perforated edge tools	30
	Non-perforated edge tools	38
	Edge tools raw materials	1
	Total	69
Multiple use tools	Grinding/percussive	5
	Total	5
Miscellanea	Perforated objects	10
	Incised objects	1
	Figurine part (?)	1
	Drill core	1
	Perforator	1
	Discoidal slabs	5
	Undetermined	1
	Total	20
	Total	388

2 The study of the assemblage is ongoing.

Table 2: The distribution of the grinding tools from Archontiko within the different occupation horizons. Horizon 1 belongs to the Late Bronze Age, while Horizons II-IV to the Early Bronze Age. The column marked with a '?' includes the specimens of uncertain date.

	Occupation phases								
Grinding tools types	**I**	**I/II**	**II**	**II/III**	**III**	**III/IV**	**IV**	**?**	**Total**
Handstone	1	4	3	2	7	-	15	27	59
Grinding slab	2	2	7	2	7	1	4	21	46
Grinding slab/handstone	2	1	3	-	1	-	8	3	18
Grand Total	5	7	13	4	15	1	27	51	123

There are only 31 intact grinding implements in Archontiko's macrolithic assemblage (Table 3). Of them 23 are handstones, and only eight are grinding slabs. The remaining items are broken, with the vast majority (c. 60%) surviving at an extremely fragmented state (<50% of their original sizes). Post-depositional causes are not the only factors that have affected the preservation of Archontiko's grinding implements. Acts of recycling, redesigning and deliberate destruction held a significant role in the life-cycles of these tools, as will be discussed below. No differences in preservation patterns have been observed between the Early and the Late Bronze Age phases.

Table 3: Plenitude proportions of the grinding implements from Bronze Age Archontiko. Proportion rates are based on the estimated original size of the tool.

Grinding tools	N	%
Handstones	60	100,0%
Intact	23	37,3%
Large part (>50%)	11	18,6%
Small part (<50%)	14	23,7%
Fragment (<25%)	12	20,3%
Grinding slabs	45	100,0%
Intact	8	17,8%
Large part (>50%)	5	11,1%
Small part (<50%)	14	31,1%
Fragment (<25%)	18	40,0%
Grinding slab/handstone	18	100,0%
Small part (<50%)	1	5,6%
Fragment (<25%)	17	94,4%
Grand Total	123	100%

The macrolithic assemblage from Angelochori comprises less than 80 artifacts (Bekiaris personal observation), among which only 14 grinding tools. Nine of them were classified as grinding slabs, and five as grinding slabs/handstones. In contrast to Archontiko, most grinding implements from Angelochori survive at an intact state. The few broken specimens seem to have been destroyed by fire, weathering or post-depositional processes. No tools with evidence of deliberate breaking were recognized in this small assemblage. Despite their intact proportions, the overall preservation of the grinding artifacts from Angelochori is not good, since their surfaces are encrusted with hard sediment.

Figure 2: a-d Grinding tools from Bronze Age Archontiko (Photos: Tasos Bekiaris).

Figure 3: a-c Grinding tools from Bronze Age Angelochori (Photos: Tasos Bekiaris).

The typology and technomorphology of the grinding implements

The Bronze Age communities of Archontiko and Angelochori employed rocks belonging to different lithological groups (e.g., sedimentary, igneous and metamorphic) for the production of their grinding equipment. In Archontiko, there is an evident predominance of igneous lithic materials, especially granites originating from Fanos area, over metamorphic (e.g., gneisses, quartz-feldspar) and sedimentary rocks (e.g., sandstones, conglomerates, limestones), which are represented with lower rates (Table 4). The Fanos granite is a leucocratic rock, medium to coarse-grained, with ferromagnesian minerals and it is described by three petrographic types corresponding to aplitic granite, granite (stated as 'Type 1' in Table 4) and to microgranite (Christofides *et al.* 1990; Michail *et al.* 2016). The Fanos granites, as well as most lithic materials of the assemblage, were collected in the form of cobbles or boulders, from the tributaries of the nearby Axios River, as indicated by the presence of waterworn surfaces on the unmodified parts of the tools. According to the macroscopic petrographic examination of the assemblage, two grinding tools are made of granitic rocks that can be characterized as 'non-local'. One is a granite (Figure 2c), probably related to Varnountas plutonic rocks, from Western Macedonia (Koroneos *et al.* 1993; stated as 'Type 2' in Table 4) and the other a hornblende granite of a yet undetermined origin. The date and context of the first implement are uncertain, while the second derives from Building A of Phase IV. No preferences in raw material choices were observed between the different habitation phases.

The grinding tools from Angelochori are also primarily made of hard igneous materials, namely granites and peridotites, but also sedimentary rocks, like coarse-grained sandstones or conglomerates (Table 5). The rocks were again acquired from local secondary sources. The preference for granites for the production of grinding implements at both sites must have been driven by two main factors: (a) the existence of the raw materials in the vicinity of the sites and (b) their mechanical properties (e.g. hardness, durability, workability, uneven texture), which were compatible with the intended uses of the tools.

Table 4: Raw material frequencies for the grinding implements from Bronze Age Archontiko.

Raw materials	N	%
Igneous	***58***	***47,1%***
Aplitic granite (Type 1)	9	7,4%
Dunite	1	0,8%
Gabbro	1	0,8%
Granite (Type 1)	35	28,5%
Granite (hornblende)	1	0,8%
Granite (Type 2)	1	0,8%
Microgranite	10	8,1%
Metamorphic	***23***	***18,7%***
Gneiss	8	6,5%
Quartz-feldspar	15	12,2%
Sedimentary	***42***	***34,1%***
Conglomerate	3	2,4%
Limestone	3	2,4%
Marl limestone	1	0,8%
Quartz sandstone	5	4,1%
Sandstone	30	24,4%
Grand Total	**123**	**100,0%**

Table 5: Raw material frequencies for the grinding implements from Bronze Age Angelochori.

Raw materials	N	%
Igneous	***7***	***50,0%***
Granite	5	35,7%
Peridotite	2	14,3%
Metamorphic	***1***	***7,1%***
Gneiss	1	7,1%
Sedimentary	***6***	***42,9%***
Sandstone	6	42,9%
Grand Total	**14**	**100,0%**

Table 6: Manufacture ratios for the grinding implements from Bronze Age Archontiko and Angelochori.

Sites	Manufacture							
	Manufactured implements		Expedient implements		Undetermined		Total	
	N	%	N	%	N	%	N	%
Archontiko	83	67%	34	28%	6	5%	123	100%
Angelochori	14	100%	-	-	-	-	14	100%

At both sites, most grinding implements were the outcome of manufacture sequences (Table 6). Two reductive percussive techniques were employed for making the grinding implements: flaking and pecking. These techniques were applied either independently or in combination for the following purposes: (a) to create one or two rough workfaces with the desired configuration, (b) to edit the overall sizes of the raw materials and (c) to partly modify the dorsal faces of the passive implements to increase stability or the backs and ends of the active tools to facilitate holding (Figure 3a). The workfaces of most grinding tools preserve only traces of pecking (e.g., Figure 2a, 3b). If flaking was somehow involved in their creation, it has been obliterated by subsequent modifications and use. Pecking marks often cut through heavily worn faces and therefore they could be attributed to curation practices, such as re-sharpening. Few expedient tools are documented in Archontiko, through cobbles that have been utilized as active grinding tools without receiving any kind of modification before their use (Table 6).

The grinding implements from both sites comprise types that are rather common in the macrolithic industries of Bronze Age Greece (cf., Bekiaris *et al.* 2020). Grinding slabs belong to the 'open' type and are characterized by their broad, unrestricted workfaces (Figure 2 and 3). Open grinding slabs would have been combined with handstones of a length smaller or equal to the width of the stationary implement or with handstones of a length that would have exceeded the width of the passive counterpart and thus would have acted in an 'overhanging' manner (cf., Hamon 2008; Stroulia *et al.* 2017). The active implements in both toolsets would have performed reciprocal movements over the passive surfaces, as is further indicated by the direction of scratches preserved on the workfaces of several implements. Both types of active tools are present at Archontiko, but not at Angelochori, where small-sized handstones are absent. Intriguingly, the narrow widths of some grinding slabs from Angelochori suggest that they could have been used with such implements. Therefore, their absence raises questions regarding the survival of small-sized handstones in the archaeological record in case they were manufactured of non-lithic, perishable materials, such as wood (cf., Delgado-Raack and Risch 2009). A similar suggestion was also made by E. Tsiolaki (2009: 62-63) to explain the vague presence of active grinding tools in Toumba Thessalonikis.

Regarding their morphology, the grinding tools from Archontiko usually have curvilinear (e.g., elliptical) or rectilinear (e.g., rectangular) plans (Figure 2, 3). The handheld grinding implements exhibit greater morphological variability than the grinding slabs, including also circular, trapezoidal and subtriangular specimens. Most of these shapes are not the result of modifications, but reflect the natural forms of the lithic raw materials. This is further suggested by the presence of the natural cortex on the sides and bases of most tools (e.g., Figure 2d). In Angelochori, rectangular/sub-rectangular and elliptical shapes occur, but in this case, the forms are elongated with the tools being larger in length and narrower in width (Figure 3). In some cases, these shapes were the outcome of manufacture. Elongated slabs were selected from river sources and usually, one of their long sides was further altered through intense flaking in order to reduce its size (Figure 3a). Such a modification would have aimed on the creation of passive surfaces with a narrow width, probably combined with small-sized handheld grinders.

The grinding toolkits from Archontiko included both large and smaller implements. Judging from the intact grinding slabs, small-sized specimens seem to predominate (<30 cm in length, Figure 2b), but if broken specimens are included in the equation the imbalance is evened since many of them derive from large-sized tools. The intact lengths of the grinding slabs range between 19-51 cm, their intact widths between 18-22 cm, their intact thickness between 7.1 and 10.4 cm and, with one exception, their weights between 7-9.6 kilos. The exception concerns an Early Bronze Age (Horizon II) intact grinding slab (Figure 2a), which weighs 17.1 kilos, while its length reaches up to 51 cm. In contrast to the portable sizes of most grinding slabs from Archontiko, this one should have remained fixed at a certain space while in use, though according to the excavation's archives no specific features seem to be associated with this tool. Tools of similar sizes are known from other Aegean sites dated both to Neolithic and Bronze Age (cf., Bekiaris *et al.* 2020). These 'bulky' implements are certainly capable of producing larger amounts of ground product, while their sizes suggest that they were probably immobile equipment that could be associated with certain specialized areas of the domestic environment (e.g., rooms/workspaces devoted to grain processing).

The handheld grinding tools from Archontiko can be divided in two groups according to their sizes: handstones 10-20 cm in length and handstones 21.5-27 cm in length that would necessitate handling with both hands (Figure 2c). The second group predominates. No size differences were observed between the grinding implements belonging to the Early Bronze Age and the few Late Bronze Age specimens. There is nothing peculiar in that uniformity since grinding implements are known to exhibit minor changes in their technical characteristics through time (cf., Bekiaris *et al.* 2020).

At Angelochori, the sizes of the intact grinding tools, both passive and passive/active, range between 32.5-38 cm in length and 18.2-22.2 cm in width and therefore are considered to be large (Figure 3). Their thickness ranges between 3.8-11.4 cm, with some of them falling below 6.5 cm (Figure 3a, 3c). These rates indicate tools that were too thin and thus vulnerable to be reused or re-pecked. Their worn faces and their thickness suggest that they had been exhausted from prolonged use.

Patterns of use, consumption and disuse

Most grinding tools from Archontiko (n=94) have only one work face with traces of abrasive wear (Table 7). Some tools, mostly handstones, have developed two parallel and opposed workfaces, while other specimens two adjacent use facets. Fewer are the cases with multiple (more than two) used surfaces.

Tools with two or more workfaces usually represent reused cases (Table 8), since at some point of their life-cycles another workface was used in more or less the same manner as the original one (cf., Stroulia 2010). In most specimens, the reused faces are identical to the originals in terms of size, configuration, use wear and use intensity. At others they deviate, indicating that they had been probably used in a slightly different way, or that they had been used for a more confined time period that had not led to the development of the exact same characteristics. Reused implements appear in all habitation phases.

Table 7: Number and relation of the use surfaces of the grinding implements from Bronze Age Archontiko and Angelochori.

	Archontiko		Angelochori	
Use surfaces	N	%	N	%
Unused	1	0,8%	-	-
Single	94	76,4%	14	100%
Two opposed	9	7,3%	-	-
Two adjacent	4	3,3%	-	-
Two overlapped	4	3,3%	-	-
Multiple	6	4,9%	-	-
Indeterminate	5	4,1%	-	-
Grand Total	**123**	**100,0%**	**14**	**100%**

Table 8: The use sequences of the grinding tools from Bronze Age Archontiko.

Use sequences	N	%
Unused	1	0,8%
Single	87	70,7%
Reused	12	9,8%
Recycled	10	8,1%
Redesigned	8	6,5%
Indeterminate	5	4,1%
Grand Total	**123**	**100,0%**

The morphology of the use surfaces across the length and width axes vary from flattish (i.e., flat/flat, flat/inclined), to slightly curved (i.e., convex/convex), and concave (i.e., concave/flat, concave/convex, concave/concave). The 'saddle' (concave/convex) configuration, which is rather common in the grinding industries of prehistoric Greece (cf., Stroulia *et al.* 2017; Bekiaris *et al.* 2020), is encountered both in passive and active implements at Archontiko and in the grinding slabs from Angelochori. Most workface configurations are the outcomes of use and they have been developed on surfaces, which were originally either flat or convex. The workfaces were affected and altered progressively by the morphology of the passive or active counterpart, the processed substance/item, curation practices, the user's body posture, kinetics and applied pressure, while others have resulted from overlapping uses occurring over the same workface (cf., Stroulia 2018: 207).

Some grinding implements are considered recycled (Table 8) since they were re-employed to a task different than the original one. Recycled implements are encountered mostly in Phase IV. Fragments

Figure 4: Curated grinding implements from Bronze Age Archontiko. (a) Part of a grinding slab recycled as a handstone, (b) small-sized handstone recycled as a pounder, (c) grinding slab redesigned through peripheral flaking to be used as a handstone, (d) grinding slab redesigned through breaking to acquire a geometrical shape (Photos: Tasos Bekiaris).

Figure 5: Fragmentary grinding tool from Bronze Age Archontiko with weathered surfaces, recycled as an active percussive implement (Photos: Tasos Bekiaris).

of grinding slabs were recycled as handstones (Figure 4a), while other grinding tools were used as hammers/pounders or as abraders (Figure 4b). Some of these implements have been redesigned before their recycling through flaking and pecking (Figure 4c, 4d). Two additional reshaping techniques are attested on these items. The first one, abrasion, is encountered rather rarely. It was applied for smoothing the broken surfaces of some grinding slabs that were meant to be reused as handstones, to ease their handling. The second could be perceived either as a practice or a technique. We are referring to the act of breaking, which is attested on several grinding implements at Archontiko. In many cases, this practice aimed at reshaping the tools, by removing large portions of their bodies with targeted and often forced strokes. Large handstones that broke intentionally to be used as one-hand items or grinding slabs that acquired new geometrical shapes through peripheral breakage, and not just flaking, are encountered rather frequently (Figure 4d). Thus, in Archontiko deliberate breaking was applied primarily in order to prolong the biographies of the grinding tools, rather than to terminate them (cf., Adams 2008; Stroulia and Chondrou 2013).

Some grinding tools from Archontiko seem to have had even more complex lives. These items represent parts of old tools that were recycled after a period of abandonment (Figure 5). Their broken parts are usually weathered and partially rounded, an evidence of post-depositional damage, while their faces and broken sections are covered with patina, suggesting a prolonged exposure to the sun. Either abrasive or percussive wear occurs over these heavily weathered surfaces, indicating that the inhabitants of Archontiko picked up these old tools and re-employed them in the context of new tasks. Some of them were later reused as building material, by being incorporated in the walls and floors of clay structures, such as bins, ovens and hearths. Such consumption patterns are well documented in Phase IV, as will be discussed below.

The inhabitants of Angelochori had not developed similar attitudes towards their grinding equipment. According to the macroscopic analysis most grinding implements seem to have been ‘single-function’ implements. They have only one workface with either concave/flat or flat/flat configuration. They have not been reused, nor redesigned. Almost all of them were re-sharpened many times, in order to remain functional until their exhaustion. However, we cannot exclude the possibility that these implements were used for processing different materials on the same workface, thus resulting to overlapping occurrences of wear, which are impossible to be discerned only through macroscopic observation.

Contexts of use and deposition

Regarding Archontiko, our study has so far focused on the contextual associations of the grinding implements deriving from the so-called Phase IV. Twenty-seven grinding implements are attributed to this phase. Most of them are handstones. Querns are encountered less frequently in this phase. Twenty-six grinding implements can be attributed to a specific context, either the interior of the buildings ascribed to this phase or their adjacent open areas (cf., Table 9). It would not be far-fetched to hypothesize that the inhabitants of these buildings would have used stone grinding tools for processing plant-food ingredients. Indeed, rich assemblages of plant food remains were retrieved from these houses. According to the archaeobotanical study (cf., Valamoti *et al.* 2008a), a wide range of cereal species such as einkorn, emmer, spelt and free-threshing wheat, as well as barley seeds were stored inside some domestic units, especially Building A (Papanthimou *et al.* 2013). Sprouted cereal grain together with masses of cereal fragments, as well as loose fragments, were identified, suggesting the grinding of malt, perhaps for the production of beer (Valamoti 2018). Initially, this material was interpreted as possible remains of pre-preprocessed cereals such as bulgur, or *trachanas*. Yet, no characteristics of boiling were observed in the limited evidence available at the time (Valamoti 2002; Valamoti 2011). These ground cereal grains clearly point to the processing of kernels with some kind of equipment. Macrolithic tools would have been suited for bulgur and *trachanas*, but perhaps less suited for the grinding of malt that is very friable, and perhaps would have necessitated the use of wooden processing equipment.

Table 9: The distribution of grinding tools from Early Bronze Age Archontiko within the buildings and open areas of Phase IV.

Grinding implements	Phase IV Contexts							Total
	Building A	Building C	Building D	Building Z	Building E	Building ST	Exterior space	
Handstone	1	1	-	6	2	2	2	14
Grinding slab	1	-	-	-	2	-	1	4
Grinding slab/ handstone	-	-	4	2	1	1	-	8
Grand Total	2	1	4	8	5	3	3	26

Despite the abundance of food remains, very few intact and still useable grinding tools were located on the floors of these houses, in the vicinity of food preparation, cooking, or storage areas, as is the case for other Bronze Age sites in northern (e.g., Sitagroi: Elster 2003; Mesimeriani Toumba: Alisøy 2002; Toumba Thessalonikis: Tsiolaki 2009) and southern Greece (cf., Bekiaris *et al.* 2020). Contrarily, the vast majority of the Phase IV grinding tools survive at an extremely fragmented state. Moreover, some of these fragments were found incorporated into clay structures, post-holes, or the buildings' walls. Even an intact and still useful grinding slab was placed inside a thermal structure in Building A. It has been suggested by D. Rosenberg, that such practices may not reflect the mere practical recycling of old stones as building material, but should be rather perceived as symbolic acts, associated with the social and economic meaning that the grinding implements had acquired during their lives (cf., Rosenberg 2013). The scarcity of in situ grinding tools from the Phase IV dwellings leads to the following hypotheses: (a) the inhabitants of Archontiko removed intact and thus still useful grinding tools from the buildings before their conflagration, to consume or dispose them elsewhere, (b) the buildings did not host grinding activities, at least by the time of their destruction and (c) grinding practices were regularly hosted outside the dwellings, in open-air areas of the settlement, as other archaeological examples from Bronze Age Greece suggest (cf., Bekiaris *et al.* 2020). The last scenario is most plausible since few intact grinding implements were retrieved from open areas located to the west of the buildings. To date, these open areas have been only partially excavated.

In contrast to Phase IV of Archontiko, intact, yet exhausted, grinding tools were unearthed in the interior of some buildings at Angelochori. The tools were found resting on the floors of the houses next to ovens and hearths, but not in the open areas. This spatial distribution is rather typical for most Bronze Age Greek sites (cf., Toumba Thessalonikis, Tsiolaki 2009: 102; Bekiaris *et al.* 2020). At Angelochori other grinding implements were found buried in secondary contexts such as pits. A lot of them were burnt, probably from the fires that had destroyed the settlement several times during its biography.

Conclusion: Grinding technology in the Bronze Age of Northern Greece

The comparison of the grinding tools from the sites of Archontiko and Angelochori have shed some light on the ways through which the Bronze Age communities of northern Greece produced and consumed their grinding equipment. Hopefully, these new data will add some important pieces in the extremely fragmented picture that we have regarding grinding technology and the macrolithic industries from the Bronze Age of northern Greece. Both typologically and technologically, the grinding tools from Archontiko and Angelochori share many similarities with other contemporary northern Greek sites (cf. Bekiaris *et al.* 2020). In terms of typology, the predominance of open reciprocal grinding slabs, of elliptical or rectilinear shapes, and the absence of basin rotary querns is characteristic for many Bronze Age sites of the region (e.g., Servia: Mould *et al.* 2000; Kastanas: Aslanis 1985; Hochstetter 1987; Mesimeriani Toumba: Alisøy 2002; Toumba Thessalonikis: Agatzioti 2000; Tsiolaki 2009; Sitagroi: Elster 2003). In addition to this, the grinding toolkits from Archontiko and Angelochori had comprised both smaller and larger toolsets, as seems to be the case for other Bronze Age sites in northern Greece, such as Mesimeriani Toumba (Alisøy 2002) and Toumba Thessalonikis (Agatzioti 2000; Tsiolaki 2009). The completion of the microwear and plant microremains analyses (Chondrou *et al.* 2019) could highlight the possible functional significance between the larger and smaller toolkits of the case studies. Neither Archontiko nor Angelochori have yielded stone pounding implements. So far, the repeated absence of stone mortars[3] from the food-processing macrolithic equipment of Bronze Age northern Greece contrasts the picture from southern Greece and the Aegean Islands, where mortars are rather common and closely associated with the material culture of the Bronze Age in the south (cf. Bekiaris *et al.* 2020).

Further similarities are recognized in the production of the grinding tools between the two sites. The preference of durable lithic materials, the exploitation of local secondary resources for their procurement, their transformation into functional tools with the same percussive techniques, but also their regular curation are common attributes that could reflect broader technological traditions and certain notions on the management of stone resources and the production of grinding implements. Certain deviations and differences (e.g., the narrow width of the grinding slabs from Angelochori, occasional variations in the manufactural sequences of some tools or in the parts subjected to modification) could point to the existence of local technological behaviors, but also to individual preferences, aesthetics, skills and time constrains in tool production. The presence of few non-local raw materials at Archontiko may have been the material results of travels, social and/or exchange networks, on which the Bronze Age community had participated. Besides Archontiko, in the case of Bronze Age northern Greece, grinding implements made of non-local raw materials are so far only known from Sitagroi (Dixon 2003; Elster 2003). On the contrary, in southern Greece there is significant evidence for the procurement of non-local raw materials or already finished grinding implements through trade routes and exchange networks during the Bronze Age (cf., Bekiaris *et al.* 2020).

Despite the similarities regarding the production of grinding tools from the two case studies, their consumption was significantly different. The inhabitants of Archontiko preferred to invest time on curating and redesigning some of their grinding implements to consume them in the context of other practices, rather than to replace them with new tools. Despite the abundance of suitable lithic materials at the immediate periphery of their settlement, at certain cases the Bronze Age stoneworkers chose to recollect weathered fragments of old tools and reuse them in new ways. Moreover, at several occasions they chose to transform their grinding equipment through breakage, sometimes in order to create new tool-types. Such acts may reflect certain choices regarding the manipulation of raw materials and the grinding equipment, personal affections or bonds to particular artifacts or symbolic connotations about the meaning of specific technological products (cf., Lidström-Holmberg 1998; Van Gijn 2014; Watts 2014). Curation patterns, disuse and destruction are rarely discussed in the relevant literature for other northern Greek Bronze Age sites (Bekiaris *et al.* 2020). Alisøy (2002: 284) mentions the co-existence of impact and abrasive wear on several grindstones from Mesimeriani Toumba, as well as the very fragmentary state of preservation of most specimens, but it is unclear if they represent recycled and/or deliberately destroyed cases, similar to those of Archontiko. Similar patterns of curation are

3 An ambiguous specimen is reported from the Phase V of Sitagroi (Elster 2003: 186).

rather vague in Angelochori, where the tools seem to maintain their grinding functions until the end of their biographies.

What is common in the life-cycles of the grinding implements at both sites, is that at some point they were used for the processing of plant-foods, as suggested by their technological attributes and the macroscopic examination of their workfaces. The preliminary results of the microwear study also confirm this hypothesis (Chondrou *et al.* 2019). There is still much ground to be covered towards understanding the grinding technologies of the Bronze Age in northern Greece. Hopefully, this study will provide a significant step towards this goal, by enriching the archaeological record with new, comparative data for future studies on these neglected technological products of Bronze Age Greece.

