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Microfossil evidence for grinding activities

Las evidencias microfósiles de la molienda

Functional and technological analyses of grinding stone tools have long played a major role in the characterization of such implements in the archaeological record. Likewise, microfossil studies from grinding stone assemblages have proved to be critical for delineating tool use and tracing processing activities. This paper deals with recent interdisciplinary research conducted at various settlement sites spanning from the Pre-Pottery Neolithic to the Iron Age. Using a selection of archaeological case studies, it examines ways in which plant microremains, primarily phytoliths, together with other archaeobotanical data (i.e. grain starches, pollen, macroremains) and diverse methodological approaches (i.e. use-wear, contextual geoarchaeological analyses) contribute to a better understanding of the functional analyses of grinding tools, as well as to reconstructing plant processing patterns and site activity areas. The contribution of experimental approaches to an improved interpretation of processing behaviors, as well as the fundamental importance of understanding taphonomic and formation processes in archaeological contexts is also discussed.

Keywords: Prehistory, protohistory, grinding stones, cereals, phytoliths, taphonomy.

Tradicionalmente, estudios tecnológicos y funcionales han jugado un papel principal en la caracterización del utillaje de molienda. En este sentido, los microfósiles revelan informaciones cruciales para trazar las actividades de procesado. En este artículo se presentan los resultados de estudios de microfósiles vegetales, principalmente de fitolitos, realizados en el marco de investigaciones interdisciplinares recientes en diversos yacimientos situados cronológicamente entre el Neolítico Pre-Cerámico y la Edad de Hierro. A través de una selección de ejemplos se demuestra como el análisis de estos microfósiles, en combinación con otras evidencias arqueobotánicas (almidones, polen, macrorestos) y a partir de la aplicación de líneas metodológicas diversas (traceología, análisis geoarqueológicos contextuales, etc.), contribuyen al estudio funcional de este instrumental y la reconstrucción de patrones de procesado en el registro arqueológico. Además se analiza la contribución de los estudios experimentales y la importancia de comprender los procesos tafonómicos y de formación para obtener una interpretación más fiable del registro.

Palabras clave: Prehistoria, Protohistoria, molinos manuales, cereales, fitolitos, tafonomía.

Introduction

Food processing facilities and grinding stone implements are common in many Late Pleistocene and Early Holocene settlement sites, especially dating from the time plants were domesticated (Wright 1994; Dubreuil 2004; Piperno *et al.* 2004; Eitam 2009; Kuijt and Finlayson 2009; Willcox and Stordeur 2012). Functional and technological analyses of grinding stone tools have long played a major role in the characterization of such materials and the development of early farming communities.

Recent microfossil studies, particularly of grain starches and phytoliths (plant silica cells), have proven critical for delineating tool use and reconstructing plant processing behavior in the archaeological record (i.e. Pearsall *et al.* 2004; Piperno *et al.* 2004; Portillo *et al.* 2009; Power *et al.* 2014). Many of these studies have been based on experimental or ethnoarchaeological research focusing primarily on major crops such as wheat, barley, millet and maize (Procopiou 2003; Pearsall *et al.* 2004; Harvey and Fuller 2005; Raviele 2011).

