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HEARTHS AND PLANT USES DURING THE UPPER PALAEOLITHIC PERIOD AT KLISSOURA CAVE 1 (GREECE): THE RESULTS FROM PHYTOLITH ANALYSES

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Abstract

The excavations of the Middle and Upper Palaeolithic layers at Klissoura Cave 1 (Peloponnese, Greece), facilitated the investigations of phytolith samples from sediments and hearths dated to the Upper Palaeolithic period. The study resulted in the reconstruction of the palaeo-landscape, the vegetation as well as the use of fire by the inhabitants of the cave. Phytoliths were abundantly identified in most of the sediment samples in relatively good preservation, especially in the uppermost layers. In contrast, phytoliths were practically absent from hearths. The dominant family identified in the course of laboratory analyses are the grasses. Moreover, their good preservation in the sediment samples permitted us to differentiate between various depositional events, due either to environmental changes and/or diverse economic activities. The relatively dry conditions in the cave during the deposition of the Upper Palaeolithic layers proved to be suitable for the preservation of the phytoliths allowing the preservation of certain fragile morphological types such as papillae cells or sedge phytoliths. Noteworthy is the presence of phytoliths from the inflorescence of grasses in some of the layers as well as the identification of sedges that points to the potential use of these plants for dietary purposes during the Aurignacian. Wood was probably the main fuel used for fires accompanied by the constant presence of grasses.

Key words: Aurignacian, Fireplaces, Ash layers, Grasses, Sedges, wood/bark.

INTRODUCTION

Phytolith analyses were carried out on different sediments, hearths and ash layers from the Upper Palaeolithic levels of Klissoura Cave 1. This work comprises a detailed quantitative and morphological study of phytoliths that complements and enhances the previous work carried out in the site (Koumouzelis *et al.*, 2001). The sedimentary sequence corresponds chronologically to the Early Upper Palaeolithic–Uluzzian, Aurignacian and Epigravettian and has been dated roughly as 40–41 kyrs BP for the Uluzzian (included in the Early Upper Palaeolithic sequence), 35–26 kyrs BP for the Aurignacian, and 14 kyrs BP for the Epigravettian (Kuhn *et al.*, this issue). Samples differ among themselves in having anthropic and/or non-anthropic origin, presenting different mineralogical compositions and thus, different formation processes. Special emphasis has been placed on the study of hearths and ash layers as product of short term activities by the inhabitants of the cave.

Phytoliths have been used in archaeological contexts since the 1970s and have allowed the identification of not only human use of plants (Rosen and Weiner, 1994; Albert *et al.*, 1999, 2000, 2003; Madella *et al.*, 2002), but also the correlation of the plants' presence (natural accumulation rather than anthropogenic) in the palaeoenvironment of certain geographical areas (Alexandre *et al.*, 1997; Barboni *et al.*, 1999; Mercader *et al.*, 2000; Tsartsidou *et al.*, 2007).

Phytoliths preserve remarkably well through time, due to their mineralogical composition

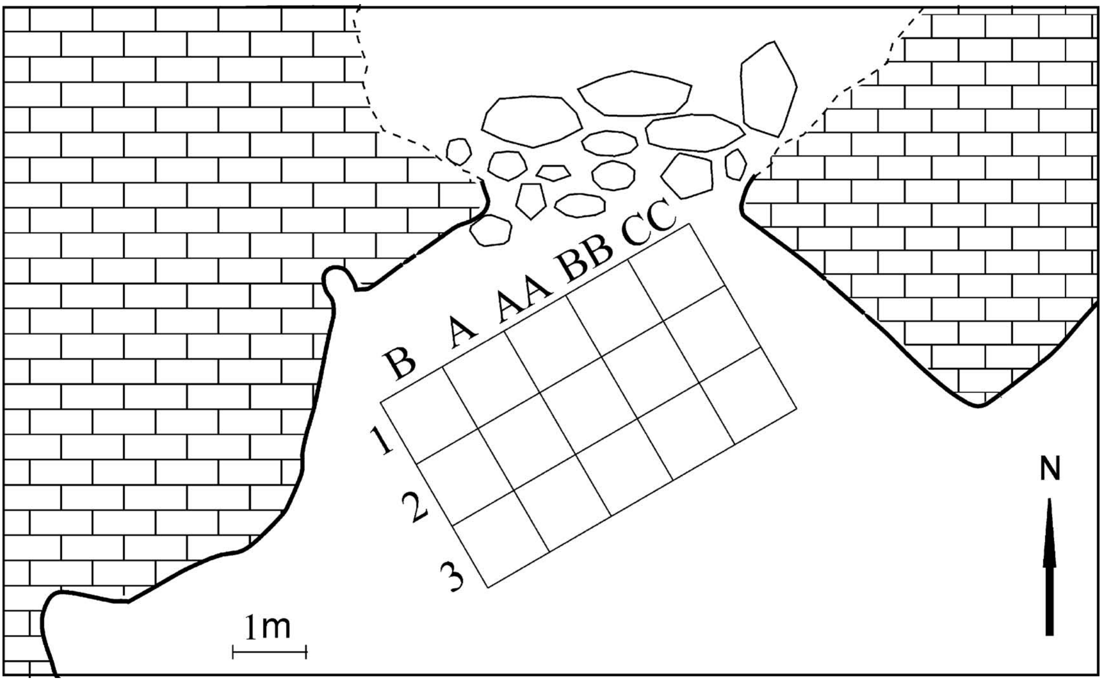

Fig. 1. Plan view of Klissoura Cave 1

($SiO_2 \cdot nH_2O$). Morphologically they reproduce the cellular tissue of different plants, which helps to identify the plants, in some cases, to the species level (Ball *et al.*, 1999; Berlin *et al.*, 2003; Albert *et al.*, 2008), as well as the plant part in which phytoliths were formed (Geiss, 1973; Piperno, 1988, 2006; Ollendorf, 1992; Bozarth, 1992; Albert and Weiner, 2001; Bamford *et al.*, 2006; Tsartsidou *et al.*, 2007).

In the Levant the use of fire by Middle Palaeolithic populations has been recorded since the beginning of the 20th century. Caves such as Tabun, Kebara and Hayonim (Israel) show an important stratigraphic record including the presence of hearths and ash levels, many of which are *in situ* (Bar-Yosef *et al.*, 1992; Schiegl *et al.*, 1996; Karkanas *et al.*, 2000). These caves provide many indications that social activities centered around the hearths (Gamble, 1999: p.171).

