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### ► **To cite this version:**

Danai Chondrou, Maria Bofill, Haris Procopiou, Roberto Vargiolu, Hassan Zahouani, et al.. Grinding practices in prehistoric north and central Greece: evidence from the use-wear analysis. Soultana Maria Valamoti; Anastasia Dimoula; Maria Ntinou. Cooking with plants in Ancient Europe and beyond: interdisciplinary approaches to the archaeology of plant foods, Sidestone press, pp.269-296, 2022, 9789464270341. hal-04836762

**HAL Id: hal-04836762**

**<https://hal.science/hal-04836762v1>**

Submitted on 13 Dec 2024

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## Grinding practices in prehistoric north and central Greece: evidence from the use-wear analysis

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### Abstract

Grinding technology is an integral part of the prehistoric material culture, implicated in various food-processing and craft activities. Over the last two decades research on grinding stone toolkits has demonstrated the existence of divergent technological choices and traditions, as well as the importance of specialised studies in highlighting this variety. In this framework, the first extensive use-wear analysis performed on selected artefacts from various prehistoric settlements in north and central Greece has a significant impact on our understanding of past grinding systems. A multi-scale use-wear analysis conducted with various means of observation and in multiple magnification scales (stereomicroscopy, metallographic microscopy, confocal microscopy) enabled the identification of specific use-wear patterns and their correlation to particular uses. The results revealed a palimpsest of diverse practices and traditions regarding the manipulation and use of grinding implements. Multifunctional tools employed in various tasks (e.g. processing of a variety of organic matter) coexist with tools reserved for specific functions (e.g. processing of oily substances) as well as secondarily used or recycled artefacts incorporated into new contexts of function. Diverse food processing methods and practices, such as the grinding of cereals with or without prior dehusking, suggest the existence of different technical choices for the same activity, while the typological and morphometric diversity of grinding equipment testified on an intra- and inter-site level has a possible functional dimension that needs further investigation. Overall, a much more generalised tendency for secondary use and recycling of the grinding gear is evident in the Bronze Age assemblages, a practice that may be coupled with a diachronic amplification of the range of functions of the grinding tools. If not associated with economic factors such as the introduction of new species into the range of human-exploited plants, it could be an indication of social changes.

**Keywords:** *grinding tools, use-wear, functional analysis, Greece, Neolithic, Bronze Age*

## 17.1 Introduction

Grinding tools have appeared as early as the Palaeolithic times (e.g. Dubreuil and Nadel 2015; Revedin et al 2010), but it was during the Neolithic period, the period of a gradual transition to the new agropastoral lifeways and the establishment and proliferation of sedentary farming communities, that their number and types multiplied marking a revolution in this technological sector. This was by no means a homogeneous process. Instead, numerous case-studies bring to light intriguing particularities underscoring local and inter-regional divergences in the grinding technological systems, their associated activities and their ascribed values (e.g. Bofill 2015; Hamon 2008a and b; Hamon et al 2011; Jaccottey 2011; Runnels 1981; Wright 1994, 2000). Such research outcomes highlight the importance of detailed material analysis as well as regional and diachronic comparisons in order to identify broader patterns pertaining to technological, socioeconomic and cultural aspects of past societies. This is particularly demanding, however necessary, in the case of grinding technology, where an apparent morphotypological uniformity may often render variations and changes undetectable at first glance.

Contrary to deeply rooted perceptions, grinding implements do not relate exclusively to cereal processing or even food-processing in general. Instead, they have a wide range of functions for a better understanding of which much research is being invested over the last two decades. The identification of particular wear patterns on the tools' use-surfaces in combination with the recovery of microbotanical remains and experimental explorations have proven invaluable lines of inquiry in the context of deciphering the way these implements were manipulated and used (e.g. Adams et al 2009; Bofill et al 2013, 2014; Dubreuil 2002; Hamon and Plisson 2008; Liu et al 2010; Portillo et al 2013; Procopiou 1998; Veth et al 1997).

Partly in analogy with the history of research elsewhere in Europe and the New World, the research in the field of grinding tools and ground stone technology as a whole in Greece, after remaining limited for many decades, is now witnessing increasing activity. Although in many -mostly generic- publications grinding tools are still being by default directly or indirectly associated with food processing activities without any other supporting evidence, innovative research attempts have made their appearance. Functional analyses (Poursat et al 2000; Procopiou 1998, 2013; Procopiou et al 1998; Stroulia and Dubreuil 2013; Stroulia et al 2017) are sporadic and thus still far from matching in frequency the technology studies, they have, however, laid the necessary foundations for further research in this promising field. Most importantly, they have proven the central importance of understanding the tools' function(s) in order to gain a deeper insight into the economic organisation of past societies, their technological choices and established traditions.

The present paper offers an overview of the methodology applied and the results obtained in the context of the first extensive and systematic functional analysis of grinding stone tools from Greece, developed as part of the multidisciplinary approach to prehistoric culinary cultures of southeastern and central Europe within the ERC-funded PlantCult project (Valamoti et al 2017). Selected grinding stone tools from nine prehistoric sites of north and central mainland Greece have been analysed and the obtained data have been merged together into a large-scale comparative synthesis. The results revealed a palimpsest of practices and traditions regarding the manipulation and use of these implements. Diverse food processing methods and practices, such as the grinding of cereals with or without prior dehusking, indicate the existence of different technical choices, while intra- and inter-settlement typological and morphometric diversity of the grinding equipment is attested, with possible functional connotations.

## 17.2 Methodology

The study of use-wear traces -i.e. the detailed observation of various function-related changes on the use-surface of a tool, and, based on them, the attempt to draw conclusions about its function- requires the application of multiple levels of analysis as well as an experimentally produced use-wear reference guide.

The multi-scale use-wear analysis applied in the context of our research comprises two essentially complementary parts, a qualitative and a quantitative analytical stage. It builds upon several studies previously developed on the functional and 3D analysis of wear on archaeological and experimental grinding stone tools as well as standardised terminology (Adams et al 2009; Bofill et al 2013; Dubreuil 2002; Procopiou et al 1998; Vargiolu 2008).

### 17.2.1 Qualitative analysis

The qualitative stage includes observations with the naked eye and different optical devices (stereomicroscope and metallographic microscope) at different magnification scales.

The general topography of the use-surface of a tool and the distribution of manufacture and use-wear traces are first described on a macroscopic scale. The observations at this level of analysis are important as they allow the identification of the use-surfaces of a tool, its active or passive role during the grinding process (i.e. whether it is used as a handstone or a quern), the kinematics involved (e.g. abrasive use in a back-and-forth rectilinear or "free" curvilinear motion; a combination of abrasive and percussive use), its mode of handling or placement, the general patterns of use-wear evolution on the overall surface topography, the existence of special function-related morphological traits (e.g. concentration of percussion marks related to use and not manufacture;

existence of facets). Moreover, these first-level naked-eye observations allow us to synthesize the following steps of analysis that involve the application of magnifying optical devices (Dubreuil et al 2015, 146).

On level 2, the observation of the wear traces on the tools' use-surfaces is conducted with a stereomicroscope with magnifications up to 100x. Aspects of wear formation detected in a microscale, i.e. microrelief and individual grains, are analysed (e.g. fractures, pits, grain fracturing and extraction, grain rounding, levelling, linear traces, polish). Further characteristics of these distinct traces, such as their location over the surface topography and their distribution, density, morphology, texture, depth, and orientation, are also recorded since they are directly related to the wear mechanisms that caused the surface alterations (see Rabinowicz 1965).

The last level of analysis focuses on micro-scale use-wear traces observed with a metallographic microscope in high magnifications (50x-500x) on the highest and smoothest plateaus of each surface sample and more specifically on the polished zones. Polish is a highly diagnostic use-wear trace; different types and characteristics of micro-polish are associated with different materials processed on each tool's surface (for the qualitative classification of micro-polish into micropitted, deposit and serrated see Bofill et al 2013; Verbaas and Van Gijn 2007).

### 17.2.2 Quantitative analysis

In order to move from qualitative to quantitative assessments, surface measurements are conducted with the use of a confocal rugosimeter. It combines a confocal microscope and an optical device that projects different wavelengths of white light on different points of the surface, in order to measure its topography. For this level of analysis silicon casts are made from selected parts of the tools' surfaces since the equipment used does not allow the examination of bulky artefacts.

Initially a laser sensor of 2,5 mm is used to scan a 14 mm × 14 mm area per sample to provide us with a statistical representation of the whole surface analysed. These macro-measurements provide information about the general aspects of the high and low topography. On the micro-scale analysis three much smaller areas (500 µm x 500 µm) inside the area initially scanned are measured with the use of a laser sensor of 400 µm. Focus is placed specifically on the polished areas of the topographic highs. The average measurements of these areas offer a statistical representation of the topographic highs of the area analysed.

Finally, the obtained data are subjected to statistical treatment. The method of the continuous wavelet transform decomposes the surface in different wavelengths of roughness and provides information on the roughness, waviness and form of the measured surface (Lee et al 1998).

The SMA coefficient represents the arithmetic mean value of the multi-scale decomposition of a surface. Previously applied in other wear analyses (Bofill 2015; Bofill et al 2013; Procopiou et al 2011; Vargiolu 2008) it proved valuable in reflecting different use-wear signatures depending on the substances each tool processed.

Overall, the applied methodology combines optical microscopic analysis and surface measurements and characterisation for distinguishing different types of micropolish and for achieving accurate identifications of the materials processed with the analysed implements, allowing for a more comprehensive, holistic approach of their functions. In the context of our research, residues have also been extracted from both the experimental and the archaeological tools. Therefore, in a second stage, the data from the use-wear analysis will be correlated with the information obtained from the microbotanical analysis (phytoliths, starch grains). The results from this integrated approach will be presented elsewhere, whereas the current paper will focus solely on the use-wear analysis.

A functional interpretation must take into account certain limitations. First of all, grinding tools may have long use-lives and complex biographies, as multiple ethnographic studies show (e.g. Horsfall 1987; Hamon and Le Gall 2013). The context of use, the users and, above all, the functions and mode of use of these tools may change throughout their use-lives, which may reach up to several decades. Over these long life-cycles, secondary use(s) -with or without prior refashioning- and recycling of the tools are common practices and should be anticipated. The overlay of functions that these practices entail may not always leave detectable traces and the identified use-wear traces may correspond to the tool's last use, obliterating signs of previous functions. Repecking, a repeated process of rejuvenation of the use-surface of a tool through the renewal of its abrasiveness, would also mean the removal of parts of the surface and, therefore, of use-wear traces. Hence, the identification of separate episodes of use and their relation to each other in terms of sequence of occurrence may prove particularly challenging (see also Dubreuil et al 2015). Finally, the substances processed with the grinding implements do not represent the whole range of substances exploited. Not all plant species, and organic substances in general, were subjected to processing through techniques of grinding and pulverizing, and those that were, may have been done so with different equipment. Stone grinding implements formed just a part of the prehistoric toolkit available for the performance of food-processing and other activities. They would have been complemented by a series of other artefacts from other materials, such as wooden pestles, wooden or earthen mortars and cupstones for pounding actions.

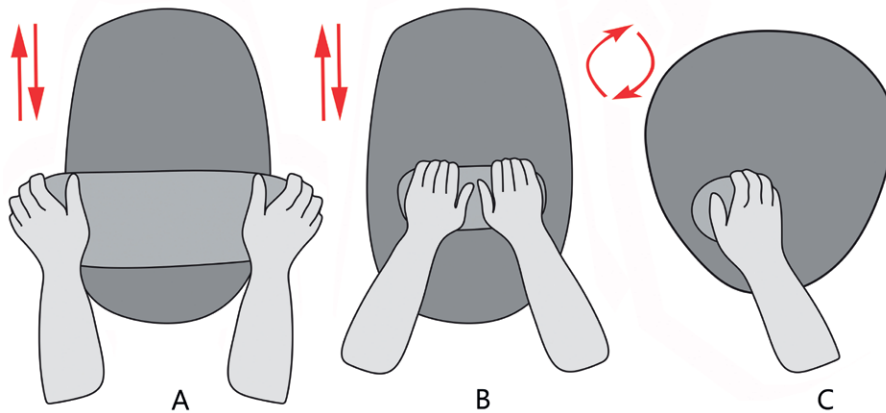


Fig. 17.1 Three main grinding tool types identified in the area under study (after Chondrou 2018).

### 17.3 Grinding experiments

For an experimental investigation of grinding stone technology, different types of tools, of various raw materials and sizes were manufactured and used (Appendix 17.1 and 17.2; for an analytical presentation of the experimental program and the various factors examined see Bofill et al 2020). Three basic tool types, identified in the archaeological record (Chondrou 2018, 147-150; 2020, 289-290, 294-295), have been selected and experimentally reproduced: a) a quern paired with an elongated handstone, whose length exceeds the width of the quern, used in a rectilinear, reciprocal back-and-forth motion; b) a quern paired with a smaller handstone (length smaller than the quern's width), also in a rectilinear, reciprocal back-and-forth motion and c) a quern paired with a smaller handstone (length smaller than the quern's width), used in a "free", curvilinear motion (Fig. 17.1). Experimental querns were designed in such a way, so as to replicate two different size-groups: one "small" with a length less than 30 cm and one "big" exceeding 30 cm in length (see Appendix 17.1 for tools' dimensions). The conventional 30 cm limit was employed in order to reflect different trends found in the archaeological record (i.e. the existence of small-sized as well as much larger tools, for a discussion of the observed image in Greece see Valamoti et al 2013; Bekiaris et al 2020). The raw materials used for the tool manufacture (sandstone, andesite, granite) were chosen based on their frequency of appearance in the archaeological assemblages, in a manner that represents the main geological categories. These rock types have different mechanical properties such as degree of surface roughness, cohesion, hardness and resistance to friction, parameters that certainly affect the grinding process (Delgado-Raack et al 2009). The general shaping of the experimental tools was done with mechanical means, whereas the active surfaces of both querns and handstones were prepared by pecking with different hammerstones (see Bofill et al 2020).