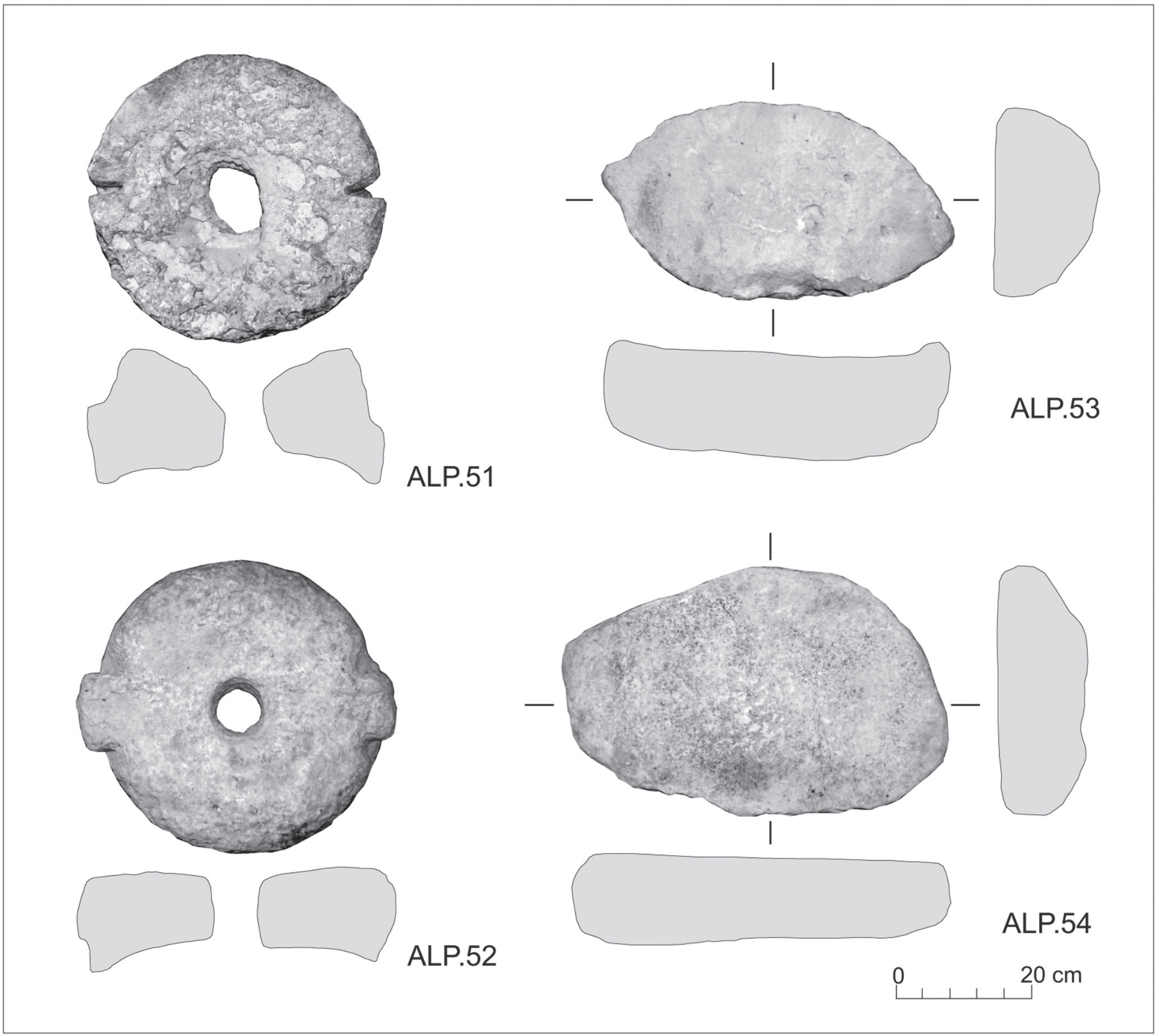

Figure 1. Grinding stones from Alorda Park, Calafell, northeastern Spain (5th century BC, US 10408). ALP51-52: rotative tools, ALP53-54: querns. Detailed contextual and tool descriptions can be found in Portillo (2006).

We present here a review of the state of the art of the study of microremains, such as phytoliths and starches, in order to understand plant processing activities in early farming and protohistoric assemblages from the Levant, Southern Caucasus and the northeastern Iberian Peninsula. We have focused on recent research conducted on grinding stone tools and particularly on microfossil plant evidence from various settlement sites spanning from the Pre-Pottery Neolithic to the Iron Age. Additionally, we draw attention to the importance of bringing together different methodological approaches in studies related to both archaeological and experimental grinding stone tools. The focus is primarily on phytolith evidence, comparing the results to other archaeobotanical data and interdisciplinary approaches, including use-wear and contextual geoarchaeological analyses. This paper also examines the contribution of phytolith experimental data to an improved interpretation of processing behaviors. In the light of this, the importance of understanding taphonomic and formation processes for reconstructing plant processing patterns and site activity areas is also examined.

Archaeological and experimental case studies

The selected archaeological assemblages discussed here are drawn from interdisciplinary research at a varied range of sites spanning from the Pre-Pottery Neolithic to the Iron Age. These case studies have been examined as part of either larger studies or specific investigations conducted at selected sites from the Levant, Southern Caucasus and the northeastern coast of the Iberian Peninsula. The sites included in this review are: early Neolithic (PPN) Jerf el Ahmar (PPNA, 9500 to 9000 cal BC), PPNB Tell Aswad (8700 to 7500 cal BC) and Tell Halula (PPNB to Halaf, 7800 to 5200 cal BC), in Syria; PPNB Ayn Abū Nukhayla, Jordan (9250 to 8700 cal BC); Neolithic Göytepe, Azerbaijan (7600 to 7400 cal BC); Early Bronze Age Tell Arqa, Lebanon (2800-2000 BC) (Thalmann 2006; Molist *et al*. 2009; Stordeur *et al*. 2010; Guliyev and Nishiaki 2012; Willcox and Stordeur 2012; Henry and Beaver 2014); and Iberian Iron Age sites: Mas Castellar-Pontós (5th-2nd century BC), Turó de la Font de la Canya (7th-3rd century BC), Alorda Park (6th-1st century BC), Castellet de Banyoles (6th-3rd century BC), Castellot de la Roca Roja (6th-2nd century BC) and Sant Jaume-Mas d'en Serrà (7th-6th century BC) (Sanmartí and Santacana 1992; Pons *et al.* 2000; Asensio *et al.* 2002; Garcia i Rubert 2011) (Figure 1).