Phytolith and mineralogical studies of fire remains began in the 1990's and focused on Middle and Upper Palaeolithic caves from the eastern Mediterranean as well as in France. Silica phytoliths are commonly found in hearths as a result of plant combustion. Their study in prehistoric combustion features has made it possible to identify fire remains not visible to the naked eye, to determine the type of fuel used for the fire, and to obtain a better understanding of the functionality of the hearth (Schiegl *et al.*, 1994, 1996; Albert *et al.*, 1999, 2000, 2003, 2007; Karkanas *et al.*, 2000, 2002; Madella *et al.*, 2002) .

The main focus of this study was to improve our understanding on the use of fire through the identification of the plants used as fuel, as well as other related activities carried out in the cave. The information obtained may shed some more light on collecting strategies and use of vegetal resources by the occupants of the cave during the Upper Palaeolithic and Epigravettian periods, as well as contributes to the reconstruction of the palaeovegetation of the area during the time that the cave was occupied.

MATERIALS AND METHODS

Thirty sediment samples from Sequences B, C, D, E and F, layers II–V were analyzed for phytoliths. Of these, eight samples corresponded to Aurignacian clay structures (Sequence E, layer

Table 1

Phytolith results from Upper Palaeolithic Layers from Klissoura Cave

Stratigraphy	Locality	% AIF	N. of phyt. 1 g AIF	N. phytoliths morphologically identified	Weathering %	Observations (* – not interpreted)
Sequence B						
Layer IIa	B1-B2-B3 west profile	39.1	3.200.000	383	18.0	brownish grey
Layer IIb	B1-B2-B3 west profile	34.7	2.600.000	385	21.8	brownish grey
Layer IIb	BB3-AA3 south profile	47.1	3.000.000	605	18.0	reddish brown with stones
Layer IId	BB3-AA3 south profile	36.6	1.600.000	354	19.4	reddish brown with stones
Sequence C						
Layer 6	B1-A1 north profile	30.9	400.000	181	24.3	grey-brown loose pit
		30.9	300.000	120	17.2	grey-brown loose pit
		14.2	90.000	18	25.0	*white flat hearth
Sequence D						
Layer III	B1-B2-B3 west profile	27.1	600.000	112	47.0	white cemented
		30.8	540.000	192	47.0	light grey
Layer IIIe'/g	B1-B2-B3 west profile	13.9	200.000	48	45.5	*white flat hearth
		11.3	140.000	46	37.8	*grey part of previous hearth
Layer IIIe	BB3-AA3 south profile	22.9	400.000	149	39.2	grey with stones
	B1-B2-B3 west profile	6.7	54.000	13	55.2	*white flat hearth
		6.2	10.000	2	--	*white flat hearth
	B1-A1 north profile	30.9	240.000	103	29.0	grey flat hearth
Layer IIIg	BB3-AA3 south profile	16	300.000	67	46.0	grey
Layer IIIf	B1-A1 north profile	21.9	160.000	28	31.7	*grey flat hearth
Sequence E						
Layer IV	BB3-AA3 south profile	38.9	500.000	230	28.8	reddish grey
	B1-B2-B3 west profile	22.2	100.000	49	45.6	*clay hearth, white lens
		28.7	100.000	31	39.2	*clay hearth, white lens on top
		30.5	70.000	27	37.2	*clay hearth, white lens on top
		7.3	40.000	10	33.3	*white flat hearth
	B1-A1 north profile	28.9	70.000	23	54.0	*clay hearth, grey lens on top
		22	140.000	44	30.2	*white lens from the above clay hearth
		29.8	100.000	43	23.2	*clay hearth, grey lens on top
	AA1-BB1, CC1 north profile	30.4	80.000	37	40.3	*clay hearth, grey lens on top
		25.6	140.000	41	37.9	*clay hearth, grey lens on top
		33.0	100.000	36	25.0	*dark grey flat hearth
		31.6	50.000	21	53.3	*grey flat hearth
Sequence F						
Layer V	BB3-AA3 south profile	16.3	100.000	31	45.6	*grey with white patches

IV), 10 to Aurignacian flat hearths (Sequences C, D and E, layers 6, III–V) whereas the other 12 were sediment samples from the same Aurignacian layers and from layer II of the Epigravettian tradition. Clay structures of 30–40 cm diameter have been defined as dark-red compact features with a basin like shape (Karkanas, this issue). The FTIR and differential thermal analyses suggest that these structures were heated to 400–600 °C and that they might have been used for cooking based on the identification of microscopically undisturbed intact wood ash and food remains (Karkanas *et al.*, 2004, this issue). Phytoliths analyses were carried out on grey and white lenses deposited on top of them. The flat hearths represent mostly intact ashes with preservation of pseudomorphs. Nevertheless, moderate signs of trampling and minor reworking were noted. The ashes are thought to be the product of several burning episodes where burning was almost complete, which might explain the lack of major amounts of charcoal (Karkanas this issue; Ntinou, this issue).

Table 1 lists all the samples analyzed, and their provenience with indication of the sequences and layers from where they were collected. All the samples were assembled from the south profile BB3-AA3, located close to the entrance of the cave, the west profile B1-B2-B3 and the north profile B1-A1, at the back of the cave (Fig. 1).

The methods used to process the samples are similar to those described in the study of Tabun cave in Israel (Albert *et al.*, 1999). In the laboratory weighed samples of approximately 1g of air dried sediment were treated for 30 minutes by the addition of 10ml of an equivolume solution of 3N HCl and 3N HNO_3. Samples were then centrifuged to separate and remove the soil carbonates and phosphates for a better identification of phytoliths. The pellets were washed and the organic material was oxidized by the addition of 10ml of 30 H_2O_2 at 70 °C. The samples were dried and the remaining sediment weighed since this is the inorganic AIF (acid insoluble fraction, which includes the phytoliths, clay and quartz). The AIF was further separated into its component minerals using 5ml of 2.4g/ml density of Sodium Polytungstate Solution [$Na_6(H_2W_{12}O_{40}).H_20$] added to the pellets. The suspension was centrifuged and the supernatant transferred to another centrifuge tube, 1.0 ml of de-ionised water was added and the tube was vortexed and again centrifuged. This cycle was repeated until no visible mineral particles remained in the supernatant.