Thus, the experimental tools, in terms of raw materials, size, shape and type, constitute a representative sample of the variability of grinding tools observed in the archaeological record of the area under study. A wide range of plant ingredients (cereals, pulses, oilseeds and nuts), with various pretreatments (dehusking, splitting, boiling, soaking, drying, roasting etc), were ground in order to explore the resulting use-wear and associated plant micro-remains (starches and phytoliths). These, too, correspond to the archaeobotanical findings in the study area (see Heiss et al 2017; Stika and Heiss 2013; Valamoti 2009, 2011; Valamoti et al 2013, 2017). One of the main goals of the experimental program was to generate a series of use-wear patterns that can be directly linked to the processing of various plant-species in order to function as a reference guide for the analysis of the archaeological grinding implements. No experiments have been conducted with non-plant materials. For the identification of related wear patterns, we relied on previous research (e.g. Bofill 2015; Dubreuil 2004; Dubreuil and Grosman 2009; Liu et al 2010).

### 17.4 Use-wear analysis of archaeological grinding tools: selected sites and samples

The sample for analysis originates from nine sites of the Greek mainland (Fig. 17.2): Early Neolithic Ayios Vlasis, central Greece (Dimaki and Souvatzi 2012); Early Neolithic Mavropigi-Fillotsairi, north-western Greece (Karamitrou-Mentessidi et al 2015); Middle/Late Neolithic Stavroupoli, central Macedonia (Grammenos and Kotsos 2002, 2004; Grammenos et al 1997); Late Neolithic Koroneia (Kotsos and Tselepi 2020, in press); Late/Final Neolithic Kleitos in north-western Greece and a much later, Middle Bronze Age pit that cuts through the Neolithic strata (Ziota 2014a and b; Ziota et al 2013); Neolithic/Bronze Age Dikili Tash in eastern Macedonia (Darcque et al 2007; Darcque 2013; Koukoul-Chryssanthaki and Treuil 2008); Early Bronze Age Ayios Athanasios (Pappa et al 2000; Mavroei et al 2006;

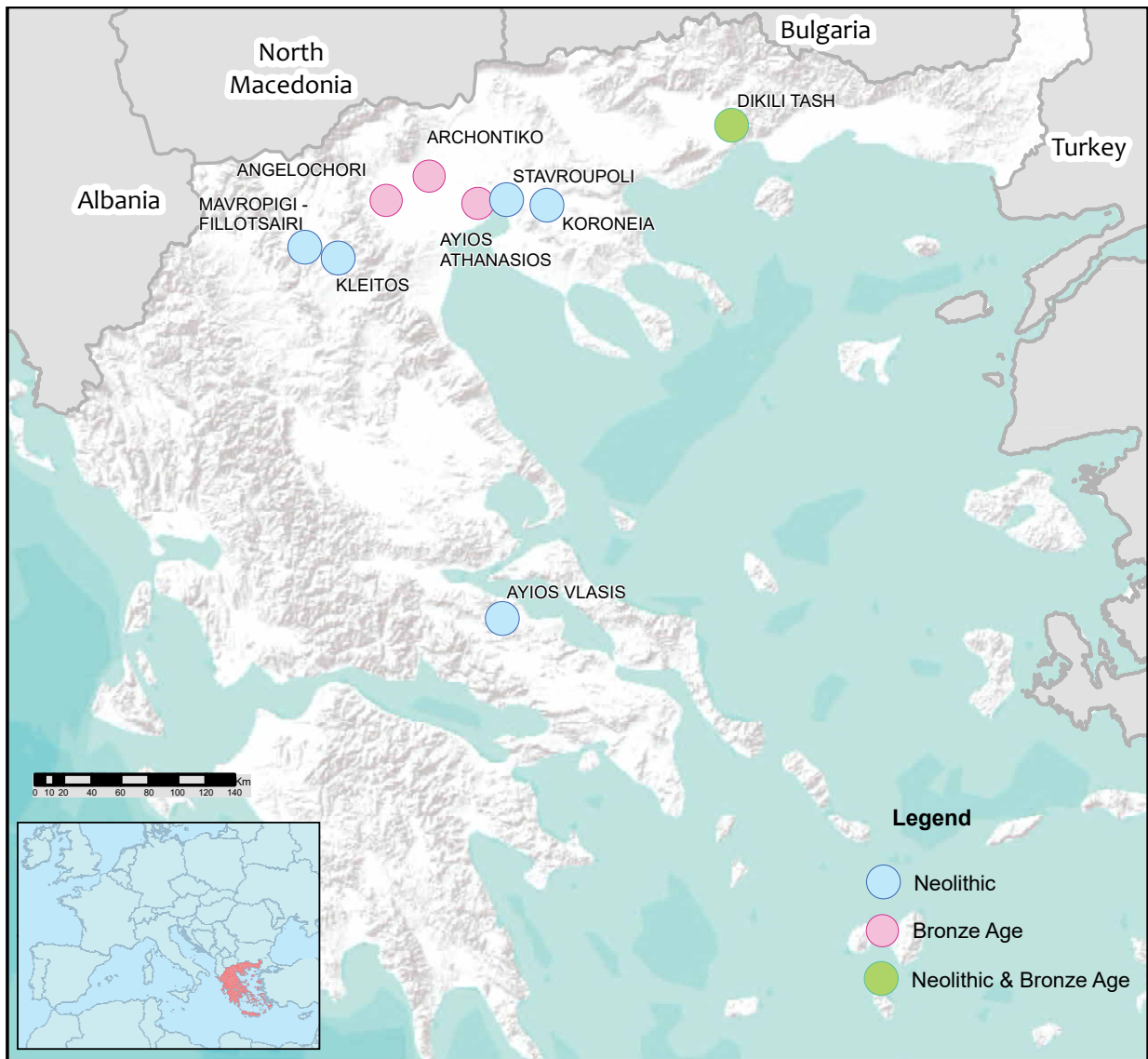


Fig. 17.2 Map with the nine Neolithic and Bronze Age sites from which the grinding implements analysed originate (Kleitos is marked as Neolithic since the Bronze Age pit does not represent a later phase of the specific settlement) Basemap sources: Esri, US Geological Society, and National Oceanic and Atmospheric Administration. Map prepared by Themis Roustanis.

Mavroeidi 2012); Bronze Age Archontiko (Papadopoulou et al 2010; Papaefthymiou-Papanthimou 2010, Pilali-Papasteriou et al 2001) and Late Bronze Age Angelochori (Maniatis 2010; Stefani 2010; Stefani and Merousis 2010), all last three located in central Macedonia, northern Greece.

Table 17.1 shows the size of the samples selected for use-wear analysis per site. Overall, a total of 112 grinding tools have been selected. Yet, due to the unforeseen Covid-19 situation, the quantitative analytical stage could not be performed for a subgroup of 41 specimens. A detailed list of the items fully analysed is given in Appendix 17.4. They include querns and handstones

of all three basic tool types (see previous section about grinding experiments), with different morphometric traits, used with various kinematics, made of a variety of raw materials. The choice of artefacts was based upon their preservation status, their context of retrieval and their typology. Seldom did the selection strand afar from these criteria, and that was only due to the high significance of the archaeological context or due to peculiarities of the artefact, worthy of further analysis. Therefore, the majority of the analysed specimens are intact or nearly intact. The use-surfaces are well preserved, even in those cases where the tools have been exposed to fire.

SITE	PERIOD	DATE BC	TOTAL NUMBER OF GRINDING TOOLS	NUMBER OF GRINDING TOOLS ANALYSED	PERCENTAGE OF TOOLS ANALYSED
Mavropigi-Fillotsairi	Early Neolithic	6600-5900	1	1	100%
Ayios Vlasis	Early Neolithic	6700/6500-5800/5600	7	7	100%
Stavroupoli	Middle-Late Neolithic	5800/5600-4700/4500	59	9	15.25%
Koroneia	Late Neolithic	5400/5300-4700/4500	49	6 (9*)	12.2% (18.4%*)
Dikili Tash	Early Neolithic-Late Bronze Age [Late Neolithic]	6678/6409-1374/1187 [5500-4000]	82	11 (32*)	13.4% (39%*)
Kleitos and pit of later dating	Late-Final Neolithic (settlement) and Middle Bronze Age (pit)	5400/5300-3300/3100 and 2300/2200-1700/1500	614	7 (24*)	1.1% (3.9%*)
Ayios Athanasios	Early Bronze Age	3300/3100-2300/2200	73	16	21.9%
Archontiko	Early-Late Bronze Age	2135/1890-1510/1400	123	10	8.1%
Angelochori	Late Bronze Age	1630/1495-1350/940	14	4	28.6%

Table 17.1 Sites examined, archaeological phases and dates (after Andreou et al 2001, Table 1; and for the sites with available radiocarbon dates: Darque et al 2021; Karamitrou-Mentessidi et al 2015; Pilali-Papasteriou et al 2001; Stefani and Merousis 2010), total number of grinding implements found at each site, number of analysed specimens and percentages. An asterisk marks the total number of objects analysed, including specimens that due to COVID-19 constraints were not subjected to the quantitative analysis. In the case of Dikili Tash, the date of the sample analysed in the current study is given in brackets.

## 17.5 Results

### 17.5.1 Experimental data: Observations per level of analysis

#### 17.5.1.1 Qualitative analysis

##### 17.5.1.1.1 Levels 1 and 2 – Macroscopic and microscopic observations of use-wear traces

The optical analysis of the experimental tools' surfaces allowed the detection of distinct wear patterns related to the processing of different materials. Cereal processing resulted in the formation of plateaus with rounded or flat-rounded cross-section and low roughness, low/medium polish development and thin, short striations. The low topography remains highly irregular, with some low rounding of separate grains. When cereals are processed in their hulled form (i.e. the grains still inside their hard husks) the plateaus on the tools' surfaces are smaller, sparser, of a more sinuous morphology, with low rounding of the grains, low polish and no linear traces. In the case of millet, the plateaus of homogenous microtopography on the tools' surfaces were more extensive and with a more reflective polish compared to the ones formed through einkorn and barley grinding. An intense dark coloration was found to be associated with the most worn areas of the tools' use-surfaces, a trait noted as well in oilseed and nut processing with sandstone tools (Bofill et al 2020) and in legume grinding with basalt tools (Dubreuil 2004), but unprecedented for cereal processing. In these areas, there was a characteristic alignment of small pits forming scratches that follow the direction of the tools' motion.

Legume grinding, on the other hand, produced extensive microfractures and flattened plateaus with low polish and no striations. The processing of greasy ingredients such as acorns and oil seeds was associated with darker, highly polished surfaces with intense rounding of single grains in high and low topography. The series of diagnostic use-wear traces generated by the experimental grinding program are summarized in Appendix 17.3. A more detailed description of the experimental results can be found in Bofill et al 2020.

Low magnification analysis of the experimental surfaces also showed the effect of tool movement (i.e. the orientation of the grinding strokes) on wear patterns. The circular motion of the handstone in tool type 3 creates rounded plateaus on tools' surfaces. In contrast, the back-and-forth rectilinear motion of the handstone in types 1 and 2 tends to create flatter plateaus with sharp edges (Bofill et al 2020).

##### 17.5.1.1.2 Level 3 – Microscopic observation of polish

The observation of polished surfaces on the microtopography of the tools with a metallographic microscope allowed the detection of three basic types of polish: micropitted, deposit and serrated (Fig. 17.3). These types of micropolish have been identified in previous studies on use-wear analysis as well and their relation to particular functions has been highlighted (Bofill et al 2013). Our analysis has validated the association between the micropitted type of polish and the processing of cereals, the deposit type and the processing of legumes and greasy matter, and the serrated type with the stone-against-stone friction.