Phytolith studies were conducted within the framework of PhD and postdoctoral research carried out at the University of Barcelona (GEPEG) and the Institute of Archaeology, University College London. Approximately a hundred phytolith samples have been analyzed from grinding stone tool active surfaces and their associated sediments whenever possible. The sediment samples came from indoor building areas (Portillo 2006; Portillo *et al.* 2009, 2013; Portillo and Albert 2014) and outdoor open areas and middens (Portillo 2006, 2008; Kadowaki *et al.* accepted). Phytolith assemblages were compared and contrasted with varied artefactual and archaeobotanical data, primarily from starches, pollen and macroremains (i.e. Willcox 2002; Emery-Barbier 2014), in addition to use-wear and contextual geoarchaeological evidence (Bofill *et al.* 2013; Kadowaki *et al.* accepted).

Additionally, comparisons between the examined phytolith archaeological assemblages and the data obtained through experimentally-produced hulled cereal processing were also carried out (Portillo *et al.* 2013). These experimental reference samples correspond to einkorn wheat (*Triticum monoccum*) grown at the Institut de Préhistoire Orientale du CNRS in Jalès, Southern France (Willcox 1992). In order to assess phytolith taphonomy and their differential production and deposition in plant tissues, the whole plant, as well as its different parts (inflorescence stem and leaves), was analyzed separately before conducting the experimental processing work. The experimental samples came from dehusking and grinding residuals using a replica quern and handstone made of basalt from the Euphrates Valley, Syria (Bofill *et al.* 2013).

A detailed description of processing techniques and samples from tool surfaces, by-products and final product (sieved flour) can be found in Portillo *et al.* (2013).

Methodology: sampling and extraction procedures, sample size; quantitative, morphologic and morphometric studies

Sediment samples were collected from active tool surfaces for phytolith analyses. It is important to note here again that additional associated sediments were examined from the same archaeological contexts for comparative purposes. Samples were obtained by washing and brushing tool surfaces with distilled water. Recent grinding stone studies dealing with methodological questions showed that both dry and wet brushing are the most effective techniques for phytolith extraction (Portillo *et al.* 2013), whereas sonication yields the greatest abundance of grain starches (Pearsall *et al.* 2004).

Phytolith and many other microfossil samples are small in comparison to bulk samples for flotation, frequently less than 1-5 g, according to internationally standardized extraction procedures (see Pearsall 1989; Piperno 2006 and references therein).

Most of the research reported here followed the methods of Albert *et al.* (1999), using around 1g of dried sediment. In addition, a new extraction protocol (Katz *et al.* 2010), which allows small sample sizes of a few mg to be obtained, was successfully applied in recent phytolith analyses conducted with a cluster of Levantine grinding stones (Portillo *et al.* 2013). This latter protocol is summarized as follows: a weighed aliquot of between 20 and 50 mg of dried sediment was treated with 50 µl of a volume solution of 6N HCl. The mineral components of the samples were separated according to their densities in order to concentrate the phytoliths using 450 µl 2.4 g/ml sodium polytungstate solution [Na6(H2W12O40)·H2O]. Microscope slides were then mounted with 50 µl of material and a covered slip placed over the suspension.

A minimum of 200 phytoliths with diagnostic morphologies were counted at 400×. Morphological identification and terminology was based on modern plant reference collections (Albert and Weiner 2001; Tsartsidou *et al.* 2007; Albert *et al.* 2013; Portillo *et al.* 2014) and standard literature (Twiss *et al.* 1969; Brown 1984; Rosen 1992; Twiss 1992; Mulholland and Rapp 1992; Madella *et al.* 2005; Piperno 2006).

The use of phytolith morphometric analyses in a number of studies, for the first time in Mediterranean contexts, has allowed taxonomical identifications to species level, crucial for tracing crop-processing patterns (Portillo *et al.* 2009, 2013; Portillo and Albert 2011, 2014). Morphometric analyses were based on Ball *et al*. (1999), using Cell D* image analysis software from Olympus. Statistical analyses used SPSS software for Windows, with calibration data from a modern plant reference collection at the Institute of Archaeology, University College London herbarium, which comprises several wild and domestic Levantine grasses (Portillo *et al.* 2010, 2014).