Approximately 1 mg of the remaining fraction was weighed and placed on a microscope slide. The samples were mixed with Entellan New (Merck), and a cover slip was placed over the suspension. Slides were examined using an Olympus BX41 optical microscope at 400 X and digital images were obtained using an Olympus Color View III.U camera and Olympus Cell D software. The number of phytoliths on the slide was counted and related to the original sediment weight.

Previous results (Albert and Weiner, 2001) indicates that the counting of 200 diagnostic phytoliths gives an error margin of around 20% whereas the counting of 50 phytoliths gives an error margin of 40%. Thus, in those situations where less than 200 phytoliths were identified, and keeping in mind the high error margin, only those samples with more than 50 phytoliths were morphologically interpreted.

Morphological identification of phytoliths was based on standard literature (Twiss *et al.*, 1969; Brown, 1984; Piperno, 1988; 2006; Mulholland and Rapp, 1992; Twiss, 1992), as well as on the modern plant reference collection from the Mediterranean area (Albert and Weiner, 2001; Albert *et al.*, 2000; Tsartsidou *et al.*, 2007). When possible, the terms describing phytolith morphologies follow anatomical terminology, and otherwise they describe the geometrical characteristics of the phytoliths. The International Code for Phytolith Nomenclature was also followed (Madella *et al.*, 2005).

RESULTS

Silica phytoliths were present, in different amounts, in the samples. Table 1 shows the list of the samples analyzed, locality and description. The table also shows the percentage of Acid Insoluble Fraction (AIF), the estimated amount of phytoliths per gram of AIF, the number of phytoliths with recognisable morphologies identified and the percentage of dissolution.

Mineralogical and quantitative phytolith results

Phytoliths were abundantly identified practically in all the sediment samples. Only sample from layer V, corresponding to the Early Upper Palaeolithic period did not show enough diagnostic phytoliths and in the Aurignacian sample from layer IIIg, less than 100 phytoliths related to a high dissolution percentage (Table 1 and Fig. 2a) were identified. Phytoliths were scarcely identified in the hearth samples, neither in the clay nor in the flat hearths (Table 1). Only one hearth from

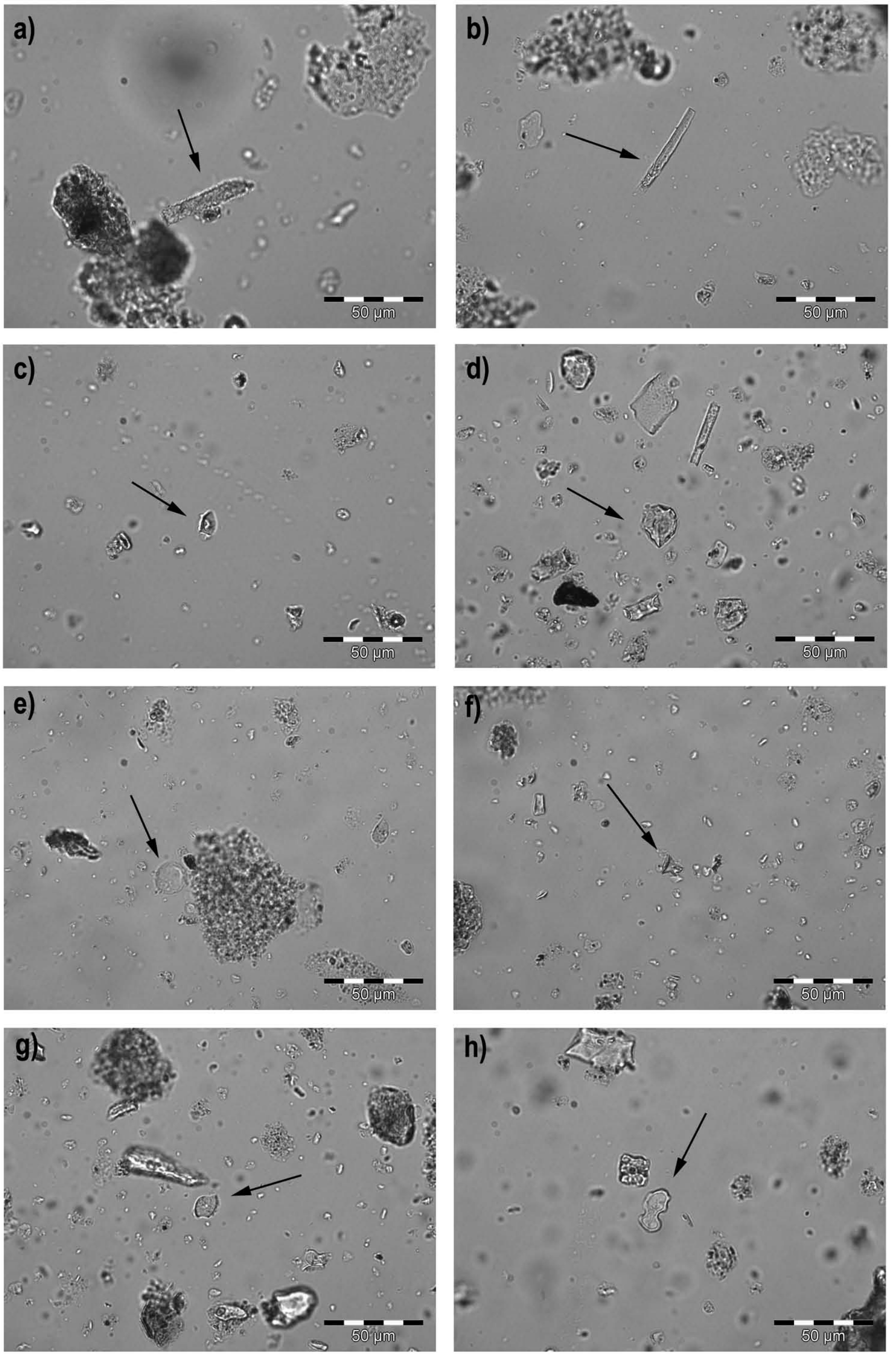

Fig. 2. Photomicrographs of phytoliths identified in Klissoura samples. Pictures taken at ×400. **a)** Cylindroid scabrate from monocotyledonous plants with evident signs of etching due to dissolution; **b)** cylindroid psilate from monocotyledonous plants; **c)** short cell from the C3 festucoid grass subfamily; **d)** hat-shape phytolith from sedge; **e)** papillae cell phytolith from the grass family; **f)** short cell from the C3 festucoid grass subfamily; **g)** short cells from the C4 chloridoid grass subfamily; **h)** short cell bylobate from grass, probably *Arundo donax* (giant reed)

layer IIIe, did present enough amount of phytoliths for a reliable morphological interpretation.