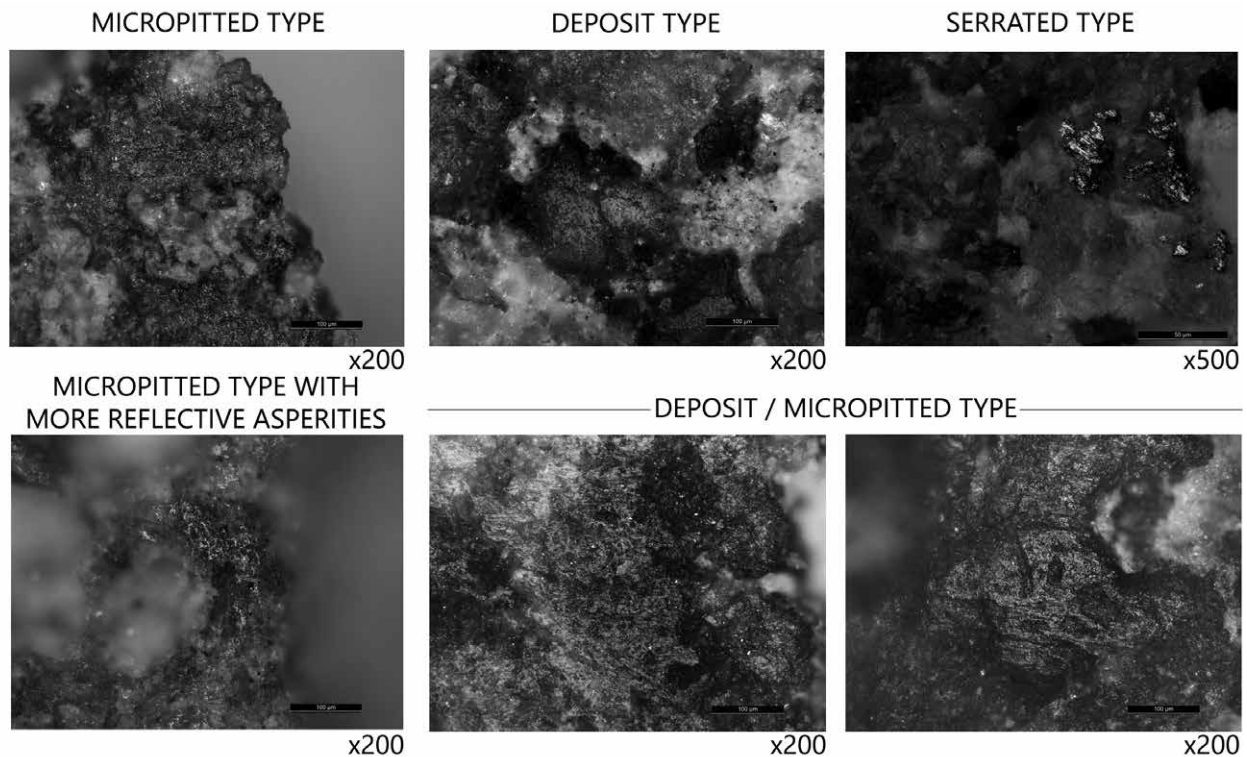


Fig. 17.3 Different types of micropolish identified on archaeological specimens from various sites (photographs taken with a metallographic microscope at the magnification indicated under each picture).

#### 17.5.1.2 Quantitative analysis

Comparing the data obtained from the 3D surface measurements with a confocal microscope and the characterization with the method of the continuous wavelet transform of tools used to process similar plant ingredients but made of different rock types (i.e. raw material) yielded significantly different degrees of wear and important variations of their micropolish. Fig. 17.4 shows different wear signatures generated by two experimental tools made of andesite and sandstone, both used to process dehusked einkorn. Instead of the homogeneous results anticipated, the SMA coefficient differs significantly reflecting the difference in the raw material of the grinding stone tools. It follows that the attributes of wear formation are drastically affected by the stone type and not only by the ground matter.

Focusing on the subgroup of the experimental specimens that were made out of the same raw material and used to process cereals, they also yielded different wear signatures depending on whether the cereals were husked or dehusked. The surfaces of the tools used to process hulled cereals have produced higher SMA values (Fig. 17.5). Husks seem to function as an abrasive agent between the quern and the handstone, conducting to the formation of rougher surfaces. These results are in concordance with the aforementioned optical observations.

Since stone raw material proved to be a parameter that heavily affects wear formation, comparisons of the SMA coefficient should be made between tools of the same stone type. In the case of experimental data, comparisons should also be made between tools used for the same amount of time since use-wear formation is a cumulative process inextricably linked to the duration of use. When comparing, for example, the same tool employed in grinding dehusked einkorn wheat after 4 and 5 hours of use respectively, shorter use time is found to produce higher SMA values. This is due to the smaller degree of wear developed and, therefore, the lesser bearing area formed, i.e. plateaus and flattening of asperities (see Procopiou et al 1998). In our experiments, we focused our comparisons on tools' surfaces with the maximum duration of use (i.e. 5 hours for experiments 1 and 2, see Appendix 17.2).

The comparative analysis of the SMA coefficient wavelengths from experimental tools manufactured from the same stone type and used for the same amount of time to process different materials revealed a certain "stratigraphy" in the SMA coefficient distribution. The highest curves represent cereal processing (the husked cereals give even higher values, Fig. 17.5), lower curves represent legumes and, lastly, greasy substances show the lowest values (Fig. 17.6). This indicates that cereal



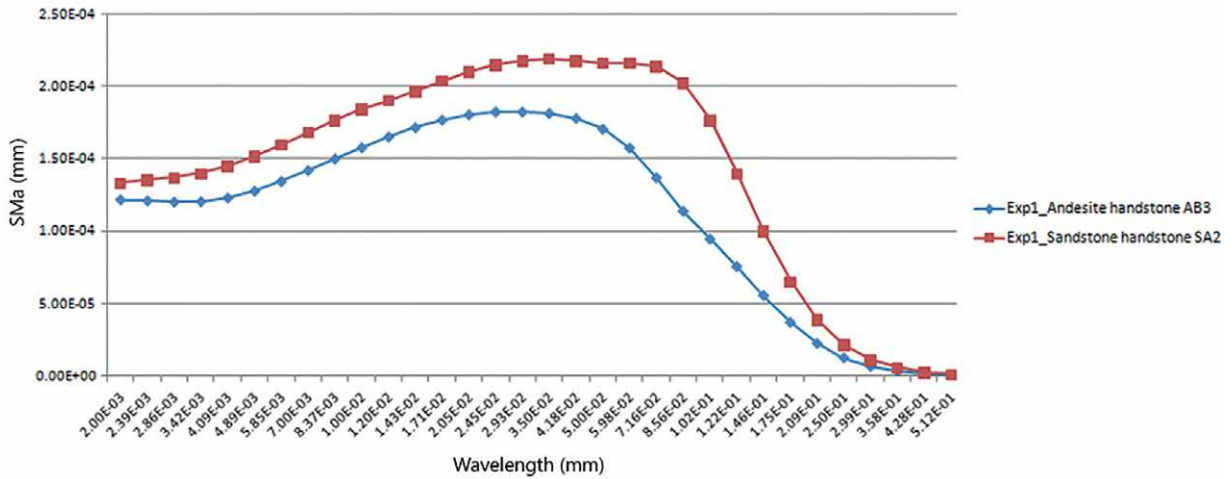


Fig. 17.4 SMA decomposition applied on experimental tools used to grind dehusked einkorn. Although the specimens had the same function, their results differ significantly reflecting their different raw material, sandstone and andesite (after Chondrou et al 2021).

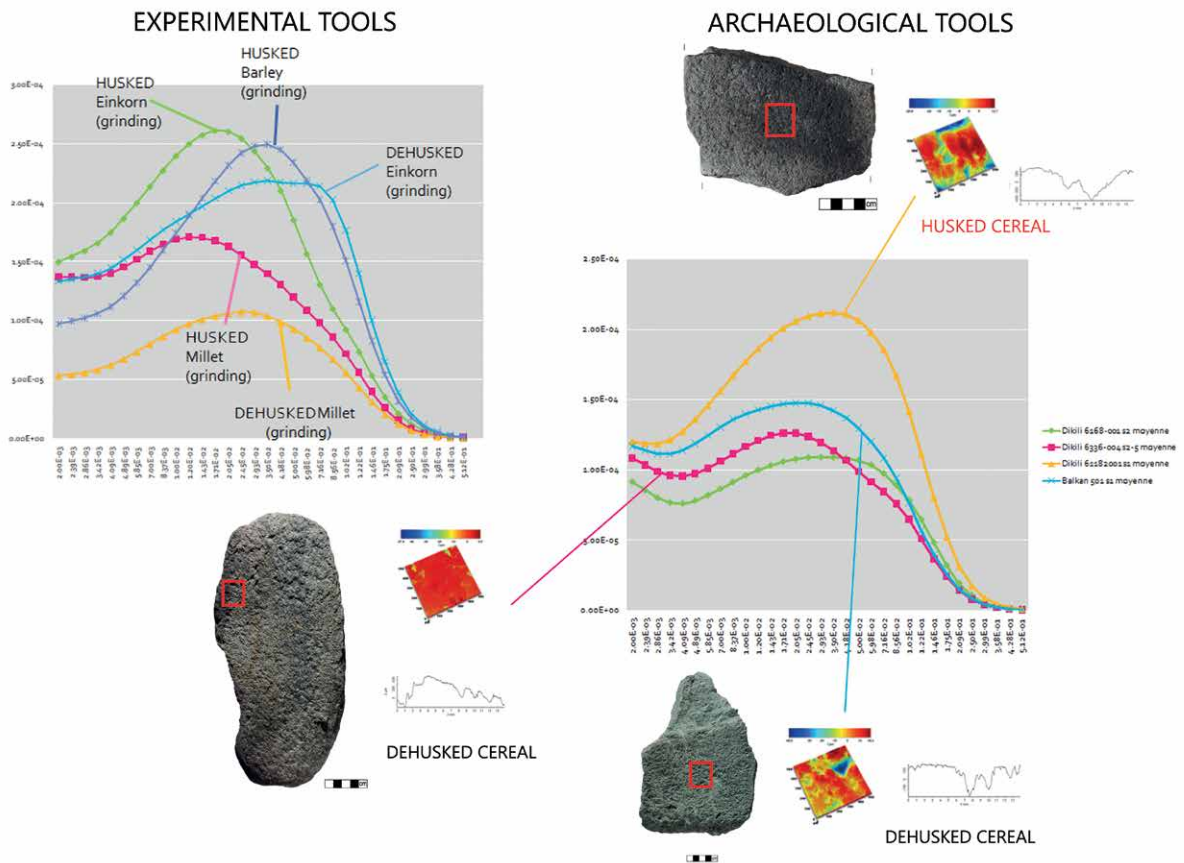


Fig. 17.5 SMA results from experimental grinding tools used for grinding husked and dehusked cereal (left graph) and SMA results from sampled archaeological tools from various sites, all considered to have been used for processing cereal in dehusked and husked form. Note that the SMA wavelengths from tools related to husked cereal processing have the highest values.

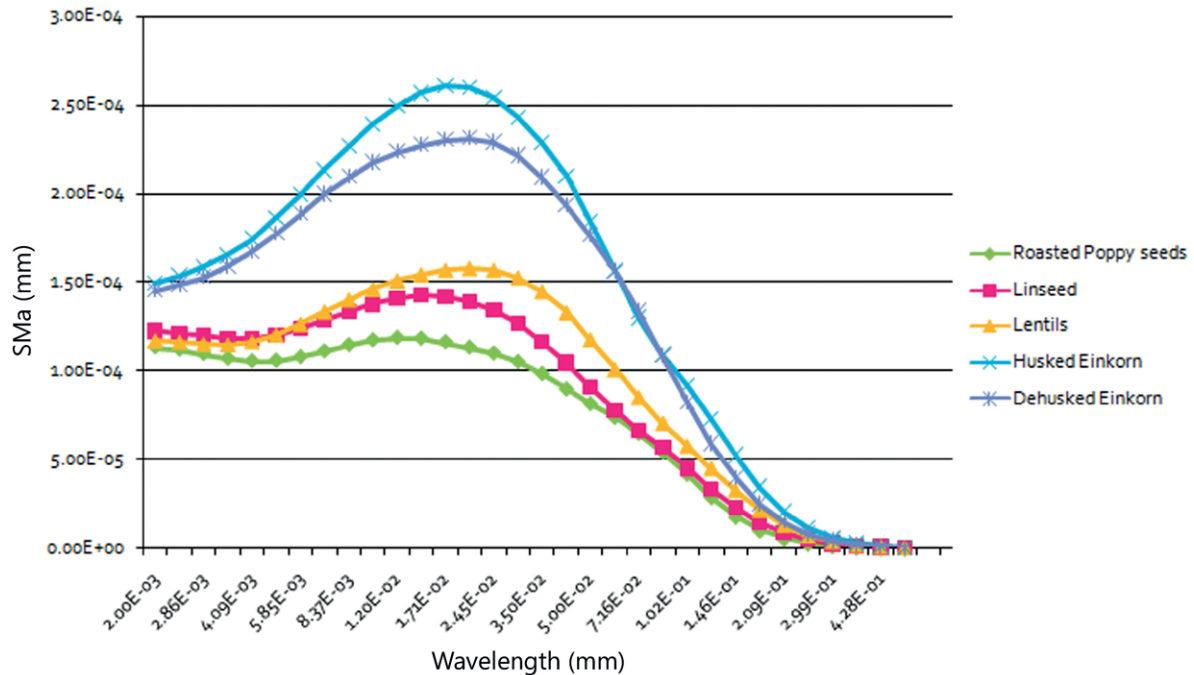


Fig. 17.6 SMA decomposition applied on experimental grinding tools made of sandstone and used for the processing of various substances.

processing results in the roughest type of micropolish compared to the much smoother micropolish surfaces generated by oily substances.

### 17.5.2 Archaeological data: Observations per level of analysis

#### 17.5.2.1 Qualitative analysis

##### 17.5.2.1.1 Levels 1 and 2 – Macroscopic and microscopic observations of use-wear traces

The archaeological querns and handstones examined showed traces of working in a back-and-forth or circular motion, representing all three basic tool types identified in the archaeological record. They all exhibit pecking on their use-surfaces and signs of rejuvenation episodes (i.e. repecking), except cases of tools being secondarily used for other purposes. Only a few implements in the selected sample present use-wear traces related to an isolated function (i.e. not in pairs), either as passive abrasive surfaces or as active, hand-held abrading/polishing tools. Based on our observations at low magnification and having as a reference guide the results of our experimental program (Bofill et al 2020), along with previous work on use-wear analysis, we were able to formulate functional hypotheses. Use-wear traces possibly related to cereals, legumes, greasy plant-substances and non-plant matter, such as minerals, have been identified (Fig. 17.7 and Appendix 17.4).