Modern plants for reference material were separated into their different part components and washed in deionized water and sonication. The dried material was burned in a muffle furnace at 500 ºC for 4h and then weighed and treated with 1N HCl. Microscope slides were mounted with around 0.4 mg of dried sample using Entellan New (Merck) and examined following the above-described quantitative procedures. Reference samples obtained from experimental einkorn wheat-processing (Portillo *et al.* 2013) were treated and examined following the same methodology.

Experimental approaches

This section examines plant microfossil evidence using experimentally produced crop processing patterns.

Many previous studies have focused on major crops such as early maize, wheat, barley and millet, as replicated through experimentally produced microbotanical evidence, primarily phytoliths and starches (Procopiou 2003; Pearsall *et al.* 2004; Raviele 2011). However, most of these studies relied on crop identification through the presence or absence of such microfossils, paying little attention to the taphonomic processes that may have affected their preservation in archaeological contexts. Recent archaeobotanical

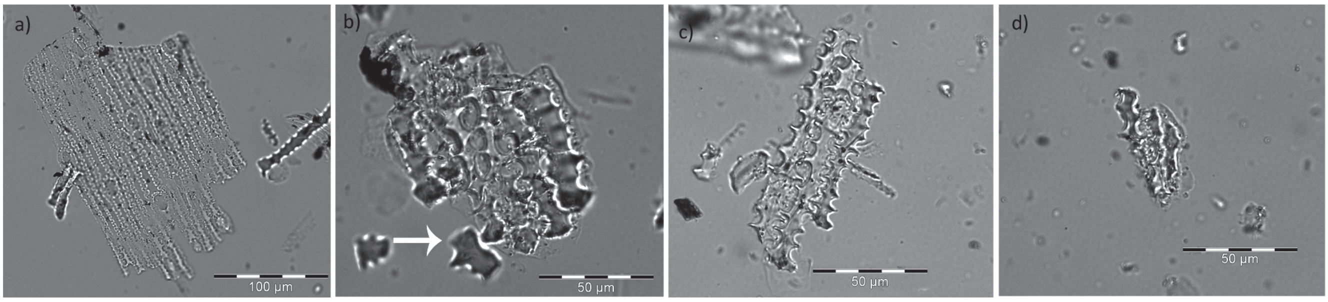

Figure 2. Photomicrographs of phytoliths identified in the samples (400×, except (a) 200×). Experimental samples: a) multicelled structure of dendritic long cells with papillae from the inflorescence of einkorn, (non-processed sample), b) multicelled structure from grinding by-product (the arrow shows long cells detached from their anatomical connection), c) multicelled structure from sieved flour (≤ 0.5 mm), d) multicelled structures from washed grinding handstone surface.

and geoarchaeological studies have highlighted the importance of understanding taphonomic and formation processes for the analysis of varied types of plant material, as well as the value of interdisciplinary approaches (see Van der Veen 2007; Matthews 2010). Phytolith preservation has been linked to depositional and post-depositional pathways, also including sampling and extraction laboratory procedures, as pointed out in a number of recent studies involving modern and fossil wheat phytoliths (Jenkins 2009; Cabanes *et al*. 2011; Shillito 2011). Nevertheless, little attention has been paid to the impact of cereal processing, particularly grinding, on the mechanical degradation of phytoliths. To better understand this aspect, a pilot experiment was recently conducted at the Autonomous University of Barcelona using a replica basalt quern and handstone (Portillo *et al.* 2013).

This experimental work focused on the quantitative and morphological study of phytoliths (mostly derived from the inflorescences, although diagnostic cells from stem and leaves were also noted), ratios between individual (single-celled phytoliths) and multicellular structures (multicelled or anatomically connected phytoliths), and phytolith size ranges expressed by numbers of single cells included in multicellular structures.

Our results showed that the size of wheat multicelled phytoliths in anatomical connection decreases as a result of both dehusking and grinding processes. These results reveal high proportions of multicells and large size ranges in samples from non-processed plant material and grinding by-products (fragmented glumes, lemma, palea, awns and spikelet bases), especially when compared to the residuals adhered to the tool surfaces, as well as the final product, the sieved flour (Figure 2). In conclusion, the breakdown of multicellular forms will be dependent on the mechanical degradation undergone by phytoliths in processing activities, in addition to other depositional and post-depositional pathways that need to be understood in order to better interpret such assemblages in their archaeological contexts.