The percentage of AIF allows for a better comparison of samples from different locations independently of their mineralogical composition regarding phosphates, carbonates and organics. The subsequent distribution of the AIF fraction into their corresponding density fractions permits a better isolation of the phytoliths and consequently a better quantification. The AIF % is especially valuable when interpreting anthropic hearths. Wood combustion produces a highly alkaline ash (pH 9–13.5) (Etiégni and Campbell, 1991) which is composed on average of 98% of fine-grained calcite and 2% of siliceous aggregates and phytoliths (Schiegl *et al.*, 1994, 1996).

In Klissoura the percentage of AIF in the sediment samples ranges between 16 to 47%, with variations among samples. Nevertheless reddish samples from layers IIb and d, as well as layer IV present a higher % AIF percentage with an average of 41% due to the presence of clay. The average % AIF for grey and white sediment samples is 27.5%.

In the hearths the % AIF goes from 6.2 to 31, with an average of 22%, which is lower than previous samples and consistent with the presence of calcitic wood ash. Taking a closer look, however, some differences related to the type of hearths can be noted. Flat hearths present a lower AIF% (17.7) whereas in clay hearths the percentage of AIF is 27.6, probably due to the partially mixing of the lenses with the clay. Within flat hearths, the AIF % in the white colored sediments is less, just 19% suggesting a higher presence of calcitic ash whereas in grey hearths this average raises to almost 30%.

The estimated amount of phytoliths per gram of AIF gives an overall indication of the plant input in the sediments related to other siliceous minerals (mainly clay and quartz). Phytoliths are particularly abundant in layer II, independently of the provenience of the samples and the type of sediments (Table 1). The weathering percentage is similar and relatively low, especially when compared to other layers.

Layer 6, which is characterized by reworked and disturbed sediments, present a much lesser amount of phytoliths with a lower dissolution degree, suggesting, either a minor presence of plants or the presence of plants which do not produce phytoliths in abundance (Table 1).

Samples from layer III represent mostly burnt features and the quantitative results suggested a lower amount of phytoliths associated to a higher dissolution rate. On the contrary, samples from layer IV showed better phytolith preservation. Nevertheless the presence of clay dilutes the phytolith abundance in these samples.

In the hearths the estimated number of phytoliths per gram of AIF lies between 10 to 240.000 phytoliths which is considerably lower than sediment samples from the same sequences. No significant quantitative differences were noted between flat and clay hearths in terms of phytolith abundance.

Morphological phytolith results

The number of phytoliths morphologically identified refers to those that have been recognized and ascribed to a plant origin. Sediment sample from sequence F, layer V, was not morphologically interpreted due to the low number of diagnostic phytoliths recovered (31) (Table 1). This sample presents, as well, the lowest estimated amount of phytoliths per gram of AIF related to a high dissolution percentage.

As already mentioned only one hearth sample presented enough number of phytoliths to be morphologically interpreted (grey hearth from the north profile B1-A1). The dissolution index of phytoliths in hearths ranges from 23 to 55%, being slightly higher in the northern samples independently of the type of hearth (Table 1).

Figure 3 shows the phytolith morphological distribution among samples according to the type of plant and/or plant part where they were formed. Note that some phytolith morphologies are non-diagnostic enough to differentiate between woody herbs, shrubs and trees so these are listed as "dicot wood/bark" or "dicot leaves". Where we cannot distinguish between herbaceous monocots, grasses and sedges these are listed as "monocots" (Fig 2a, b).

Morphologically, grasses and monocotyledonous plants are the major component of the phytolith record. Characteristic grass phytoliths dominate in samples from layers II and 6 (Figs 2c, 3). Monocotyledonous phytoliths are more common in samples from layer IIIe and IIIg. Dicotyle-

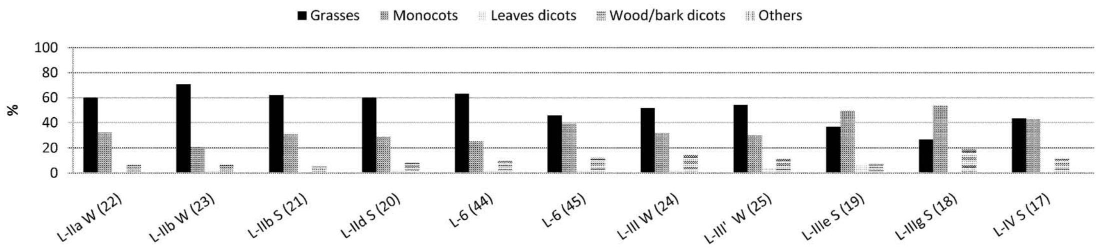

Fig. 3. Histogram showing the morphological distribution of phytoliths according to the type of plant and/or plant part where they were formed

donous plants (including leaves and wood/bark) were identified as well in the samples, although in much lesser number. The morphological results from the grey flat hearth analyzed differ considerably from other samples presenting a lower number of characteristic grass phytoliths, a higher presence of monocotyledonous phytoliths and a higher amount of wood/bark phytoliths (Fig. 3). Only two samples from layer IIIe and IIIg from the south profile were dominated, as well, by monocotyledonous plants. The latter also showed more wood/bark phytoliths (Fig. 3). Sedges were noted in layers IIIe and in lesser amount in layers IV and II (Figs 2d and 3). It is noteworthy that sedges, though they produce phytoliths in abundance (Ollendorf, 1992; Bamford *et al.*, 2006), they are not well represented in soils due to their fragile silicification, and dissolve soon after their deposition in the soils (Albert *et al.*, 2006). Consequently their identification in these layers entail for an extraordinary preservation of these microremains.