##### 17.5.2.1.2 Level 3 – Microscopic observation of polish

All three basic types of micropolish (micropitted, deposit and serrated) have been identified in the archaeological samples analysed. Furthermore, we were able to distinguish a subtype of the first type of polish, a polish with micropitted texture and more reflective asperities, and to successfully correlate it, through its comparison with the experimental data, with the processing of husked cereals. Finally, a combination of micropitted and deposit types of polish that has been observed in a number of tools suggests a secondary use or a multifunctional character for these specimens (Fig. 17.3 and 17.7).

##### 17.5.2.2 Quantitative analysis

The macro-scale 3D topographic measurements conducted with the confocal rugosimeter and a laser sensor of 2,5 mm on the archaeological specimens highlighted further attributes of wear formation related to the kinematics of the tools. The majority of the analysed archaeological tools were used in a linear reciprocal motion. Indeed, the relief profile that coincides with the axis of motion of the tool itself, in the case of a handstone, or its paired implement, in the case of a quern, is higher (i.e. the asperities are more elevated and the elevational difference between topographic highs and lows is greater) and presents greater rounding (Chondrou et al 2021, Fig. 17.8). This observation has its merits in the case of tools whose active or passive role is uncertain due to fragmentation rate.

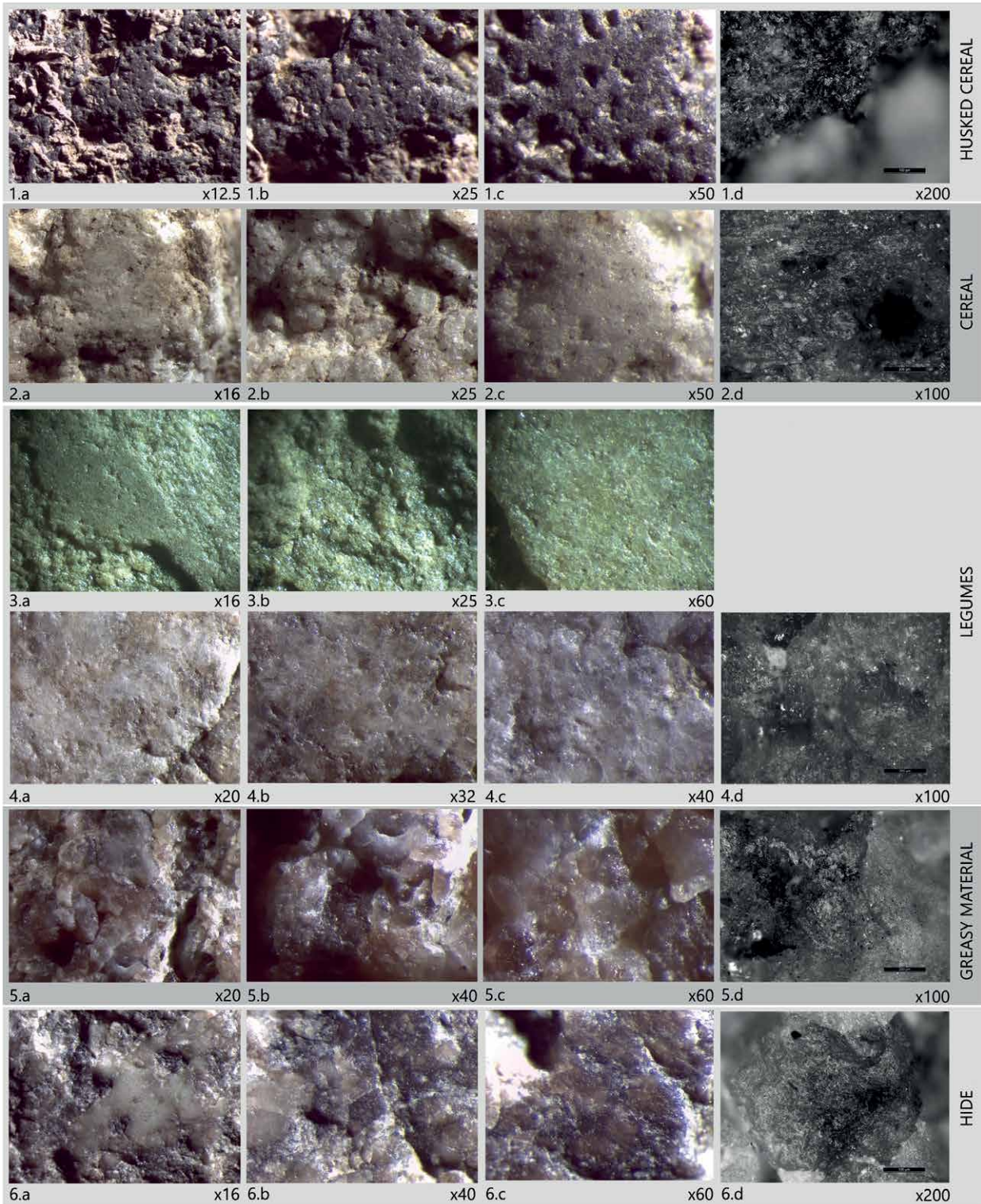


Fig. 17.7 Types of use-wear associated with the processing of cereals, legumes, greasy matter, and hide observed on various archaeological specimens from various sites. Observations with a stereomicroscope and a metallographic microscope (photographs originally taken at the magnification indicated under each picture).

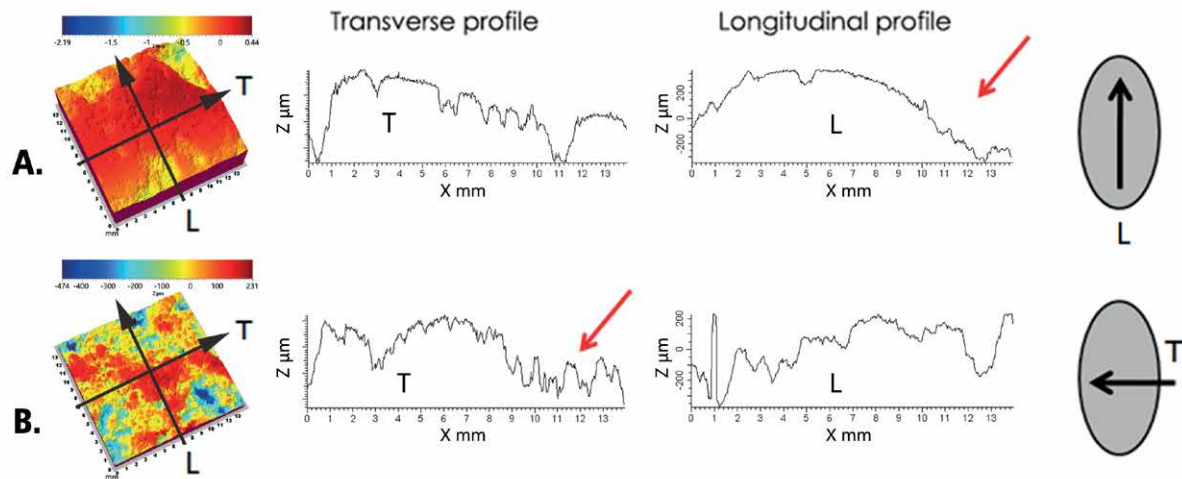
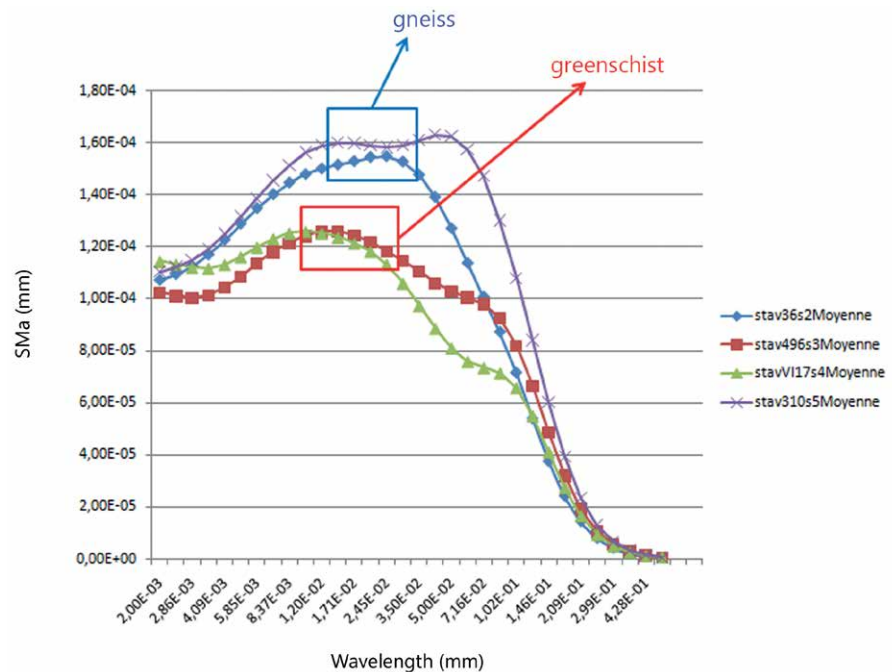


Fig. 17.8 Macro-scale surface measurements and profiles from two different archaeological specimens, showing the influence of kinematics on wear formation: the profile coinciding with the axis of motion of the tool -indicated with an arrow- is higher and rounder compared to the profile of the other axis (modified from Chondrou et al 2021).

Fig. 17.9 SMA decomposition applied on handstone surfaces from the Stavroupoli assemblage that exhibit use-wear associated with cereal processing. Two distinct subgroups are formed, the one represents tools made of greenschist (stavV117s4 and stav496s3) and the other one tools made of gneiss (stav36s2 and stav310s5) (modified from Chondrou et al 2021).



Comparing the SMA coefficient of the archaeological tools under analysis yielded, as in the case of the experimental tools, divergences related to the raw material variation and not only to functional factors (Fig. 17.9). For a comparative analysis of the SMA coefficient wavelengths between archaeological specimens or between experimental and archaeological tools, all specimens need to be of the same raw material. The examined archaeological specimens were made of gneiss, sandstone, conglomerate, schist, basalt, granite and a few ophiolitic rocks. Our experiments were conducted with tools made of sandstone, andesite

and granite. The granite implements, however, showed a very low degree of wear and, therefore, were considered statistically not comparable to the archaeological ones. The fact that there is a specific sequence in the SMA values depending on the particular matter processed by each tool is exactly what allowed us to benefit from the SMA coefficient analysis even in those cases where the raw materials of the archaeological specimens were not compatible with the experimental ones from our comparative collection, but the samples were plenty enough to form a sequence. Based on the sequence of the SMA curves, we were able to test the

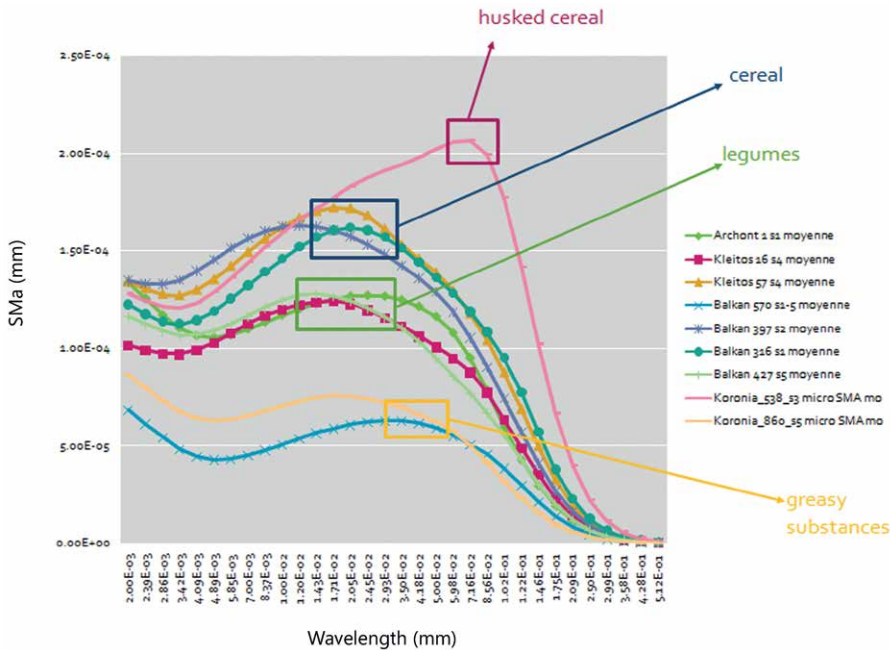


Fig. 17.10 SMA decomposition applied on grinding tools made of gneiss from various sites. The SMA wavelengths present a clear clustering since implements associated with the processing of similar matter yielded similar curves.

functional hypotheses we had formulated on the basis of the observations made in the previous stages of our analysis. From these, the samples originating from implements made of gneiss material generated the clearest results, i.e. patterned sequences of SMA curves forming distinct groups that reflected different tool functions (Fig. 17.10). On the other hand, separate functional groups are less clearly distinct in the sequences yielded by the schist samples. This could relate to intrinsic traits of the raw material itself: mica is a soft ingredient and often presents mass loss after the grinding process, resulting in surfaces with a rougher texture, dense pits and crevices preventing the creation of extensive and smooth homogeneous zones.