Archaeological case studies

A selection of different case studies is examined here to show ways in which plant microfossil evidence, primarily phytoliths, contribute more widely to the functional analyses of grinding stone tools and to reconstructing plant processing behaviors in the archaeological record.

Functional analyses

The immediate implication for using plant microfossil evidence on grinding tools is the ability to identify the nature of the processed vegetal matter, which is critical for delineating tool use. Using phytoliths it is possible to distinguish between monocotyledonous and dicotyledonous plants, to recognize their different part components (i.e. inflorescences or floral parts, stems and leaves), to discriminate wild from domestic species, and to identify specific taxa down to genus or species level through morphometric analyses.

At the PPNB site of Ayn Abū Nukhayla (Wadi Rum, Southern Jordan), plant microfossil studies (phytoliths, starches and pollen) were conducted on various *in situ* grinding tools made of local sandstone and their associated sediments from well-defined living floors, including both handstones and their lower parts, namely querns. It should be noted that multicellular structures (multi-celled phytoliths), often good indicators of the plant down to genus level, and macroremains (i.e. seeds) were absent from the samples. Consequently, a pilot morphometric study focused on dendritic cells that were common to all the examined tool samples and related sediments.

The results indicated the presence of emmer wheat (*Triticum dicoccum*) in two grinding stone samples (Portillo *et al*. 2009). In an effort to obtain more information on the cereals processed at the site, the morphometric study was enlarged to other samples from different indoor site locations (Portillo and Albert 2014). The results again indicated strong resemblances to measured morphologies of emmer wheat, thus confirming the previous results. This is consistent with other direct evidence from corroded or damaged starch granules in the same grinding tool samples, as well as Cerealia pollen in these contexts, which have been also related to grinding processes (Emery-Barbier 2014).

Similarly, phytolith analyses conducted with two grinding tools from PPNB Tell Aswad (Damascus Basin, Southern Syria) allowed the identification of

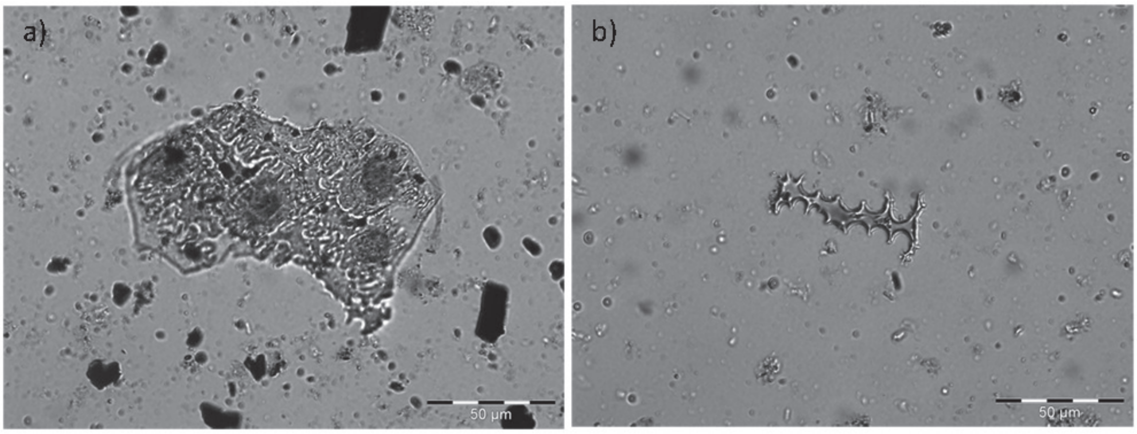

Figure 3. Phytoliths identified in PPNB Tell Aswad grinding stone samples (Damascus Basin, Southern Syria) (400×). a) multicelled structure of dendritic long cells with papillae from the husks of wheat (*Triticum* sp.), b) dendritic long cell.

the same type of cereal (Portillo *et al*. 2013). The examined assemblages corresponded to the active surfaces of a vesicular basalt quern and handstone. These samples yielded multicelled phytoliths from the *Triticum* genus (figure 3a), although in low amounts. In order to identify these down to species level, a morphometric study conducted on well-preserved single dendritic phytoliths allowed the identification of emmer wheat in the examined grinding tools (figure 3b). Emmer processing is consistent with use-wear results, which were associated with working in couples and with a back-and-forth or circular motion, probably related to the treatment of cereals (Bofill *et al*. 2013). Direct evidence was also obtained from charred macrobotanical remains at the site (Van Zeist and Bakker-Heeres 1985).