Fig. 4 shows the grass phytolith morphological distribution according to the plant part where they were formed. Short cells that appear commonly in the leaves and the inflorescences, have been grouped independently. Short cells are known to be the first cells in becoming silicified regardless of the moisture availability (Piperno, 2006). The results reveal that short cells are dominant in most of the samples, namely those from layer II, layers III and III' and layer IV. It is significant to note the high number of inflorescence phytoliths recovered from layer IIIg and to a lesser degree from layers IIIe and 6. Phytoliths from the inflorescence are characterized by presenting elongated morphologies with echinate and/or dendritic margin formed in the glumes, paleas and lemmas that surround the grass seedhead. The identification of the frequently fragile papillae cells, also formed in the inflorescences and associated to the elongated forms, in all layer II samples as well as in layer III, independently of the type of sediment, indicate, together with the sedge phytoliths, for especially good preservation in these layers (Fig. 2e).

The sample from the grey hearth differs from the rest in demonstrating a dominance of phytoliths of leaf/stem of grasses whereas short cells are less abundant. In addition inflorescence phytoliths are present in this sample (Fig. 4).

The short cells belong mostly to the festucoid subfamily (C3 photosynthesis pathway) common in the Mediterranean region (Fig. 2c, f). Nevertheless, samples from layer II present a higher variation of short cells indicating also the presence of C4 grasses, saddle type (Fig. 2g). Short cells bilobate that might correspond to reeds (*Arundo donax*) have been identified in most of the samples except for layer III (south profile) and layer IV (Figs 2h, 5). *Arundo donax* is a giant reed, common in the Mediterranean, growing in fresh and moderately saline waters. Short cells from the festucoid subfamily were observed only in the hearth samples.

INTERPRETATION AND DISCUSSION

With the exception of the hearths, phytoliths are abundant and well preserved in the Upper Palaeolithic layers at Klissoura cave. The morphological variability of the phytoliths indicate difference in plant input related to the provenience of the samples within the cave. Hearth samples differ from sediment samples in presenting different mineralogical composition, lower phyto-

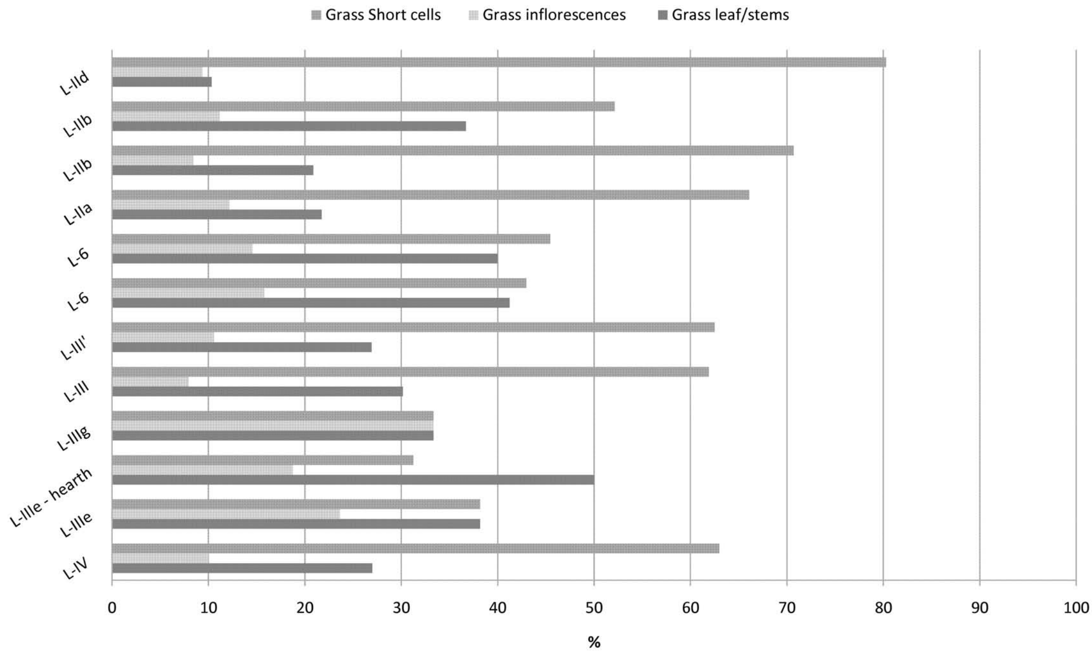

Fig. 4. Histogram showing the morphological distribution of grass phytoliths related to the plant part where they were formed

lith abundance as well as different phytolith morphotypes. Table 2 lists the samples studied with the main results obtained and, when possible, the interpretation derived from them.

Sequence E – Layer IV

This sequence is attributed chronologically to the Early Upper Palaeolithic, one of the most densely occupied periods of the cave as attested by the richness in bones and artifacts. Phytoliths were abundant only in the reddish grey sediment and were practically absent from the rest of the samples that correspond to the hearths. The low estimated amount of phytoliths per gram of AIF observed in the former is due to the presence of clay, probably from the decay of clay structures that diluted the amount of phytoliths (Table 1). This sample was collected from the southern profile close to the entrance of the cave, and therefore the possible natural plant input from outside should be taken into consideration.

Sequence E was deposited during the later stages of MOI3. This was a time of fluctuating climatic condictions marked by alternating stadials and interstadials. The dominant presence of grasses from the C3 festucoid subfamily, in terms of climatic reconstruction for the Klisoura environs (Figs 2c and 2f) attests the presence of sufficient precipitation to support temperate C3 grasses. On the other hand, the higher presence of short cells in relation to other phytolith morphotypes, reflecting better preservation of phytoliths, may indicate a drier climate as noted by the studies of the charcoal (Ntinou, this issue) and micromorphology (Karkanas, this issue). This proposed interpretation may remain a viable hypothesis since the accumulations in the cave are not solely geogenic and may reflect the selection of plants and plant parts by humans who brought them in. However, the climate during this period would be more humid than in later periods, such as those prevailing during the formation of layer II, as stressed below. The identification of sedges (Fig. 3) indicates the presence of nearby water sources during this period. These results are supported by the study of shells demonstrating that about 8% of these correspond to fresh water species. Fresh water lakes, marshes and estuaries