### 17.5.3 Results per site

The Early Neolithic settlement of Mavropigi-Fillotsairi, although fully excavated, yielded a very limited pounding/grinding tool assemblage: four mortar-like tools and only one grinding implement with a flat working surface, a type 1 handstone (see also Ninou et al this volume). They have been recovered from various contexts: open-air spaces, a pit and a dwelling. The use-wear analysis conducted on this single specimen pointed towards legume processing: on a macroscopic scale the use-surface has a rough texture with the development of homogeneous flattened areas in certain areas of higher abrasive wear (Fig. 17.7.3a-3c). Microscopically the extensive plateaus present flattened summits and some rounding of their contours, signs of chipping, polish of medium reflectivity and visible striations. On the other hand, the 4 mortar-like tools in the same assemblage are very interesting if we consider

the general scarcity of stone mortars in Greek Neolithic assemblages (Bekiaris et al 2020). These implements have rather shallow cavities, with use-wear traces that suggest a combination of grinding and pounding actions of varied intensity, possibly in association with wooden pestles (with one possible exception). Some have clear signs of successive episodes of use and re-use, even after breakage. The preliminary results from the starch and phytolith analysis from one of the mortars reveal the processing of husked cereals (Kasapidou pers. comm.). Therefore, what we have, so far, is an early farming community where the pounding tools are dominant, at least one of which is associated with the processing of husked cereal, while the sole example of grinding equipment with flat use-surface presents use-wear that links it to legume-processing.

The sample from Early Neolithic Ayios Vlasios includes seven type 1 querns and handstones of generally small dimensions. The majority of the analysed specimens were found in an open area in association with an elliptical clay platform, indicating a probable food-processing area (Dimaki and Souvatzi 2012, 1122). Four out of five handstones have two use-surfaces and five out of seven tools show signs of intensive/extensive use. They all bear use-wear traces associated with cereal grinding, two of them related with the processing of husked cereals (Fig. 17.7.1a-1d, Chondrou et al 2021). One of the handstones shows signs of secondary use as a passive abrasive surface. It is noteworthy that the small excavation of Ayios Vlasios yielded also a significant number of pestles (Chondrou pers. observ.), few of which have been sampled for microbotanical analysis.

The sample from Middle/Late Neolithic Stavroupoli originates from a small area of the settlement, from both Middle and Late Neolithic strata and includes querns and handstones of all three basic tool types (Ninou pers. observ.). Most of the implements show signs of intensive/extensive use, some being (almost) worn-out, and one bears traces of reshaping and secondary use. All nine implements that comprise our sample present use-wear associated with cereal grinding. In three of them, the observations suggest processing cereal in their husked form (Chondrou et al 2021).

The sample from Late Neolithic Koroneia (Almasidou 2019) comprises seven type 1 handstones and querns, a single type 2 handstone and an abrader that morphologically resembles a handstone. They originate from the interior of pit-dwellings as well as from external spaces. The majority yielded evidence of cereal processing, but there are also isolated instances of tools associated with husked cereal and legumes, and one used initially in cereal grinding and, on a later stage, in the processing of a greasy substance. The abrader was found to have been related to hide processing.

The main characteristics of the assemblage from Dikili Tash are the high presence of heavily used tools, the homogeneity in terms of raw material (almost all tools are made of schist) and the existence of morphometric variations. A total of 32 artefacts have been analysed, although the quantitative analytical stage has been delayed for more than half of the samples. The available results permitted the identification of tools used for the processing of cereals and greasy substances.

At Dikili Tash the grinding implements are systematically found in house interiors and present a repetitive close association with thermal/cooking features and storage structures (e.g. House 1). Although the use of grinding implements in outdoor spaces cannot be rejected with absolute certainty, building interiors seem to have formed the primary grinding context in the settlement. Examining specific buildings belonging to the Late Neolithic phases, the rectilinear House 4 of substantial dimensions (11 X 6 m) was partitioned into three equal-sized and non-communicating rooms. Their internal organisation with an oven, a platform and several vessels is similar. Grinding implements have been recovered from all three spaces, but in uneven numbers. Three of them have been subjected to use-wear analysis. The results reveal functional diversity since two tools from the same area (Room A) were reserved for different functions, one for the processing of greasy substances and the other for the processing of cereals in their husked form. The latter, a fragmented and heavily worn handstone with no signs of recent re-pecking, presents a rather distinct surface morphology with very small but dense plateaus, low rounding of the separate grains and low polish of

micropitted type with brighter asperities. This suggests its use for dehusking the grains rather than dehusking and grinding them into flour since the action of grinding would result in more extensive plateaus due to stone against stone friction.

The two neighbouring Kleitos I and Kleitos II settlements have been excavated almost entirely yielding a huge grinding tool assemblage (Chondrou 2018). Based on the data obtained from the use-wear analysis of a very small sample so far, a variety of uses have been established, including the processing of cereal, legumes and greasy substances.

A unique find is a grinding slab with two use-surfaces, one of which is highly concave due to prolonged use. The less worn surface presents use-wear traces indicative of cereal processing. The other surface is ochre-stained with use-wear pointing to hide processing, possibly representing a secondary use of the tool (Fig. 17.11). Ochre is a substance well-known for its hide tanning, colorant and anti-bacterial use from various ethnographic records. Numerous archaeological examples testify to the use of stone implements for the processing of ochre and several cases reveal a connection between ochre and hide-processing (e.g. in flaked industry Audoin and Plisson 1982; Becker 1999; Hayden 2002; in ground stone industry Adams 1988; Bofill and Taha 2013; Dubreuil 2002; Dubreuil and Grosman 2009; González and Ibáñez 2002). In the case of ground stone implements, the archaeological examples include handstones, abraders or polishers, i.e. hand-held, moving upper-active implements. There are two possibilities regarding the use of this implement: a) the tool was first used for ochre grinding (or the direct rubbing of ochre pieces on its surface) and then for hide-processing; b) the tool was used as a passive/stationary work surface for the rubbing of hide in combination with ochre. The abundance and distribution of the ochre over the whole use-surface of the quern suggests that the latter explanation is more plausible. Although the combined use of ochre and hide is well known for handstones, this is, to our knowledge, the first example of a quern combining ochre residues and use-wear related to hide processing. Ochre could have been initially ground (or directly rubbed) on the surface of the quern. Then the hide would have been placed on top of this surface and rubbed with an active tool used in a rectilinear reciprocal stroke in order to absorb the ochre. This action would probably also make the skin softer. The presence of ochre in both the asperities and interstices of the surface microtopography, in some cases accumulating in small cavities (see Logan and Fratt 1993, 423), as well as the extensive, highly reflective sheen could suggest the presence of an additive mixed with the ochre (for a similar observation see also Dubreuil and Grosman 2009, 949).

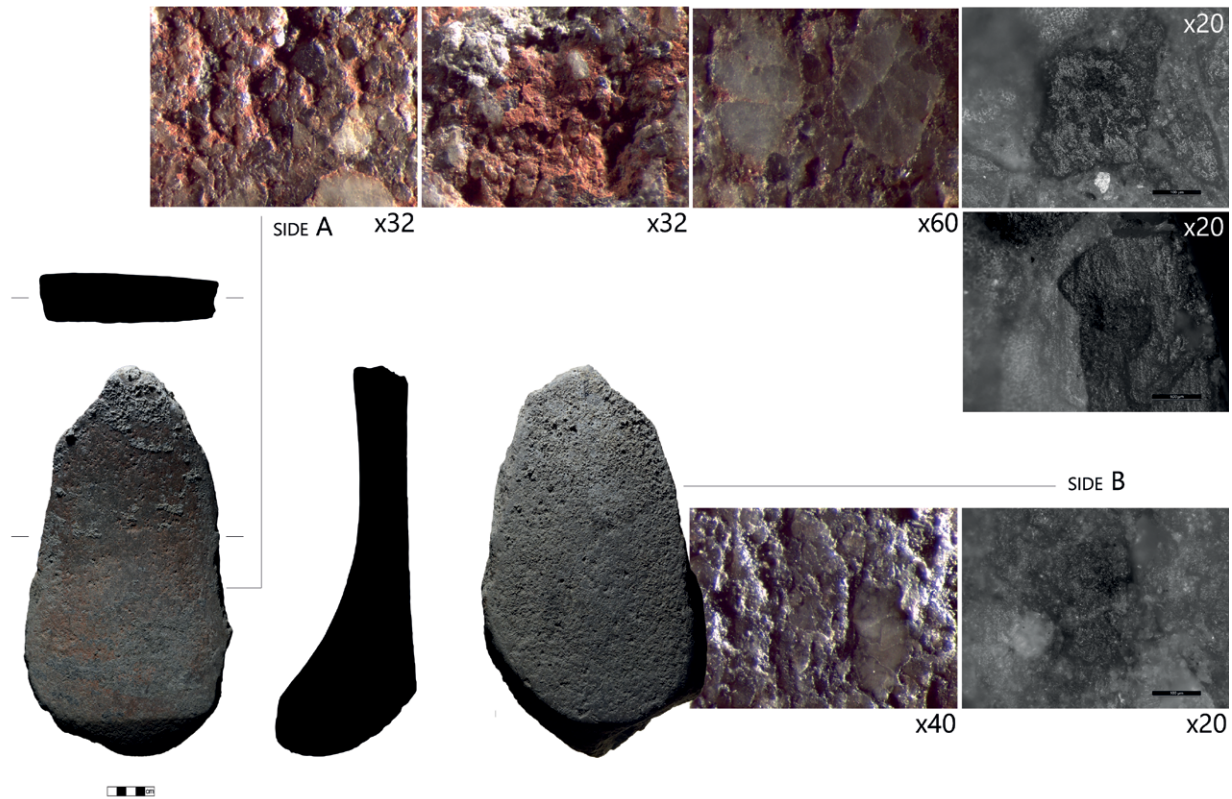


Fig. 17.11 A fragmented grinding slab from Kleitos II with two use-surfaces, one ochre-stained with use-wear pointing to hide processing and one less worn used for cereal processing.

Lastly, three grinding implements recovered from a Middle Bronze Age pit cutting through the Neolithic deposits of Kleitos II have been also analysed. These tools, a quern with a length of over 56 cm and two handstones weighting over 6 kg, the intact one having a length of 39cm, are massive. They are all made of gneiss and bear traces of cereal processing (Fig. 17.7.2a-2d).

Regarding the spatial distribution of the finds, Kleitos grinding tools are found both indoors and outdoors and, as a rule, do not present close spatial association with thermal/cooking facilities. This clearly suggests a different organization of the food-preparation sequences when compared, for example, to Dikili Tash (see also Chondrou 2018; Chondrou and Ziota in prep) or other settlements in the wider Balkan region, where a clustering of activities around thermal structures is detected (see Hodder 1990; Bailey 2000 for various examples). In the case of the remarkably well-preserved first phase of Building 3, the two recovered handstones had different uses. One was related to cereals, the other to pulses, but previously it had also been used for processing cereals.

The rescue excavation of the Early Bronze Age settlement of Ayios Athanasios brought to light the remains of three building sectors. Its grinding assemblage

presents 1) a very limited number of worn-out tools, 2) both type 1 and type 2 tools, and 3) high diversity in raw material choices (Chondrou et al in prep). There is quite a variability in the morphometric traits of the handstones, yet their correlation to distinct functional differences was not possible. Our analysis allowed the detection of distinct functional groups, such as tools used for cereal and others for legume processing (Fig. 17.7.4a-4d) as well as some unique cases. For example, a big type 1 handstone was probably initially used for cereal grinding and at some point reused for the processing of hard mineral (Fig. 17.12a). Two other grinding tools have been secondarily used as passive abrasive tools, i.e. as stationary work surfaces for shaping objects, whereas a third one has been associated with hide (Fig. 17.7.6a-6d).

Of special interest is the case of a rather small oval handstone (Fig. 17.12 b). Use-wear analysis revealed distinct evidence of cereal processing, possibly millet (phytolith/starch analysis results were inconclusive). If this is truly the case, this processing tool is valuable indirect evidence for the presence of millet in the settlement and its use for human consumption, since no millet has been identified in the archaeobotanical record of Ayios Athanasios, contrary to other Bronze Age settlements in northern