As previously argued, functional and typological studies were conducted with a selection of grinding stones from different protohistoric sites on the Iberian Peninsula (Portillo 2006, 2008) (see above for the list of sites). The assemblages corresponded to various morphological types (querns, handstones and rotative grinding stones, figure 1) made from different raw materials (primarily basalt, granite, sandstone and limestone); for a detailed description see Portillo (2006). Grass inflorescence phytoliths from the Pooid subfamily (figure 4a) were the main plant component noted on their active surfaces, regardless of the implement's morphology (querns vs. rotative tools), thus suggesting similar uses related to the processing of Pooid grains, probably the grinding of cereals.

Hulled barley (*Hordeum vulgare*) and free-threshing wheat (bread or common wheat/hard wheat, *Triticum aestivum/durum*) were the most common cereals grown during the Iberian period (see Buxó 1997; Alonso 2000 and references therein). Diagnostic phytoliths from leaves and stems were also noted in all samples (figure 4b), which, according to our experimental data, can be also found in residuals from grain processing adhered to active tool surfaces. Additionally, diagnostic phytoliths from palm leaves (figure 4c) were observed in assemblages from Alorda Park and Sant Jaume-Mas d'en Serrà, although to a lesser extent. At this latter site, the impressions of chaff temper from cereals and palm leaves are commonly found in the remains of construction materials (M. Mateu, personal communication). Native palm species (*Chamaerops humilis*) are still common in the site area today (Garcia i Rubert 2011). Alternatively, their presence in building areas could also be linked to matting, basketry and cording, as well as to various domestic items, such as brooms, brushes and sieves (possibly related to grain cleaning).

Common to all these functional studies conducted on Iberian assemblages were the poor preservation conditions of the phytoliths, due both to mechanical degradation and chemical dissolution (figure 4d), which did not allow an accurate morphometric taxonomic identification down to genus or species level. The presence of silicate minerals in the samples, as well as the differential degree of phytolith dissolution, possibly relates both to the type of sediment and the lithology of the grinding stones. A second issue is the mechanical degradation of a large amount of the phytoliths noted, as well as the near complete absence of multicelled structures. This pattern has also been observed in grinding assemblages from many other archaeological sites from different geographical areas and periods, including the two above-described early Levantine farming case studies (Ayn Abū Nukhayla and Tell Aswad), where multicelled phytoliths were scarce or even absent (Albert and Portillo 2005; Portillo and Albert 2012; Kadowaki *et al.* accepted). These observations are consistent with the data obtained from the above-described experimental research.

Site spatial organization: identifying grinding activity areas

Integrating functional analyses of grinding stone tools within varied lines of interdisciplinary methodological approaches and detailed contextual analyses contributes significantly to our understanding of plant processing behaviors and the spatial organization and distribution of activities. Such integrated approaches of content and context are critical for delineating the development of farming communities.

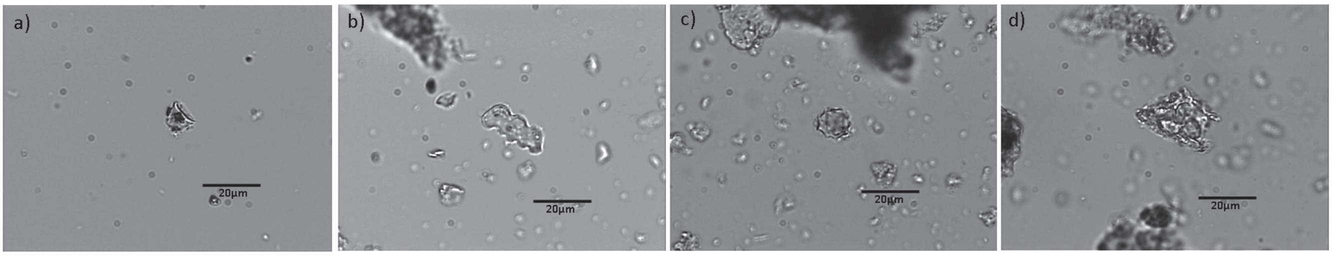

Figure 4. Phytoliths identified in protohistoric grinding stone samples (northeastern coast of the Iberian Peninsula) (400×). (a-b) Alorda Park, Calafell, (c-d) Sant Jaume Mas d'en Serrà, Alcanar. a) short cell rondel, b) long cell polylobate, c) sheroid echinate, d) phytolith altered by dissolution (weathered morphotype).