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10. Pounding Amid The Cliffs: Stationary Facilities And Cliff Caves In The Judean Desert, Israel

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Introduction

The use of cliff caves in the Judean Desert during the Late Chalcolithic period (c. 4500-3800 BCE) is worldly renowned since 1961. In that year, a hoard containing over 400 metal objects was found in a cave in *Wadi Mahras* (Mishmar Valley, Heb. *Nahal Mishmar*), one of the deep dry ravines draining into the Dead Sea (Bar-Adon 1980). The Cave of the Treasure, as it came to be known, and the circumstances that led to the caching of the hoard, gained growing scholarly interest in the following decades (e.g., Garfinkel 1994; Goren 2008; Moorey 1988; Sebbane 2016; Tadmor 1989; Tadmor *et al.* 1995; Ussishkin 1971). In tandem, little attention was paid to the regional aspects of this phenomenon, though Late Chalcolithic presence was identified in numerous cliff caves in the Judean Desert (Davidovich 2008). Since their initial discovery in the 1950s (Aharoni 1961a; de Vaux 1961), these hazardous, difficult-to-access caves were understood as places for temporary refuge, serving groups that fled from sedentary Late Chalcolithic communities in turbulent times (e.g., Avigad 1962: 180; Haas and Nathan 1973; Ussishkin 1980: 41). While by no means exclusive, this interpretation seems to be best suited to the environmental, geographic, material and ecofactual evidence collated (Davidovich 2008) compared with other interpretations proposed over the years (e.g., Bar-Adon 1980; Gates 1992; Ilan and Rowan 2015).

One of the least investigated, yet most remarkable features accompanying the Late Chalcolithic presence in the cliff caves of the Judean Desert are stationary rock installations, hewn in limestone and dolomite rocks in and near caves. They are remarkable, because they signify stability and durability in what appears to have been a rather episodic, short-term, if not chaotic, existence. Moreover, while some of these installations are placed in easily fathomable locations, commonly in well-lit spaces near cave openings, others are peculiarly set in more remote localities, away from cave mouths within the precipitous landscape. Understanding the role of these installations entails a detailed scrutiny of their distribution, typology, spatial relations, and chronology. Concurrently, a thicker description of several outstanding examples, advocating a sensorial approach to landscape (Hamilakis 2013: 97-104), is needed to uncover other, more covert behaviours associated with life amid the cliffs.

Corpus

24 stationary installations are known to date from ten cave sites in the area stretching between *Wadi an-Nar* (Qidron Valley) in the north and *Wadi Hafhaf* (Rahaf Valley) in the south, encompassing the lion's share of the Judean Desert in which cliff caves containing ancient occupations were attested (Figure 1). Roughly one third of all cliff cave sites with late prehistoric occupations investigated in this region over the last 70 years (see Davidovich 2008 for details) yielded evidence for at least one installation, yet it is not improbable that in other caves similar installations are still covered by accumulation or were left undocumented. Half of the cave sites included in the corpus (Table 1) are located within high sheer cliffs, and accessing them demands, today as in the past, walking on steep slopes above deep abysses, and use of ropes or ladders to reach cave mouths. No attempts at improving ways of access to the caves were noted, and there are no signs indicating that access was significantly different during

the Late Chalcolithic. Other caves are located in more accessible locations, in proximity to valley floors or to the desert plateau. All caves were used in their natural state, usually involving the occupation of

Figure 1: Location of the Judean Desert in its Eastern Mediterranean context (upper left), and distribution of caves containing stationary facilities together with late prehistoric occupations (prepared in ArcGIS Pro by Ido Wachtel).

dark, narrow, unventilated spaces; only rare examples of artificial modifications (e.g., floor levelling) were observed in these caves apart from those discussed in this article.

Table 1: Corpus of stationary facilities in the cliff caves of the Judean Desert.

#	Type	Cave/Complex	Location	Diameter/ Length	Depth	Diam./Depth Ratio	Publication
1	Basin	Naqeb Mazen	External	30	15+		-
2	Cupmark	Christmas	External	15	8	1.88	Davidovich 2008: 381
3	Cupmark	Pool	Internal	14	6	2.33	Cohen 2015: 36
4	Cupmark	Pool	Internal	12	3.5	3.43	Cohen 2015: 36
5	Cupmark	‘Arugot 304C	Internal	12	7	1.71	Porat 2006: 60, fig. 68: 6
6	Cupmark	Hever B	External	15	9	1.67	-
7	Cupmark	Hever A-B	External	?	?		-
8	Grinding Facility	Hever A-B	External	?	?		-
9	Grinding Facility	Hever A-B	External	?	?		-
10	Cupmark	Treasure	Internal	23	12	1.92	Rosenberg and Davidovich 2015: 156-158, SRF1
11	Grinding Facility	Treasure	Internal	41	11		Rosenberg and Davidovich 2015: 156-158, SRF2
12	Cupmark	Treasure	Internal	19	14	1.36	Rosenberg and Davidovich 2015: 156-158, SRF3
13	Grinding Facility	Treasure	Internal	43	2		Rosenberg and Davidovich 2015: 156-158, SRF4
14	Cupmark	Miqveh	Internal	15	10	1.50	Davidovich 2008: 234-235
15	Cupmark	Zeelim LCC 33	Internal	13	14	0.93	Rothenberg 1966: 168
16	Cupmark	Zeelim LCC 33	Internal	10	6	1.67	Rothenberg 1966: 168
17	Cupmark	Zeelim LCC	External	16	8	2.00	Davidovich 2008: 207
18	Cupmark	Masada South 2	Internal	20	17	1.18	Yadin 1965: 115; Davidovich 2008: 191-192
19	Cupmark	Masada South 2	Internal	DNP	10+		Yadin 1965: 115; Davidovich 2008: 191-192
20	Installation	Masada South 3	Internal	22	12	1.83	-
21	Cupmark	Upper Rahaf	External	?	?		Davidovich 2015b: 401
22	Cupmark	Upper Rahaf	External	?	?		Davidovich 2015b: 401
23	Cupmark	Upper Rahaf	External	?	?		Davidovich 2015b: 401
24	Cupmark	Upper Rahaf	External	?	?		Davidovich 2015b: 401

The stationary installations did not draw the attention of most surveyors and excavators of Judean Desert caves in the early decades of exploration, and detailed treatments are absent from the literature. Brief mentions of such installations were given in four instances (Table 1). In other cases, stationary facilities were first noted only in recent years, when previously-explored caves were revisited and restudied (Davidovich 2008; Eshel and Porat 2009; Frumkin [ed.] 2015; Porat 2006). The renewed field studies involved detailed descriptions, measurements, photographing and sketching of stationary facilities, as well as examination of their spatial associations. Table 1 presents the data for all installations included in the corpus (see Davidovich 2008: 115-116 for a brief earlier treatment, and Rosenberg and Davidovich 2015 regarding the Cave of the Treasure installations).

Typology

The stationary installations associated with the Judean Desert cliff caves consist of three categories: cupmarks, elongated shallow facilities, and basins. Cupmarks comprise the dominant category (n=18, 75%), and they are found in all sites but one (Table 1). Their shape is typically bowl-like, i.e., conical with a rounded (rather than pointed) bottom. Based on measurements taken in 13 cupmarks, they range between 10-23 cm in their upper diameter (15.3 cm in average) and 6-14 cm in depth (9.5 cm in average), except for a single specimen from the Cave of the Pool which is only 3.5 cm deep. The cupmarks are generally shallow, with diameter/depth ratio rarely below 1.5 (i.e., diameter values are typically at least 50% greater than depth values). The inner faces of all cupmarks are smoothened from use, even if abraded due to post-formational erosion. No evidence as to their carving techniques could be detected, though this probably involved chiselling and/or drilling followed by inner surface smoothening. Cupmarks were hewn in otherwise-unmodified rock surfaces, and had no artificial connection to other, hewn or built, elements. In half of the sites at least two cupmarks were discerned, either sharing one rock surface (e.g., Ze'elim Valley Cave 33; Figure 2), or located on neighbouring surfaces (e.g., Cave of the Pool). In several sites (outside Hever Caves A and B, and inside the Cave of the Treasure), cupmarks

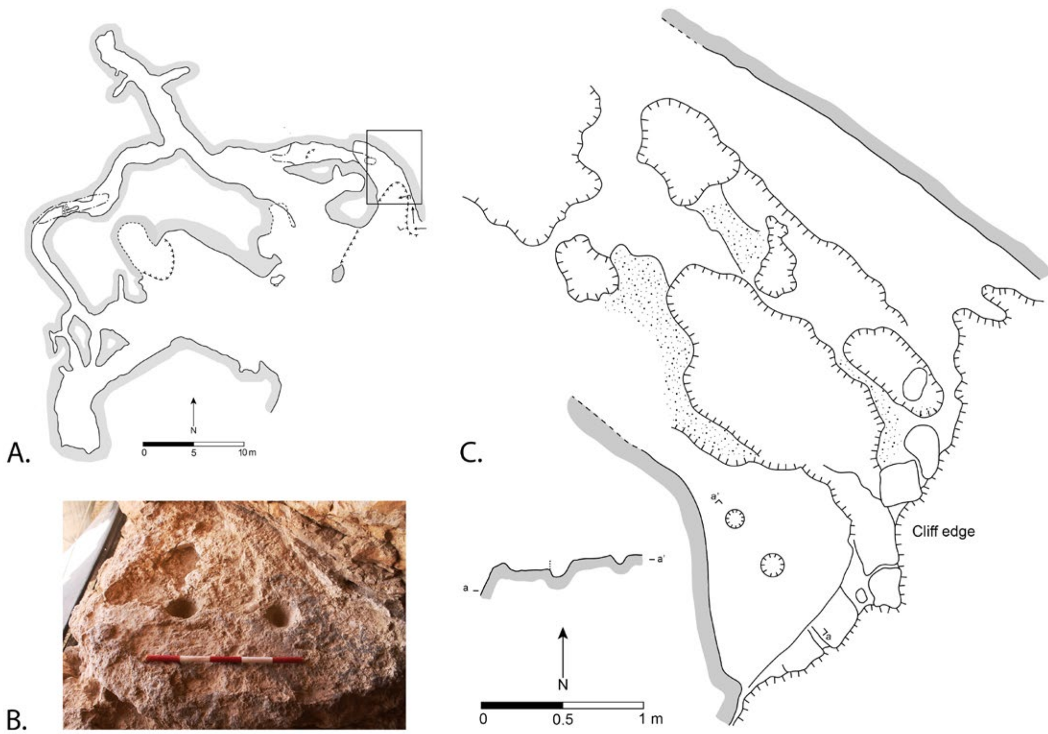

Figure 2: A. Plan of Caves 32-33 in the Large Cave Complex of Ze'elim Valley. Black box indicates location of enlarged plan C (mapping by Roi Porat and Uri Davidovich, 2007); B. Photograph of two cupmarks hewn in bedrock in Cave 33, looking southwest (photo by Micka Ullman); C. Detailed plan of the outer part of Cave 33, showing the two cupmarks and numerous natural cavities (mapping by Micka Ullman, 2016; graphic imaging by Micka Ullman, 2020).

were found next to installations of another type – the shallow, elongated grinding facility – but with no apparent connection between them. Rock surfaces bearing cupmarks are located either on exposed bedrock outcrops or on immovable collapsed boulders, and both arrangements can be found either inside or outside caves (see below).

Other than a single basin, the only other type of bedrock installation studied in this research is a shallow, elongated facility with smooth, concave longitudinal section and semi-abrupt lateral margins. Four such installations were recorded thus far, in two cave sites (Table 1). Only the two installations from the Cave of the Treasure were measured and analysed (Rosenberg and Davidovich 2015: 156-158); both are slightly above 40 cm in length, while their width (28 and 35 cm) and depth (11 and 2 cm) vary. As in cupmarks, their inner surface is smoothened and worn from use whereas the outer surfaces remained unmodified. It appears that all four specimens are examples of a common type of bedrock facility recently identified outside Late Chalcolithic settlement sites in the Judean Lowlands (*Shephela*), with several instances observed also in the Judean Highlands and desert fringe in association with Late Chalcolithic deposits (van den Brink 2008; cf. Neuville 1951). This type of installation, which appears in dozens (and sometimes hundreds) on the outskirts of settlement sites, was convincingly identified as a grinding instrument, functioning as a substitute for portable lower grinding stones.

A singular hewn installation, the northernmost bedrock facility described in this article, comprises a cylindrical basin 30 cm in diameter carved on top of a large boulder in front of, and *c.* 15 m away from, a pair of caves (Naqeb Mazen Complex; Davidovich 2015a). This basin is at least 15 cm deep, and its bottom is currently filled with sediments. Two artificial slits (75 and 55 cm long) lead into the basin from a higher (eastern) segment of the boulder, each 2-3 cm wide and *c.* 1 cm deep (Figure 3). This installation, which

Figure 3: Left: A view of a basin and two slits hewn in a boulder in the Naqeb Mazen Complex, looking east towards the Dead Sea; Right: A detail of the basin and the slits (photos by Micka Ullman).

has no parallels in other cave sites in the Judean Desert, seems to be connected to water harvesting or to processing of liquids (olive oil production?). Since the Early Roman and Byzantine/Early Islamic periods constitute the main phases of occupation in this cave complex (Tal and Oron 2002: 191), with only meagre evidence for earlier activities, this installation probably dates to the last two millennia, hence it will not be discussed further in this article.

Chronology

Dating of bedrock facilities is a notoriously difficult task, due to their typically indistinct forms and the lack of clear-cut stratigraphic associations (Horn 2015: 29). On the regional scale, three main periods are attested in the material assemblages of the Judean Desert cliff caves: Late Chalcolithic, Early Bronze Age IB (the end of the 4th millennium BCE; Davidovich 2012), and Early Roman (1st-2nd centuries CE; e.g., Eshel and Zissu 2020; Eshel and Porat 2009; Yadin 1971). While it is possible that stationary facilities were hewn in each of these periods, as well as in other, more sporadic occurrences (compare Davidovich 2008), it is nonetheless probable that many of them are indeed Late Chalcolithic in origin. This assessment is based on the following arguments:

1. The Late Chalcolithic is the main late prehistoric phase observed in the Judean Desert cliff caves in general, and more specifically in the caves included in this corpus (Davidovich 2008, 2013). In terms of the scope and variety of the material cultural assemblages found in the cliff caves, there is a significant difference between the Late Chalcolithic and the Early Bronze Age I assemblages.

2. Cupmarks were not found in Judean Desert caves containing solely Roman-period remains. While these multi-functional, nondescript installations are occasionally found in Roman-period settlement sites, they are much more common in late prehistoric contexts (for Late Chalcolithic settlement sites located in areas with exposed carbonate rocks, see, e.g., van den Brink *et al.* 2001; Scheftelowitz and Oren 2004).

3. The type of shallow, elongated facilities found in the Cave of the Treasure and outside Caves A-B in Hever Valley was credibly dated to the Late Chalcolithic based on spatial, environmental and typo-technological considerations (van den Brink 2008; Eitam 2009). Its spatial association with cupmarks located on the same collapsed blocks (in the Cave of the Treasure) or bedrock ledges (in the case of Hever Valley Caves A-B) lends further support to the dating of cupmarks to the same period (compare Rosenberg and Davidovich 2015: 156-158).

In addition to these arguments, the unique case of Masada South Cave Complex illustrates the significance of stationary cupmarks in their Late Chalcolithic context. This complex, located in the southern cliff of Masada, comprises three difficult-to-access small caves opened in the lower segment of the sheer cliff. It was first investigated by the Masada Expedition led by Y. Yadin in the early 1960s, when one of the caves (Masada South 2 in Table 1) was excavated in its entirety (Yadin 1965: 115). The cave complex was reinvestigated between 2007 and 2009, in collaboration with R. Porat and N. Marom (Davidovich 2008: 185-194), and systematic excavations were conducted in Cave 3 (also designated Yoram Cave; see Mascher *et al.* 2016). Unlike all other caves included in this study, Masada South Cave Complex contains only one phase of occupation, dated (both materially and radiometrically) to the Late Chalcolithic. In Yadin's excavations of Cave 2, a well-preserved earthen floor was unearthed inside the small cave. This floor, which can still be seen today, comprises mostly dry organic matter, including fragments of twigs, spikes, seeds and other vegetal elements, mixed with light brown, fine-grained sediment that was hard-beaten and flattened. Two cupmarks, *c.* 60 cm apart, were embedded in this floor (Figure 4). Unlike all other cupmarks observed in Judean Desert Caves, these two are shaped with the same material used in the construction of the floor, a unique arrangement which, to the best of my knowledge, is unparalleled in other Levantine Late Chalcolithic contexts. The southern cupmark was preserved intact, and has a deep (17 cm) conical shape with an upper diameter of 20 cm. The northern cupmark was preserved

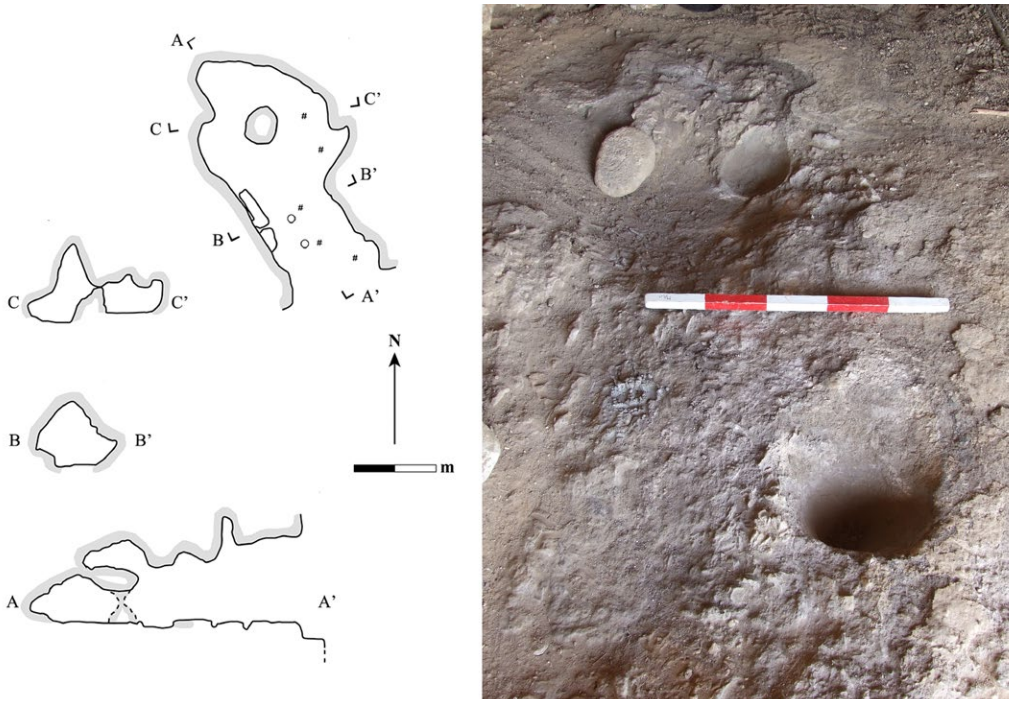

Figure 4: Left: Plan and sections of Masada South Cave 2 (mapping by Roi Porat and Uri Davidovich, 2007); Right: Photograph of the two constructed cupmarks, looking north (photo by Roi Porat).

only in its lower part, but it seems that its outline and dimensions were similar to those of the southern cupmark. Both cupmarks are covered with a thin (<3 mm) layer of whitish material, probably of carbonate source, that has yet to be studied. A similarly-constructed installation, though slightly larger than a cupmark, was uncovered in Cave 3 and recently sampled for mineralogical and residue analysis. While the Masada South Complex' cupmarks are unique, their indisputable Late Chalcolithic date and the efforts and proficiency manifested in their construction reflect the importance of such devises to the occupants of the cliff caves during this period, as will be discussed below.

Spatial Considerations

A significant aspect in deciphering the nature of the hewn features in the cliff caves of the Judean Desert is their spatial configuration. Generally, the stationary facilities can be divided into internal and external installations (Table 1). Preferable internal locations comprise exposed rock surfaces in well-lit spaces close to cave openings. Among this group, cupmarks hewn in bedrock surfaces can be found in Cave 304C in 'Arugot Valley, Cave of the *Miqveh* in *Wadi Maradhif* (Harduf Valley), and the couple of cupmarks in Cave 33 in the Large Cave Complex of Ze'elim Valley (Figure 2). Two cupmarks and two grinding installations are found on large collapsed boulders in the main hall of the Cave of the Treasure (Rosenberg and Davidovich 2015: 156-158). The only case in which hewn installations are located deeper inside a cave was observed in the Cave of the Pool in *Wadi Sdeir* (David Valley), where two small cupmarks were hewn on two collapsed rocks in the 'twilight' zone of the cave, *c.* 10 m from the entrance.

In all aforementioned cases, internal locations typify caves with highly difficult access. These caves are opened in vertical cliffs, and accessing them not only entails arduous journeys to the immediate surroundings of the caves, but also requires negotiating high vertical obstacles to reach cave mouths (Figure 5). In these cases, external flat rock surfaces are not easily approached from the caves, which makes the hewing of internal stationary installations a plausible solution. Conversely, external facilities characterise caves with easier access, commonly located along cliff bases that can be reached through

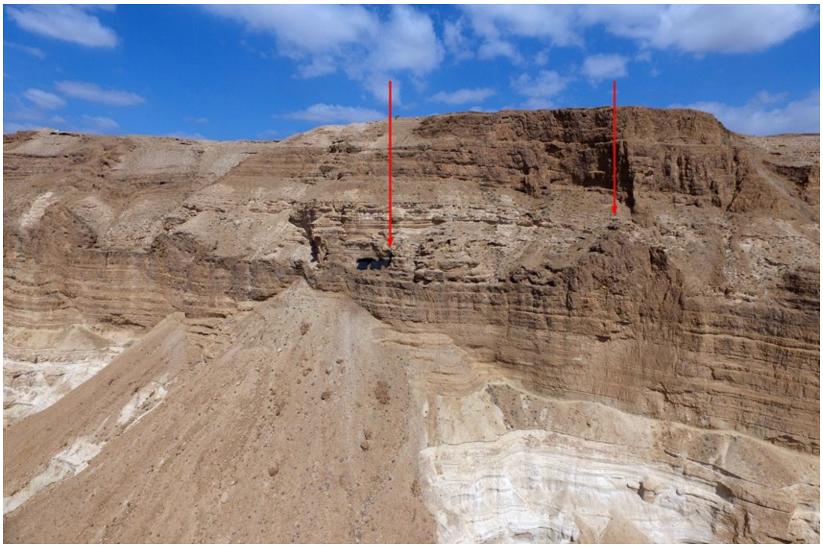

Figure 5: The Large Cave Complex in Ze'elim Valley, looking northwest (drone photo by Guy Fitoussi). The left arrow points to the location of Cave 33 (see Figure 2), while the right arrow denotes the location of an isolated cupmark (see Figure 7 and text for details).

scrambling on moderate screes. For example, Hever Caves A-B are located above the high dry waterfall which marks the head of the lower valley canyon, in an area of moderate slopes and low vertical bluffs. A single cupmark is found on a wide bedrock shelf above a local gorge *c.* 15 m away from the entrance to Cave B, while another cupmark and two grinding installations are grouped together on a rock ledge between and below the two caves, closer to the valley floor.

In both internal and external locations discussed above, locational patterns of stationary installations seem to reflect rational, function-oriented decision making. That is, locations were chosen in accordance with availability and accessibility of suitable rock surfaces (either bedrock exposures or large boulders) and the assumed functional properties of the hewn installations (pounding, grinding). However, three examples of externally-positioned cupmarks, to be described below, seem to illustrate other, perhaps less functional considerations in their locational preferences, and may thus be associated with other behavioural realms.

Cupmarks in their Landscape

Christmas Cave is a large cave in the southern bank of *Wadi an-Nar* (Qidron Valley), *c.* 2 km upstream from its outlet into the Dead Sea Valley, that was discovered on Christmas Day of 1961 by J.M. Allegro (Allegro 1965). The cave was excavated the following year and yielded evidence for Late Chalcolithic and Roman-period occupations that remained largely unpublished to date. While the entrance to the cave is relatively easily approached, it is also small and concealed from sight, obscured by limestone bluffs. A narrow passage extending from the entrance gives way to the inner space of the cave, arranged as a series of chambers ending abruptly in another opening, hanging as a window in the cliff face (Porat 2015; Porat *et al.* 2012). Although exposed rock surfaces exist both inside the two openings and immediately outside the more accessible entrance, a single small cupmark was hewn on top of the cliff above the cave, in a location that requires a relatively long walk from the cave entrance. The cupmark is hewn on a flat rocky surface, *c.* 70 cm from the edge of the precipice. When standing in this location, one has a commanding view on the valley below as well as on certain areas of the desert uplands on both sides of the ravine, but obviously no eye contact with the cave located immediately below. No evidence for other artificial elements was noted in the vicinity of the cupmark, which acts as a singular mark of human activity outside the hidden cave.

A somewhat similar situation, albeit in an entirely different scenery, is found in the Large Cave Complex of Ze'elim Valley, in the southern Judean Desert (Figure 5). This cave complex, located in the high northern escarpment of the deep canyon, was identified and excavated in 1960 (Aharoni 1961b). It comprises one large cave (Cave of the Skulls) and a dozen smaller caves and alcoves, many of which produced archaeological remains dated to the Late Chalcolithic, Early Bronze Age IB and Roman periods (Davidovich 2008: 207-232, 2015c). In the mouth of one of the smaller caves (#33), two small cupmarks were hewn (Figure 2). To approach the cave complex from the top of the escarpment one has to climb down through steep, hazardous screes that bypass vertical bluffs before reaching the upper tier of caves. At a certain point, *c.* 150 m northeast of the caves, the route passes near a narrow rocky spur, from which a small flat ledge is partially detached. This ledge, which measures 4.5X2.1 m, is both a prominent landmark on the way to the caves and a remarkable viewpoint over the canyon sprawling below. A single cupmark is hewn in the northern part of the ledge, the surface of which is slightly tilted in the same direction. The cupmark is fairly shallow, 16 cm in diameter and 8 cm deep, and its inner surface is slightly weathered due to post-formational erosion. No other modifications were noted on the ledge, and, as in the case of the Christmas Cave discussed earlier, this cupmark is the sole remnant of human activity between the cliff top and the caves.

