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A palaeoenvironmental reconstruction (based on palaeobotanical data and diatoms) of the Middle Pleistocene elephant (*Palaeoloxodon antiquus*) butchery site at Marathousa, Megalopolis, Greece

M.H. Field^{a,*}, M. Ntinou^{b,f}, G. Tsartsidou^{c,f}, D. van Berge Henegouwen^a, J. Risberg^d, V. Tournloukis^e, N. Thompson^e, P. Karkanas^f, E. Panagopoulou^c, K. Harvati^e

^a Faculty of Archaeology, Leiden University, van Steenisgebouw, Einsteinweg 2, 2333CC Leiden, The Netherlands

^b Plantcult, ERC CoG, Horizon 2020, Aristotle University of Thessaloniki, KEDEK, Balkan Center, Building B, 57001, Thessaloniki, Greece

^c Ephoreia of Palaeoanthropology – Speleology, Ardittou 34b, 11636, Athens, Greece

^d Department of Physical Geography, Stockholm University, S-10691, Stockholm, Sweden

^e Senckenberg Centre for Human Evolution and Palaeoenvironment, Eberhard Karls Universität Tübingen, Rümelinstraße 23, 72070, Tübingen, Germany

^f Malcolm H. Wiener Laboratory for Archeological Science, American School of Classical Studies, Soudias 54, 10676, Athens, Greece

A B S T R A C T

Exposures of Middle Pleistocene lacustrine sediments at the margins of an open-cast lignite mine at Marathousa near Megalopolis, western Arcadia, Greece yielded the partial remains of a *Palaeoloxodon antiquus* skeleton which exhibited signs of being butchered. Sedimentation occurred between ca. 400 and 480 ka. Lithic artefacts were found in close spatial and stratigraphic association with the elephant remains. A palaeobotanical investigation (involving carpological, phytolith and wood remains) as well as diatom analysis led to a detailed reconstruction of the local environment at the time of sediment deposition. The results of this study enabled the environmental context of the butchering of the *Palaeoloxodon antiquus* carcass to be established. Palaeobotanical data show that sediment deposition at the *Palaeoloxodon antiquus* site occurred in shallow water in front of a reed swamp with trees in the immediate surroundings (particularly *Alnus* and *Salix*) on a flat plain where the water table was at or just below the ground surface. Warm conditions prevailed at the time of sediment deposition allowing aquatic plants typically recorded in the climatic optima of European interglacial assemblages to occur (e.g. *Brasenia schreberi*) and palms (Palmae) to live close-by. This suggests that the organic-rich sediments that contain the archaeological finds represent a transition between the underlying clastic sediments deposited during colder conditions and the overlying lignite that was deposited during warm climatic conditions as reported in previous studies.

1. Introduction

At times during the Pliocene and Pleistocene a graben basin located between mountains in the centre of the Peloponnese, western Arcadia, Greece was occupied by lakes (Vinken, 1965). Sedimentation in these lakes lead to the accumulation of lacustrine deposits that, at certain levels, developed into commercially important lignite horizons. Extraction of these lignite deposits has taken place in open-cast mines leading to on site electricity production in two power stations near Megalopolis (Fig. 1). Geological sections exposed during these operations have provided a unique opportunity to not only investigate the lithology, sedimentology and stratigraphy of the sediments, but also to study the fossils (both botanical and faunal) which they contain, as well

as to conduct a targeted survey to identify signs of human presence in the Pleistocene (e.g. Harvati, 2016, Thompson et al., this issue, Tournloukis and Havati, 2018). Fossiliferous sediments of this type are rare in the Mediterranean region.

A recent archaeological excavation at the margin of the lignite open-cast mine at Marathousa (37° 24' 31" N, 22° 5' 29" E) near Megalopolis (locality Marathousa 1 or MAR-1), conducted by the Ephoreia of Paleanthropology and Speleology (Greek Ministry of Culture) in collaboration with the University of Tübingen, Germany in the framework of the ERC Project 'Paleoanthropology at the Gates of Europe' (PaGE, Harvati and Tournloukis, 2013), exposed fossiliferous lacustrine sediments which contain lithic artefacts and an incomplete elephant skeleton of *Palaeoloxodon antiquus* (Panagopoulou et al., 2015;

* Corresponding author.

E-mail address: m.h.field@arch.leidenuniv.nl (M.H. Field).

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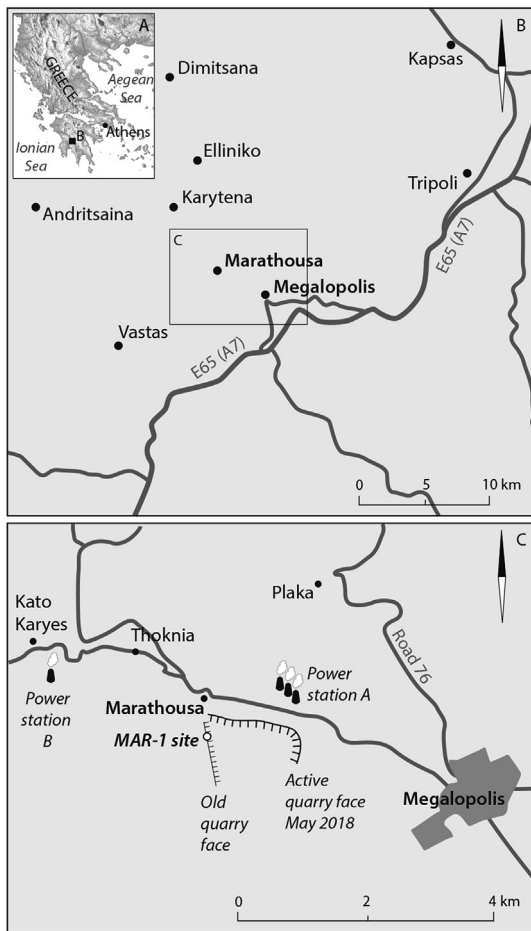


Fig. 1. Location of the Marathousa 1 site near Megalopolis, western Arcadia, Greece. At the site Area A is located approximately 60 m north of Area B.