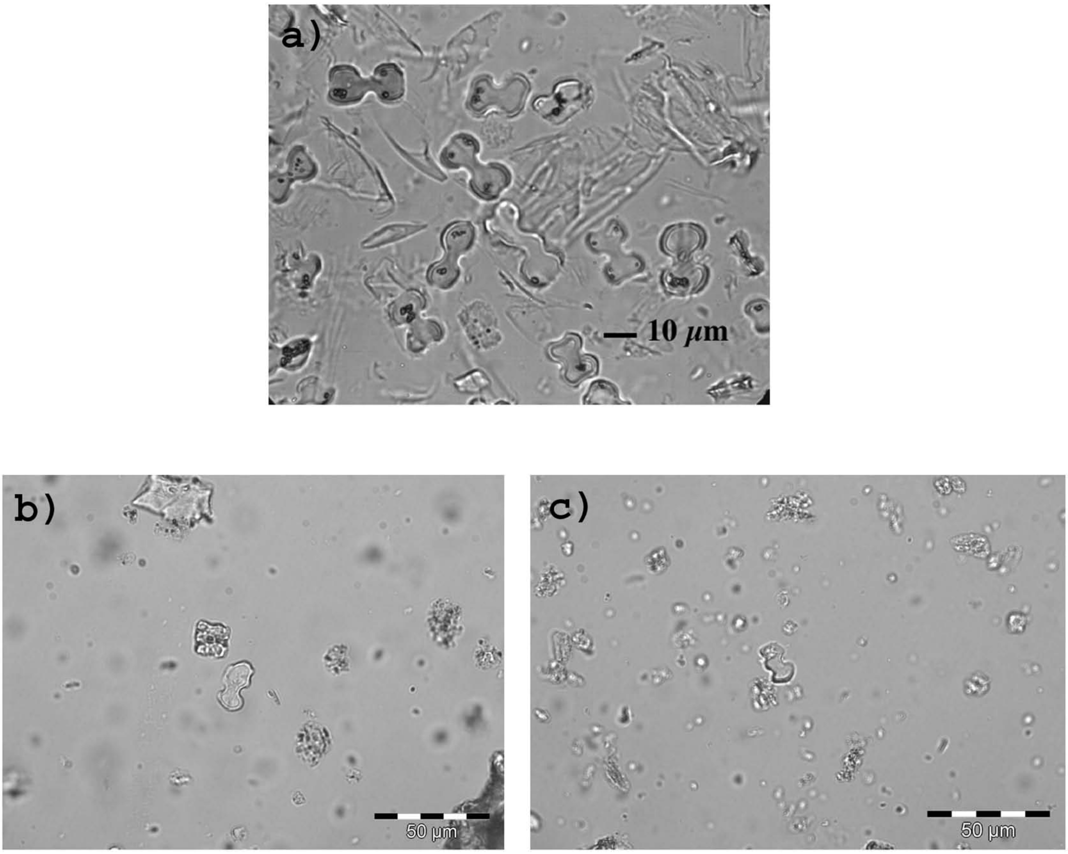

Fig. 5. Photomicrographs of phytoliths. Pictures taken at ×400. a) Short cell bilobate phytoliths from *Arundo donax* (giant reed) from the Levant; b) and c) short cells bilobates probably from *Arundo donax* giant reed identified in Klissoura samples

would be present north and east of the cave (Stiner, this issue). The faunal collections exhibit a slightly higher presence of ungulates related to wet forest environments (Starkovich *et al.*, this issue).

The presence of sedges may reflect a kind of dietary habits. As stated above during this time the cave was densely occupied and therefore different resources should have been exploited to fulfill the needs of the occupants. Considering the dietary advantages, sedges are a valuable source since the rhizomes provide starch and proteins.

Out of the eleven hearths (clay and flat white and gray hearth) analyzed from different profiles of the excavation, none presented adequate amounts of phytoliths for a reliable plant interpretation (Table 1), thus hampering us from making inferences concerning the function of the hearths as either made for cooking or other purposes. The absence of phytoliths from the hearths cannot be explained by dissolution since the frequency of weathering does not substantially differ from the observations of other samples (Table 1). In consequence, the variation in the presence of phytoliths must be related to some anthropic selection of the plant material used for the fires. This observation holds for all the hearths independently of their stratigraphic provenience. The most plausible explanation for the absence of phytoliths is the use of wood as fuel for the fires. Phytoliths are not abundant in these parts of the plants and sometimes they are practically absent (Albert *et al.*, 1999; Tsartsidou *et al.*, 2007). This is especially true for species such as *Olea* and *Pistacia* which

Table 2

Summary of phytolith results with plant presence and interpretation. Only those samples with more than 50 phytoliths morphologically identified have been interpreted

<table>
<tr><th>Stratigraphy</th><th>Locality</th><th>Description</th><th>Dominant group Plants</th><th>Grasses</th><th>Interpretation</th></tr>
<tr><td colspan="6">Sequence B</td></tr>
<tr><td>Layer IIa</td><td rowspan="2">B1-B2-B3 west profile</td><td rowspan="2">brownish grey</td><td rowspan="2">Grasses</td><td rowspan="2">Short cells</td><td>C3 and C4 grass + reeds. Drier environment</td></tr>
<tr><td rowspan="2">Layer IIb</td><td>C3 grass</td></tr>
<tr><td rowspan="2">BB3-AA3 south profile</td><td rowspan="2">reddish brown with stones</td><td rowspan="2">Grasses</td><td>Short cells, leaf-stems</td><td>C3 and C4 grass + reeds. Drier environment</td></tr>
<tr><td>Layer IId</td><td>Short cells</td><td>C3 grass</td></tr>
<tr><td colspan="6">Sequence C</td></tr>
<tr><td rowspan="2">Layer 6</td><td rowspan="2">B1-A1 north profile</td><td rowspan="2">grey-brown loose pit</td><td>Grasses</td><td rowspan="2">Short cells, leaf-stems</td><td rowspan="2">C3 grass</td></tr>
<tr><td>Grasses/monocots</td></tr>
<tr><td colspan="6">Sequence D</td></tr>
<tr><td>Layer III</td><td rowspan="2">B1-B2-B3 west profile</td><td>white cemented</td><td>Grasses</td><td>Short cells</td><td>C3 + reeds</td></tr>
<tr><td>Layer III'</td><td>light grey</td><td>Grasses</td><td>Short cells</td><td>C3 + reeds</td></tr>
<tr><td rowspan="2">Layer IIIe</td><td>BB3-AA3 south profile</td><td>grey with stones</td><td>Monocots</td><td>Short cells, leaf-stems, inflorescences</td><td>C3 grass. Higher flower input. Little grass variation. Temperate and humid environment</td></tr>
<tr><td>B1-A1 north profile</td><td>grey flat hearth</td><td>Monocots, wood/bark</td><td>Leaf/stem, inflorescences</td><td>C3 grass</td></tr>
<tr><td>Layer IIIg</td><td>BB3-AA3 south profile</td><td>grey</td><td>Monocots</td><td>Short cells, leaf/stems, inflorescences</td><td>C3 grass. Higher flower input. Little grass variation. Temperate and humid environment</td></tr>
<tr><td colspan="6">Sequence E</td></tr>
<tr><td>Layer IV</td><td>BB3-AA3 south profile</td><td>reddish grey</td><td>Grasses/monocots</td><td>Short cells, leaf/stems, inflorescences</td><td>C3 grass, sedges. More humid environment, fresh water sources nearby</td></tr>
</table>