A third and final case to be presented here is a complex of four caves in Rahaf Valley, several kilometres south of Ze'elim Valley. These caves were discovered and briefly excavated in 1964 by a team from the Masada Expedition led by Y. Yadin, but the results of this operation were never published (Yadin 1965: 115, n. 105). They are located in the upper reaches of this valley, immediately above the high dry waterfall that constitutes the main landmark along the upper canyon of the ravine. Recently, this cave complex was re-identified and scrutinized (Davidovich 2015b), reaffirming its identification as one of the late prehistoric and Roman-period cave occupations typical of the eastern margins of the Judean

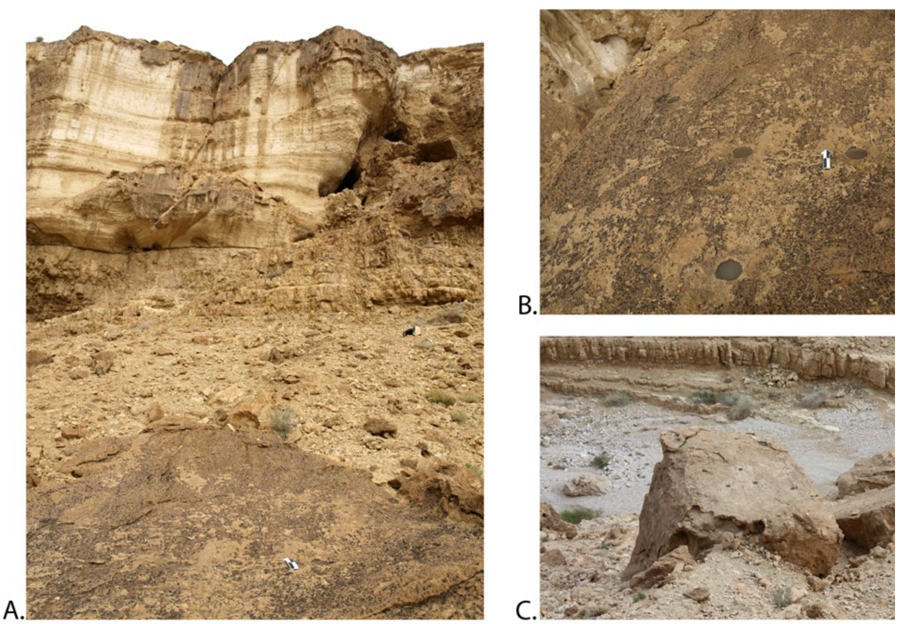

Figure 6: A. Rahaf Valley Cave Complex as seen from a boulder with hewn cupmarks; B. A closer look at the four cupmarks full of rainwater (Winter 2013); C. The boulder as seen from the lower caves, looking south (photos by Micka Ullman and Boaz Langford).

Desert. Only a short climb on a steep scree from the valley floor is needed to reach the caves, all of which are small and contain relatively little accumulation above bedrock. Several large boulders that collapsed from the cliff in which the caves were formed are scattered on the scree. One of those boulders, located some 30 m from the lower caves and *c.* 15 m downslope, has a quasi-flat upper surface in which four small cupmarks are carved (Figure 6). Although the cupmarks are grouped together on one boulder they do not form a clear pattern, and the rock surface surrounding them remained unmodified. At the time of our visit (February 2013) the cupmarks were full of rainwater, but so are larger, easily approachable seasonal waterholes in the valley immediately below. It should be stressed that exposed rock surfaces are abundantly found within and between the caves, but no stationary facilities were observed there.

Discussion

Stationary facilities reflect premeditated attempts of landscape domestication in the wild sphere of the Judean Desert cliff caves. As construction of paths, access ways, walls, floors and built installations was sporadic, carved rock installations constitute the key architectural testimony left by those who found shelter in this precipitous environment for the perception of occupation as a prolonged reality. Several obstacles, mostly related to the lack of direct dating and stratigraphic associations with other elements and archaeological deposits, preclude a firm contextual understanding of these installations. Nevertheless, their morphological and spatial traits, in combination with a sensorial approach to landscape and data gathered from other realms of investigation, enable to raise several hypotheses, and possible interpretations, as to their purpose and role.

It is reasonable to assume that most cupmarks, located either within caves or in their immediate vicinity, were used for routine activities; the elongated grinding facilities found in two of the cave sites invoke a similar notion. The small volume of the cupmarks implies that they were not used to collect seasonal rainwater even when located outside caves, while the smoothness of their interior surface reflects use-wear created through activities such as pounding and grinding. Owing to the dearth of reports concerning groundstone tools in the cliff caves (Davidovich 2008: 113-115), it is impossible in most cases to know whether the stationary facilities were accompanied by portable items used for similar purposes. Nonetheless, Masada South Cave 2 serves as a case in point, since in our renewed investigation it turned out that apart from the two constructed cupmarks in the cave floor, six grinding stones were uncovered during its 1960s' excavation and were fortunately left inside the cave following this operation. This assemblage comprises four lower grinding stones and two upper grinding stones (or handstones) (Davidovich 2008: 190-192); only one side of each stone has been modified to serve as a working surface. The multitude of portable grinding stones, probably related to the processing of cereal grains, may imply that the two constructed cupmarks in the same cave were used for pulverizing and pounding of other foodstuffs. Although grains form an important staple in the cliff caves of the Judean Desert, and specifically in Masada South Cave Complex (Mascher *et al.* 2016), numerous other vegetal resources were brought to the caves, including legumes, fruit, and acorns (e.g., David 2015; Zaitschek 1961, 1962).

The cornucopia and diversity of vegetal resources observed in numerous Judean Desert cliff caves, discussed rarely and in passim in the literature with regard to the Late Chalcolithic period (see Davidovich 2008: 128-130 for details), suggest that gathering, storage and consumption of vegetal foods were among the major activities in these caves. The multiplicity of hitherto neglected stationary and portable stone devices related to the processing of vegetal resources in these caves serves as another support for this hypothesis. This has important implications concerning the interpretation of the caves as temporary refuges, as it is expected that at times of stress concerted effort will be devoted to the preparation of food stocks. Such efforts are also expressed in other realms of the archaeological record, for instance the profusion of large and closed ceramic vessels intended for storing and cooking at the expense of small vessels common in settlement sites (Davidovich 2008: 111-112). By the same token, the available evidence contrasts with competing explanations as to the nature of Late Chalcolithic presence in cliff caves, e.g., mortuary-related hypotheses (Ilan and Rowan 2015).

Most cupmarks seem to fit well the functional, 'positivist' interpretation presented above, owing to their occurrence within caves or in favourable locations near them. However, certain cases – i.e., those of Christmas Cave, Ze'elim Valley Large Cave Complex, and Rahaf Valley Cave Complex – seem to deviate from common, function-driven practices. In these instances, the deliberate selection of focal points in the landscape (in the first two) or the multitude of cupmarks in one location (in the latter), all at

Figure 7: The view from the isolated cupmark in Ze'elim Valley (marked by arrow), looking southeast towards the canyon outlet into the Dead Sea Valley (Photo by the author).

considerable distances from the caves, cannot be easily explained through a functionalist perspective. One cannot avoid sensing that in these cases, the landscape was as essential to the associated behaviour as the cupmark, which formed the sole cultural component in otherwise-barren, almost virgin, desert scenery (Figure 7). In both Christmas Cave and Ze'elim Valley Cave Complex, the caves are entirely hidden from sight in relation to the isolated cupmarks, but the caves could be sensed, even if nebulously, through conspicuous sounds (e.g., people shouting) and smells (e.g., fire making). The dramatic desert vistas seen (and sensed) from these cupmarks do not seem to reflect a desire to administer and control the landscape, although these points could well have been used to fulfil such needs. Instead, it is more probable that these isolated cupmarks were appropriated certain social significance, perhaps in relation to symbolically-laden behaviours associated with the tempestuous, ephemeral existence in extraordinary and hazardous desert landscapes.

The proposed narrative regarding the isolated cupmarks intimates that while the primary motivation behind the occupation of cliff caves in the Judean Desert should be sought in response to societal upheavals, symbolic behaviors were part and parcel of the presence in this remote, mysterious province. This contemplation may have implications with regard to the interpretation of other unusual phenomena associated with the Late Chalcolithic use of cliff caves (e.g., Davidovich *et al.* 2013), as well as the necessity for more informed and nuanced readings of seemingly functional behaviours of the type discussed in the bulk of this paper. Future studies, other than documenting and presenting overlooked material and ecofactual categories and their contexts with greater attention and detail, should attempt to unravel their potential veiled capacities.

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11. Quernstones in social context: the early medieval baker's house from Wrocław

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Introduction

The Early Middle Ages in Poland date from the 6th to the mid-13th century AD and featured a number of breakthroughs in settlement development, material and spiritual culture, and relations between the people and the environment (Buko 2008; Curta 2004; Godłowski 2000; Trzeciecki 2017). The emergence of the Polish state in the second half of the 10th century was the most important threshold for the rise of the central West Slavic societies (Kara 2009; Kurnatowska *et al.* 1994; Labuda 1989; Strzelczyk 2000). Not only did the distribution of the culturally homogeneous settlement change, but also the political and ecclesiastical organisation. The Congress of Gniezno in the year 1000 sealed the new order. Duke Bolesław's two-week visit to Emperor Otto III resulted in the tightening of the mutual political bounds and establishing the archdiocese in Gniezno, with subordinate dioceses in Kraków, Kołobrzeg and Wrocław. The latter was located on the Ostrów Tumski island and ruled by bishop John (Davies, Moorhouse 2002: 79; Thiethmar 2001: 406).

The establishing of the diocese in the year 1000 triggered a buoyant growth of the merely ca. 50-year old settlement. Its location on the crossing of the north-south and east-west trade routes quickly made the city become a regional craft and distribution centre for all sorts of material goods (Kaźmierczyk 1990: 14; Moździoch 2004: 335; Pankiewicz 2019). At the same time, the nearby production sites and masonry centres in the Sudetian Foothills (south of the city) sustained the needs of the rapidly growing city (Lisowska 2018: 178).

The dense architecture of the Ostrów Tumski island comprised both dwelling houses and various production/household features (Kaźmierczyk 1991; 1993; 1995; Piekalski 2015: 217; Robak 2008). Clusters of log, post-and-wattle and post buildings were intersected with traffic routes – changing their course and orientation over time. The old buildings were torn down and replaced with new houses. Alternatively, new walls were built upon the old structures (Limisiewicz *et al.* 2015a). In this context, the situation in which the end of a building's life is marked with three massive quernstones is unique. Although such practices were by no means extraordinary in prehistory (Bradley 2005: 53–55; Peacock 2013: 162–178), in the early-state Eastern European contexts, deposits marking the symbolic death of buildings are rare (Macháček 2010: 302–305).

Archaeological background

The archaeological excavations of the early medieval site on the Ostrów Tumski island, initially supervised by Rudolf Jamka, were launched in 1946. In the 1950s and 1960s, Wojciech Kóčka and Elżbieta Ostrowska continued Jamka's work (Kóčka & Ostrowska 1953; 1955; 1956; Ostrowska 1957; 1959; 1960; 1961; 1961a; 1963; 1964). The 1970s and 1980s saw Józef Kaźmierczyk overtake the investigations of the stronghold (Kaźmierczyk *et al.* 1974; 1975; 1976; 1977; 1978; 1979; 1980). Since the 1990s the excavations on the island have been conducted by several institutions and private companies (Pankiewicz 2012; Limisiewicz, Pankiewicz 2015a). The investigations included over 30 various cut-troughs, test trenches

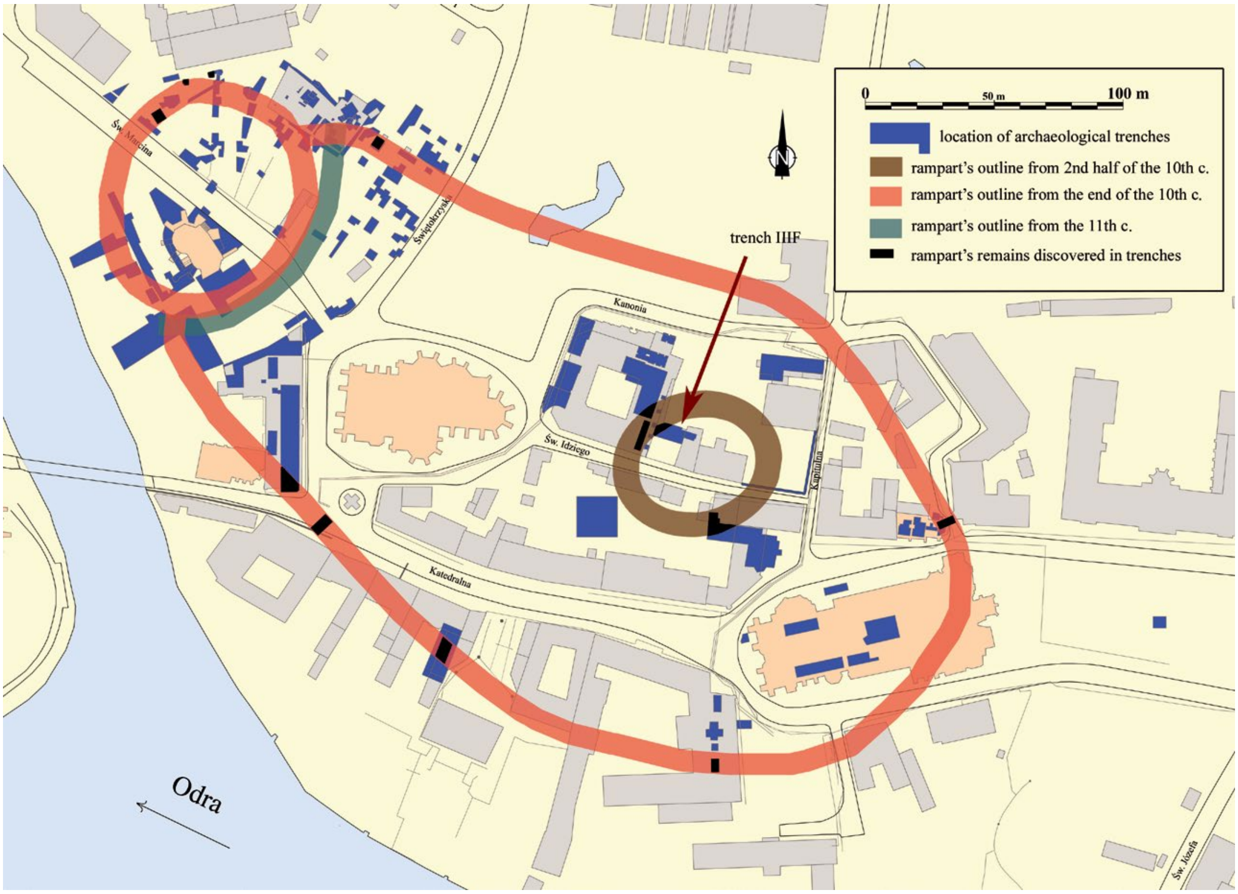

Figure 1: Wrocław-Ostrów Tumski: reconstruction of the ramparts and localisation of archaeological trenches 1949-2015 (after: Pankiewicz 2015: Figure 8. Modified by the Author).

and excavation projects (Limisiewicz, Pankiewicz 2015b) (Figure 1). Non-invasive surveys aimed at detecting the outline and outreach of the early medieval fortifications have also been conducted (Limisiewicz *et al.* 2015b). The trenches yielded layers dated from ca. mid-10th to ca. 13th century – based on dendrochronological analyses and studies of the pottery style.

The quernstone deposit was found in trench IIIF excavated in the years 2000–2001. The project was conducted by a private company and the summary results came into light in 2015 (Limisiewicz, Pankiewicz 2015a).

The stratigraphy of trench IIIF included layers dated from the mid-10th century to modern time (Limisiewicz *et al.* 2015a: 56–57). Quernstones were found in layers D, E1 and E2 which belong to occupation levels 6 and 7 (Figure 2). Below these levels, remains of a rampart pulled down at the end of the 10th century were identified. The rampart surrounded a small enclosure located in the central part of the Ostrów Tumski island and established in the mid-10th century. The quernstones were clustered inside of a half-open, square building (named in the field documentation as the feature 1) and in its surroundings (Limisiewicz *et al.* 2015a: 70–73). The building's walls were made of laths and wickerwork but its' northern side remained open. The preserved size of the building was 400 x 400 cm. The walls were orientated according to cardinal directions. The northern part of the shelter featured a domed, clay oven and the southern part – the quernstone cluster. The 200 x 100 cm oven was oval and had a round, 75–80 cm hearth. By the northern wall, a two-part wooden trough was found (Figure 3). The 85 x 29 cm vessel consisted of two 27 x 18 cm chambers for moulding loaves (Limisiewicz *et al.* 2015a: 72). Similar moulds occur both in the archaeological and ethnographic material are known for example from the British Isles, central and eastern Europe (Earwood: 1993; Thoms 2015: 170; Ziubrovskyi 2018: 64). The shelter also yielded a bone spike, a piece of flint, a fragment of copper wire, 1129 pottery sherds, and 500 bone fragments (including rodent bones). In the direct surroundings of the feature (no farther than 1 m away from its walls), a fishhook, five glass beads, five bone combs, over 600 pottery sherds, and 350 fragments of animal bones were recorded (Limisiewicz *et al.* 2015a: 73–78). The occupation level discussed above dates back to the turn of the 10th and 11th century and the first half of the 11th century – based on the relative and absolute chronology of the finds (Pankiewicz 2015).

Despite the detailed find catalogue, we must bear in mind that the excavations took place more than 20 years ago. Some of the techniques providing precious information on the cultural layers – now routinely applied in the archaeological fieldwork – were not available or not common at that time. Thus, even with such impressive documentation (as compared to the contemporaneous archaeological investigations), the processes which occurred within trench IIIF cannot be fully depicted.

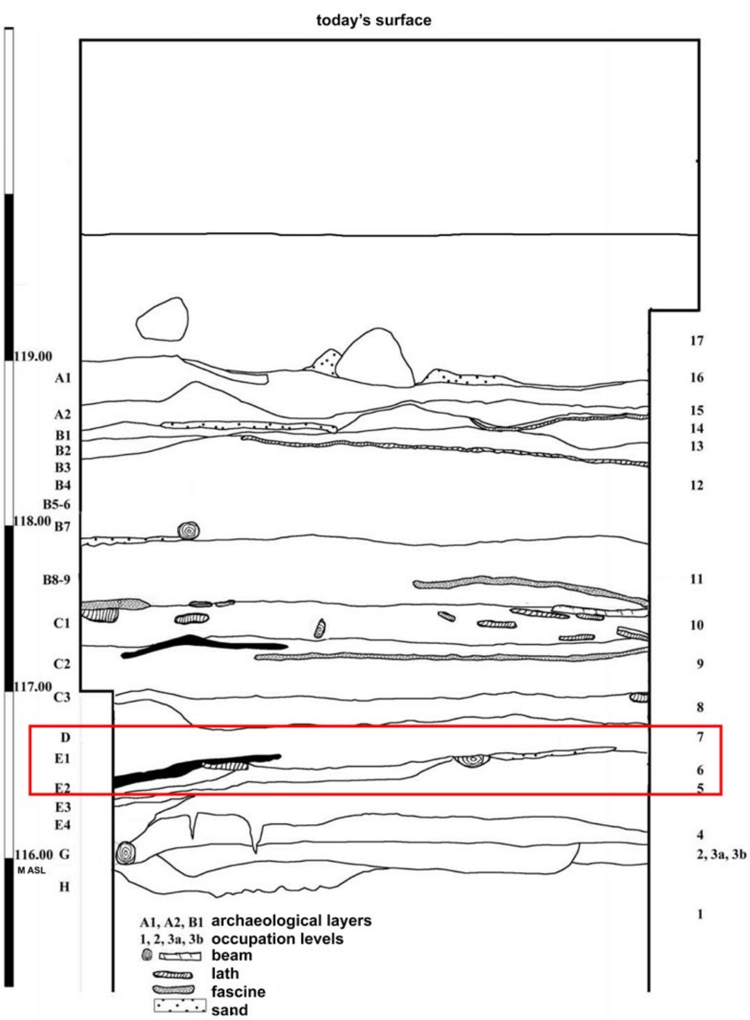

Figure 2: Wrocław-Ostrów Tumski: Trench IIIF – the northern profile. Section specifies archeological layers (left A1-H) and occupation levels (after: Limisiewicz et al. 2015a: 57). The box shows layers and levels discussed in the paper.

Figure 3: Wrocław-Ostrów Tumski: wooden through for kneading bread – 11th century (after: Limisiewicz et al. 2015b: 73; photo: K. Bykowski, M. Opalińska-Kwaśnica).

The "baker's house"

A detailed analysis of the building's (feature 1) stratigraphy and inventory convinced us that it was an 11th century bakery (Figure 4a). Among the archaeological arguments for proving that the building functioned as a bakery, the following can be mentioned: the presence of an oven (probably a bread oven), dough molds, quernstones, millet and wheat grains and the remains of rodents that eagerly choose dry places. Rodent remains have been recorded very rarely in Ostrów Tumski, and their presence may be related to the availability of food, for example cereal grains. Since the occupation of the Ostrów Tumski island was continuous and uninterrupted, we could precisely date the construction of the building. The rampart enclosing the 10th-century ducal stronghold was pulled down at the turn of the 10th and 11th century. The house built in the rampart's place produced pottery dated to the first quarter of the 11th century and a beam dendrochronologically dated to the time after 970 AD. Thus, the "bakery" might have started its operation within the first two decades of the 11th century. The northern part of the building included a domed oven, most likely used for baking, and a wooden container resembling a bread mould deposited close by. Remains of rodents suggest that grain also was stored in the building. Plant macro-rests from trench IIIF included large amounts of millet and smaller quantities of wheat. The latter could potentially serve for baking bread.

In the vicinity of the "bakery", a massive, 150–cm long and 33–cm wide beam with a 15–cm wide and 13–cm deep cut was found. It might have been part of a grain grinding device – all the more that quernstones were found close by. Such devices are present in the later Silesian iconography (The life of Saint Hegwig: fig. 40) but might have been in use already in the 11th century.

Most likely, the "bakery" ceased to operate in the mid–11th century. Considering the early medieval demography, this would mean that it worked for two, perhaps three generations (30 to 50 years).

Above the "bakery" building between the boundary surface of the next occupation level there were found three quernstones, that look as they were sealing the abandoned building.

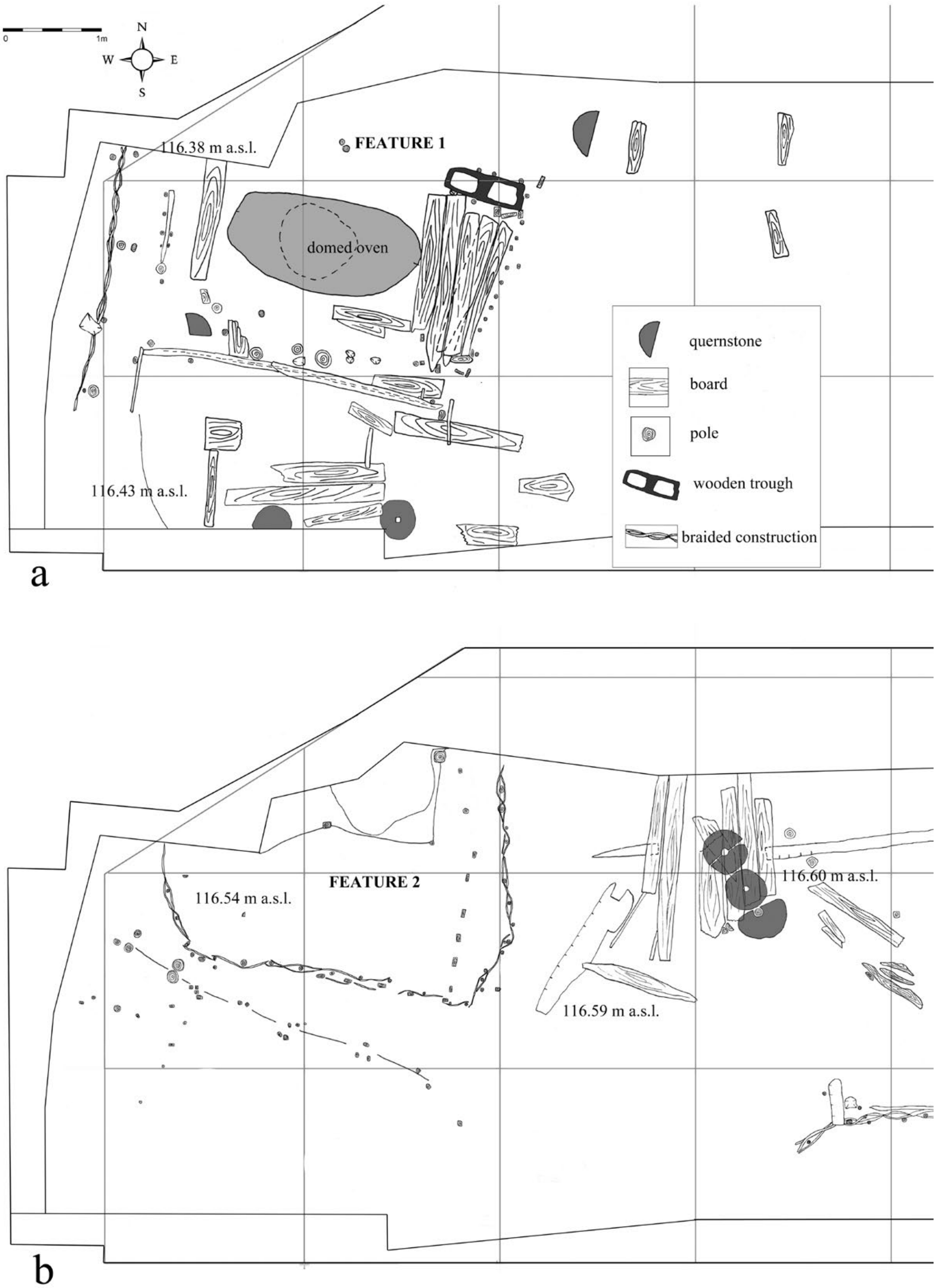

Figure 4: Wrocław-Ostrów Tumski: a – fragment of the sketch of the trench IIIF, layer E1; b – fragment of the sketch of the trench IIIF, layer E2 (after: Limisiewicz et al. 2015b: 75, 79; drawing: M. Opalińska-Kwaśnica. Modified by the Author).