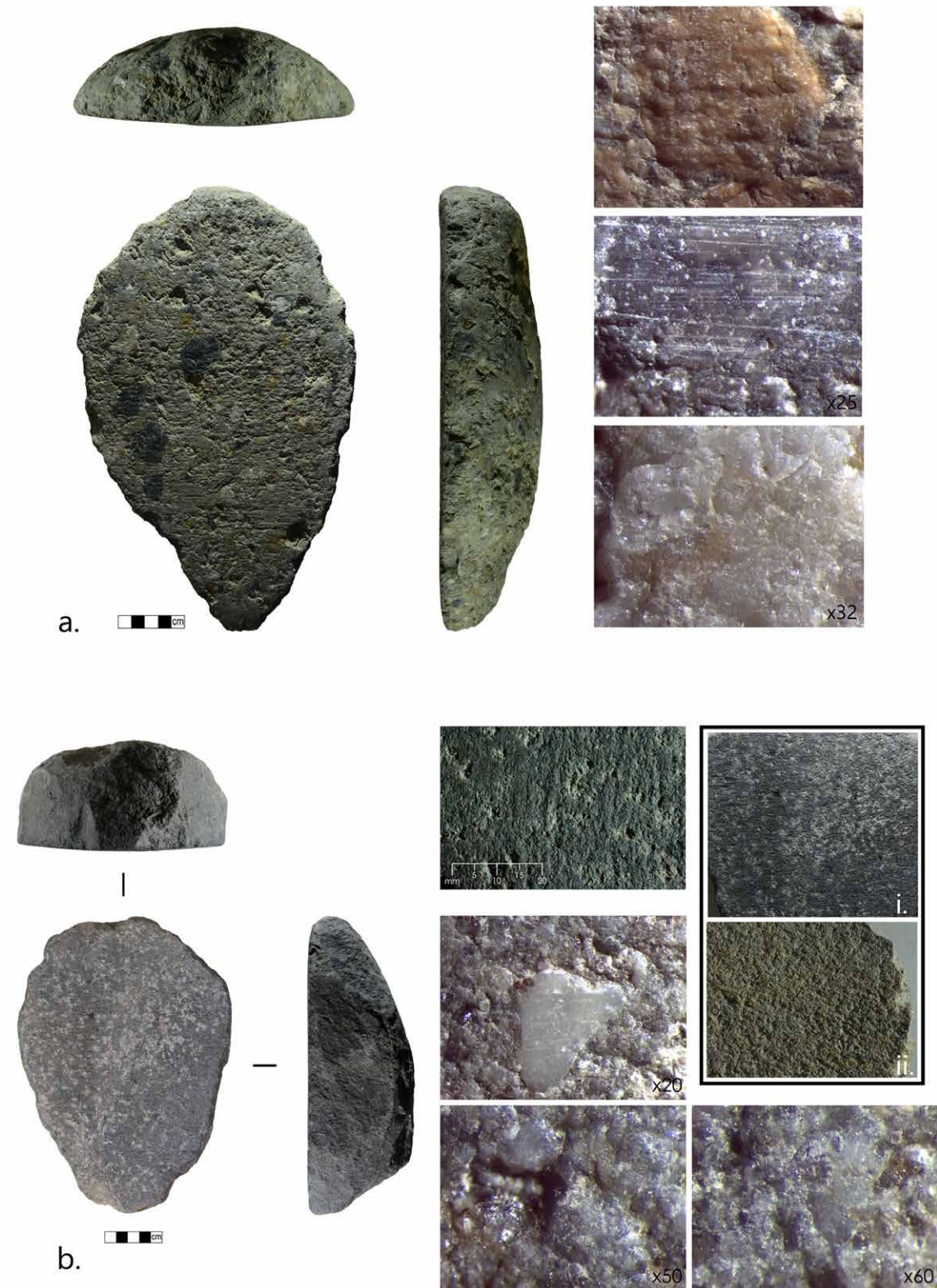


Fig. 17.12 a A big type 1 handstone from Ayios Athanasios probably initially used for cereal grinding and reused for the processing of hard mineral; b A rather small oval handstone from the same settlement with distinct use-wear that possibly links it to millet processing. Note the sporadic and shallow pecking of its use-surface (i) in contrast to the dense and deep pecking of another tool from the same settlement (ii).



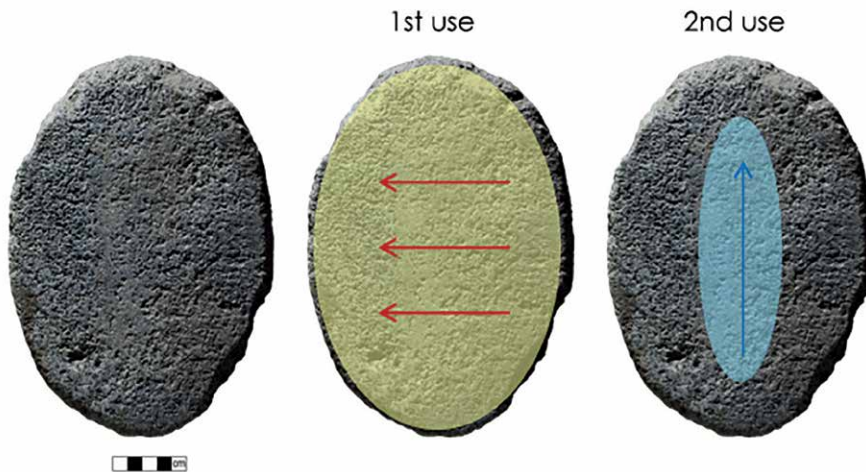


Fig. 17.13 The example of a handstone from Archontiko that has been reused as an abrasive slab for the shaping of artefacts. Note the change that occurs between the two episodes of use in the size of the use-surface and the direction of motion.

Greece (see Valamoti 2017 for an overview of the data). The specific tool also stands out from the assemblage due to its rather “sloppily” pecked use-surface that contrasts the densely pecked and re-pecked surfaces of almost all the rest of the tools (Fig. 17.12 b, i compared to ii). As we know from ethnographic sources, quite often tools used in the processing of small-sized grains (such as millet itself) bear no pecking at all, therefore this technical peculiarity might very well be use-related (Nixon-Darcus and D’Andrea 2017).

Regarding the spatial distribution of the analysed finds, cereal processing is evident in all three building sectors, same as the tendency for secondary uses of the grinding implements. As far as the context of grinding is concerned, the evidence shows that it was mainly limited to building interiors. Grinding implements found in external areas are few and only in the Eastern Sector do we have a concentration in an open-air area with clay thermal structures (Chondrou et al in prep).

In the tell site of Archontiko the functional analysis revealed a wide range of uses with most of the implements showing evidence of secondary use, often associated with the processing of greasy substances (Fig. 17.7.5a-5d). For example, an intact type 1 handstone (Fig. 17.13) was at some point reused as an abrasive slab for the processing of semi-hard matter (e.g. bone), finally ending up in the interior of a clay thermal structure, either recycled or stored (see also Bekiaris et al 2021). A fragmented type 1 handstone (Fig. 17.14) was initially used for cereal grinding and later reused for the processing of greasy plant matter.

From the ten analysed specimens, nine date back to the Early Bronze Age, with the majority -seven implements- belonging to Phase IV (Early Bronze Age, 2135-1980 cal BC, Papadopoulou 2010), whereas one originates from the Late Bronze Age stratum. From the Phase IV findings, four can be safely attributed to building interiors and the other three very close to their margins. Very few were found to

be associated with cereal processing and (almost?) none seem to be in their primary context of use, having been secondarily used or recycled instead (see also Bekiaris et al 2021). The houses of phase IV in Archontiko, full of various household items and stable features, such as pots for cooking, storage or consumption, storage bins, hearths, platforms and ovens (Papadopoulou 2010; Papaefthymiou-Papanthimou and Papadopoulou 2014), and a wide array of (stored?) cereals, such as einkorn, emmer, spelt, free-threshing wheat and barley (Papaefthymiou-Papanthimou et al 2013; Valamoti et al 2008; Valamoti and Petridou this volume), are (almost) empty of tools for cereal grinding. We can assume that the primary grinding context, at least as far as cereals are concerned, was not house interiors (see also Bekiaris et al 2021).

Finally, the Bronze Age site of Angelochori yielded a limited assemblage of grinding implements (Bekiaris et al 2021) from which four items, three originating from building interiors, were selected for functional analysis. They all presented a combination of use-wear traces and micropolishes, with more characteristic the co-presence of the micropitted and deposit type. It seems very plausible that they were initially used for cereal processing and secondarily applied in different activities (i.e. grinding of legumes, oily/greasy substances and hard mineral).

## 17.5 Discussion

Overall, contrary to past perceptions that prescribed to grinding stone tools a function related to cereal processing exclusively, it is proven that throughout the Neolithic and Bronze Age times these artefacts were used for a variety of activities. Processing of legumes and greasy/oily substances, hide working and mineral grinding should be added to their range of uses.

Cereal processing with grinding implements with flat working surfaces (i.e. querns and handstones) is well illustrated in all of the examined sites. There is

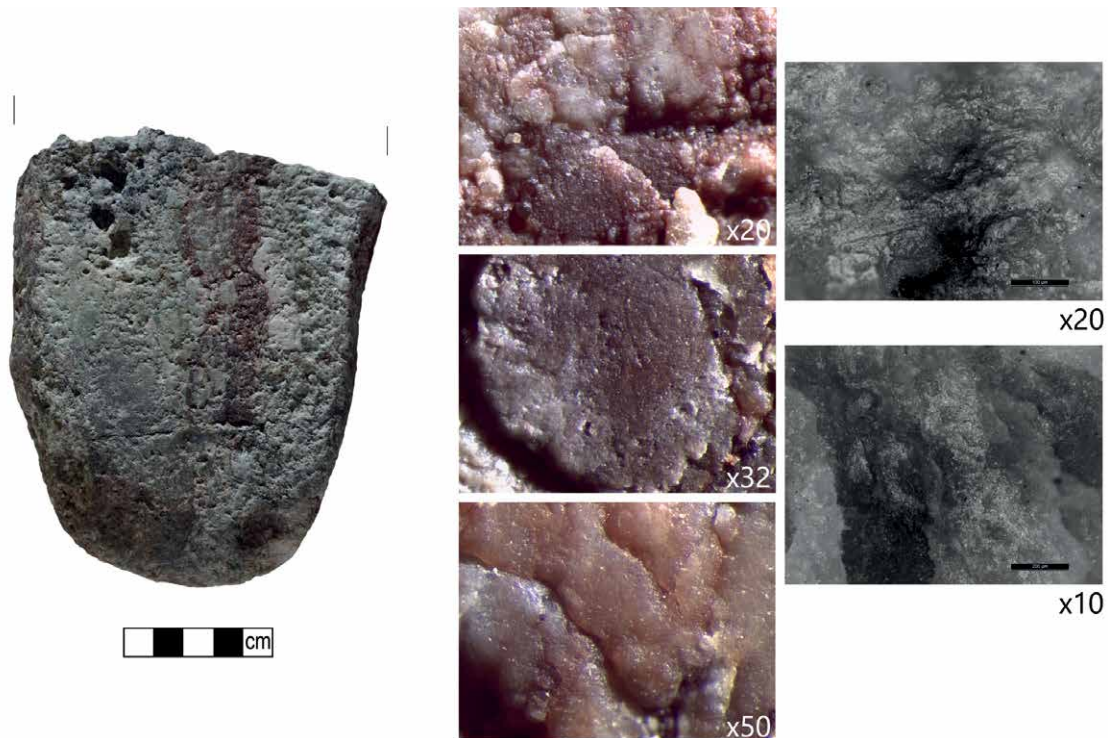


Fig. 17.14 A fragmented type 1 handstone from Archontiko with use-wear that suggests processing of cereal and on a later stage processing of greasy substances. Polish of serrated and micropitted texture is detected in some areas, whereas in others it is covered by a deposit type of polish.

only one exception, the Early Neolithic settlement of Mavropigi-Fillotsairi, whose assemblage is dominated by mortars. The only detected flat-surfaced specimen presents use-wear linked to legume processing. This clear divergence could be an indicator of differences in culinary practices (Ninou et al this volume). Ayios Vlasis, the other early Neolithic settlement in our sample, yielded also a high number of pestles and a few shallow mortars. These tool types are quite rare in the overall Greek Neolithic, which could be signalling diversified traditions of plant exploitation (Ninou et al this volume). In contrast to Mavropigi-Fillotsairi, nevertheless, the small assemblage from Ayios Vlasis contained also a group of querns and handstones that were found to have been associated with cereal processing.

Overall, among the identified cereal processing tools in our sample, there are several cases from Ayios Vlasis, Dikili Tash and Stavroupoli, where the use-wear analysis suggests the processing of cereals in their husked form. Our results, therefore, offer evidence for the diversity of culinary practices even within the same community. The pounding of spikelets in mortars (stone, wooden, or earthen) and the subsequent winnowing and sieving for the removal of the husks and the acquisition of clean seed for grinding is well documented ethnographically. The prevalence of grinding tools with use-wear associated with clean grain

processing and the common presence of cereal processing by-products in prehistoric archaeobotanical assemblages from Greece (Valamoti 2010) certify archaeologically the application of this processing sequence. Grinding cereals in their husks, on the other hand, would entail a different process, one which would certainly include sieving, maybe in several successive stages, so that the fragmented husks are removed (Chondrou et al 2021; Procopiou 2003). This would depend on the desired thoroughness and would naturally affect the texture and taste of the end product. The complete refinement of the ground product was not always pursued. The starch and phytolith analysis conducted in pots from the Neolithic Stavroupoli showed that in some cases cereals were intensively cleaned prior to their cooking, in others not (García-Granero et al 2018). Moreover, in the Late Bronze Age site of Akrotiri, Thera, the analysis of “flour” samples revealed their richness in glume phytoliths (Procopiou et al 2002; Sarpaki 1992). On the other hand, these tools with use-wear signatures related to husked cereals might correspond only to the dehusking process and not to the subsequent grinding of the grains. The use of grinding stones for glume wheat dehusking has proven experimentally feasible (Bofill et al 2013), but less efficient compared to pounding with a pestle and mortar (Meurers-Balke and Lüning 1992). This is particularly possible for at least one of the specimens

FUNCTION	Mavropigi-Fyllotsairi	Ayios Vlasis	Stavroupoli	Koroneia	Dikili Tash	Kleitos	Ayios Athanasios	Archontiko	Angelochori
Cereal processing (dehusked)		+	+	+	+	+	+	+	+
Cereal processing (husked)		+	+	+?	+				
Legume processing	+					+	+	+?	+?
Hide/other greasy matter				+	+	+	+	+	+
Mineral processing							+		+
Abrasive stone (as secondary use)							+	+	
Pitted stone (as secondary use)			+						
Other / unidentified							+	+	+

Table 17.2 Types of activities identified through the use-wear analysis of selected grinding specimens.

from Dikili Tash. In that case, it would mean that we have specific implements reserved for specific stages of the cereal processing sequence. There is also a grinding tool from Ayios Vlasis with two use-surfaces that yielded different wear signatures, one related to the processing of husked cereals and the other of dehusked ones. Again, a clear distinction between these activities is suggested, with each use-surface of the same tool being employed for a different stage of cereal processing for food (dehusking and grinding of the grain).