contain a very low number of phytoliths both in their wood and bark (Albert *et al.*, 2000; Albert and Weiner, 2001). Moreover, the micromorphological study exposed the abundance of wood ash crystals and a high degree of calcination of the ash components (Karkanas, this issue). This fact, added to the low phytolith abundance, supports the possible function of hearths for cooking purposes consistent with the results obtained through the study of ethnoarchaeological fires among the Hadza people (Mallol *et al.*, 2007).

Sequence D – Layer III

Culturally this sequence has been assigned to the Aurignacian cultural tradition although there is some discussion concerning layer III' which according to the tool industry does not seem to correspond to this chronological time-period (Kozłowski, this issue). Nevertheless, in terms of mineralogy and phytolith abundance our results indicate homogeneity among all analyzed samples.

Mineralogically all the samples show a higher calcitic component due to the high presence of burnt features in this sequence (Table 1). The higher dissolution of phytoliths observed here might be related to water dripping or ponding that increased the pH and accelerated the phytolith dissolution. This phenomenon has been observed through the micromorphological analyses locally and in all the sequences (Karkanas, this issue). Morphologically, however, there were variations related to the different stratigraphic sub-layers, types of sediment, among the southern and western samples.

Samples from the southern area of layers IIIe and IIIg, close to the entrance of the cave, show some morphological differences. The grey sample with stones from layer IIIe presents the high abundance of dicotyledonous leaves phytoliths whereas the grey sample from layer IIIg exhibit the dominant presence of wood/bark phytoliths. These morphological differences could be related to anthropic activities more than changes in vegetation since both represent different parts of dicotyledonous plants. It is noteworthy among the grasses, the presence of inflorescence phytoliths suggesting an important input of plant material during the flowering season. Moreover, the minimal phytolith morphological variability in these samples probably indicates that only few species from the C3 festucoid grass subfamily were introduced into this southern area of the cave. Hence, the occupation of the layers IIIg and IIIe in the south profile reflects a low variation of grasses that have been collected during the flowering season, and in layer IIIg, associated with a considerable input of wood/bark. The reason for the high presence of inflorescence of grasses in these layers is not obvious. The possibility of using grasses for dietary purposes in Klissoura cave during the Upper Palaeolithic period should not be disregarded and would explain both the important presence of inflorescence phytoliths as well as the minimal variability of grass plants. Grass seeds, as well as other plant seeds were already identified during the previous studies of several hearths at Klissoura (Koumouzelis *et al.*, 2001), suggesting that consumption of plant seeds was common during the Aurignacian times. Madella *et al.* (2002) identified the use of grass seeds as part of the diet in Amud cave already during the Middle Palaeolithic period in Israel. Thus, the inhabitants of Klissoura were able to bring to the cave selected grasses for consumption. Once they extract the seeds from their surrounding cover where the phytoliths are found this wasted material found its way to the cave deposits. Similarly sedges were also consumed as mentioned above concerning layer IIIe (Fig. 3).

Samples from layers III and III' from the western area practically presented identical results in terms of mineralogical composition, phytolith abundance and morphological record even though they correspond to two different types of sediments, namely, the white cemented and light grey, suggesting that these deposits were formed under similar conditions and with same vegetal input in terms ofantity and type (Table 1, Figs 2, 3). These results support the dates that are statistically undifferentiated (Kuhn *et al.*, this issue) and are independent of the changes in cultural behaviors as reflected by the lithic analysis.

Grasses in layers III and III' show a dominance of short cell phytoliths from the festucoid subfamily and probably some reeds similar to that observed in layer II (such as *Arundo donax*) (Table 2).

Phytoliths from six hearths were analyzed and in only one (the grey flat hearth from layer IIIe) they could be morphologically interpreted. The most important difference noted in this hearth in relation to the surrounding sediment samples, in addition to the remarkably lower abundance of phytoliths, relates to the variation in plant-part distribution, indicating that certain plant parts or groups of plants were selected for the fires, namely the leaves/stems of grasses and wood/bark of dicotyledonous plants. Herbaceous plants and dicotyledonous leaves were probably used in the hearths to assist in starting the fire. Charcoal analysis indicates that the hearths from this period employed more mesophillous species such as *Ulmus*, *Prunus* and deciduous *Quercus* (Ntinou, this issue). The identification of phytoliths from the C3 festucoid subfamily does not indicate important changes in the climatic conditions during this period in comparison to the previous one.

Sequence C – Layer 6

The two samples analyzed derived from a large pit (Karkanas, this issue) were defined as being mainly formed by grey-brown loose sediment. Mineralogically, as well as quantitatively, the samples are similar to one another, even though there are some important differences in phytolith morphological composition. Characteristic grass phytoliths are more common in one sample whereas monocotyledonous phytoliths, that may include grasses and other plants such as sedges, are more abundant in the other. The distribution of grass phytoliths is very similar in both samples; there is little morphological variation with a major presence of leaves than in the previous layers. Festucoid C3 grasses are the only morphotypes recognized. The lower amount of phytoliths per gram of material in both samples, taking into account the low dissolution rate observed, indicates that in layer 6 (derived from the north profile at the back side of the cave) plants were either less abundant or the assemblage composed of plants that produce fewer phytoliths. If this area is interpreted as a dumping area, the lower plant input was probably due to the mixing with other discarded remains. On the other hand the noted morphological differences may well point to two different depositional events either during the same period or from different areas.