Early medieval quernstones from Ostrów Tumski

The early medieval occupation layers on the Ostrów Tumski island produced an assemblage of 21 quernstones (Kaźmierczyk 1990: 157) which in 2011 underwent a detailed petrographic analysis. The excavation report from trench IIIF made it possible to analyse 10 further quernstones, which makes almost a half of the previous assemblage. The quernstones recorded during the earlier investigations differ substantially from the stones found by the "bakery".

Most of the quernstones found before 2010 were secondary deposits, often fragmented and used as parts of hearths and ovens, and sometimes transformed into other tools (e. g. polishing stones). Only two of the 21 specimens were fully preserved (Lisowska 2013: 88–107). In the other items, the preserved parts of the circumferences and working parts allowed for reconstructing the quern sizes and their place in the rotary mechanism.

Considering all that, the assemblage from trench IIIF (including the "bakery") is significantly different from the other quernstones found on the Ostrów Tumski island (Lisowska 2015: 293–299). Besides the three quernstones sealing the abandoned house, the bakery building and the superimposed layers produced seven other quernstones. Two stones occurred right by the house in the contemporaneous layer E2. Three further were found in a layer deposited shortly after the bakery had ceased to operate (mid–11th century)(Figure 4b). In this layer occured also another building (feature 2) which do not refer to the bakery, and it is a completely separate building. Layer C2, dated to the third quarter of the 11th century, and layer B4, dated to the first half of the 12th century, yielded one stone each.

Half of the 10 quernstones from trench IIIF were preserved in one piece. Only one stone from the uppermost layer (mid–12th century) was possibly secondarily used for securing a bridge. Thus, while the whole site produced fragmented, re-used and probably re-deposited quernstones, the analysed trench IIIF yielded a compact, well-preserved assemblage including 50% of complete stones. No deposit matching the "baker's house" collection had previously been recorded within the Ostrów Tumski island. As far as other artefact categories are concerned, such concentrations might result from the production and craft activities, ritual practices, and other processes (Peacock 2013: 162–180).

Querns' petrography

Both in the quernstones recorded between 1949 and 1995 and in the finds from trench IIIF (2000–2001), we determined the type of the raw material and its origin (Gunia 2015; Lisowska *et al.* 2014). The petrographic analyses included macroscopic observations, optical microscopic analysis of thin rock sections, electron microprobe analysis (EDS, WDS) and rare-earth element analysis.

The quernstones from the Ostrów Tumski island in Wrocław were made of two types of rocks quarried in the Sudetian Foothills (Figure 5). Most of the tools (28 out of 31 specimens) were of biotite granite. In the Early Middle Ages, such granite was quarried on the northern slopes of the Ślęża Massif (Kaźmierczyk 1990: 158; Jaworski 2008: 76), ca. 40 km south of Wrocław as the crow flies. The archaeological investigations of the Ślęża masonry centres showed that the initial processing of stone took place already in the quarries and the nearby production settlements (Domański 1965; Jahn 1929). Finished products were distributed all around Silesia and found their way to the Ostrów Tumski island (Lisowska 2013: 198–202).

Only three quernstones from the whole assemblage were made of garnet mica schists. Mica schists occur in the area of Kamieniec Ząbkowicki, ca. 70 km away from Wrocław as the crow flies. Also here, the initial processing of the raw material was carried out in a settlement located by the quarries (Jaworski 2008: 76). It is noteworthy that the three mica-schist quernstones were completely preserved, as mica schists are more resistant to mechanical stress than biotite granite. In the considerably larger assemblage of granite quernstones, only five specimens (out of 28) survived in undamaged condition.

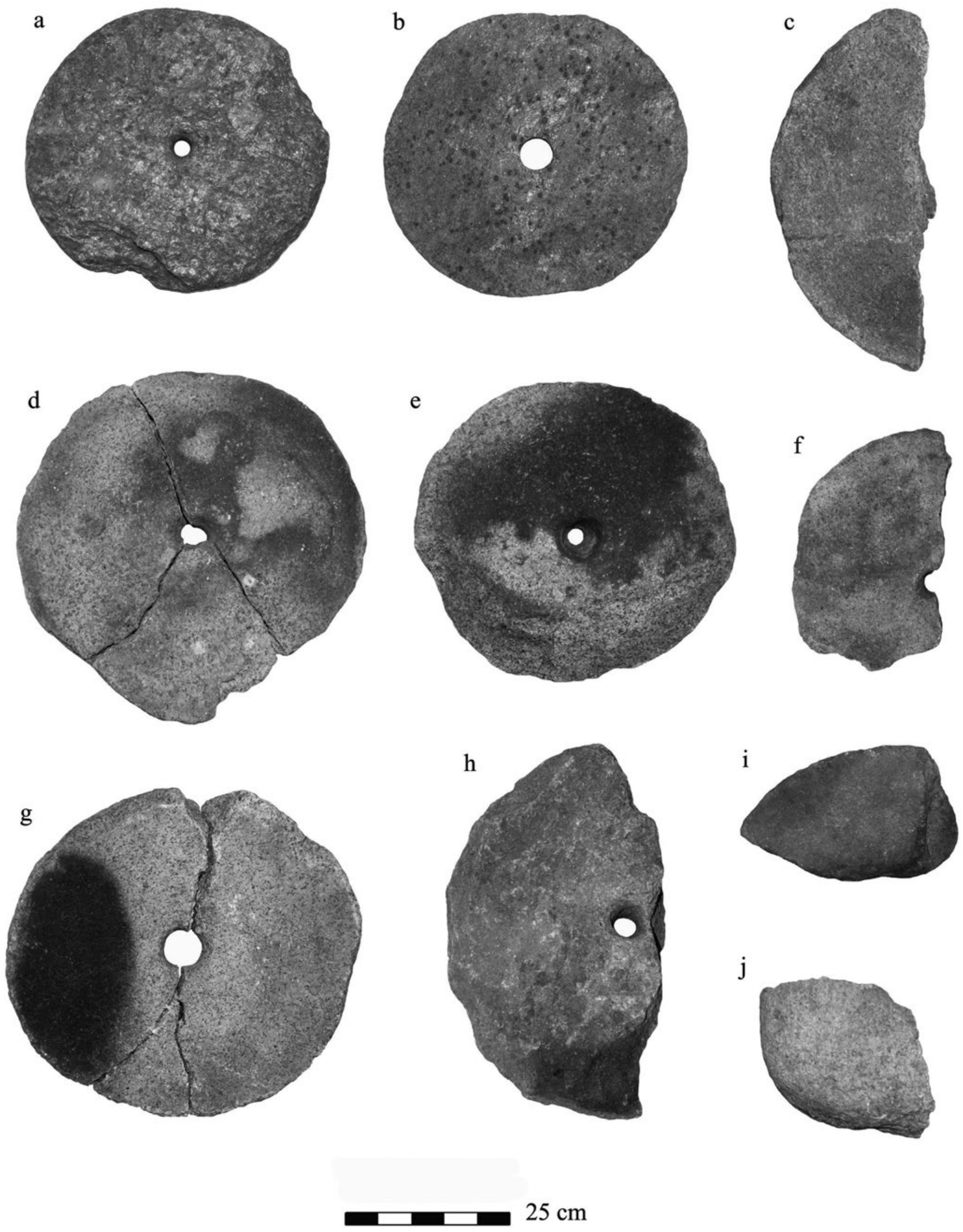

Figure 5: Quernstones found in the trench IIIF in Wrocław-Ostrów Tumski:
a-b – quernstones made of mica schists; c-j – quernstones made of granite (Photo and digital proccesing by Author).

Quernstones in the social context

For thousands of years, quernstones played an essential role in the prehistoric and medieval societies (Peacock 2013: 1–6). Their heavy symbolic load is reflected in a wide span of beliefs, cults and rituals which have been subject to several studies (Watts 2014a). In the Slavic and early Christian world, grinding grain was mainly a female task, only exceptionally conducted by men. This pattern, however, started to change in the Late Middle Ages and ended in almost total domination of male millers in modern times (Rzepkowski 2015: 27–40). In the modern Polish language, and many other Slavic languages, occupations such as baker and miller are masculine nouns (although feminine noun forms are also acceptable). It is worth mentioning that the first preserved sentence written in Polish and recorded in the Book of Henryków in 1268–1273 (Księga Henrykowska 1949: 51) was: *Day, ać ja pobruszę, a Ty poczywaj* (*Let me, I shall grind, and you take a rest*). The sentence was supposedly uttered by Bogwał to his wife standing by the querns[1].

In the early medieval West Slavic area, quernstones were most probably a desirable and expensive product. They are usually found in fragments, less often as isolated finds and – but for a few exceptions – do not occur in deposits. Despite the buoyant development of Christianity in the Early Middle Ages, pagan practices did not vanish. Not only did they include burial customs, worship of the old gods and natural forces, as well as various types of magical behaviour but also shaped people's mindset and daily routines. Foundation sacrifices, recorded in the house and rampart foundations in the whole Slavic area, illustrate this phenomenon very well (Buko 2008: 133–142; Słupecki 1994; Wenska 2015: 279–287). Items typically deposited in this way include animal skulls, metal items, ceramic vessels, and agricultural products. Their quality, quantity and type reflected the local religious attitudes, socio-political situation, and the wealth of the depositing group (Buko 2008: 139–143; Curta 2004: 317; Sedlar 1994: 140–196).

Practices marking the end of the functioning of certain features were much less prevalent in the Slavic zone. Such rituals might at first seem obvious, as they occurred in multiple cultural contexts over time (Robb 1998; Watts 2011: 345–346; 2014: 101; 2014a). Cultural anthropology, ethnology and archaeology might provide abundant evidence of these practices (Bradley 2005). At the same time, in the Slavic area, the ritual sealing of production facilities (such as bakeries) and workshops (connected most likely to the end of their use), is rare or archaeologically undetectable. Burning the unused structures seems to have been a more popular way of indicating their symbolic death (Buko 2008: 110–142).

The abandoning of the Ostrów Tumski bakery was sealed with three quernstones (Figure 6). Two of them were still fully usable. We cannot say whether the facility was left due to the death of the people who worked there or because the bakery moved to a different location. In any case, the place must have had a significant position in the local tradition and social consciousness.

Such practices, rooted in pagan rituals or local traditions, were unacceptable for the Church. They might have been symbols of birth, death, life cycle, as well as express wishes of good fortune and prosperity (Brück 2001; Peacock 2013: 162–180; Watts 2014a).

Finds from early medieval Ireland testify a very specific type of this practice. To signify the abandoning of a house or a food-processing facility, it was sealed with a quernstone (O'Sullivan, Kenny 2008; O'Sullivan 2017–18: 110–112). The stones were placed inside of the walls, by the entrance or in the street close to the structure. Such arrangements occurred at over a dozen archaeological sites in Ireland (O'Sullivan

1 The full sentence was: Boguchwał's wife stood by the quern and ground grain. When her husband, Boguchwał, saw it, he felt pity on her and said: Let me, I shall grind, and you take a rest (Bogwali uxor stabat, ad molam molendo. Cui vir suus idem Bogwalus, compassus dixit: Sine, ut ego etiam molam. Hoc est in polonico: Day, ut ia pobrusa, a ti poziwai).

Figure 6: Wrocław-Ostrów Tumski: set of the quernstones used to seal the abandoned house (photo: K. Bykowski, M. Opalińska-Kwaśnica).

2017–18: 112–113). The stones were often deposited with other items connected to food processing, such as oak kneading troughs. The deposits are usually interpreted as linked to female activities and the sealing was performed when the woman in charge died. Comparable finds were also recorded by the grain roasting devices (Lisnagun in Great Britain) and probably had a similar symbolic and ritual significance (Peacock 2013: 172).

Discussion and conclusion

At the beginning of the Christianisation process, the Slavic people widely practised their rituals and magic – as it is indicated both by the deposits and the written sources (Buko 2008: Minniyakhmetova 2018; Moździoch 2004; 2013; Rosik 2020, 192-193; Słupecki 1994). In prehistory, ritual acts connected to the life cycle, fertility and food processing were natural and ubiquitous, as it is reflected by the numerous deposits of quernstones found all over the world. Similar deposits are known from Neolithic Mediterranean sites, British Isles, Near East and other (Graefe *et al.* 2009; Peacock 2013; Watts 2014). Quernstones were of critical importance for the Slavs, as they also occur in grave contexts in the early Middle Ages (Macháček 2010: 301–305; Marek, Skopal 2003: 518–519). Burials with bodies crushed with a quernstone were recorded in Bohemian and Moravian cemeteries (Dostál 1982: 179; Macháček 2010: 304; Marek, Skopal 2003: 518–519). Querns are sometimes found in wells, which is interpreted as a ritual closing of these facilities. Finds of querns by the gates might, according to J. Machacek (2010: 304), reflect a ritual end of the stronghold's life. The presence of the querns in pits used for storing grain might be explained in the same way.

The impressing number of the deposits in which quernstones have a purely ritual function demonstrates their significance as symbolic items. While the presence of quernstones in wells, storage pits and strongholds might have several explanations, their occurrence in graves and hoards of metal items shows that they played a key role in the Slavic spiritual world. They represented the rite of passage between the living and the dead, as well as they symbolised fertility, life and abundance (Brück 2001; Fendin 2000; 2006; Heslop 2008; Rzepkowski 2015; Watts 2014).

Evaluating ritual behaviour is one of the chief problems in archaeological studies. Discussions on the quernstone deposits in the utilitarian space never definitely answer the question of whether the deposit was intentional, and the act of deposition ritual. The West Slavic area did not yield any quernstone deposits of ritual character in household contexts. Perhaps the investigators were cautious enough not to present such hypotheses – even for the sites (e.g. Mikulcice, Pohansko in Moravia) with numerous quernstone finds in the production and residential zones. Therefore, the clear context of the deposit from Ostrów Tumski makes it critical for the further studies of the phenomenon.

The data presented above does not allow for determining the reasons behind performing the house sealing ritual. For the small community inhabiting the stronghold in Ostrów Tumski, the "bakery" was probably of great importance and social significance. Thus, the deposit might be interpreted as an expression of an irrecoverable loss after the baker's death or the abandoning of the facility. At the same time, it might have been a tribute from the local community to the baker and their family. In this case, social context of the three quernstones ending the lifecycle of the "baker's haose" is visible in using them as a magic stone-seal buried symbolically with all remains of the daily material culture of its owners.

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12. Stone Mortars: A Poorly Known Component Of Material Culture, Used In France Since The Iron Age. Including Recent Data For Late Medieval Trading Reaching The Baltic

Geert Verbrugghe

Inrap France[1]

Introduction

"*Mortel oc stampae*", mortars and pestles in medieval Danish, are mentioned in two recipes from two manuscripts of the *Libellus de arte coquinaria*,[2] a Scandinavian cookbook tradition of the beginning of the 14th century. The study of Helge Søgaard illustrates the everyday use of mortars in Denmark through entries in post-mortem inventories during the 14th/early 15th centuries (Søgaard 1962: 478). Ten years later, Mogens Bencard (1972) published 23 stone mortars, mainly from the danish port of Ribe. According to the petrographic identifications of Arne Noe-Nygaard,[3] all these mortars turned out to be produced from imported stones, nine of which are Caen stone (Normandy, France).

Rescue excavations in 2005 in the Caen castle (France) exposed the first published examples in Normandy of this local production (Verbrugghe 2015a). Sandstone mortars comparable with Meuse/Rhine estuary and Ribe findings were uncovered during two excavations in the Belgian Meuse valley (Verbrugghe 2018c; 2019b). On the other hand, the discovery of a cerith (a fossil shell) in a limestone mortar from Bruges (Belgium) confirmed the marketing of a second French production by North Sea outposts.

All these reasons make the 3rd AGSTR meeting an interesting opportunity to present recent results concerning mortar productions traded to Denmark. Moreover, it gave also an opportunity to reexamine some exported specimens of these productions. It also made it possible to add new Scandinavian evidence confirming the trade of this utensil reaching the Baltic Sea.

Stone mortars, a poorly-known component of Roman and Iron Age material culture

In Northwestern Europe, mortars appeared to concern almost exclusively pottery utensils, and especially those linked to Roman material culture. However, as early as the late 1960s, studies demonstrated the use of stone mortars in various regions of the Roman Empire[4]. Present in large quantities in most Roman contexts, the *mortaria* are systematically studied as part of pottery productions. Therefore, research questions on this utensil have mainly focused on culinary preparations, including logically issues involving the adoption of Roman ways of doing and/or adopting Mediterranean ingredients. This culinary focus has overlooked written sources such as the 'Natural History' by Pliny the Elder,

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1 We wish to thank Yee Hsien Tan, Sonja Willems (Inrap, France), Eric Goemaere (geologist, Royal Belgian Institute of Natural Sciences) and Martin Makinson proof-reading my English.

2 Conserved at the Royal Library of Copenhagen, online: https://www.uni-giessen.de/fbz/fb05/germanistik/absprache/sprachverwendung/gloning/tx/harp-kkr.htm.

3 Mineralogical Museum, Copenhagen (after Bencard 1972: note 8).

4 Dunning 1968 (online illustration: Verbrugghe 2016); Cool 2005; Palmer 2014 (with online database: http://www.palmyra.me.uk/pur-mortar.html) for the UK; and from Italy to Belgium: Caffini 2010; Bertrand, Tendron 2012; Vilvorder 2013.

precising the use of specific stones for different types of mortars (book 36: XLIII et XLIV). At least two archaeological findings document the medical use. In both cases, they concern mortars associated to elbow shaped pestles: i) the French inhumation of Saint-Médard-des-Prés (Figure 1) that includes ophthalmic tools and preparations (Santrot, Corson 2012); ii) a wide set of mortars and pestles in the medical office of a Rimini surgeon (Ortalli 2000: 521-522).[5] The rescue excavation of a *villa* north-east of Lyon (Silvino *et al.* 2011) demonstrate nonetheless the use of marble mortars and pestle in a funeral banquet dated to the late 1st/early 2nd century AD. In Apicius' *De re coquinaria*, a cookbook compiled between the 1st and the 4th century AD (Figure 2), 50 mentions illustrating different culinary uses of mortars occur. It not only documents sauces, but also the actions involving this utensil: grinding or pounding ingredients; the addition of liquids prior to flavouring; and transferring the preparation (Florent, Deru 2012: 281-282).

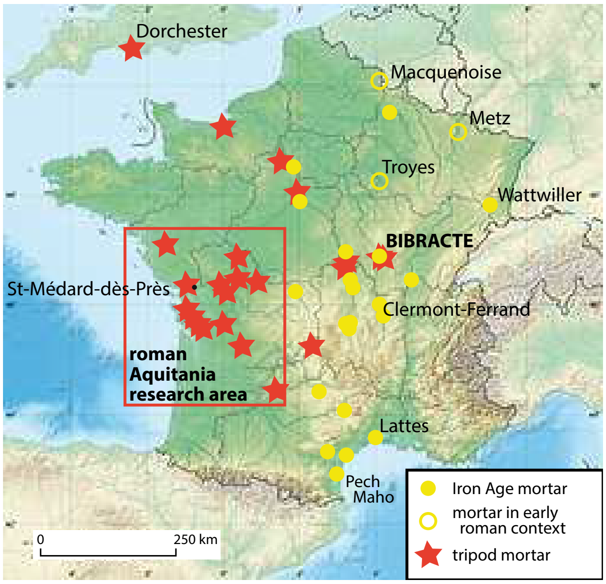

Figure 1: Distribution map of reported Iron Age/early Roman and tripod stone mortars, including data from the studies of the Mediterranean area, Roman Aquitania and the territory of the Arverni (respectively: Py 2016; Bertrand, Tendron 2012; Mennessier-Jouannet, Deberge 2017).

The approach centered on Roman ceramic mortars does not necessarily take into account neither the discoveries of stone versions of this utensil in contexts as early as the 5th century BC in Mediterranean Gaul (Figure 1, Figure 2),[6] nor the recent evidence for the distribution of the ceramic productions that reached central France (Augier, Ralston 2001: 8). As of the 2nd century BC, mortars mainly carved in basalt are recorded in rural settlements in the Auvergne region.[7] Similar mortar types are recorded in the late Iron Age *oppida* of the *Arverni* people (Figure 1)[8], but also further north at *Bibracte*. More than 50 fragmented stone mortars and two stone pestle ends from this *Aedui oppidum* are presently the subject of a reappraisal. A preliminary overview of the results was presented during the 2019 AGSTR meeting now online (Verbrugghe 2019b). Beside the extremities of two pestles in local granite, it concerns hemispherical, flat based and tripod mortars (Figure 3) discovered throughout the 200 hectares of this settlement. This significant amount of these 'newly' adopted utensils cut in various local or regional stones as early as the second quarter of the 1st century BC leads to the question of their use(s). Moreover, this issue relevant not only to central places, but also to occurences, often single ones, throughout

5 Online photography: http://www.palmyra.me.uk/zRiminiSurgeonsMortars.html.

6 With the exception of some isolated findings, this map illustrates a state of research mainly documented by millstone studies in the north east, by the *Aquitania* mortars (red rectangle) and by Michel Py's publication of Mediterranean sites.

7 Online illustration: Verbrugghe 2016.

8 Mennessier-Jouannet, Deberge 2017: 40, 45 and 49; and a university master's degree focusing on three *oppida*, including *Bibracte* (Constant 2016).

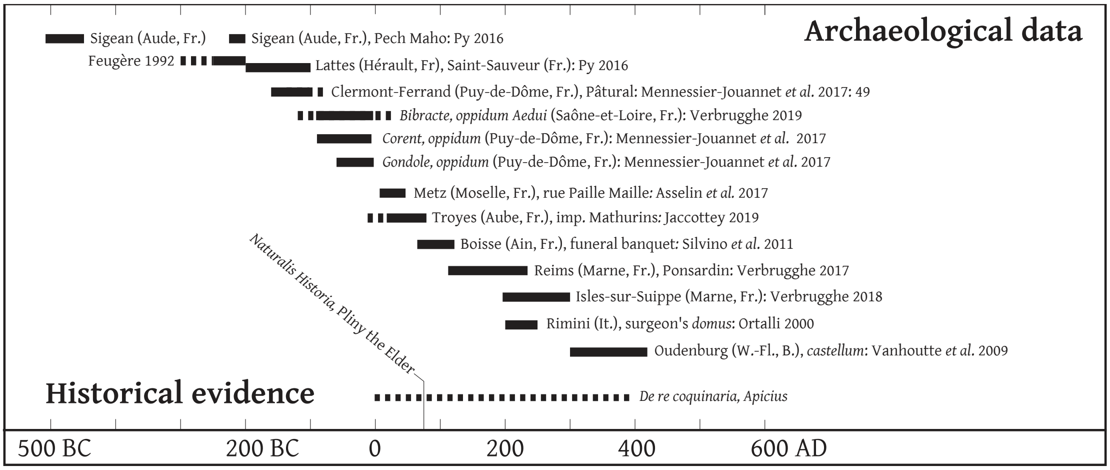

Figure 2: Selection of archaeological data and written sources relating to stone mortars between the 5th century BC and the 6th century AD.

France (Figure 1). For instance, apart from the *Aedui oppidum*, only two sites in Burgundy yielded each a single tripod mortar. If *Bibracte* specimens are generally produced in sandstone, the twenty *Aquitania* tripods are all in basalt (Bertrand, Tendron 2012: 391-392). Two finds from Dorchester illustrate a Purbeck limestone variant with quadripartite lugs and a pouring groove.[9] The *Bibracte oppidum* also yielded two mortars in Vaugnerite, a magmatic stone, also recorded[10] a hundred kilometres north of its extraction area in north Burgundy (Jaccottey 2019). A 3rd century context excavated at Reims documents another production of mortars next to millstones, here in a sandstone extracted north-east of Paris (Figure 4). For *Gallia Belgica* mortars, mainly (if not exclusively) local or regional stone resources are recorded (Verbrugghe 2016) on a par with what has been observed in *Britannia* (Cool 2005). In *Aquitania*, besides the above-mentioned basalt tripods, five elbow-shaped pestles and eight marble[11] mortars are noteworthy (Bertrand, Tendron 2012: 390-393). Several elbow-shaped pestles in marble or marble limestone (ident.: L. Jaccottey & F. Boyer) are kept in the museum of Autun,[12] the Roman capital replacing the *Bibracte oppidum*. They illustrate the adoption of "new" stone types, which is also the case for instance for Richborough (Dunning 1968).

The Autun museum preserves also a mortar rim fragment in a hard metamorphic stone, different from the stones used for millstones or mortars from Autun or *Bibracte* (Figure 4). A similar multifaceted lug in Belgian blue limestone mortar was discovered in a 3rd century rural settlement north of Reims (Figure 4). Mortars with this specific morphological trait are for the moment comparable to five of the nine mortars of the Rimini *domus*. These are carved in a dark Syenite stone originating in Assouan (Egypt) (info.: J. Ortalli). With two specimens in Proconnesos marble (Turkey) and an Italian limestone, this surgeon's assemblage agree closely with Pliny the Elder's indications.