The existence of inter- and intra-site morphometric diversity of the grinding equipment has also been revealed. Although type 1 grinding tools dominate, other tool-types exist as well. It is the functional dimension of this variety that needs further investigation. Although no clear handstone size-function correlation has been observed in our samples like the one detected in Western Europe, where small handstones have been found to be associated with the processing of husked cereals and bigger ones with dehusked cereal grinding (Hamon 2008a, 1517-1518), all tools that yielded use-wear traces associated with the processing of hulled cereal belong to type 1, i.e. the “overhanging type” (Fig. 17.1, A). Also, in the case of Dikili Tash, the generally rare -compared to type 1- type 2 and 3 tools are, according to the optical observations, not associated with cereal processing.

Different strategies of tool manipulation are also clearly attested. Some settlements exhibit an exhaustive use of their grinding equipment (e.g. Early Neolithic Ayios Vlasis, Middle/Late Neolithic Stavroupoli, Late Neolithic Dikili Tash), whereas others feature tools that have not been used until the point of exhaustion (e.g. Late/Final Neolithic Kleitos, Early Bronze Age Ayios Athanasios). Moreover, the distribution of the tools tends to suggest inter-settlement differences regarding the spatial organisation of the grinding activities which are allocated either outdoors or indoors, with or without the thermal structures as their focal point. Some cases suggest the selection of certain implements for specific functions in the context of a single household (e.g.

Late Neolithic Dikili Tash) and others hint at possible tool multifunctionality (e.g. Late/Final Neolithic Kleitos II).

The data seem to suggest that the range of functions of grinding tools is amplified through time (Table 17.6), yet the size of our samples does not permit us to support such a claim. What can be said, however, with some certainty is that there is a clear tendency for secondary use and recycling in all three Bronze Age sites of our study, much more generalized than in the Neolithic sites examined. Two of these sites (Ayios Athanasios: Chondrou et al in prep; Archontiko: Bekiaris et al 2021) also present the highest diversity in raw material exploitation for the manufacture of grinding tools. This could actually support the idea of a more “diverse” functional exploitation of the grinding implements. It seems tempting to associate this pattern with the introduction of new species into the range of plants exploited by humans during the Bronze Age era. It is during this period that various plants with seeds rich in oil, such as *Lallemantia* (Lamiaceae), flax/linseed (*Linum usitatissimum*), gold-of-pleasure (*Camelina sativa*), and opium poppy (*Papaver somniferum*) are used offering new ingredients to prehistoric cuisine (Stika and Heiss 2013; Jones and Valamoti 2005; Valamoti 2009, 119-125). On the other hand, it could be an indication of other economic or even social changes that resulted in a more opportunistic use of the available technical means in a broader spectrum of activities.

From a methodological standpoint, our analysis has demonstrated the great potential that the combination of optical observations and quantitative analysis holds for a more detailed understanding of the tools’ functions and associated processing activities of the past. Surface measurements with a confocal microscope and characterisation with the method of the continuous wavelet transform permitted the identification of distinct wear signatures, as well as various key factors affecting use-wear formation. Tool raw material variation proved to be one of them: tools made of different rock types but used to process the same material yielded significantly different

SMA results, hinting at the role played by the different tool raw material properties in the evolution of use-wear and, thus, highlighting the necessity of use-wear comparisons between tools of the same raw material. Tools' kinematics proved also to be an important parameter. More case-studies in the future will enhance this methodological package permitting more detailed reconstructions of past activities.

To conclude, this extensive functional analysis of grinding tools from Greek prehistoric sites revealed a mosaic of traditions and trends related to plant consumption and beyond. This study laid the foundations for further research in this region, necessary to gain a clearer insight into past food production and culinary practices.

## Appendix

TOOL VARIABLES		
Type of motion	1	Rectilinear
	2	Circular motion
Raw material	1	Sandstone
	2	Andesite
	3	Granite
Size in cm (lower / upper tool)	A1	28 x 20 / 30 x 12
	A2	28 x 20 / 14 x 12
	A3	28 x 25 / 12 x 8
	B1	40 x 24 / 36 x 14
	B2	40 x 24 / 14 x 12
	B3	40 x 34 / 12 x 8

Appendix 17.1 The experimental tool variables (Chondrou et al 2021)

Appendix 17.2 List of the conducted experiments and of the plant ingredients used (modified from Bofill et al 2020, 7, Table 2).

Experiment	Ingredient	State / pre-treatment	Processing	Duration	Tool types used	Number of replicas used
E1	Einkorn ( <i>T. monococcum</i> )	Dehusked	Fine grinding	5 hours	All types	15 grinding pairs
E2.1	Einkorn ( <i>T. monococcum</i> )	Dehusked	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.1b	Einkorn ( <i>T. monococcum</i> )	Hulled (untreated)	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.3	Barley ( <i>Hordeum vulgare</i> )	Hulled (untreated)	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.4	Millet ( <i>Panicum miliaceum</i> )	Dehusked	Fine grinding	5 hours	Type 2 (A2) – sandstone / Type 3 (A3) – andesite	2 grinding pairs
E2.4b	Millet ( <i>Panicum miliaceum</i> )	Hulled (untreated)	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.5	Barley ( <i>Hordeum vulgare</i> )	Malt, commercial	Coarse grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.6	Bitter vetch ( <i>Vicia ervilia</i> )	Untreated	Splitting	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.6b	Bitter vetch ( <i>Vicia ervilia</i> )	Split/sieved/winnowed	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.7	Linseed ( <i>Linum usitatissimum</i> )	Untreated	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.7b	Linseed ( <i>Linum usitatissimum</i> )	Roasted	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.8	Acorns ( <i>Quercus</i> sp.)	Dried	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.8b	Acorns ( <i>Quercus</i> sp.)	Roasted	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.9	Lentils ( <i>Lens culinaris</i> )	Untreated	Splitting	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.9b	Lentils ( <i>Lens culinaris</i> )	Split/sieved/winnowed	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.10	Poppy seeds ( <i>Papaver somniferum</i> )	Untreated	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.10b	Poppy seeds ( <i>Papaver somniferum</i> )	Roasted	Fine grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E2.11	Spelt ( <i>T. spelta</i> )	Grünkern: Unripe and smoked	Coarse grinding	5 hours	Type 2 (A2) – sandstone	1 grinding pair
E3.1	Einkorn ( <i>T. monococcum</i> )	De-husked	Fine grinding	10 hours	Type 2 (A2) – sandstone	1 grinding pair
E3.2	Einkorn ( <i>T. monococcum</i> )	Hulled	Fine grinding	10 hours	Type 2 (A2) – sandstone	1 grinding pair
E3.3	Einkorn ( <i>T. monococcum</i> )	De-husked	Coarse grinding	10 hours	Type 2 (A2) – sandstone	1 grinding pair
E3.4	Grass Pea ( <i>Lathyrus sativus</i> )	Untreated	Splitting	10 hours	Type 2 (A2) – sandstone	1 grinding pair
E3.4b	Grass Pea ( <i>Lathyrus sativus</i> )	Split/sieved/winnowed	Fine grinding	10 hours	Type 2 (A2) – sandstone	1 grinding pair
E4	Barley ( <i>Hordeum vulgare</i> ), millet ( <i>Panicum miliaceum</i> ), Grass Pea ( <i>Lathyrus sativus</i> ), acorns ( <i>Quercus</i> sp.)	Hulled barley, de-husked millet, split/sieved/winnowed grass pea, roasted acorns	Fine grinding	8 hours	Type 2 (A2) – sandstone	1 grinding pair

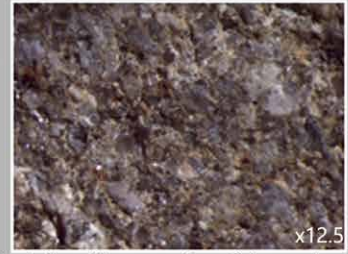
### Grinding dehusked einkorn

#### Observations after 3 hours of use

**Use-wear traces:** Single grains present rounding and levelling of the summits on the high topography. There is no visible macroscopic polish. Few short striations have developed over the big crystals in the case of the sandstone tools, but none on the andesitic ones. **Distribution of use-wear:** Loosely distributed levelled areas. Pits from the pecking process remain all over the surface. Edge rounding has started to appear in the lower topography, but is not very developed. **Morphology of topography:** The levelled areas have a sinuous/rounded cross-section morphology and medium roughness.

#### Observations after 5 hours of use

**Use-wear traces:** Grain removal and rounding on the high topography. Low macroscopic polish on the central area of the use-surface. Striations on bigger inclusions. **Distribution of use-wear:** Formation of major plateaus in the centre of the use-surface, where previous traces of pecking have been worn out through grinding (stone against stone abrasion). These plateaus alternate with pecked areas less affected by grinding, especially on the lateral sides of the use-surfaces. Only some low degree of grain levelling is detected in low topography. **Morphology of topography:** Flat and sinuous plateaus in type 1 and 2 tools, more rounded morphology in type 3 tools.



### Grinding husked einkorn and barley

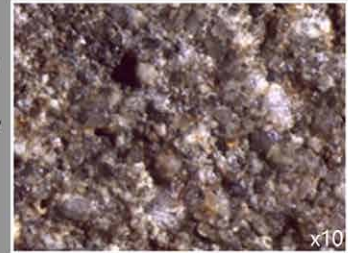
#### Observations after 3 hours of use

**Use-wear traces:** Single grains on the highest zones of the surface present microfracturing and some rounding of their summits but no levelling. Few linear traces are found concentrated in the areas with the highest abrasive wear. There is no macroscopic polish but grains appear slightly more shiny compared to earlier stages of use. **Distribution of use-wear:** The pecked surface has been preserved. The low topography remains unaltered. Only the highest asperities have developed levelling of a rough texture. Grains preserve clear margins in these areas.

**Morphology of topography:** Intense stone against stone abrasion between the quern and the handstone has created small levelled areas concentrated in certain parts of the use-surface. In the central zone of the surface, the uneven topography is preserved due to the presence of husks during grinding.

#### Observations after 5 hours of use

**Use-wear traces:** Low grain rounding. Low polish on the summit of individual grains (due to the presence of silica in the processed husks). Microfractures preserved form the manufacturing sequence. Absence of linear traces. **Distribution of use-wear:** The pecked surfaces from the initial manufacturing process are preserved to some extent after the grinding. Some rough levelling is detected in areas where the contact between handstone and quern was more intense (i.e. central area). The low topography remains almost unaltered. **Morphology of topography:** Sinuous plateaus and grains with angular edges.



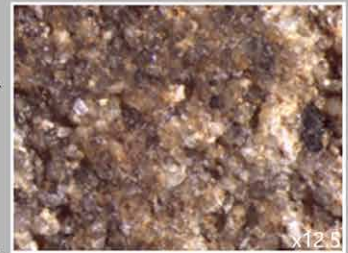
### Grinding millet

#### Observations after 3 hours of use

**Use-wear traces:** Dark coloration macroscopically visible. Short striations on separate crystals. Some rounding of the grains. **Distribution of use-wear:** The central, more irregular zone of the surface presents dark coloration. In the same area, grains in the high topography present some rounding of their summits. **Morphology of topography:** The central zone of the surface is rough, with small levelled areas with sharp irregular limits. The lateral parts of the surface are more levelled due to higher stone against stone abrasion.

#### Observations after 5 hours of use

**Use-wear traces:** Dark coloration in macroscopic view seen as polish under magnification. Grain borders are highly diffused. Linear traces appear in the form of pecking pits alignment and small, short striations on the bigger crystals. **Distribution of use-wear:** A homogeneous rough surface has been generated by the abrasion. Extensive platforms with dark coloration have formed in the periphery of the irregular central zone of the surface without extending to its margins. The dark coloration is visible on the levelled areas as well as on individual big crystals. **Morphology of topography:** Rounded morphology of plateaus in tool type 3, flat with sharp limits in types 1 and 2. Grain rounding in low topography and intermediate zone, observed in hulled millet processing as well.



### Grinding acorns

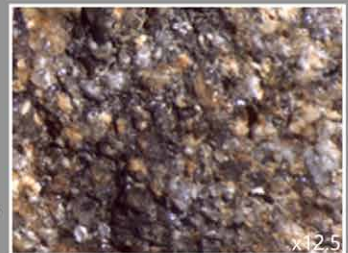
#### Observations after 3 hours of use

**Use-wear traces:** Microfractures and grain removal due to the action of pounding (for the crushing of acorns prior to their grinding) and some grain rounding. No visible linear traces, no polish. **Distribution of use-wear:** In the high topography, grains present some rounding of their summits. The low topography is irregular.

**Morphology of topography:** The overall surface has a very rough topography due to pecking and pounding. The edges of the grains are sharp, except for low rounding in high topography.

#### Observations after 5 hours of use

**Use-wear traces:** Grain rounding, but not total levelling of the plateaus. Some striations produced by grain removal and microfractures. Low polish in the microscopic scale, especially in the intermediate zone between low and high topography. **Distribution of use-wear:** The processing of roasted acorns caused more intense use-wear patterns, such as more extended smooth areas and a darker, matte coloration, compared to dried acorns. The pounding strokes to crush the nuts maintained the rough, pecked area in the centre of the active surface. **Morphology of topography:** The plateaus have angular edges. No alterations in low topography.