One of the few intact burnt features – the white flat hearth – located in this sequence could not be interpreted in terms of the presence of phytoliths thus indicating a different plant input in respect to the surrounding sediment samples, and the probable use of wood as fuel. The low AIF percentage indicates a very high calcitic component and suggests the use of wood as fuel. Moreover, according to the micromorphological study, this layer 6 was overloaded with pure wood ash (Karkanas, this issue).

Sequence B – Layer II

The samples corresponding to the Epigravettian culture tradition were the richest in phytolith (Table 1). Samples were defined as “brownish grey” and “reddish brown with stones”. Nonetheless, the results were homogeneous with a similar phytolith dissolution percentage, estimated number of phytoliths per gram of AIF and AIF %. Phytoliths were found in relatively good preservation and were easily identified. There are no differences among these samples whether among the distribution of morpho-types, presence of characteristic grass phytoliths associated with monocotyledonous and dicotyledonous wood/bark phytoliths. Regarding grasses, the phytoliths from the inflorescences were noted in lesser number than in the samples from layer III. Noteworthy is the identification in two of the samples of short cells phytoliths from the C4 group (chloridoid subfamily) associated with C3 grasses, and possibly reeds such as *Arundo donax*. Surprisingly these two samples correspond to two different sub-layers from different profiles and different type of sediment. One sample was collected from layer IIa B1-B2-B3 west profile from brownish grey sediment, whereas the second sample was collected from layer IIb, BB3-AA3 in the south profile, from the reddish brown sediments with stones. The other brownish grey sample from layer IIb also bear phytoliths, probably from reeds, but to a lesser degree. The identification of C4 phytoliths from the short grass chloridoid subfamily suggests a drier environment than older layers associated to a more open landscape. This interpretation is consistent with the anthracological study that marks the disappearance of the mesophilous component and the presence of *Prunus amygdalus/spinosa* which grows in relatively arid and more open environments (Ntinou, this issue). It should be noted, that, although drier conditions were recorded for previous times, no C4 grasses were identified until this period, suggesting a more drastic change in the climatic conditions that favored the development of the short grasses and which coincides with the early Last Glacial Maximum, the expansion of the open steppic landscape and the disappearance of many of trees.

The archaeological study revealed that during the Epigravettian period the intensity of the occupation was less intense than during the Aurignacian in sequences C, D and E. Furthermore, as Klissoura is a relatively open cave thus the impact of the natural plant input from outside during periods of non-occupation should be taken into account.

SUMMARY

The presence of plant material in Klissoura cave 1 varied according to the different locations in the cave, different stratigraphic sequences and different archaeological provenience. Sediment samples show a relatively abundant presence of plants probably reflecting different uses and allowing for a climatic reconstruction of various periods. Moreover, the study of the phytoliths proved to be critical on showing the drastic changes in climate that occurred during the early Late Glacial period identified by the proliferation of C4 grasses in layer II times. Nevertheless, it did not have the same resolution when we examined the variations dated to the later stages of MIS3 where C3 grasses remain constant with no independently apparent changes reflecting climatic fluctuations. The only indication of drier climate during these periods could be the major presence of short cells which are formed in plants regardless of moisture availability. Nevertheless, and as it has already been stated, this assumption should remain as hypothesis since the deposit, are mostly anthropogenic and thus with a potentially important human impact. In this regard, the interpretation of the phytoliths should rely on other results such as micromorphology or anthracological analyses to better interpret the climate reconstruction of the periods of the Early Upper Palaeolithic and the Aurignacian.

Concerning the anthropological interpretation of phytoliths, the higher input of phytoliths observed in layer II is perhaps not entirely related to anthropic activities but to plant deposition reflecting the natural environment surrounding the cave. In the lower layers III and IV the decreased amount of phytoliths is related to a more intense human occupation, when plants were brought into the cave for different purposes such as food source, fire, bedding, etc. Of great interest is the identification of grass inflorescences in all the samples and most particularly in layers IIIe and IIIg where it could have been indicative of dietary consumption of grass seeds. Worth noting is the exploitation of sedges as part of the human diet mainly during the deposition of layer III as well as in layers IV and II.

The study of hearths deserves special mention due to the important differences noted in the comparison to the sediment samples. The total absence of phytoliths in the hearths, independently on their type, main mineralogical component and location, indicates a different plant input for fuel. There is only one sample that points to the use of leaves/stems of monocotyledonous plants and wood/bark consisting the main fuel. The presence of wood was undoubtedly more important than its representation by the occurrence of phytoliths. Wood/bark of dicotyledonous trees produces 20 times less phytoliths than grasses (Albert and Weiner, 2001). Moreover the presence of phytoliths from wood and bark among some Mediterranean trees is very low and sometimes practically absent (Albert *et al.*, 1999, 2007; Albert and Weiner, 2001; Tsartsidou *et al.*, 2007). The use of wood/bark for the fires is supported by the presence of calcium oxalate crystals identified during our previous study of the hearths (Koumozuleis *et al.*, 2001) and by the abundant presence of wood ash crystals identified during the micromorphological study (Karkanas, this issue). Therefore it is plausible to assume that wood/bark would have been the main component of fuel for making fires. According to both, phytolith and micromorphological results (Karkanas, this issue), herbaceous plants and dicotyledonous leaves were not particularly used to help setting up the fire probably because wood was collected dried, thus facilitating the combustion.

CONCLUSIONS

Plants are abundantly represented in most of the Upper Palaeolithic sediment samples but not in the hearths. Grasses are the most important component among the plants and generally correspond to the C3 festucoid subfamily which is also the most common in the Mediterranean area. However, other grass phytoliths have also been identified belonging to the C4 grasses and probably several reed species (e.g., *Arundo donax*) in sequence B, suggesting a drier and more open environment during the Epigravettian period. The important presence of phytoliths from the inflorescences in some of the samples from sequence D, layer III and sedges from sequences D and E, layers IIIe and IV points to the possible use of these plants for consumption during the early Aurignacian. Hearths did not contain phytoliths in the same proportion as their corresponding sediment samples indicating, a different and selective plant input for the hearths, related to a higher use of dicotyledonous wood/bark plants and leaf/stem of grasses and other monocotyledonous plants, but in lesser abundance.

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