From a strictly chronological point of view, to this day, a lugged mortar rim found in the Belgian *castellum* of Oudenburg is the latest find in Gaul (Vanhoutte *et al.* 2009: fig. 54) (Figure 2).

9 Online illustration: http://www.palmyra.me.uk/zWessexCourtTripodMortar.html.

10 Online illustration: Verbrugghe 2016.

11 The designation of "marble" does not necessarily distinguish 'marble limestones' (*op. cit.*: fig. 7) from 'geological' marbles.

12 Online illustration: https://www.pop.culture.gouv.fr/notice/joconde/01610011806 (via search 'pilon-broyeur Autun'.

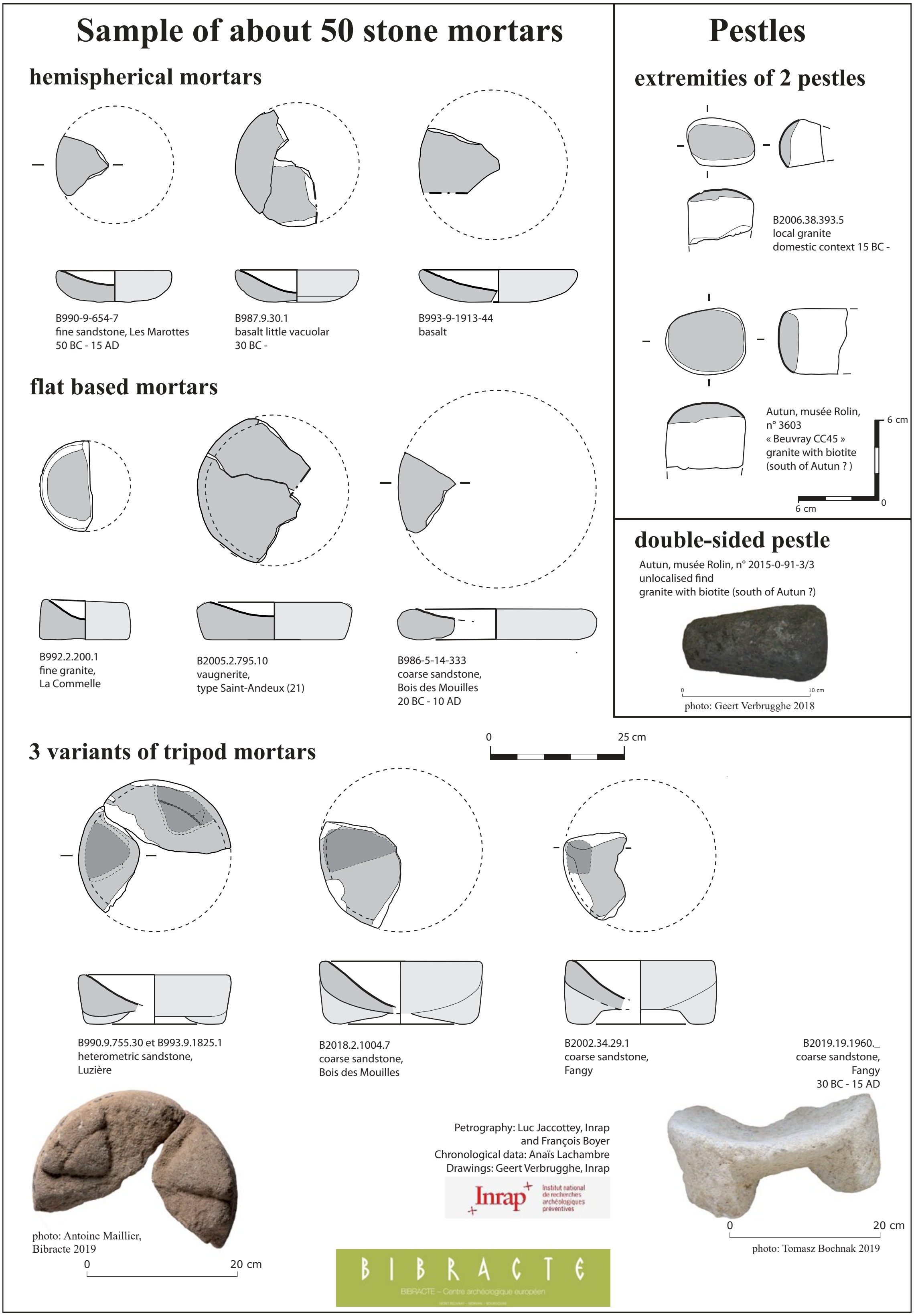

Figure 3: Sample of stone mortars and pestles from the oppidum of Bibracte and the museum of Autun.

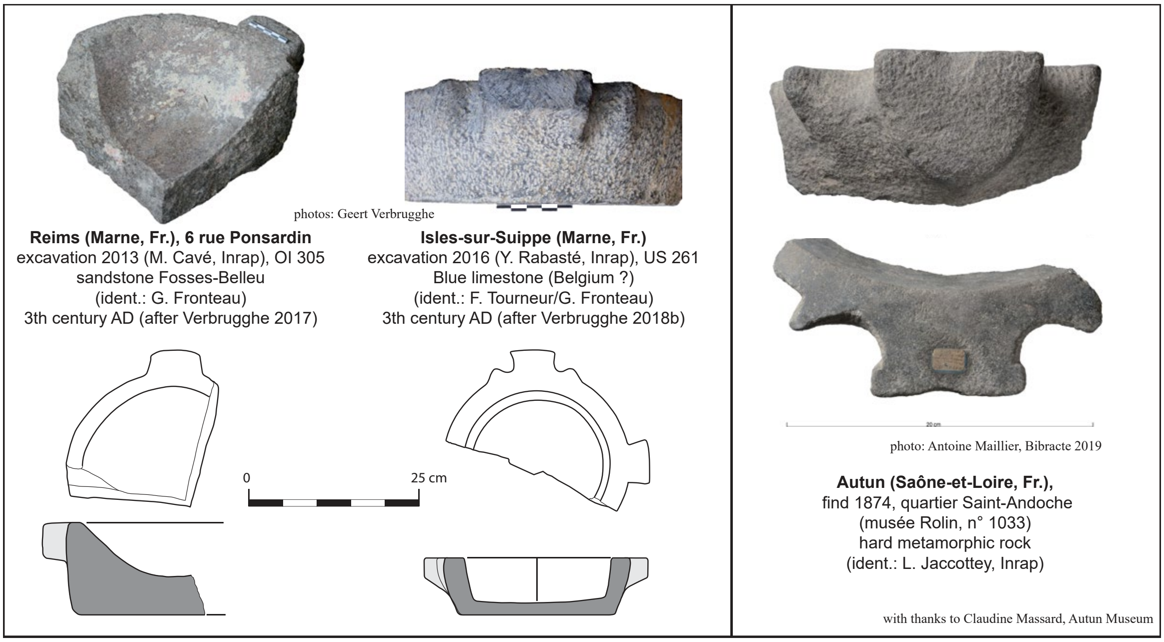

Figure 4: Roman stone mortars from the Remi territory and from Autun (France).

Medieval stone mortars: from the (still) 'Dark Ages' to the 12th century

For Western Europe, the *portus* of Dorestad (Netherlands) reveal again archeological records (Kars, Broekman 1981 ; Kars, Wevers 1982) to be assigned mostly between the mid-8th and the mid-9th centuries (*op. cit.*: 428; Willemsen, Kik 2010) (Figure 5). Approximately a hundred fragmented conical mortars on circular bases were discovered throughout the excavated area. They display a wide range in size and shape, with various morphological characteristics. At least 85 specimens carved in bioclastic limestone from the French Moselle region are presumed to be reused Roman construction materials, suggested by an inscription under the base of one specimen (Kars, Broekman 1981: fig. 69). Similar reuse evidence concerns a stone mortar of the French *portus* of Quentovic (Soulat 2012).

And then finds concern an early 10th century context in the fortified site of Elten on the lower Rhine (Figure 6) and a late 10th century example from a Lincolnshire manor (UK) (Binding *et al.* 1970: 166; Beresford 1987: 196). Also in France, stone mortars were uncovered in "elite" installations (Aubourg, Josset 2003; Racinet 2008: 59), with a special mention for Andone (Charente) illustrating their use near the *aula* of this *castrum* (Bourgeois 2009: 249-250 et 488). Scattered discoveries also relate to towns/*vici* (Jallet *et al.* 2012: 174), 'simple' rural contexts (Verbrugghe 2015b; Peytremann 2016) and also a pottery production site (Guadagnin 2000: 150).

The Catalonia charters document the use of mortars as early as the 11th century. Three wills testify to the use of *morter* as early as 1027 (Zimmermann 1992: 439; Sanahuja 1961: 28; and Baucells i Reig 2006: 28). To elaborate on influences via the Iberian peninsula, one should also mention Arabic cookbooks from the late 12th/early 13th centuries describing the use of mortars (Chalmeta Gendrón 1967). The *Kitâb al-Tabikh* specifies the suitable material for mortars (wood, stone or metal) in function of the various ingredients to be processed (Guillaumond 1991: 57).

In central France, discoveries from the rescue excavations of a craft quarter of the city of Bourges (Figure 7) deserve to be highlighted (Fasse-Moreau 2013). The detailed study of the 38 late medieval mortars illustrates a local or micro-regional stone supply and the growing popularity of mortars from the 12th century onwards, initially with a circular base.

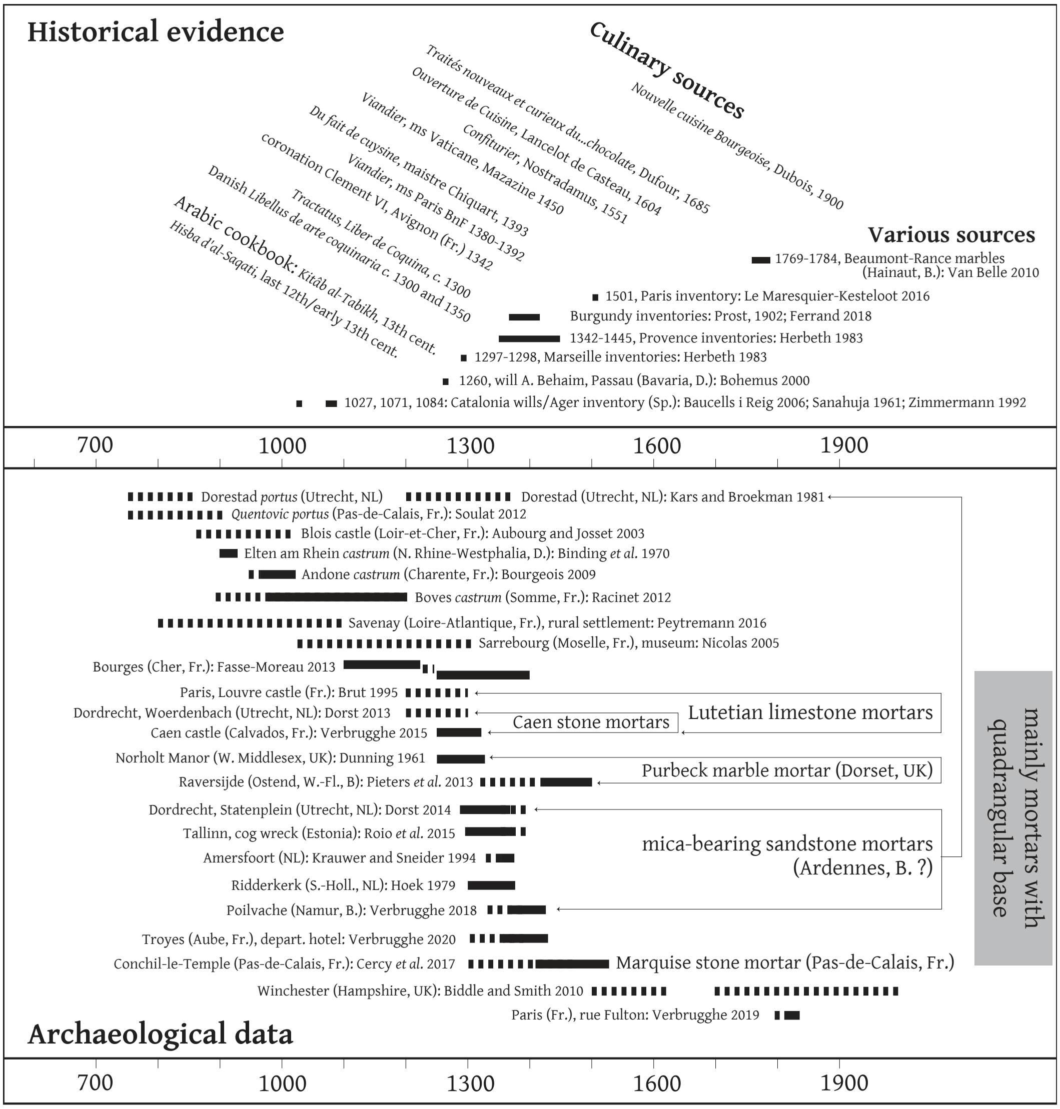

Figure 5: Selection of written sources and archaeological data relating to medieval and modern stone mortars.

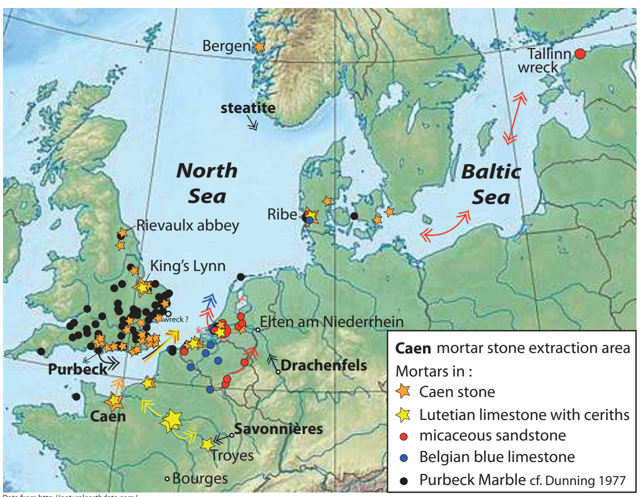

Figure 6: Distribution map of mentioned stone mortar productions concerned by North Sea and Meuse/Rhine trading.

Late medieval mortars in North-western Europe

From an archaeological viewpoint, stone mortars were at their apex between the 13th and 15th centuries with the introduction of the quadrangular-based mortar, documented by the aforementioned Bourges finds. Indeed, mortars are almost absent from pottery assemblages, except for some specific productions. On the other hand, the wooden and metal specimens are rarely preserved. A few exceptions occur, such as the wooden pestle that was preserved in the 'drowned meadows' excavations in the suburbs of the Flemish city of Ypres (Van Bellingen *et al.* 1994: fig. 21). The increasing number of written sources can, as already said, fill in some of the archaeological biases, and allow us to place them in a broader historical perspective, such as illustrated in the next paragraph.

Mortars and written sources

In Europe, the late medieval written sources document the use of mortars in various contexts. The gift to the Bavarian hospital of Passau in a will of 1260 is so far now one of the oldest mentions of a Northwestern mortar (<Bohemus> 2000). Unfortunately, the material of the utensil was not specified, which is also the case in the first western cookbooks. Apart from two manuscripts written in Latin around 1300, several culinary sources exist in different vernacular languages[13]. Worthy of note are the aforementioned Danish cookbook manuscripts with a possibly German origin or influence (Laurioux 1997: 207-208).

When analysing the French and Belgian cookbooks,[14] one can see that varied culinary actions are mentioned, such as grinding, pounding, diluting, stirring, pouring etc. of a large variety of ingredients for different recipes, recalling some those described by Apicius. If grinding is a verb that is generally used; pounding is associated only with specific ingredients/recipes. In the Anglo-Normand/Flemish *Tractatus* (Laurioux 1997: 38-39), rice is pounded for a *Blanc mangier* (Tr. IV, 1),[15] whereas in the *Viandier* tradition, hulled barley is pounded to make a gruel, in both cases 'as said for wheat'. In 1604, barley is described to be '*estamper*' (f° 45)[16] in one of the two stone mortars mentioned in the *Ouverture de Cuisine* of Lancelot de Casteau, master cook of three bishops of Liège (Belgium). Mortars are still closely related to spices and sauces, whereas they are not necessarily thought of as meant for some other recipes. For instance, a recipe for sick people involves mortar for crushing and mashing wholly cooked poultry, including its bones. Other recipes concern fish, such as lamprey in galantine. In this recipe, boiled fish is poured into a mortar "or a clean bowl (*jate*)", "stirred continuously until it is cooled", and then refined with spices. Other ingredients such as liver[17] are used for flavour enhancement, whereas verjuice, wine and vinegar were used for diluting the ingredients being grounded. Almonds are also a recurrent ingredient: according to the 1555 Nostradamus 'jam maker', they are ground in a marble mortar with sugar (fo. 203)[18].

Maître Chiquart's *Fait de cuisine* (1420) is an ostentatious display of the culinary arts at the court of the Duke of Savoy. He specifies the use of 'beautiful and tall' mortars during *honnourable* feasts for the high society (kings, queens, dukes ...). Moreover, the master cook's testimonies are substantiated by 14th century accounting sources. Indeed, for the papal coronation of Clément VI in 1342 in Avignon, the purchase of twelve stone mortars, six big and six mid-size, was registered in their invoices (Schäfer 1914:

13 Several are online: https://www.oldcook.com/en/medieval-cookery_books_europe.

14 See previous note, but mainly by https://histolf.ulb.be/index.php/textes-gh, viewed 14 September 2021.

15 Cf. https://www.uni-giessen.de/fbz/fb05/germanistik/absprache/sprachverwendung/gloning/tx/mul1-tra.htm.

16 Cf. http://www.staff.uni-giessen.de/gloning/tx/ouv3.htm.

17 Three recipes in the *Enseignemenz* (around 1300) and of *saulce poetevine* in the Viandier tradition.

18 See https://histolf.ulb.be/index.php/textes-gh, viewed 14 September 2021.

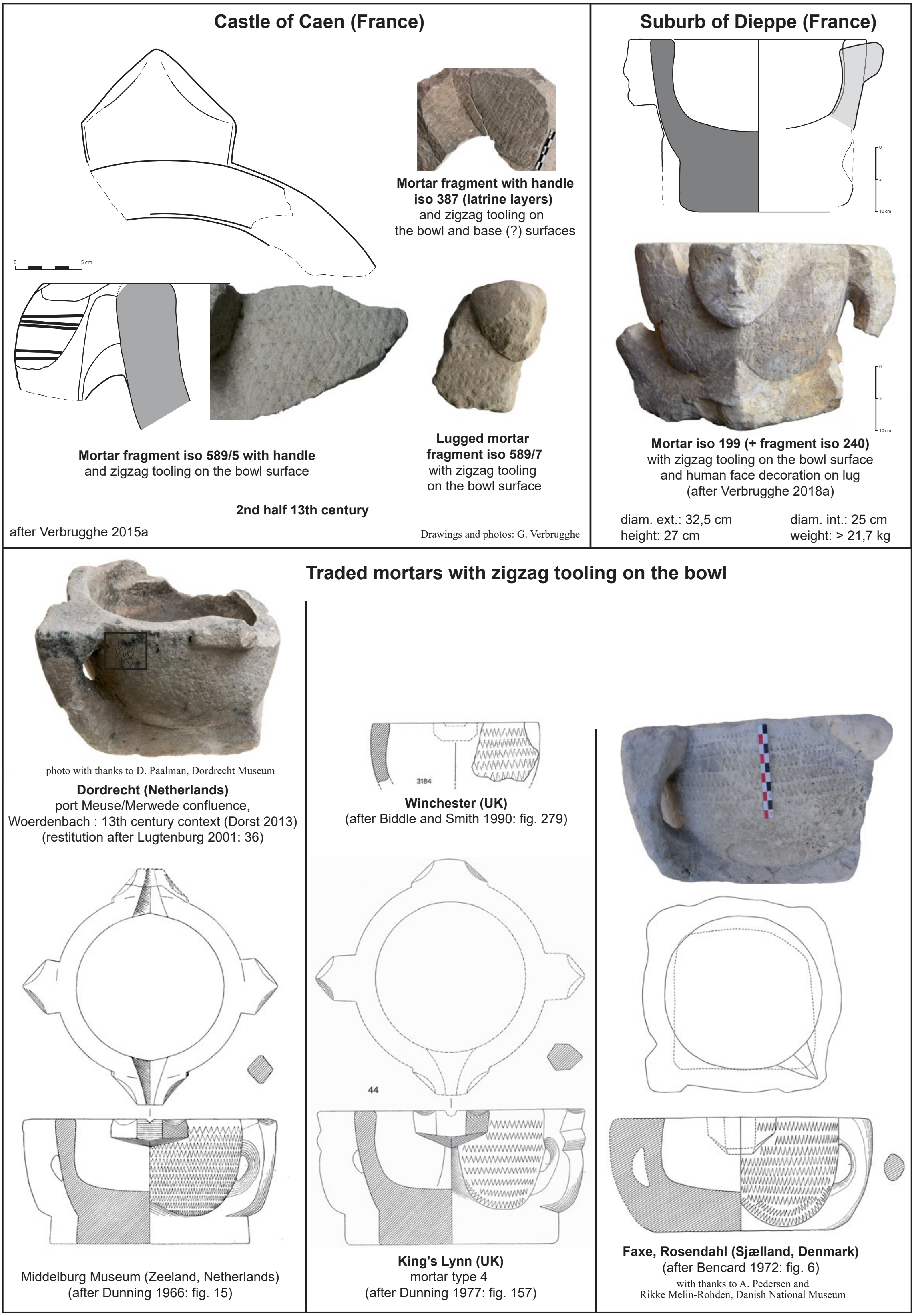

Figure 7: Limestone mortars with zigzag decorative finishing on the bowl from Caen, Dieppe (France); Dordrecht, Middelburg Museum (Netherlands); Winchester, King's Lynn (UK) and Faxe (Denmark).

188). In 1387, the garrison expenses of the duke of Burgundy mention a copper mortar and a pestle in the kitchen, whereas five mortars and 12 wooden pestles are recorded in the *saucerie*, a sub-departement of the kitchen meant for preparing sauces (Prost 1902: 262; Morel 2015: 224-227).

A French medieval guidebook for running the household suggests the use of a mortar and a pestle for preparing a six-table feast for the late 14th century bourgeoisie of Paris, and one recipe specifies the use of a stone mortar for fine grinding of spices (Ménagier de Paris 1846: vol. 1, p. 241; vol. 2, p. 115, 123 et 221). At least two 14th century iconographical sources illustrate the use of pestle and mortar at a feast: the English Luttrell psalter and a manuscript attributed to Tournai (Belgium)[19].

Different types of inventories also provide insights on the use of mortars and pestles, as well as on their raw materials. The post-mortem and dowry inventories from the French Provence region in the southeast of France are currently some of the most extensively documented (Herbeth 1983; Bresc-Bautier *et al.* 1984). For the western part of the Provence region, it is known that 44 households in the city of Arles possessed 15 wooden, 3 ceramic, 3 metal and 54 stone mortars (Démians d'Archimbaud 1980: note 23). The study of the Sicily inventories suggests an increasing ratio of marble mortars compared to those in metal between the 14th century and later (Bresc-Bautier, Bresc 2014: vol. 1, p. 235).

For the city of Dijon (Burgundy), the inventories between 1390 and 1408 have been extensively published recently (Ferrand 2018). They mention 40 stone mortars for a wide range of inhabitants: knights, priests, masons, bakers, dyers, winegrowers, etc. Three household inventories, including a pharmacy, reveal as early as 1388 the use of metal mortars and pestles (Ferrand 2018: 31, 48; Prost 1902: 3077). In one of these, a stone mortar and a pestle have been inventoried in the kitchen, whereas the workshop contains three copper mortars to pound *appothicarie* and several iron pestles. The use of metals for mortars and pestles in medical uses is attested in the *Cyrurgie* of Jan Yperman, surgeon of the Flemish city of Ypres (ca 1260-1332)[20].

Later, in 1501, a Parisian inventory mentions a mortar cut in the local Lias limestone (Le Maresquier-Kesteloot 2016 : 200).

Late medieval stone mortars and archaeological research

As already mentioned, the recently published mortars from the excavated part of Bourges illustrate the importance of stone quadrangular-based mortars during the 13th and 14th centuries (Fasse-Moreau 2013). Since the English and Danish publications of the 1960s, several excavations have renewed our data. Before the 21st century, information available in France and Belgium was scarce, unpublished or hard to find. Since the 19th century some museum inventories are noteworthy, but also some specific contributions which mainly raise questions about identification concerning capacity measures[21] or stoups, which seem frequently to be reused mortars.

Late medieval stone mortars and recent culinary contexts in France and Belgium

As early as 1961, Gerald Clough Dunning published seven mortars in two types of English stones. These utensils were found in contexts of the second half of the 13th/first half of the 14th century (Figure 7); they were located in the kitchen area of Norholt Manor, west of London (Dunning 1961).

19 Online manuscripts: London, British Library, Add. Ms. 42130, f° 207v; and Oxford, Bodleian Library, ms. 264, f° 170v.

20 Online: http://volkoomenoudeherbariaenmedisch.nl/Jan%20Yperman.htm

21 See recent review of French inventory, including some stone mortars, often reused ones: Darrou 2005.

An increasing number of stone mortars have been uncovered in excavations of the early 21st century. In tandem with an increasing focus on lithic artefacts, and a tendency for more standard reports, mortars are generally better described within their archaeological context. Despite the multiplication of discoveries, it is not easy to link stone mortars directly to culinary usage. Indeed, late medieval housing is generally characterized by a limited number of multifunctional rooms, with kitchens a rather conspicuous exception. Nevertheless, some French excavations have revealed stone mortars related more or less directly to culinary contexts.