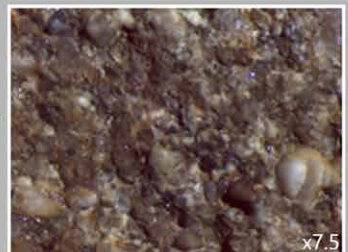
### Grinding legumes

#### Observations after 3 hours of use

**Use-wear traces:** Small levelled plateaus of rough texture, due to microfracturing and grain removal. No visible linear traces, no polish. **Distribution of use-wear:** The levelled plateaus are loosely distributed over the surface of the quern. On the handstone, an alignment of pecking pits is observed parallel to the axis of motion. **Morphology of topography:** The overall surface is homogeneous rough. The plateaus have a sinuous/flat cross-section morphology. The low topography is irregular, the grain edges are angular.

#### Observations after 5 hours of use

**Use-wear traces:** General grain rounding. Levelled areas are created through the rounding and levelling of grain summits. Separate grain borders are well defined. Few short striations are detected on bigger crystals. No polish. Microfractures and grain removal from the manufacture still remain visible. **Distribution of use-wear:** Levelled areas are loose over the whole surface topography, except the central zone, where levelling is denser. **Morphology of topography:** Sinuous texture and rounded morphology. The low topography is almost unaltered, with angular edges in general, and only some grain levelling in the centre. The handstone surface exhibited more levelling.



Appendix 17.3 Macroscopic and low magnification characteristics of use-wear observed on the experimental grinding tools (based on Bofill et al 2020, 18-19, Table 4).

### Grinding oily seeds (linseed, poppy seed)

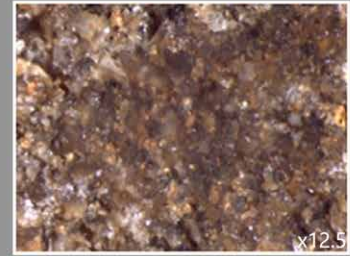
#### Observations after 3 hours of use

**Use-wear traces:** Dark coloration of the surface, extensive levelled plateaus, rounding of the grains and levelling of their summits. Thin and dense linear traces detected on high topography. **Distribution of use-wear:** Rounding of grains in both low and high topography. Polish more visible in the intermediate zone, on the ridges of the plateaus and protruding grains. **Morphology of topography:** Flat and smooth plateaus with a deposit type of polish that affects the low topography as well.

#### Observations after 5 hours of use

**Use-wear traces:** A sticky appearance and a "deposit" dome polish, especially over grey crystal grains of sandstone surfaces. Polish affects the topographic asperities and the intermediate zone. Grain borders are diffused. No significant difference detected between the polish caused by the processing of linseed and poppy seeds.

**Distribution of use-wear:** Macroscopically, the development of use-wear is more pronounced (in terms of intensity and extent) compared to other experiments. **Morphology of topography:** Roasted linseed produced more pronounced coloration but less extended levelled areas compared to untreated linseed. Smooth and flat platforms.



### Coarse grinding of malt and grünkern

#### Observations after 3 hours of use

**Use-wear traces:** Grain removal, very low rounding of grains, no linear traces, no polish. **Distribution of use-wear:** The central zone of the surface is more irregular. In the same zone, grains in the high topography present some low rounding of their summits. **Morphology of topography:** Overall the surface is irregular and rough. Individual grains present microfracturing but also some low degree of rounding. The low topography remains unaltered.

#### Observations after 5 hours of use

**Use-wear traces:** Levelling of the grain summits only. Grain rounding on querns and plateaus with sharper edges on handstones. No linear traces and no polish. **Distribution of use-wear:** Very low development of use-wear. Some loosely distributed levelled areas caused by stone against stone contact. **Morphology of topography:** Sinuous platforms with rough texture. The low topography is almost unaltered.



Appendix 17.3 continued.

Appendix 17.4 (following page) List of analysed artefacts (catalogue number, provenance, type and subtype, preservation, number of use-surfaces, raw material and functional hypothesis). In cases of secondarily used and reshaped artefacts, the state and percentage of preservation regarding their initial form are given in brackets. Note: only implements for which all stages of analysis have been completed are included.

Artefact number	Site of provenance	Tool type	Sub-type based on kinetics	State of preservation	Percentage of initial tool preserved	Number of use-surfaces	Raw material	Functional hypothesis based on use-wear
1247-1630	Ayios Viasis	quern	Type 1	whole		1	basalt	cereal processing
1296	Ayios Viasis	quern	Type 2	intact		1	sandstone	cereal processing (with different previous use?)
1587	Ayios Viasis	handstone	Type 1	fragmentary	>3/4	1	basalt	cereal processing
1284	Ayios Viasis	handstone	Type 1	fragmentary	<1/2	2	basalt	side A: cereal processing / side B: husked cereal processing
1248	Ayios Viasis	handstone?	Type 1	fragmentary	<1/4	2	sandstone	cereal processing
1633	Ayios Viasis	handstone?	Type 1	fragmentary	<1/4	2	greenschist	side A: husked cereal processing / side B: cereal processing
1632	Ayios Viasis	side A: quern / side B: handstone?	Type 2	fragmentary	<1/2	2	basalt	cereal processing
FGS 203	Mavropigi-Filotsairi	handstone	Type 1	intact		1	sandstone	legume processing
36	Stavroupoli	handstone reused possibly as anvil	Type 1	Intact / [fragmentary]	[>2/3]	1	gneiss	cereal processing
219	Stavroupoli	quern	Type 3	fragmentary	>3/4	1	gneiss	cereal processing
224	Stavroupoli	handstone	Type 1	fragmentary	>3/4	1	greenschist	husked cereal processing
285	Stavroupoli	quern	Type 1 or 2	fragmentary	<1/2	1	greenschist	husked cereal processing
310	Stavroupoli	handstone	Type 1	fragmentary	>1/2	1	gneiss	cereal processing
360	Stavroupoli	quern	Type 3	fragmentary	<1/2	1	gneiss	cereal processing
496	Stavroupoli	handstone	Type 1	fragmentary	<1/2	1	greenschist	cereal processing
526	Stavroupoli	handstone	Type 1	fragmentary	<1/2	1	gneiss	husked cereal processing
Vip.17	Stavroupoli	handstone	Type 1	fragmentary	<1/2	1	greenschist	cereal processing
16	Kleitos	handstone	Type 1	fragmentary	3/4	1	gneiss	legume processing (1st use: cereal)
24	Kleitos	handstone	Type 1	fragmentary	<1/2	1	gneiss	cereal processing (combined with something else?)
57	Kleitos	handstone	Type 1	fragmentary	<1/2	1	gneiss	cereal processing
131	Kleitos	quern	Type 1	almost intact		2	sandstone	side A: hide + ochre / side B: cereal processing
I17_#5_A	Kleitos	quern	Type 1	intact		1	gneiss	cereal processing
I17_#5_B	Kleitos	handstone	Type 1	almost intact		1	gneiss	cereal processing
I17_#5_125	Kleitos	handstone	Type 1	intact		1	gneiss	cereal processing
538	Koroneia	handstone	Type 1	fragmentary		1	gneiss	husked cereal processing
544	Koroneia	handstone	fragmentary	fragmentary	>1/2	1	gneiss	hide processing
739	Koroneia	handstone	Type 2	intact		2	gneiss	side A: cereal processing / side B: cereal processing (with different previous use?)
860	Koroneia	quern	Type 1	fragmentary	>2/3	1	gneiss	1st use: cereal processing / 2nd use: something greasy?
883	Koroneia	quern	Type 1	fragmentary	-2/3	1	gneiss	cereal processing
1018	Koroneia	handstone	Type 1	almost intact		1	gneiss?	cereal processing
6336-003	Dikili Tash	handstone	Type 1	fragmentary	>1/2	1	schist	husked cereal processing
6336-004	Dikili Tash	handstone	Type 1	almost intact		1	schist	cereal processing
6339-004	Dikili Tash	quern	Type 1	fragmentary	<1/2	1	schist	cereal processing
6168-001	Dikili Tash	handstone	Type 1	fragmentary	>1/2	1	schist	cereal processing
6182-002	Dikili Tash	quern?	Type 1	almost complete		2	schist	indeterminable due to preservation factors
61181001	Dikili Tash	handstone	Type 2	fragmentary	<1/4	1	schist	processing of greasy matter
61182001	Dikili Tash	handstone	Type 1	fragmentary	<1/2	1	schist	husked cereal processing
30210432-04	Dikili Tash	quern	Type 1	almost complete		1	schist	cereal processing
30210432-011	Dikili Tash	handstone?	Type 1	complete		1	schist	indeterminable due to preservation factors

Artefact number	Site of provenance	Tool type	Sub-type based on kinetics	State of preservation	Percentage of initial tool preserved	Number of use-surfaces	Raw material	Functional hypothesis based on use-wear
29910642-008	Dikili Tash	quern	Type 1	fragmentary	>1/2	1	schist	husked cereal processing
SectV_prov. p.	Dikili Tash	quern	Type 1	fragmentary	>3/4	1	schist	processing of greasy matter
226	Ayios Athanasios	quern	Type 1	fragmentary	<1/2	1	sandstone	1st use: cereal processing / 2nd use: processing of greasy matter
316	Ayios Athanasios	quern	Type 2	fragmentary	<1/2	1	gneiss	cereal processing
331	Ayios Athanasios	quern	Type 2	fragmentary	<1/2	1	dunite	cereal processing
397	Ayios Athanasios	quern	Type 1	fragmentary	<1/2	1	gneiss	cereal processing
425	Ayios Athanasios	handstone	Type 1	fragmentary	>1/2	1	conglomerate	cereal processing
427	Ayios Athanasios	handstone	Type 1	fragmentary	>3/4	1	gneiss	legume processing
429	Ayios Athanasios	handstone	Type 1	almost intact		1	amphibolite	millet? processing
458-509-510	Ayios Athanasios	handstone	Type 1	whole		1	conglomerate	1st use: cereal-processing / 2nd use: unidentified matter
501	Ayios Athanasios	quern	Type 1	fragmentary	<1/2	1	greenschist	cereal processing
551	Ayios Athanasios	quern	Type 1 or 2	intact / [fragmentary]	<1/2	1	gneiss	1st use: processing of greasy matter? / 2nd use: abrasive slab
566	Ayios Athanasios	quern	Type 1	fragmentary	<1/2	1	gneiss	cereal processing
567	Ayios Athanasios	handstone	Type 1	almost intact		1	sandstone	cereal processing
570	Ayios Athanasios	quern	Type 1	fragmentary	<1/2	1	gneiss	processing of greasy matter (with possibly different previous use)
572	Ayios Athanasios	handstone	Type 1	intact		1	conglomerate	1st use: cereal processing? / 2nd use: hard mineral processing
589	Ayios Athanasios	quern	Type 1	fragmentary	>3/4	1	gneiss	cereal processing
595	Ayios Athanasios	handstone	Type 2	fragmentary	>2/3	1	conglomerate	indeterminable due to preservation factors
1	Archontiko	quern	Type 1	fragmentary	>1/2	1	gneiss	1st use: cereal processing / 2nd use: unidentified matter (possibly a short term episode)
12	Archontiko	handstone	Type 1	fragmentary	>2/3	1	granite	processing of greasy matter
19	Archontiko	handstone	Type 1	intact		initially 1 (2 related to its 2ndary use)	gneiss	1st use: processing of greasy matter / 2nd use: abrasive slab
33	Archontiko	handstone	Type 1	fragmentary	<1/2	1	sandstone	1st use: cereal processing / 2nd use: something greasy? (possibly a short term episode)
34	Archontiko	quern	Type 2?	almost intact		1	granite	processing of greasy matter?
36	Archontiko	handstone	Type 2?	intact / [fragmentary]	>1/2	1	sandstone	1st use: cereal processing / 2nd use: processing of greasy matter
37	Archontiko	handstone	Type 1	fragmentary	>1/2	1	gneiss	legume processing?
37 s.c	Archontiko	handstone	Type 1	fragmentary	<1/2	2	granite	1st use: cereal processing / 2nd use: processing of greasy matter
57	Archontiko	handstone	Type 2	fragmentary	<1/2	1	conglomerate	processing of greasy matter
78	Archontiko	quern	Type 1?	fragmentary	<1/6	at least 1	ophiolitic group (maybe dunite)	1st use: cereal processing / 2nd use: processing of greasy matter
3	Angelochori	handstone	Type 1	almost intact		1	granite	1st use: cereal processing / 2nd use: hard mineral
6	Angelochori	handstone	Type 1	fragmentary	<1/2	1	sandstone	1st use: cereal processing / 2nd use: processing of greasy matter
9	Angelochori	quern	Type 1	fragmentary	>3/4	1	sandstone	1st use: cereal processing / 2nd use: legume processing?
16	Angelochori	handstone	Type 1	intact		1	granite	1st use: cereal processing / 2nd use: processing of greasy matter?



## Acknowledgements

This research was funded by the European Research Council (ERC Consolidator Grant, GA 682529, Horizon 2020) as part of the Project “PLANTCULT: Identifying the food cultures of ancient Europe”. The authors would like to warmly thank the following archaeologists for providing ground stone tools for study in the context of project PLANTCULT: Pascal Darcque, Sonia Dimaki, Areti Hondroyianni-Metoki, Aikaterini Papaefthymiou-Papanthimou, Stavros Kotsos, Chaido Koukouli-Chrysanthaki, Dimitra Malamidou, Maria Pappa, Liana Stefani, Zoi Tsirtsoni, Christina Ziota. The authors thank Georgia Kasapidou, Georgia Tsartsidou and Calla McNamee for providing unpublished information on plant microremains mentioned in the text.

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