A number of archaeological sites from the Near East have provided direct microfossil evidence for early cereal processing, primarily pre-domestication wheat and barley. Among the earliest direct evidence of grain processing, recognized at the Upper Paleolithic site of Ohalo II (Sea of Galilee, Israel), revealed starch granules from barley and possibly wheat in sediments adhered to a grinding stone (Piperno *et al*. 2004). Their association with an oven-like hearth suggests that the ground seeds were baked, thus providing early evidence for both grinding and cooking of selected wild cereals, about twelve thousand years before their domestication. A second example is the PPNA site of Jerf el Ahmar in the Euphrates Valley (Northern Syria), where grinding stones and building installations were devoted to the systematic production of food from wild cereals and barley in particular (Willcox 2002; Willcox and Stordeur 2012). Phytolith results from the active surface of a limestone quern found in the kitchen of House 10 yielded diagnostic morphotypes from the *Hordeum* genus (Portillo *et al*. 2013). In addition, use-wear analyses showed reciprocal motion and work in couples associated with cereal grinding, as well as percussion traces in its central area related to pounding. Processing of wild barley, and perhaps also of other edible plants, is consistent with abundant charred plant macroremains, including well-preserved seed cakes made of finely crushed grains associated with grinding tools (two of these querns were set into their bases) and limestone basins related to soaking and/or food storage. The presence of such processing facilities in specialized rooms equipped with grinding tools, as well as large storage structures in communal buildings, provides direct evidence of large-scale cereal exploitation dating to the tenth millennium cal BC (Willcox and Stordeur 2012).

Research conducted at the early Neolithic site of Ayn Abū Nukhayla in Southern Jordan centered on defining domestic activities, including cereal grinding, and assessing their spatial distribution with regard to the scale of both the households and the community within the site. The direct microfossil evidence (phytoliths, pollen and starches) revealed the use of specific indoor activity areas for cereal processing (Albert and Henry 2004; Portillo *et al*. 2009; Emery-Barbier 2014; Portillo and Albert 2014). Moreover, beyond simply identifying tool use and activity areas, these findings provide an important approach to evaluating the specific depositional pathways responsible for the behavioral residuals and taphonomic processes of the examined indoor contexts. The association between clusters of grinding stones (both handstones and querns) and direct microfossil evidence (single-celled phytoliths from emmer wheat, Cerealia pollen and damaged grain starches) indicate cereal processing on certain floors. In addition, sediments from storage cists from the same context also revealed corroded starch granules probably related to the grinding or cooking of cereals. In contrast, macroscopic and microscopic behavioral residuals in other contexts failed to define indoor grain processing activities, but instead the location in which the processing equipment was stored or cached.

Recent studies at the Neolithic settlement of Göytepe (Azerbaijan, Southern Caucasus) have revealed direct archaeobotanical and contextual evidence for both cereal storage and grain processing (Kadowaki *et al.* accepted). Circular clay bins are common storage features at Neolithic sites in the Southern Caucasus. At Göytepe most of these bins are found to contain secondary fillings such as domestic refuse, including fecal remains or the residuals of dung fuels, as indicted by the identification of dung spherulites (calcitic microfossils that form in animal guts, Canti 1999) (figure 5a). Although these may not be indicative of primary uses, they may suggest domestic activities such as firing and cooking behaviors. The find of a bin containing white-colored bottom filling deposits consisting of inflorescence phytolith concentrations (mostly single-celled phytoliths, figure 5b), in association with two complete *in situ* grinding stones, suggests the remains of plant processing activities, such as cereal grinding or dehusking. Charred macrobotanical remains from the rachises and chaff of wheat and barley were also noted in the upper bin fillings, whereas micromorphological observations indicate that the bottom part consisted almost entirely of phytolith-rich deposits with fine amorphous organic matter and few small charcoal fragments. Interestingly, the presence of particularly elongate phytoliths from leaves and stems from grasses oriented parallel to each other creating a layered laminated appearance in the bottom wall, suggests that the bin may have been lined with plant material that drove moisture out of the stored material, mainly chaffs. These results emphasize the importance of understanding the precise depositional contexts of the microfossil assemblages to better define