North of Lyon, preventive excavations in 1994 at the abbey of Tournus have uncovered a sandstone mortar relief in the culinary refuse of one of the four chimneys of the kitchen beside the refectory (Saint-Jean Vitus 2014: 116-119). The fine Gothic bas-relief of this mortar is composed of a rosette flanked by architectural friezes that include arched columns directly related to the ecclesiastical context.

North of the Somme estuary, the Conchil-le-Temple farm excavated in 2005 stands out with its 15th/early 16th century kitchen that includes a vast reconstructed fireplace with chimney (Cercy *et al.* 2017). The kitchen demolition layers revealed the fragmented handle of a limestone mortar (*op. cit.*: 134). In the middle of the masonry of a 16th century reconstruction phase of the medieval farm, another stone mortar was found reused as construction material (*op. cit.*: 148-152). This impressive, 'handsome' mortar[22] has a quadrangular base with a pronounced pyramidal profile (ext. diam.: 30 cm; height: 28 cm; weight: >26,6 kg). A prominent feature of this mortar is its pronounced zigzag pattern under the rim and the human faces decorating the upper part of the four lugs/handles. The stone was identified to as regional, so-called Marquise stone (Jurassic), extracted northeast of Boulogne-sur-Mer (ident.: D. Vachard, Lille Univ.). Several mortars also combining zigzag decoration on the base and human faces in a similar, but not identical way, have been recorded, not only at the regional level, but also for instance south of the Champagne region (Troyes[23] and Auxerre[24]); and Ypres (Belgium). The cases of Ypres and the departmental hotel of Troyes (Pertuisot 2014) point out to what extent these decorated exemplars are outstanding finds. Indeed, in both cases, they are part of important assemblages of stone mortar finds (resp. 38 and minim. 88 mortars), as is also the case for other flourishing urban craftsman contexts[25]. These data highlight the ostentatious character of such decorated mortars, though a symbolic meaning cannot be dismissed.

Excavations of the 15th century sector of the fisherman's settlement of Raversijde, illustrate on a village-scale the reuse of stone mortars as building material. Constructions were then mostly in brick (Pieters *et al.* 2013). An almost complete mortar in Purbeck Marble (Pieters 1994: fig. 6) was found in a rudimentary floor-covering associated with one of the buildings. Faunal remains confirm that the activity in the village strongly relied on fish processing (Van Neer, Ervynck 1994; Van Neer, Pieters 1997), while macro-residues from a studied latrine reveal not only spices, but also pomegranate pips (Pieters *et al.* 1999). Pomegranate is mentioned as a topping for preparations such as *blanc mangier* in the *Viandier*.[26] The preserved remains of this exotic and perishable fruit can be considered indicators of commercial food processing for short-term preparations involving mortars, such as pies and galantines.

The rescue excavations in the western part of the castle of Caen (Normandy) have led to exceptional archaeological finds, including eleven fragmented mortars in a filtration layer between two particularly

22 Online illustration: Cercy, Verbrugghe 2007.

23 Online photograph: https://www.inrap.fr/les-tanneurs-medievaux-de-troyes-5068.

24 Chopelain *et al.* 2005.

25 Other excavated urban quarters should be added: 38 mortars without any decoration in Bourges (Fasse-Moreau 2013); and a unique human face on seven mortars in Dieppe (Figure 7).

26 Cf. https://histolf.ulb.be/index.php/textes-gh, viewed 14 september 2021.

rich waste deposits (Figure 8). These deposits revealed a large amount of pottery remains, but also preparation refuse of a (very) wide range of faunal waste resulting of festive events, whereas the ceramics suggest that they correspond to two successive feasts between the second half of the 13th century and the late 13th/early 14th centuries. The importance of highly decorated ceramics, but also the wide range of faunal remains, remind a 13th century Louvre castle (Paris) deposit (Brut 1995). In agreement with the data of written sources (see above), the amount of stone mortars seems likely to be linked to the deposit of the first feast event. They illustrate in a concrete manner the use of a substantial number of mortars on such occasions as mentioned in 14th century written sources. This well-dated context groups a wide range of forms and sizes documenting not exclusively local, but also extra-regional production. Their sizes range from a rather small example with a circular base to a 'huge' mortar (Figure 8). The morphological characteristics of the handle and the different finishing of the surfaces of three mortar fragments from this deposit are reminiscent of the Île-de-France mortars (Figure 9). This morphological approximation was confirmed by their macroscopic examination, revealing Lutetian limestone including cerith fossils (ident.: G. Fronteau).

The Late medieval trade of stone mortars in the North Sea area and beyond

As with other lithic artefacts, the "raw material" considered here, stone, offers a wide range of approaches. One of them allows the provenance(s) to be identified by geological affiliation. As early as the 1960s, this type of research enabled Gerald Clough Dunning and Mogens Bencard to illustrate the trade of this late medieval utensil across the Channel, the North Sea and even beyond (Dunning 1966; 1977; Bencard 1972). In Southeastern France, as early as 1980, the petrographic analysis of these medieval artefacts from the *castrum* of Rougiers can be considered as a pioneer approach (Démians d'Archimbaud 1980). More recently, the petrographic study of the mortars from the craftsman's quarter in Bourges concluded that these were of local origin (<50 km) (Fasse-Moreau 2013). Another example comes from the Croncels quarter of the Champagne fair city of Troyes (Figure 6): petrographic study revealed three different stone supplies, two being situated east of the city and the third one west (Fronteau 2011).

§ Mortars of Lutetian limestone with cerith fossils

Unlike the Savonnières limestone, transport via the Seine seems probable for the Lutetian limestone mortars. According to their morphological characteristics and finishing of their surfaces, the presence of this production was confirmed petrographically in the normand excavations in the Caen castle, in the port of Dieppe, but also in Bruges (Belgium) and Ribe (Danemark) (Figure 9).[27]

Caen stone mortars

An almost complete mortar was uncovered in a 13th century occupation of Dordrecht (Netherlands)[28] (Figure 7). At the present stage, the morphology and the faint traces of zigzag finish on the outer surface of this bowl seem to confirm its identification as a Caen production (Lugtenburg 2001 : 36). Indeed, the location of this previously mentioned decorative finishing allows, at the moment, to differentiate this type of Caen stone mortar from those of Île-de-France, but also the Marquise and Savonnières stone mortars. Pending petrographic verification, this decorative finish has indeed only been observed on mortars said to be carved in Caen stone on the both sides of the Channel and North Sea, but is now also attested on the eastern shores of Denmark (Figure 7). Indeed, the verifications of Anne Pedersen

27 With thanks to Morten Søvsø, Claus Feveile and the Ribe team for welcoming me. Since then, Ribe mortars are online: http://sol.sydvestjyskemuseer.dk/.

28 Our thanks to D. Paalman and M. Dorst for facilitating access to the data relevant to these finds.

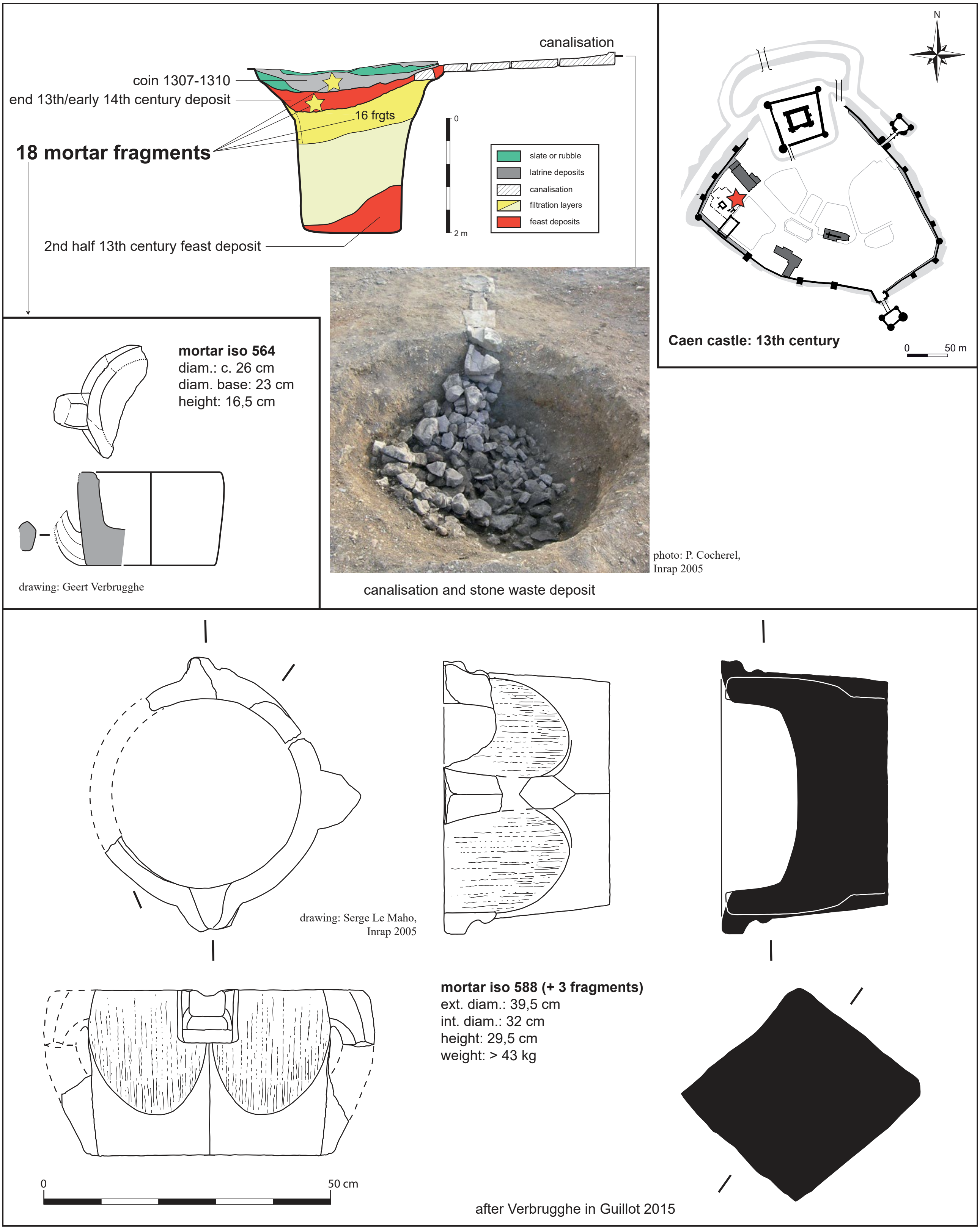

Figure 8: Archaeological context of the 13th century discovery of stone mortars from the castle of Caen showing two complete examples.

(Danish National museum) allowed to pinpoint the place of discovery in south Sjælland of a mortar, published by M. Bencard as of unknown provenance.[29]

On the other hand, a recent discovery south of Dorestad illustrate transport of a Caen stone mortar also upstream of the river Waal (Kars 2001).

Two recent rescue excavations have exposed the first examples of Caen stone mortars in Normandy, two in the previously mentioned and published Caen assemblage, another in a craft quarter of Dieppe (Verbrugghe 2018a: iso 199). The latter illustrates a new variant for this Normandy production. It combines the zigzag finish on the bowl surface, with a human face, seen here on a single lug without a spout (Figure 7).

Mortars in Purbeck Marble

Cross-Channel trade is also illustrated by new finds of mortars in Purbeck Marble (Figure 7) on the coasts of Northern France and Belgium (Pieters 1994; Cercy *et al.* 2008; 2011; and Bruges[30]), but also for Ribe.[31] The importance for our documentation of such coast sites, to which King's Lynn can also be added, is therefore closely linked to maritime transport. G.C. Dunning (1977: 325 et 336) relate so three offshore discoveries among which a possible ship cargo containing unused mortars in Purbeck and coarse shelly limestone.[32] On the other hand, another concerns a mortar with traces of wear suggesting its use in a galley, interpretation now confirmed by an Estonia salvage excavation (Roio *et al.* 2015).

Sandstone mortars combining roped edging and human faces

In Estonia, indeed the kitchen area of a 14th century cog wreck delivered in fact a large sandstone mortar (Figure 8). Rhineland stoneware and faunal evidence for Baltic and North Sea fish processing reflect its "very broad geographical background". The stone mortar possesses all the characteristics of a production with a wide distribution pattern: the combining of roped edging with 'basic' human faces, the finishing of the handles and of the outer surfaces of the bowl. Beside Ribe[33], Ridderkerk (Hoek 1979) and Dorestad, these features are now, well documented in the Meuse valley (Figure 8), mostly described as carved in micaceous sandstone (Verbrugghe 2019c). Dordrecht findings highlight the production's links with this waterway with at least ten fragmented specimens. Mica not being mentioned for the Dordrecht corpus, including several sandstone mortars a part of this production may remain unidentified, as undecorated mortars in micaceous sandstone have been identified not only in the medieval estuary of the Meuse, and but also further north, on the 14th century market of Amersfoort (Figure 8).

29 The number actually marked on the base, D.218-1950 (=Bencard 1972: 38), 'was proven to be originally no. D1381 and has allowed that location'. Thanks to Anne Pedersen and Rikke Rohden Melin for welcoming me, and allowing me to look anew into the mortars published in 1972. Visual comparison with splinters of a spalled mortar base of Dieppe (Verbrugghe 2018a: iso 168) seem to confirm the Caen stone material, also for the Stagsevold base (D.99-1964).

30 Online: https://collectie.raakvlak.be/98006/156?nav_id=2-1&index=3&id=825951, identified in 2018 by R. Dreesen as Purbeck Marble.

31 72 Ribe mortars, including 21 Purbeck ones, are now online: http://sol.sydvestjyskemuseer.dk/.

32 The Museum of Leiden (Netherlands) keeps the 24 mortars (no. U 1975/1-26) of this dredging find, acquired by Leendert Louwe Kooijmans, that I want to thank with the current director, Luc Armkreutz.

33 Online illustrations: http://sol.sydvestjyskemuseer.dk/, ASR M7157.

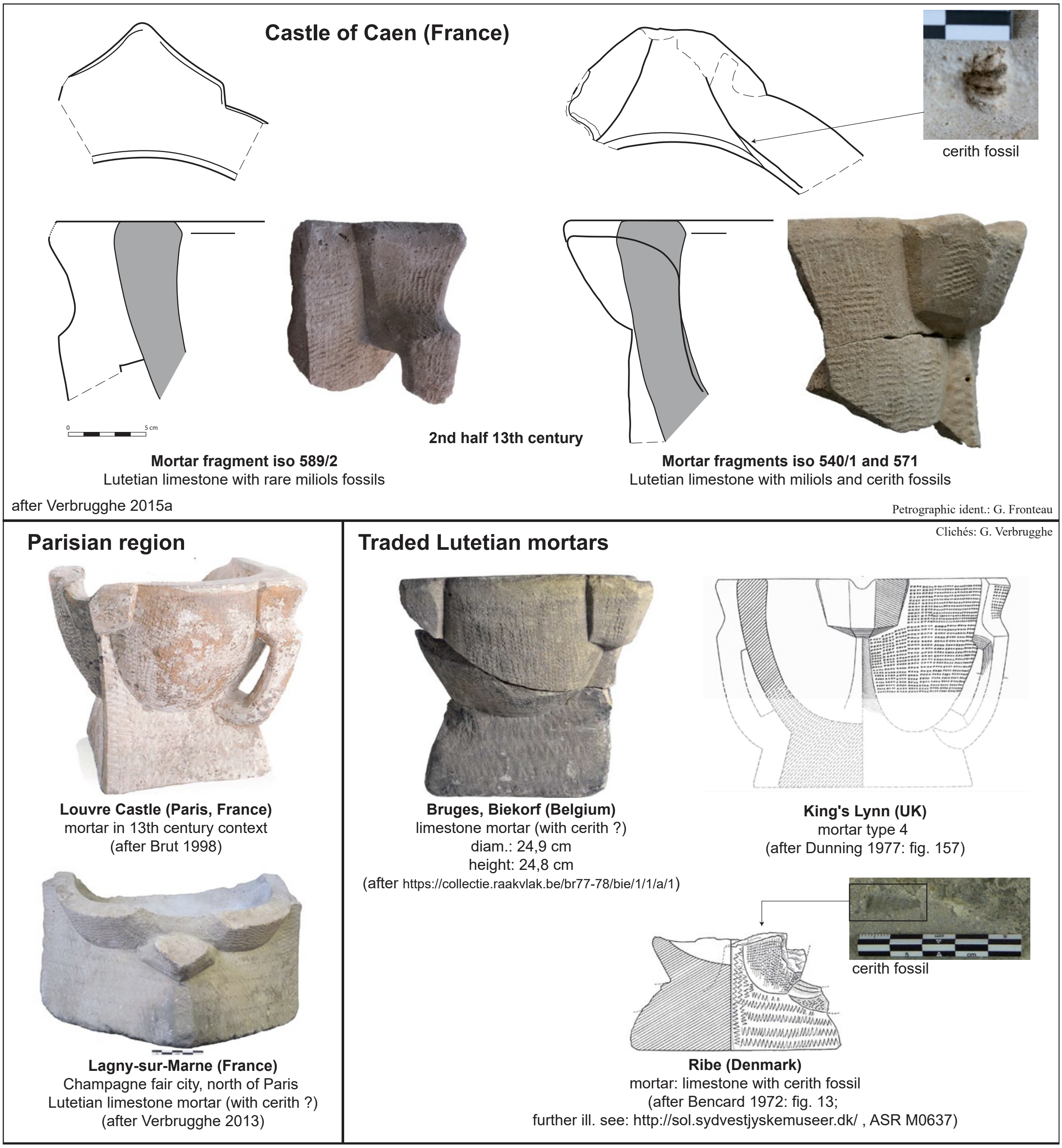

Figure 9: Examples of limestone mortars with zigzag decorative finish on the sides of base from Caen, Paris, Lagny-sur-Marne (France); Bruges (Belgium); King's Lynn (UK) and Ribe (Denmark).

Trachyte mortars from Drachenfels, Germany

Trade of a trachyte mortar production from Drachenfels (Germany) downstream the Rhine is documented by Dorestad, Utrecht and Dordrecht findings (Kars, Wevers 1982; Lugtenburg 2001: 34-35 ; Bouma *et al.* 2013: 77-78) (Figure 8).

Belgian blue limestone mortars

Mortars in blue limestone are also reported in Ribe[34] and the Netherlands (Pruissen, Melkert 2010 ; Loopik *et al.* 2016). Pending a petrographic confirmation or new evidence, the discovery of specimens in the Scheldt estuary (Hulst; Ghent?) , in Brussel (Belgium) (cf. my 2021 contribution in the Tournai congres https://congreswapi2020.be/) and in Lille (France)[35] does not contradict the proposed attribution to a Tournai stone production.

Long-distance trade and the importance of a petrographic approach

These data from now-identified traded mortars reveal a complex exchange pattern for this utensil that cannot be understood without a more systematic petrographic approach of the various stone types. As regards French productions, the lack of evidence for international trade of mortars in the so-called Marquise stone, extracted northeast of Boulogne-sur-Mer, is intriguing. Although only the decorated mortar from Conchil-le-Temple (see above) is confirmed in this stone type, of architectural stones and baptismal fonts in this stone are already reported to be traded through the Channel (Drake 2003 ; Salamagne 2011 ; Debonne, Dreesen 2015).

Online data, such as is already available for Bruges, Ribe and the Netherlands, provide a chance to develop, interconnect and deepen in a nowadays way this international aspect of mortar research.

Mortars in modern/recent times

After the Middle Ages, mortars are mainly documented by museum collections (Søgaard 1962; Wittop Koning 1989; Launert 1990) and some archaeological records. At present, only a Parisian and a Winchester mortar can be mentionned (in archaeological research Biddle, Smith 1990; Verbrugghe 2019a) (Figure 7).

As to the written sources, they appear still in recipes involving, beside sugar (see above), also cocoa[36]. For the end of the 18th century, the load accounts of the Ardennes marble masons include numerous mortars shipped up to Paris, Rouen, etc. (Van Belle 2010). At the end of the 19th century, the “new bourgeois *cuisine*” still underline the importance of stone mortars, especially in preparing stuffing (Dubois 1900 : 100-101).

Research perspectives in a nutshell

Since the 1990s, archaeological research has revealed an increasing number of well-documented stone mortars in France and in the Lower Countries. This has permitted to better know, and thus also better recognize these items, including during fieldwork when archaeologists are faced with ‘shapeless rocks’.

34 Online: http://sol.sydvestjyskemuseer.dk/, ASR 111/67.

35 Information: Christine Cercy (Inrap) for Debs *et al.* 2006.

36 See https://histolf.ulb.be/index.php/textes-gh, viewed 14 september 2021.

Figure 10: Sandstone mortars combining roped edging and human faces from the belgian fortress of Poilvache, the city of Dinant; the dutch sites of Ooltgensplaat, Dordrecht, Amersfoort; the ports of Ribe (Denmark) and Tallinn (Estonia).

Stone mortars dating to the Iron Age renew questions concerning the adoption of this utensil in Gaul, while mortar research remain centred on the particularly common Roman pottery *mortaria*, necessarily undertaken within the framework of the study of the abundant ceramic finds. According to written sources and archaeological evidence, roman mortars are meant for both, culinary and medical use, including marble mortars involving long-distance trade. These different uses compel scholars to focus on archaeometric approaches, particularly through the analysis of organic residues like those carried out on British Iron Age and Roman ceramics (Cramp *et al.* 2011).

As for the medieval period, a 'return' of archaeological data reporting stone mortars since the 8th/9th century can be noted. Beside those of the *portus* of Dorestad (Netherlands), but also of Quentovic (France), these concern mostly single finds that need to be further documented.

The appearance and development of a new type of mortar during the 13th century, with a quadrangular base, heralds a flourishing period for stone mortars meant for culinary uses, a period during which only some pottery workshops produced this type of utensil. Although this part of Late Medieval material culture still remains poorly known in current archaeological research, the increasing quantitative and qualitative data gathered since the 1990s permit a renewed overview of the studies by Gerald Clough Dunning and Mogens Bencard, published in the 1960s and 1970s. Recent data have revealed the importance of new stone mortar productions in northern France and Belgium and called back also the long-distance trade across and beyond the North Sea (Figure 8). The increasing number of mortars published online (Brugge, Netherlands provinces, Ribe) provides new perspectives for international research on these utensils, in need however of a more systematic inclusion of petrographic data[37]. The wide range of contexts also allows a socio-economic approach, for example in the case of Champagne fair cities. These archaeological data can be compared with several cases documented by detailed written sources, such as the Dijon, Provence and Sicily inventories. In addition to cookbook traditions, some finds can also be linked even more to faunal, floral, and organic remains, as shown for the Caen castle, Bourges (France), and the Raversijde fishermen's village (Belgium).

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37 Cf the online stone reference collection https://flepostore.ugent.be/rocks

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13. Telling Textures: Surface Textures May Reveal Which Grains Were Ground in Northern Ethiopia

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Introduction

In the villages of Northern Ethiopia the tradition of grinding goes back thousands of years. Grinding stones were recovered from the archaeological sites of Mezber and Ona Adi located in the Gulo Makeda *Woreda* (District) of Tigrai, from contexts dating to *c.* 1600 BCE to 700 CE. The grinding stones still used in homes today have a strong resemblance to those from the distant past. Observations of ethnographic grinding stones in the villages around Mezber and Ona Adi revealed two types of sets of grinding stones. Saddle querns include *maṭhan* (Figure 1) and *madqos* (Figure 2). Handstones include the *madit* (large two handed stone used with *maṭhan* and shown resting on the *maṭhan* in Figure 1) and the *wedimadqos* (palm sized stone used with *madqos* and shown resting on the *madqos* in Figure 2).

An ethnoarchaeological study was conducted to understand the use of these grinding stones. Interviews with local consultants demonstrated that surface textures of grinding stones matter. To achieve different textures, suitable for grinding different types of grains, users prepare the surfaces through maintenance. Maintenance of surfaces can include either repecking (to produce deeper interstices and roughen the surface) or grinding stone on stone (sometimes with intermediate substance) to reduce topographic heights and smooth the surface. The method of grinding stone maintenance is decided based on what type of grains the user plans to grind next. Large size grains such as wheat (*Triticum spp.*) and barley (*Hordeum vulgare*), were imported from southwest Asia from the late 2nd to early 1st millennium BC at Mezber (Beldados *et al.* in prep) and require a rough surface. Small sized grains such as the locally domesticated *t'ef* (*Eragrostis tef*) and finger millet (*Eleusine coracana*) are processed on smoother/finer textured grinding stones. Experiments were conducted to determine the benefits of using different stone surface textures for grinding different sized cereal grains. The experience substantiated that it was more effective to grind large cereal grains with a coarse grinding surface and small cereal grains with a fine or smooth textured surface.

What Are Others Saying About Grinding Stone Textures

Woodbury (1968: 55) states that grinding stones with smooth or rough grinding surfaces recovered from Jeddito Valley sites in Arizona were the result of previous use, with smoother surfaces having been used more and not resharpened. Phillipson (2012) refers to varying surface textures on handstones found in Seglamen and Kidane Mehret near Aksum, Ethiopia as a reflection of a transition from husked grains to free-threshing grains. I would argue that rather than worn through use, or a sign of transition, varying surface textures such as fine/smooth and coarse, can be more reflective of a population using a broad spectrum of grains in their diet. A broad spectrum of grains would allow for variety in the diet and would serve perhaps to build resilience to potential problems e.g., failure of a particular crop due to climate or pests that can arise when subsistence is too reliant on a narrow range of resources.