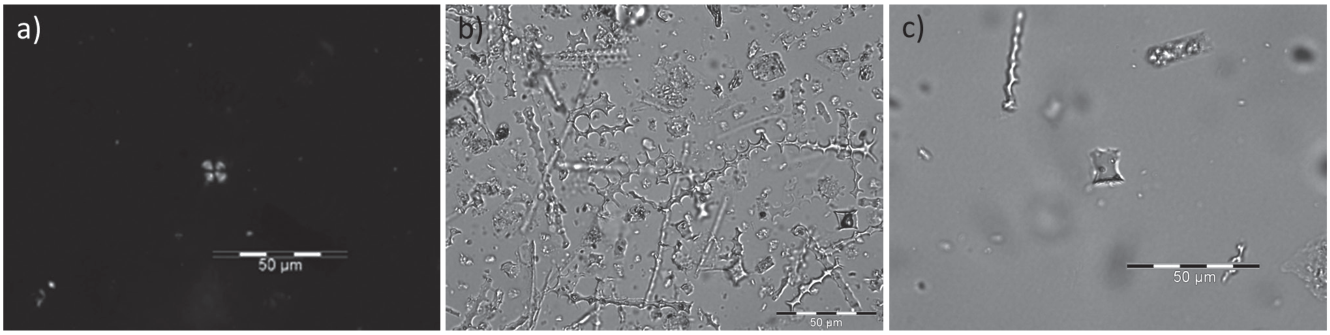

Figure 5. Microfossils identified in Göytepe bin samples (Azerbaijan, Southern Caucasus). (400×) a) dung spherulite from upper bin filling sediments, b) phytolith rich-sediments from bottom fill white deposit associated to two complete grinding stones, c) short cell rondel from grinding tool surface.

formation processes and sociocultural dynamics. Not only do the findings of this initial study at Göytepe show the specific taphonomies of the examined storage assemblages and tools, but they also furnish a means of delineating a more comprehensive picture of the reconstruction of household food processing and early farming storage practices.

Conclusions

Integrated studies of plant microfossils provide useful information regarding vegetal exploitation in archaeological contexts, including tool use, food preparation, cooking and storage. Phytoliths in particular offer a consistent dataset for distinguishing certain plant species and their different parts, which may be better preserved when other plant sources are unavailable or are partially uninformative (i.e. charred remains, pollen and starch grains). Thus, the ability to consistently distinguish certain cereal species through phytolith morphometric analyses is an effective tool for explaining plant uses. The integration of several lines of methodological approach (i.e. micromorphology, micro- and macrobotanical studies) and the use of experimentally produced data contribute to the exploration of the depositional and taphonomic processes, which are fundamental for interpreting site formation processes and sociocultural practices.

The research reported on here examines the contribution of plant microfossils, primarily phytoliths, to functional analyses of grinding stone tools and the reconstruction of plant processing behaviors in Neolithic and protohistoric contexts. Functional analyses have allowed the nature of the processed vegetal matter to be identified. Recent morphometric studies carried out on well-preserved phytoliths from early Neolithic grinding stones (PPNB Ayn Abū Nukhayla and Tell Aswad, in the Levant) have provided direct evidence of emmer wheat processing. Functional and typological studies conducted with a selection of protohistoric grinding stones from the coast of the Iberian Peninsula suggested similar uses relating to pooid grain processing, probably cereals such as hulled barley and free-threshing wheat, according to the macrobotanical record, regardless of the tool's morphological type (querns vs. rotative).

In addition, phytolith results at specific sites (Alorda Park and Sant Jaume Mas d'en Serrà) showed the presence of other types of plant material (i.e. chaff from grasses and palm leaves) that may be related to household debris, such as building materials, matting, basketry, cording and varied domestic items (i.e. brooms, brushes and sieves). The last of these could also be related to crop exploitation and particularly to grain cleaning.

The selected case studies have provided direct evidence for early cereal processing, including grinding, cooking and storage, primarily from major cereals (wheat and barley microfossils: phytoliths, starches, Cerealia pollen and charred macroremains), before their domestication (PPNA Jerf el Ahmar), as well as in latter Neolithic phases (PPNB Ayn Abū Nukhayla and PN Göytepe). Beyond identifying tool use, plant processing patterns and onsite activity areas, these findings have also furnished means of delineating the specific taphonomies responsible for these macro- and microscopic assemblages. For example, at Ayn Abū Nukhayla, a series of *in situ* grinding tools and concentrations of cereal microfossils indicated specific indoor areas devoted to food processing, as well as other locations in which the lack of co-variation between both macro- and microscopic assemblages implied that the same type of equipment was stored or cached.

Detailed analyses of content and context at storage bin features at Göytepe have allowed the identification of the stored material, two grinding stones and the residuals of cereal processing (wheat and barley macroremains and phytolith-rich sediments), in conjunction with examining depositional and diagenetic processes, as well as possible vegetal linings in the bottom walls (elongated multicelled phytoliths creating a layered laminated appearance). These examples show the importance of understanding the precise depositional contexts of these behavioral remains and their associations with artifacts and other residuals to better trace the site formation processes, activity areas and ecological and socio-cultural practices.

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