Ethnoarchaeological studies have shown that smooth and coarse textures in Gulo Makeda reflect the grinding of different types of grains – small and larger sized grains respectively.

Figure 1: Maṭhan Quern Built into Udo Table with Madit Handstone Resting on Top.

Figure 2: Madqos Quern with Wedimadqos Handstone Resting on Top.

Teklu (2012: 71) also noted in Lakia'a near Adwa, Tigrai that this practice of using smooth textured grinding stones for small size grains such as *t'ef* and finger millet and course textured grinding stones for large size grains such as wheat and barley was employed. Knowing the cultural preference for different grinding surface textures to process different sized grains can aid in understanding how artifact surface textures can indicate the type of grain worked on that surface. A coarse surface with exposed angular edges of quartz inclusions can shear and tear the outer layers of larger cereal grains, including barley, sorghum (*Sorghum bicolor*), wheat and maize *(Zea mays)*, removing the outer hulls for later separation during sieving. Horsfall (1987: 341-342) refers to raw material design constraints selecting for rough/vesicular stones for grinding due to their ability to catch and freely cut the cereal grains in the topographic variances as the handstone meets the quern. However, a smooth surface for these grains would just crush the grain and make it more difficult to separate the chaff from the flour. Alternatively, fine textured or smooth surfaces are required for grinding *t'ef* and finger millet because these are small grains that can get caught in the interstices of coarse surfaces during grinding and remain intact (unground). In South Africa it has been reported that different handstones were required for sorghum versus maize due to the different types of grinding needed to reduce the grains to flour and according to Huffman (2006: 68) different grinding stones can be reliable indicators for the processing of different crops. I would argue that even different surface textures can be reliable indicators of different crops.

Surface textures can also reflect the particular goals of the grinder for producing coarse or fine flour. David (1998: 23) mentions that with multiple querns in a supporting table in Sukur, one would have a rougher surface for coarse grinding and one with a smooth surface for finer grinding. From the Northern Black Mesa excavations in Arizona, both coarse and fine raw material *metates* were recovered and the explanation was that there were multiple grindings first coarse, then fine to achieve a finer textured flour (Parry and Christenson 1987: 55). Handstones from Guatemala have a course surface for the rough grind and a smooth surface for the fine grind (Searcy 2011: 102). Both of these last two cultures are processing maize (*zea mays*), and in Tigrai it was learned that maize is first ground using coarse surface *maṭhan* quern and/or coarse textured *madit* handstone (Figure 1), then water is added and it is ground a second time on the *madqos* quern with a *wedimadqos* handstone (Figure 2). The second grinding of maize seems to be a cross cultural practice.

What Are Others Saying About Grinding Stone Maintenance

Resharpening through repecking seems to be a common modification made to grinding stone surfaces and is important because it informs us about past behaviours related to the upkeep of grinding stones. Several studies have been completed on grinding stone maintenance that past people performed to purportedly retain an effective tool and/or make it more efficient (for example see Conlee 2000: 382; David 1998: 23; Gorecki *et al.* 1997: 146; 148; Holmberg 1998: 132; Horsfall 1987: 341; Pritchard- Parker and Reid 1993; Searcy 2011: 96; Smith 1986: 33; Teklu 2012: 71; Wright 2008) or to create a new tool (Simms 1983). Depending on the raw material of the tool, grinding stones are resharpened after extended use because the surface becomes too smooth to grind effectively and/or efficiently. Grinding stones can also be pecked to achieve different textures for different types of flour, such as preparing a roughened surface for coarse flour and then using a smoother surface for fine flour. As grinding stones wear out, or break they can even be repecked to reuse for a secondary purpose, for example a worn quern used for grinding flour can be repecked to grind legumes, coffee, ochre, metals, and other various materials.

In a previous study, grinding stone artifacts were analyzed from the Pre-Aksumite sites of Seglamen and Kidane Mehret in western Tigrai (Ethiopia) by Phillipson (2012). She concludes that changes observed in the morphology of the grinding stones, specifically surface texture, are an indication of a change in the types of processed grain. According to Phillipson (2012: 528-529) predominantly husked grains (e.g., hulled barley and emmer wheat (*Triticum dicoccum*) were processed, probably wet, on fine textured, smooth grinding stones. Free threshing southwest Asian wheat grains (*Triticum spp.*) were processed on coarser surfaces. A limitation of this study is that although she mentions 'enquiry among local informants' (Phillipson 2012: 524) related to grinding stone breakage, alternative explanations for the conclusion made about surface textures in this study were not explored via a thorough ethnoarchaeological study. There is a need to add ethnoarchaeological studies to this literature to include all the modern reasons for grinding stone maintenance, including how it relates to the types of products being ground, not just the need for a roughened surface.

Northern Ethiopia – In the Words of Grinding Stone Users

Ethnoarchaeological research was conducted within the region of Gulo Makeda, Tigrai, Ethiopia, at multiple villages throughout the valley. This population has not had extensive exposure to the world economy and are still practicing non-mechanized farming. Until recently people produced flour by non-mechanized means, in particular the women employed stone grinding equipment which was manufactured by local men.

Sampling for ethnoarchaeological interviews followed a snowball or chain sampling strategy (Marshall and Rossman 2006:71). Inquiries began with excavation workers about potential consultants who had grinding equipment in their home. Contacts were made to set up initial appointments based on these referrals. To increase sample size additional interviews were generated by asking interviewees, or consultants, if they knew of anyone else that might consider an interview. In other instances, we approached people we met while walking, or approached houses on our routes, to ask if we could set up an interview. Through this probability sampling strategy, men and women of various ages and socio-economic classes were interviewed. This resulted in a representative sample of this region that would allow for data to be analyzed to produce basic generalizations about the manufacturing, use and discard of grinding equipment in Gulo Makeda (the full range of data can be found in Nixon-Darcus 2014).

In 2012, 35 interviews were conducted with the aid of interpreter Yemane Meresa, M.A. in the villages of Kertsodo, Membro, Aby Adi, Tsa-eda Hamed, Hamado, Adis Alem, and Adi Mhigay over a six week field season. During a similar period in 2013 interviews were completed in the villages of Aby Adi, Menebeity and Dahane. The goal of the second year was to complete enough interviews to determine if there were major differences between the two areas, and to confirm any commonalities. Fifteen interviews were conducted in 2013 and it was determined that responses were similar enough to those from Mezber in 2012 to reach a point of redundancy. The few differences noted were due to the longer period of time that villages around Ona Adi have had access to more conveniently located mechanical mills (Nixon-Darcus 2014). During the 2019 field season 13 additional interviews were conducted around the archaeological site of Mezber and in the nearby city of Adigrat. These interviews were designed to gather further information about grinding stone use. Particular attention was paid to questions about using different grinding stone surface textures for processing different types of cereal grains.

Most interviews took place within the home or courtyard of the advisors. Interviews normally lasted between one and two hours. Three to five days per week were spent in the field conducting interviews and the number of interviews per day ranged from two to four. Interviews were semi structured with questions prepared prior to entering the field, but also permitting the discussions to depart from the questionnaire if unanticipated information came to light. The interviews included both open and closed questions.

In the 2012/13 ethnoarchaeology study, most people interviewed (90% (28) of women, and 87% (14) of men) described two types of *maṭhan* quern, one with a coarse, rough surface for grinding large cereal grains such as sorghum, barley, wheat, and maize, and second type with a fine texture or smooth surface for grinding smaller cereals including *t'ef* and finger millet (Nixon-Darcus 2014). During the 2019 interviews, questions were also asked about how women prepared the surfaces for grinding. Photographs and microscopic Dinolite[tm] images were taken of ethnographic grinding surfaces that were used for separate grinding of large versus small size cereal grains. The intent was to develop a reference collection of images to compare use-wear from ethnographic grinding stones of known use to use-wear observed on archaeological grinding stones with unknown use.

During interviews with northern Ethiopian consultants, it was explained that the *madqos* quern and *wedimadqos* handstone (Figure 2) were used for grinding salt, peppers, spices, beans, and for a second wet grinding of maize and sorghum. The other set of grinding stones, the *maṭhan* quern and *madit* handstone (Figure 1) are used to grind grains into flour for making: breads (including *injera*, an Ethiopian pancake type of bread with dough made usually from *t'ef* but also from wheat which has been fermented and cooked on a griddle); *teheni* (roasted and ground barley squeezed into a compressed form of coarse dough for eating as a snack); *sua* (fermented beverage, similar to beer); and for grinding chick peas for *shiro* (chick pea based spicy sauce served with *injera*). It is important to note that 93% (n=41) of women and 87% (n=14) of men interviewed specifically described two types of *maṭhan* quern and *madit* handstone surfaces. One type has a coarse surface used for large cereal grains such as sorghum (Sorghum bicolor), barley, wheat and maize, and a second type has the smoother surface for grinding smaller cereal grains including *t'ef* and finger millet. Women owned either separate grinding stones –separate sets of *maṭhan* querns with *madit* handstones - or just multiple *madit* with differing surface textures. Several women described how their mothers had more than one *maṭhan* quern. Others used a single set of grinding stones and reworked the surfaces depending on what they were planning to grind. Women also talked about grinding side by side suggesting more than one *maṭhan* quern was present.

The requirement for hand grinding is diminished now due to the introduction of mechanical mills, so one *maṭhan* quern and *madit* handstone per household could suffice. Many houses I visited only had one *maṭhan* quern, and it was explained that to accommodate the different type of grains, the women would 'rehabilitate' or resharpen the surfaces of both hand and base stones to create the coarseness or smoothness needed for the different types of grains. *T'ef* and finger millet could also be ground after the larger cereal grains were processed, as the initial grinding of those larger grains would smooth the grinding surface enough for the smaller grain to be processed. This information becomes important when analyzing archaeological samples of grinding stones because the type of grinding surfaces can suggest the types of grains that were processed in the past. It also becomes important when finding multiple grinding stones in the same archaeological context as they might have been used for different products.

Are Textures Due to Wear and/or Maintenance

In the study area in Northern Ethiopia, repecking is required to create the necessary surface textures depending on which material is being processed. To create a coarse grinding surface for the processing of large cereal grains a hammer stone (a basalt cobble that was often shaped by flaking at one end) (Figure 3) or, in more modern contexts, metal hammers are used to pound the grinding stone surface to create depressions. To create a smooth or fine surface for small cereal grains, hammer stones are used to make shallow depressions by light hammering and then topographic highs are removed by grinding stone on stone or by grinding large cereal grains as an intermediate substance. Medium textured surfaces are likely worn surfaces that were once coarse and intended for grinding large size grains, but had not yet been resharpened. Consultants in Tigrai explained that once coarse surfaces were worn to a medium texture they could continue to be used for grinding large size grains, however grinding would become more difficult and the resultant flour would not be as fine. They also indicated that a medium surface would still be too rough (coarse) for grinding smaller grains.

Regarding the artifacts of this study, the possibility that the fine textured/smooth surfaces were simply worn due to grinding rather than prepared for small grain processing was considered and discounted for several reasons. The first argument against this proposition is that on the examined fine textured/smooth surfaces the asperities or raised grains/projections on the surface are in close proximity, leaving narrow interstices. Where there is a coarse or medium textured surface, the grains are further apart and interstices are wider. It would seem that if these were just worn surfaces, the interstices would still be wider from the original pecking of the coarse surface, however this is not the case.

Another indication that these fine textured/smooth surfaces are not worn is that many of the surfaces show some evidence of resharpening (peck marks), indicating that the fine textured/smooth surface had been maintained on these grinding stones, not left to wear down. Consultants from Gulo Makeda also advised that they would need to resharpen surfaces as soon as they had become worn to a medium texture to effectively grind the larger grains. They would however allow the surface to become worn further if they were planning to grind smaller grains, or would prepare a fine texture for this purpose.

Figure 3: Waizoro (Mrs) Letay Alemayo Resharpening ("Rejuvenating") a Broken Madit Handstone with a Mokarai (Hammerstone).

Considering the bifacial *madit* stones, with two types of surface textures, there are studies that suggest handstones can be turned over to avoid grinding these tools into wedge shapes (Adams 1993; Bartlett 1933). Several of the *madit* bifacial stones from this study are wedge shaped, suggesting the biface is not a result of turning the stone to avoid substantially changing the dimensions of the tool. A more parsimonious explanation for biface handstones may be the need to maintain different types of surface textures on one tool.

The Ancient Grinding Stones and Their Textures

A large number of grinding stones were recovered from the archaeological sites of Mezber (a rural site) dated 1600 BCE – 1BCE/CE and Ona Adi (a town site) dated *c.* 750 BCE – 750 CE (Taddesse 2019:339). An analysis of the types of grinding tool surfaces resulted in the discovery of fine textured/smooth surfaces (Figure 4), medium textured surfaces, and coarse textured surfaces (Figure 5).

When the different textures are broken down by site there some interesting differences emerge. At Mezber the breakdown of textures for the *madit* hand stones is 18 fine/smooth, 31 medium and 21 coarse (Table 1). A medium textured surface is still too coarse for the smaller grains as the grains would fall into the interstices and not be ground into flour. For this reason, the medium textured surfaces were combined with the coarse textured surfaces and it is assumed that both were used to grind the larger cereal grains. Combining the medium and coarse surfaces they represent 74.3% of the collection. The fine/smooth textured grinding stone representation at Mezber is 25.7%. At Ona Adi the breakdown of textures for 184 *madit* handstone surfaces is 87 fine/smooth, 11 medium, and 86 coarse (Table 1). The combined medium and coarse textures represent 52.7% of the collection while fine/smooth textures represent 47.3%. If individuals were using the same types of textures for the same types of grains at both of these sites, it would appear that for the areas excavated so far, more grinding of smaller grains such as *t'ef* and finger millet was done at Ona Adi compared to Mezber. If the medium and coarse surfaces were used to grind wheat and barley, a higher percentage of grinding of these large type cereal grains occurred at Mezber (74.3%) compared to Ona Adi (52.7%). A further analysis of variations in grinding-stone assemblages by time periods is warranted.

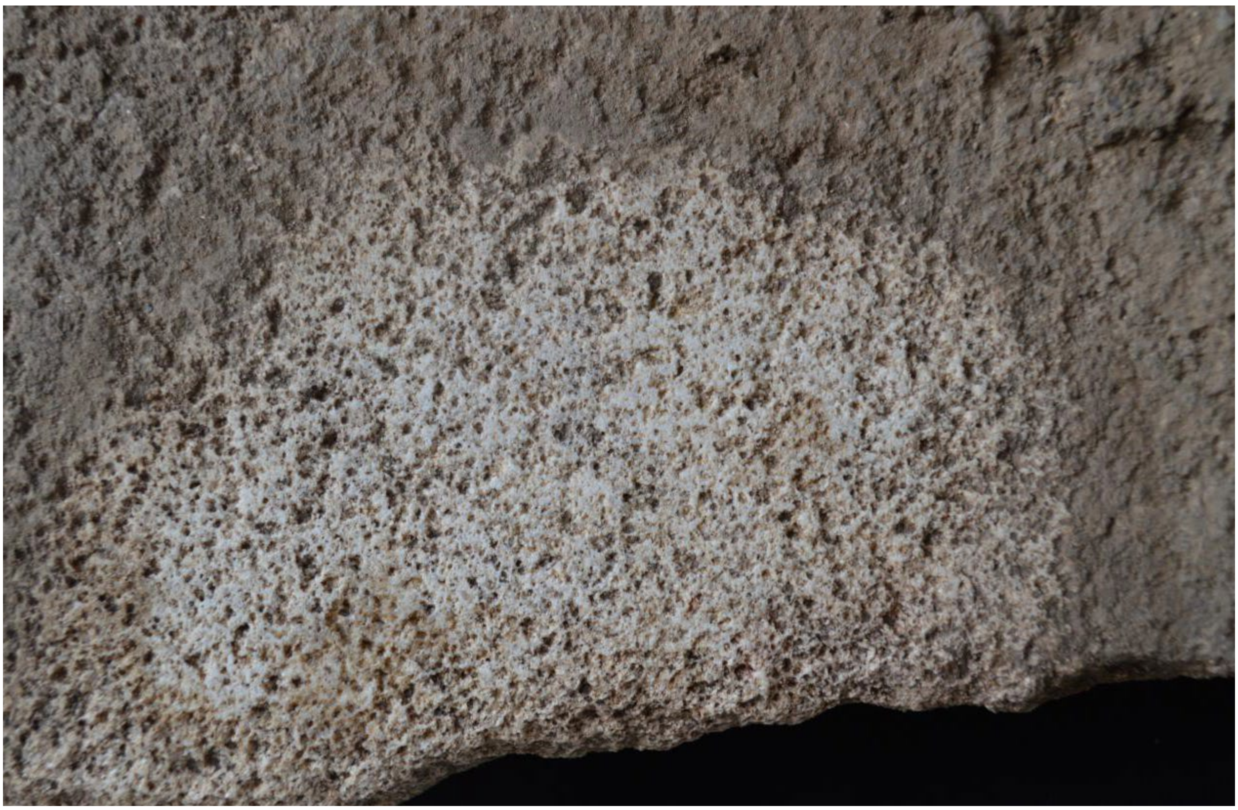

Figure 4: Bifacial Madit Handstone Smooth Surface - SN 1832, Mezber Square E1, Locus 8, Pail 8.

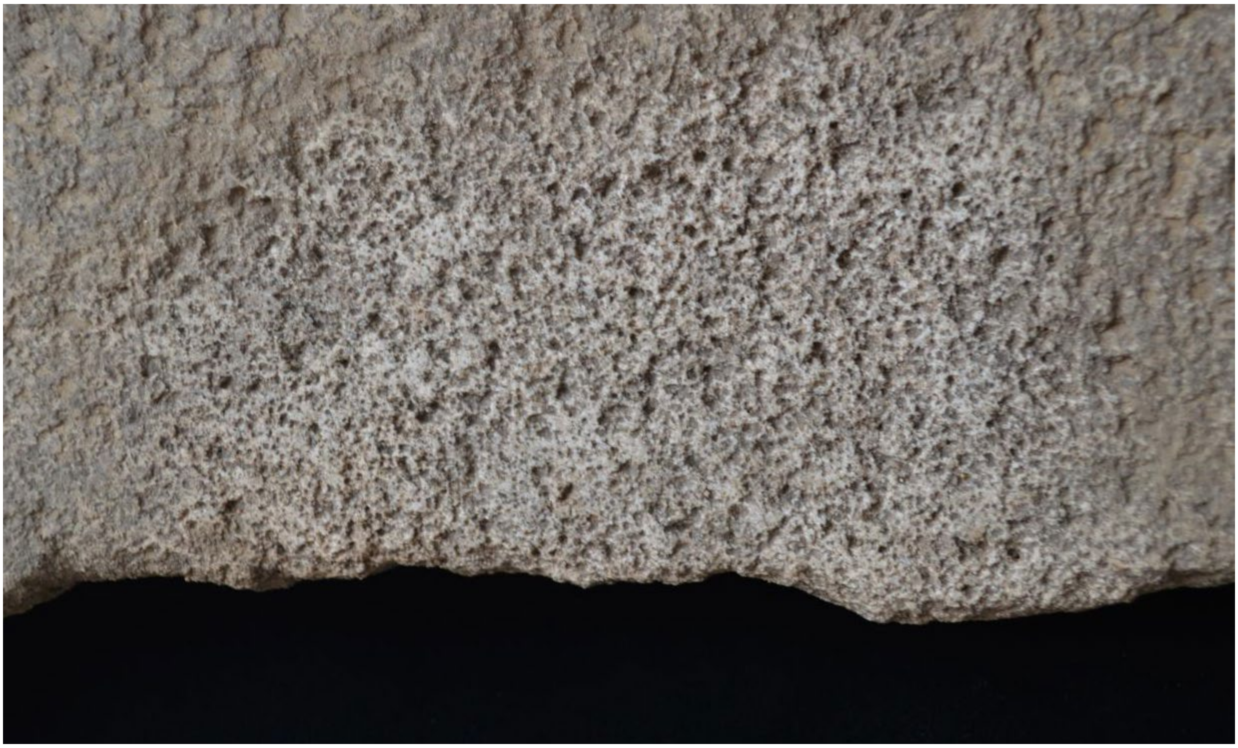

Figure 5: Bifacial Madit Handstone Coarse Surface – SN 1832.

Table 1: *Madit* Grinding Handstone Surface Textures at Mezber and Ona Adi.

Site	Total Artifacts	Fine/ Smooth		Medium	Coarse	Total Medium + Coarse	% Medium + Coarse	% Fine/ Smooth
Mezber	70	18		31	21	52	74.3	25.7
Ona Adi	184	87		11	86	97	52.7	47.3

The Bifacial Madit

A key discovery was made while analyzing archaeological *madit* handstone surface textures. During analysis it was noted that some *madit* handstones had opposing use surfaces. In this paper these are referred to as bifacial *madit*. Observations of the bifacial Mezber *madit* handstones revealed that 54% (n=13) have one fine/smooth surface while the other side has a medium to coarse texture (Table 2). Bifacial *madit* grinding stones were likely used for grinding two different kinds of grains. It is unlikely that the smooth surface was worn smooth through handling. The surface of the handstones is relatively long and flat, so any handling use would occur only where hands would have been placed during grinding. Ethnographically it was noted that women place their hands on the ends of the handstone, not on the dorsal side of the stone. If in the past it had been different, and grinders placed hands on the dorsal side, the length of the handstones exceed the distance covered by two hands side by side. So there would be areas showing no smoothing where hands were not in contact with the stone. This is not the case on ancient artifacts of Mezber and Ona Adi archaeological sites, rather the smooth texture covers most of the use surface. The practice of having two textures available on a single handstone was probably to accommodate grinding differently sized cereal grains when the need arose. The practice of using bifacial *madit* handstones continued at Ona Adi with 60% (n=12) having one fine/smooth surface and one medium or coarse surface (Table 2).

Table 2: Mezber and Ona Adi Bifacial *Madit* Handstones.

Explanation of Table: The textures are denoted along the top row as 'surface 1 texture/surface 2 texture', for example, Fine/Medium means surface 1 has a fine texture and surface 2 has a medium texture. (Note: Fine refers to both Fine and Smooth Textures)

Site	Total Artifacts	Fine/ Fine	Fine/ Medium	Fine/ Coarse	Medium/ Medium	Medium/ Coarse	Coarse/ Coarse
Mezber	24	1	9	4	3	5	2
Ona Adi	20	3	1	11			5

The Ona Adi *madit* handstones include more bifacial stones with the same texture on both sides (three fine/fine and five coarse/coarse) (Table 2), however if medium and coarse are combined, as both are suitable for grinding large grains, Mezber has a higher number of medium to coarse textures on both surfaces of the same stone (n=10 or 41.7%) compared to Ona Adi (n=5 or 25%) (Table 3). Having the same texture on both surfaces may reflect a type of *madit* handstone that is dedicated to one type of grain, in this case a medium or coarse surface to serve for grinding large cereal grains such as imported wheat and barley. As one surface becomes worn and less effective, the stone could be turned over to the coarser surface and continue to be used efficiently.

Table 3: Mezber and Ona Adi Bifacial *Madit* – Medium/Coarse Textures Combined.

	Fine/ Fine	% of Total	Fine/ Medium- Coarse	% of Total	Medium- Coarse/ Medium-Coarse	% of Total
Mezber	1	4.2	13	54.2	10	41.7
Ona Adi	3	15.0	12	60.0	5	25.0

Table 4 breaks down the number of all bifacial *madit* handstone surfaces for each of the textures and again we see that the medium to coarse surfaces make up a larger percentage of the total at Mezber (68.8%) than at Ona Adi (55%). This could reflect a higher amount of processing south Asian large grains such as wheat and barley at Mezber while at Ona Adi there was more equal production of large grains (55%) and locally domesticated small grains such as *t'ef* and finger millet (45%). I believe these were multifunctional tools in that at last use prior to disposition they were used for different types of grains, suggesting that a variety of grains were being used and ground into flour during all Pre-Aksumite and Aksumite phases at Mezber and Ona Adi.

Table 4: Mezber and Ona Adi Bifacial *Madit* Use Surfaces.

Site	Total *Madit* Surfaces	Fine/ Smooth	Medium	Coarse	Total Medium + Coarse	% Medium + Coarse	% Fine/ Smooth
Mezber	48	15	20	13	33	68.8	31.3
Ona Adi	40	18	1	21	22	55.0	45.0

Experimentation

Exploratory experimentation was conducted to investigate the benefits of using different surface textures for different grains. These experiments were conducted in Canada and a full description of the experiments and results will be the focus of a future publication. For the purposes of this paper, the highlights of the experiment and results are presented here.

The goal to test the results of grinding different grains (wheat and *t'ef*) required that the variables in the experiment were keep to a minimum. The same type of raw material was used for both sets of grinding stones. The same experimenter conducted both experiments on elevated surfaces. Five hours was spent grinding wheat and five hours was spent grinding *t'ef* using their respective stones. Grinding both types of grains occurred in the same location. The only variables introduced were the surface textures (which in the end were quite similar) and the processed materials – wheat and *t'ef*.

Grinding would take place while standing, on a raised platform, as was observed in northern Ethiopia. Grinding stones were placed into a rectangular plastic bin. This would capture all materials coming directly off the *maṭhan* (flour, pieces of stones that became disengaged, unground seeds). The grinding structure was built under cover and next to the house west wall to protect the area from wind as much as possible, similar to what was observed ethnographically in northeastern Tigrai where grinding stones and their tables were placed against a wall under cover, often with at least one open wall.

The first step in experimentation was to obtain raw materials suitable for making grinding stones. Quartzitic sandstone, such as that used in northern Ethiopia, was unattainable, so British Columbia mined white granite was selected as a close and reasonably comparable alternative due to its granular composition and hardness factor. Quartz and black amphibole hornblende were prominent in the matrix. Two separate sets of grinding stones were acquired and modified using hammering techniques. Tools included a small sledge hammer, ballpeen hammer (rounded head) and chisel to remove larger pieces. The goal was to shape the stones to resemble the size and shape of grinding stones found in northern Ethiopia. One set of grinding stones, to be used for wheat grinding, was prepared with a coarse surface through pecking. The second set of stones had a relatively smooth surface, and additional smoothing was attempted by grinding the handstone against the quern surface to level the asperities in preparation for grinding *t'ef*. Due to the hardness of the granite, it was difficult to completely smoothen the surface or even get it to a fine texture. It was determined this would be a good test of the need for smooth or fine textured surfaces for effective grinding of *t'ef*. A total of eight hours was spent shaping the grinding stones and preparing the grinding surfaces.

When grinding the small *t'ef* cereal grains it was noted that the surface was still too coarse and most seeds got trapped in the interstices without being ground. The experimenter had to move these seeds to more flattened areas of the surface to ensure they were ground. It was obvious very quickly that to grind *t'ef* a smooth or very fine grained surface is needed so that the seeds can be processed. It would take some time to grind down these experimental surfaces to a smoother texture. For the purposes of this experiment the experimenter instead chose to keep moving the seeds to the lateral edges of the quern where flattened areas had begun to form. Even then, many unground seeds were expelled into the bin and even off the grinding platform.

Grinding wheat on the other set of grinding stones which were prepared with coarse surfaces was very efficient at first. Unlike the *t'ef*, most of the wheat grains were ground and very few fell outside of the bin. After the first hour the surface began to smooth out and loose its coarseness and the grinding was less effective. The smoothened surface still had topographic lows in places, and it was here that flour accumulated. Newly added seeds would become lodged into these flour filled crevices and could not be ground. After approximately every four to six strokes, the unground seeds needed to be swept by hand about the surface to land between higher asperities and become ground into flour. At 15 minute intervals after the third hour of grinding, the flour in the interstices was also wiped off the surface of the grinding stone, which proved effective since the grains could not become nested in with the trapped flour. Resharpening was not attempted as it was hoped wear would accumulate on the surfaces for future use-wear analysis. Wheat grinding was most effective with a coarse surface enabling the high asperities to move the grains and 'rip' them apart between asperities to produce flour.

Conclusion

Ethnoarchaeological investigations of grinding practices in northern Ethiopia revealed that women prefer different stone surface textures for grinding different size grains. A coarse grinding surface is preferred when grinding large cereal grains such as wheat, barley and sorghum while a smooth or fine textured surface is considered best for grinding smaller cereal grains such as *t'ef* and finger millet. This preference is culturally situated within northern Ethiopia. Others have noted different textures used depending on the preferred resultant coarseness of the meal or flour ground and defined by social constructs (see for example Adams 2014: 122; David 1998), and different resulting textures which develop on surfaces due to the types of products processed and the specific techniques used by grinders (see for example Robitaille 2016: 24,26; Woodbury 1954: 55). The results from this particular study reflect a specific cultural group and may not apply to other cultural situations. However, exploratory experimentation results revealed that it is more effective to grind wheat with coarse textured surfaces on grinding stones, and attempting to grind *t'ef* on a relatively coarse to medium textured working surface resulted in many grains remaining unground as they got trapped within the interstices. Grinding *t'ef* only became effective when the cereal grains could be moved to a relatively flattened and smoothed section of the grinding surface.

To enable comparison of experimental results with ethnoarchaeological data more experimentation is needed using the same raw materials as are used in northern Ethiopia, however initial data confirms the claims made by consultants that surface textures matter when grinding cereal grains. In addition, it would be beneficial to conduct use-wear analysis on experimental and ethnographic grinding stones used for grinding different sized grains to determine if there are discernible differences in the use-wear patterns. The results of use-wear analysis of ethnographic and experimental grinding could be used to build a model and a reference collection to compare to the archaeological grinding stones of Mezber and Ona Adi. That research is currently in the planning stages.

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Biography

Laurie Nixon-Darcus is currently a PhD candidate in Archaeology at Simon Fraser University (SFU). She completed her SFU MA on the cultural context of grinding stones in Northern Ethiopia in 2014 and resumed graduate work in 2017, continuing to focus on grinding stone studies in the same region. As a co-author her published works thus far have been featured in two books and two journals. Laurie is also an avid volunteer in her community.

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14. The Bored Stone, *Nougouil*: Weighted Digging Sticks In Ethiopia

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Introduction

In the Oromo lands, surrounding the enclave of the old walled city of Harar in Ethiopia, agricultural practices include the employment of a weighted digging stick. In these lands, the soil is dense and compact, and unsuitable for the simple Ethiopian plough. The weighted stick is primarily used as a tilling instrument and is an integral component of a horticulturalist's toolkit. The weight used for this purpose is made of a hard rock, shaped into a (sub-)sphere through which a hole is bored.

Bored stones are ubiquitous in sub-Saharan African archaeology and seem to be related to Later Stone Age cultures (40,000-6,000 BP, Villa 2012). The earliest examples were found in South Africa and date to ca. 22,000-21,000 BP (Ouzman 1997:74; Villa 2012:13211). Bored stones have also been found in Uganda, Ghana, Congo (former Zaire), Zimbabwe, Botswana, Malawi, Zambia and Ethiopia (Balfour 1929:161; Bell 1876; Clark 1944; Dart 1948; Fagan 1962; Jeffreys 1967; Hromnik 1986; Moffett 2017; Ouzman 1997; Posnansky 1964; Van Noten 1977; Van Riet Lowe 1941; Waldron 1987; Weatherby 1965). In Ethiopia, bored stones are still in use only in a limited area, in the North East of the country, in the Oromo lands of the East Hararghe region.

In the Harari dialect, the stone, which is used as a weight mounted on top of the digging stick, is called *Nougouil,* and is bored and shaped by pecking. At Oromo villages around Harar, the word: "*Zegna*" [hae] is also used for this kind of bored stone. The stick, on which the *Nougouil* is placed, is called *Inji* [har]. The other end of the *Inji* is armed with an iron tip, called *Marasha* [har] (Waldron 1987). *Nougouil*, *Inji*, and *Marasha* (Figure 1) are locally manufactured and sold in a range of sizes at a shop in the heart of Harar's central market.

In the early 40's, Clark (1944: 31) investigated where *Nougouil* was used in Ethiopia and identified that its use was primarily associated with the Harar Plateau:

> *[...] From the right bank of the east of the Rift, eastwards to Harar, Dire Dawa, and the borders of the Danakil desert, east of Harar to Djidjiga and Hargeisa in Somaliland. The southern limits are not clear. [...] (But could be associated with the border of the old Harar Emirate.)*

Nougouil, is not used in the desert area, so we may conclude that it is only used by the terrace agriculturalists, the Oromo and Harari populations, at the Harar plateau. My ethnoarchaeological expeditions confirm Clark's (1944) observation on the spatial limits of the use of the weighted digging stick.

More than twenty different uses have been suggested for bored stone tools (e.g. weapon, bolas, game trap, spindle whorl, toy, or for religious and symbolic use) in archaeological and anthropological contexts (Balfour 1929:161; Dart 1948; Hromnik 1986; Lombard and Parsons 2003:81; Ouzman 1997:76-91; Robertson 1961; Van Der Merwe 1987). Most ethnographers, however, report that bored stones are primarily used as weights for digging sticks to upturn hard soils in preparation prior to sowing (Dart

Figure 1: Weighted digging stick (Inji) with a bored stone (Nougouil), photograph taken by the author in Harar.

1948; Ouzman 1997:91-103). Additionally, Ouzman (1997: 91-100) has identified several Late Stone Age panels of South African rock art depicting women using weighted sticks for digging and/or uprooting plants (see particularly Figure 5, in Ouzman 1997: 91). There is also photographic evidence dating to 1884 and 1911 (Bleek and Lloyd 1911; Bleek 1936; Ouzman 1997: 78-79) showing women using weighted sticks for digging. Clark (1944: 32), however, reports that in addition to upturning soils, *Nougouil* were also used as weights for pestles, enhancing the pounding force when processing *sarbuse* or *khat* (*Catha edulis*) in a mortar. Lastly, Waldron (1987: 69) has explored the meaning and etymology of local words used in Ethiopia for bored stone tools, lending further support to their use as digging sticks:

> *In Harari [har], an Ethiopian Semitic language, the digging stick is called a maxra, from the infinitive 'to dig', also maxra. The Oromo, in the vicinity of Harar, [...] use the term dongora, probably related to danqara, 'a bar (for gate or door)', or danqaraa, 'stick used to keep doors closed' [...]. Oromo is an Eastern Cushitic language [hae].*

Further descriptions of the digging sticks made by Waldron (1987) report that *Inji* [har], the stick, may be made from any suitable wood: Kitkita (*Dodonaea viscosa*, hopbush) or Woira (*Olea chrysophylla*, olive tree), but that eucalyptus often is favoured. The *Nougouil* is preferably made from igneous rocks such as basalt (Waldron 1987), but also from metamorphic rock types (Clark 1987).

Bored stones seem to have been well documented in the ethnography and archaeology of South Africa (Balfour 1929; Bell 1876; Fauvelle-Aymar 2006: 261-265; Goodwin 1944; Hromnik 1986; Jeffreys 1967;

Lombard and Parsons 2003; Moffett 2017; Ouzman 1997; Robertson 1961; Van Der Merwe 1987; Villa 2012). In contrast, only a few Ethiopian bored stones were last studied only a few decades ago (Clark 1944; Waldron 1987). The new ethnoarchaeological study reported here provides some preliminary results, following an exploratory ethnoarchaeological expedition to the Harar plateau. It aims to document the manufacture, function, and technique of use of the *Nouguil* and provide a record for comparison with similar (ethno-)archaeological finds. It hopes to enrich our knowledge on the *Nougouil* craftsmen's and users' social identities and show the potential for further research in this area.

Methodology

The research described in this paper was conducted in February 2019 on the Harari plateau. This paper draws on interviews with craftsmen who make *Nougouil*, farmers who buy and use them, and the only merchant in Harar who buys and sells them at her shop. Harar is the largest town in this area and an important trade centre since the 13th century (Ahmed 2015; Desplat and Østebø 2013). The *Nougouil* is made by the Oromo and then sold to the Harari at the shop in Harar. I interviewed *Nougouil* users from both the Oromo and the Harari ethnic groups.

I began my research at the Harar market, where I interviewed the merchant and recorded and analysed 20 *Nougouil*. I enquired about the *Nougouil* manufacture and the source of the raw material and was directed to the village of Kersa, 26 km West of Harar, East of the Rift valley. At Kersa, I recorded 17 finished and unfinished *Nougouil.* I also observed and interviewed two farmers who manufacture *Nougouil* and often travel into the highlands to sell their bored stones, and two farmers who buy and use *Nougouil.*

I conducted my interviews with focus on technique and function and inquired about sociocultural aspects of use and manufacture. I observed and documented the sequence of raw material sourcing, *Nougouil* manufacture, sale, use and discard. This research offers insights into the *chaîne operatoire* of *Nougouil* from procurement to discard, and into the craftsmen's, merchant's, and users' perspectives.

Raw material acquisition

Several quarries are used for the extraction of raw material for the bored stones. Usually, the farmers who manufacture *Nougouil*, go to a specific quarry close to their village. The quarry which they currently prefer is 5 km from the village of Kersa, in an area called Ijleo. In the quarry, more than ten men may collaborate in the extraction of the raw material and the production of preforms. The preforms are split equally amongst them at the end of the working day. A specific kind of rock is preferred because of its property to resist breakage during manufacture. In the quarry, this type of rock is identified by the sound produced during percussion as well as by its colour. According to my interviewees, the best kind of stone is hard and grey, qualities corresponding with basalt and other igneous rocks in the area. In the quarry, after the extraction of appropriately sized rocks, they are shaped into sub-cubic blocks using an iron hammer. The *Nougouil* manufacturer estimates the appropriate size by hand, without the use of measuring tools. On a good day, a manufacturer can make up to ten preforms. The preforms are brought to his house where they will be further worked into *Nougouil*.

Manufacture

Mr Sadic Mummai Ourso and Mr Ibrahim Abdulla Waari (Figure 2), both farmers from the Oromo group, specialize in the manufacture of *Nougouil.* They have 30 and 20 years of experience making bored stones:

'I learnt from my father. I learnt how to break the stone at the quarry and make the stone round and then bore it.', Mr Sadic Mummai Ourso told me when I asked how he learnt to make *Nougouil*. Now, he teaches others. The

Figure 2: Mr Ibrahim Abdulla Waari (left) and Mr Sadic Mummai Ourso (right) making Nougouil.

teaching-learning is done through demonstration and practice. The manufacture of *Nougouil* is reserved for the men of the tribe. Men of any social standing are allowed to make them. Although members of a family usually work together, the knowledge of how to make bored stone tools is not necessarily passed down from generation to generation within a family. At Mr Ourso's house, the son of his neighbour is also a keen learner and one of his most talented students.

Mr Sadic Mummai Ourso explained that nowadays, preforms obtain their final shape at home with the use of a little iron hammer (*Burush*) and a chisel (*Chibiliga*) [hae]. Firstly, the shape of the stone is finalized with the use of a *Burush*. Next, the stone is perforated. For the perforation, a chisel is used as a percussor on a chosen face of the stone, first on one side and then on the opposing one until it is fully pierced (Figure 2). The perforation of the stone must be fairly straight, and the size of the hole must have appropriate dimensions so that it can be easily mounted onto a stick.

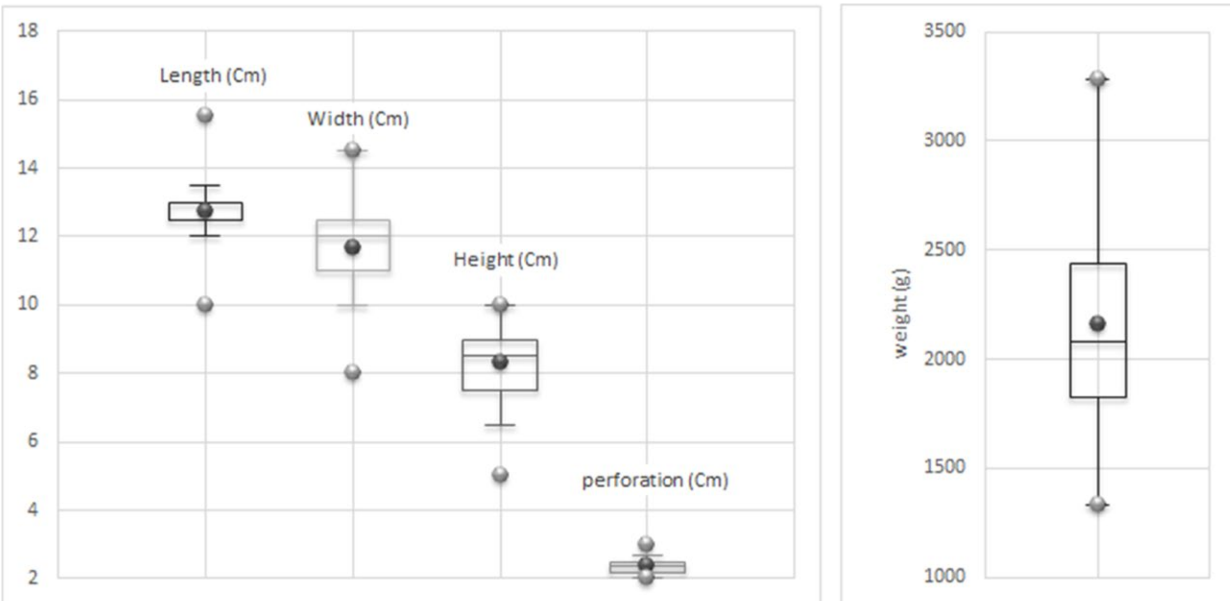
According to Mr Sadic Mummai Ourso, the size of the bored stone varies depending on the age of the customer; small *Nougouil* are made for young men and the bigger ones for adults. However, some farmers reported that a smaller *Nougouil* is preferred because it is easier to use due its lower weight. According to these farmers, the size of the stone depends on the strength of the user. As the digging stick *Maxra* is used only by men, the number of such tools in a household depends on the number of boys in the family, if the family can afford one for each boy or man in the household.

A *Nougouil* manufacturer can finish five to six bored stones per day during the dry months (December to February) when work in the field is limited. This side job offers some of the farmers a good supplement to their income. *Nougouil* are directly sold to the merchant in Harar (Figure 5) and other farmers in the village.

Morphology

In total, thirty-seven *Nougouil were analysed*, four of which were unfinished, lacking complete perforations. The table and graph in Figure 3 plot the dimensions of the thirty-seven *Nougouil* and of the thirty-three finished perforations. Generally, a *Nougouil*, is sub-spherical or doughnut-shaped, no smaller than 10 *cm* and no larger than 16 cm in diameter and weighs no less than 1 kilo and no more than 3.5 kilos. The perforation is between 2 to 3 cm in diameter.

Because of the dimensions of the *Nougouil* (Figure 3), the percentage of the ratio of the standard deviation to the mean shows an extent of coefficient variation (cv) of 8.31% for the length, 10% for the width, 12.4% for the height, and 10% for the diameter of the perforations. Since these values are around 10% cv, the sample shows standardization in form and therefore, specialized manufacture (EErkens and



Statistic	Length	Width	Height	perforation	weight
Nb. d'observations	37	37	37	33	37
Minimum	10.00	8.00	5.00	2.00	1333.00
Maximum	15.50	14.50	10.00	3.00	3281.00
1er Quartile	12.50	11.00	7.50	2.20	1823.00
Médian	13.00	12.00	8.50	2.40	2082.00
3ème Quartile	13.00	12.50	9.00	2.50	2437.00
Average	12.74	11.65	8.29	2.38	2159.78
Standard deviation (n-1)	1.08	1.20	1.06	0.24	478.44

Figure 3: Graph of boxplots and table presenting the dimensions of 37 Nougouil from Harar

Figure 4: Mr Houman Harmed working in his field, using a Maxra with Nougouil.

Figure 5: Mrs Sahada Madar's husband waiting for customers at the doorway of her shop in Harar, surrounded by Nougouil, Marasha, Inji and Maxra.

Bettinger 2001). This is an expected result since the sample this study is based on essentially comes from one workshop; the farmers-manufacturers at Kersa are the suppliers of the shop at Harar.

Use and discard

> *The most important [uses of Nougouil] are turning over blocks of soil under conditions of (i) water saturation, and (ii) heavy grass roots, as in fallow lands; it is also utilized (iii) where soil or terrain conditions render the wooden ox plough inefficient.* (Waldron 1987: 69)

In correspondence with Waldron's (1987: 69) observation, my ethnographic study too witnessed Nougouil being used as tilling instruments. The area surrounding Harar features hard clay soils, for which the weighted digging stick Maxra is a suitable form of plough. The *Maxra* is customarily used with two hands. *Nougouil* is always placed on the upper part of the stick *Inji* [har] and facilitates the downwards push of the tool into the ground. The operator lifts the stick to about chest height, with its iron covered tip *Marasha* pointing down, and thrusts it down into the earth. As the ground is penetrated, the operator pulls the stick back and forth with the weighted end towards his body, thus tearing up clods of earth with the *Marasha* (Figure 4).

One of my interviewees, Mr Houman Harmed, a farmer and user of *Nougouil* (not a manufacturer), reported that the tool is normally used during the rainy season (March to October), but it can also be used at any time of the year for uprooting or weeding. However, in the dry season, the land is too hard to work. Mr Houman Harmed also informed me that working with a *Nougouil* ensures the fertility of the earth and the success of the harvest. The *Maxra*, including stick, iron tip and Nougouil has a very long use-life and is often passed from generation to generation.

My research did not witness any secondary use of the *Nougouil.* My interviewees informed me that if it breaks, they discard it without much consideration, usually just off their fields.

Nougouil at the market

The retail price of the finished bored stone is between 15 to 20 Birr (1 Birr is about 0.03 €). Mr Sadic Mummai Ourso remembers to have sold bored stones even for as little as 0.50 Birr in the past. So, the current price of the *Nougouil* is good for the manufacturer. However, the current average monthly living wage in Ethiopia is about 5000 Birr (150 euros), although this is the official figure and a very large number of people earn significantly less than this. So, although the *Nougouil* manufacture is a specialized craft, it can only be performed as a part-time side job. Full-time *Nougouil* manufacture would not be a viable way of subsistence. Farmers-manufacturers from Kersa mainly sell their *Nougouil* at the shop in Harar, but they may also sell them directly to other farmers. At times of need, they may visit regular open markets at certain villages on the plateau and try to sell their *Nougouil* also there.

Mrs Sahada Madar has been the main *Nougouil* and *Maxra* merchant in Harar for twenty-five years now. I interviewed Mrs Sahada Madar in her small shop in Jegol, in the old town of Harar. This market in Jegol is called Magala Guddo, and out of the five markets in Harar, this was the only one where I found *Nougouil* for sale. Mrs Sahad Madar only sells *Nougouil* from Kersa. She also sells iron tips, *Marasha* [har], which are made in the old town and the wooden sticks (*Inji*), which she buys from farmers. The cost of a *Maxra*, including iron tip, stick and *Nougouil*, is 350 Birr. Mrs Sahada Madar told me that there is no difference in the price between a big or a small *Nougouil*. She buys *Nougouil* for 15 Birr and sells it for 40 Birr. She sells most of them when agriculture takes place, during the rainy season, and can live on this income.

Discussion

Nougouil manufacture involves intimate knowledge of the landscape and of the rock outcrops from where suitable rock can be quarried. The choice of suitable rock also involves knowledge of rock mechanics. One must obtain the necessary skills to distinguish between rock types to select the correct type of rock for *Nougouil*. The way to make *Nougouil* is taught and learnt. Experience in its manufacture is required for the completion of a successful specimen. The manufacture of *Nougouil* is a bonding experience among craftsmen of the Oromo tribe. They collaborate in the quarrying of the stone and share their resources equally. They keep each other company while working on a *Nougouil* bringing it into shape, and teach each other the craft, passing it on to the next generation. Women are excluded from this process.

This level of peer collaboration, equal resources sharing and willingness to teach the young openly and freely may have its roots in the old Oromo *Gadaa* socio-economic, political, and religious system. In pre-colonial Ethiopia, an age system of eight-year cycles promoted collaboration and solidarity among Oromo peers (Baxter 1979; Hinew 2012: 90-91). Involvement in governance depended on age, and success in rites of passage within every age group of men. Men and women under the *Gadaa* system had specific and distinct roles. Children were considered holy and the responsibility of the entire community (Hinew 2012: 92, 96). In the modern federal state of Ethiopia, the *Gadaa* system of governance does not apply. However, its cultural aspects are deeply rooted within the Oromo psyche (Baxter 1996, Hassen 1990, Kuto 2018). Gender ascribed roles regarding the manufacture and use of this tool should be understood within the old *Gadaa* cultural system where young girls are to be protected and women are not to be involved in strenuous labour.

This new ethno-archaeological study has examined a considerable number of bored stone tools, adding to previous works in this area which featured only small numbers of objects (Clark 1944; Waldron 1987). It is hoped that the morphometric information, the method of use and function of the *Nougouil* will assist the archaeological identification of *Nougouil* and research on bored stones of the Late Stone Age. Further research could compare the tools from this sample with those from different archaeological and ethnographic contexts in sub-Saharan Africa (Clark 1944; Dart 1948; Hromnik 1986; Jeffreys 1967; Fauvelle-Aymar 2006; Moffett *et al.* 2017; Ouzman 1997; Van Noten 1977; Van Riet Lowe 1941; Waldron 1987; Weatherby 1965). Preliminary results of a size comparison between the South African examples and this Ethiopian sample show that the diameter of the perforation of the Ethiopian *Nougouil* is larger than the South African equivalents. Villa (2012: 13211) notes that digging sticks in South Africa have a diameter smaller than 2cm and argues that the fragment of a bored stone found in Border Cave must have been used as a weight for a digging stick. Cooke (1955) and Moffett (2017) provide examples of similar dimensions with Villa (2012), but Kleindienst (1961: Plate 1c) offers current South African examples of much larger dimensions. Goodwin (1944:195) suggests that current examples of bored stones are significantly larger than their prehistoric counterparts and therefore, they bear larger perforations. An example of a bored stone from Zambia (Fagan 1962:197, Fig. 1c), another from Zimbabwe (Cooke 1977) and a last one from Uganda (Posnansky 1964) have much larger overall perforations than the South African examples, resembling more of the Ethiopian bored stone.

Further ethno-archaeological research could increase the number of specimens under study and further examine typo-morphological variation. Visits at other Oromo villages at the Harari plateau may reveal more *Nougouil* workshops. Mr. Sadic Mummai Ourso informed me that there are other villages where bored stone tools are produced. A second expedition could examine *Nougouil* made at other villages and explore typo-morphological differences or similarities with this sample. A comparison between the samples from Kersa and other villages may also reveal different modes of production. It would also be interesting to see whether other workshops at other villages make *Nougouil* of different dimensions or whether standardization in morphology is functionally determined.

Through this study new insights into the *chaîne opératoire* of the *Nougouil* manufacture were obtained. The process of *Nougouil* manufacture was recorded for the first time and social relations entailed in its manufacture, sale and use were explored. Through interviews and observation, this study has identified that bored stones were used as weights on digging sticks for tilling the earth for agricultural purposes. No secondary uses were identified and no special discard of a disused *Nougouil* was observed.

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