Panagopoulou et al., this issue; Fig. 1). Cut marks on some of the elephant bones show that hominins were using stone tools to butcher the animal at the time of sediment deposition (Konidaris et al., this issue). Tourloukis et al. (a - this issue) remark that the MAR-1 lithic assemblage includes small-sized flakes together with a few cores, some retouched tools, and much debris. Their interpretation is that this was a special-purpose site where knapping focused on tool manufacture and maintenance. Dates of between ca. 400 and 480 ka, obtained using OSL and ESR (Blackwell et al., 2016 & Jacobs et al., this issue), indicate that the sequence that yielded the *Palaeoloxodon antiquus* remains is Middle Pleistocene in age and correlates with MIS 12 (Tourloukis et al., b - this issue).

The fossiliferous deposits are sandwiched between two lignite units (II – the lower and III – the upper) (Fig. 2). The MAR-1 fossiliferous sediments were sampled from two excavation areas (Area A and Area B) to allow analyses of plant macrofossils (carpological and wood remains), diatoms and phytoliths. The aim was to use the palaeobotanical data generated from these investigations to make local, detailed reconstructions of the vegetation and environment just before, at the time of, and immediately after hominin activity at the site. The botanical fossil types studied allow detailed, local palaeoenvironmental reconstructions because of their taphonomy (often they are not transported far from source) and, particularly in the case of the carpological remains, the level to which they can be identified (if preservation is good species determinations are often possible). A comparison of the palaeobotanical data from Areas A and B was made to attempt to determine the location of the shoreline at the time of sediment deposition. In addition, biostratigraphic markers were used to contribute to the

understanding of the age of the sediments. Owing to the ongoing nature of the excavation, the results presented here are those from the first phase of the site investigation.

2. Lithology, sedimentology and stratigraphy of the Marathousa 1 sequence

Karkanias et al., (this issue) give a comprehensive description and discussion of the 4–5 m thick lacustrine and fluviolacustrine clastic sediments sandwiched between Lignite Seam II and III at Marathousa 1. They comment that Marathousa 1 is situated on the western side of the Megalopolis basin and here the clastic sediment sequence between Lignite Seam II and III is relatively thin compared to other parts of the basin where the sequence of clastic sediments can be up to 15 m thick. Previous studies have concluded that the lignite seams were laid down as peats in a limno-telmatic environment that experienced high pH, reduction conditions. Palaeobotanical studies suggest that the peats (which eventually formed the lignite) were deposited during warm and humid periods, while the clastic sediments were deposited under cold, dry climate conditions (e.g. Nickel et al., 1996; van Vugt, 2000; Okuda et al., 2002).

It is worth briefly summarizing Karkanias et al.'s (this issue) interpretations of the relevant stratigraphic units within the lacustrine and fluviolacustrine clastic sediments here to provide a basis for understanding the environmental and stratigraphic context of the palaeobotanical data presented in this paper.

Karkanias et al., (this issue) describe Unit UA4 as a bluish grey, massive muddy sand, which they interpret as being deposited during sediment flows into the lake margin (Fig. 2). Sedimentary structures were observed which they considered to be post-depositional slump structures formed in liquified conditions. They concluded that in most places the unit is reworked and mixed with the base of the overlying Unit UA3. Above this two cycles of organic-rich sedimentation were observed. They start at the base with intraclast-rich sediments considered to be deposited during mudflows (UA3c and UA2b) and are overlain by massive organic silts with sand laminae representing discrete surges (UA3a) or fluvial flows (UA2a).

In Area B Karkanias et al., (this issue) describe Unit UB6 as a bluish grey, massive muddy sand which contains deformational sedimentary structures and is stratigraphically correlated with Unit UA4 in Area A. They interpret Unit UB6 as a sediment flow deposited in marshy areas at the edge of the lake which was occasionally influenced by wave activity. Sedimentary structures suggest that post-deposition slumping affected this unit. Above this Unit UB5b/c is described as a dark grey, laminated sand to silty sand with some organic material. This is considered to represent higher energy fluvial flows entering the lake. Next is Unit UB5a, which is a dark grey, organic-rich massive muddy sand which they suggest represents dense sediment flows. Overlying this there are three cycles of organic rich sedimentation identified in units UB4, UB3 and UB2. Each sedimentation cycle is further divided into three parts. The basal component, part c, is an intraclast-rich sediment regarded as being deposited during mudflows, the middle part (part b) is made-up of massive organic silts occasionally interbedded with sand laminae probably deposited by discrete surges, and finally an upper part (part a) is composed of massive silts thought to be deposited as a result of dense sediment flows. Both sequences UA3 to UA2 and UB4 to UB2, in Areas A and B respectively, are transitional organic rich facies below the overlying Lignite Seam III and overlay an organic-poor silt and sand sequence (UA7 to UA4 and UB9 to UB6).

The correlation of the stratigraphic units from Area A to Area B and the stratigraphical position of the archaeological remains are shown in Fig. 2. The archaeological level occurs on an erosional contact that is found between units UA3-UA4 and UB4-UB5 in Area A and B, respectively. It is possible to correlate this level using lithostratigraphy, geochemistry, and analysis of the spatial pattern of lithic artefacts and faunal remains (Karkanias et al., this issue; Giusti et al., this issue).

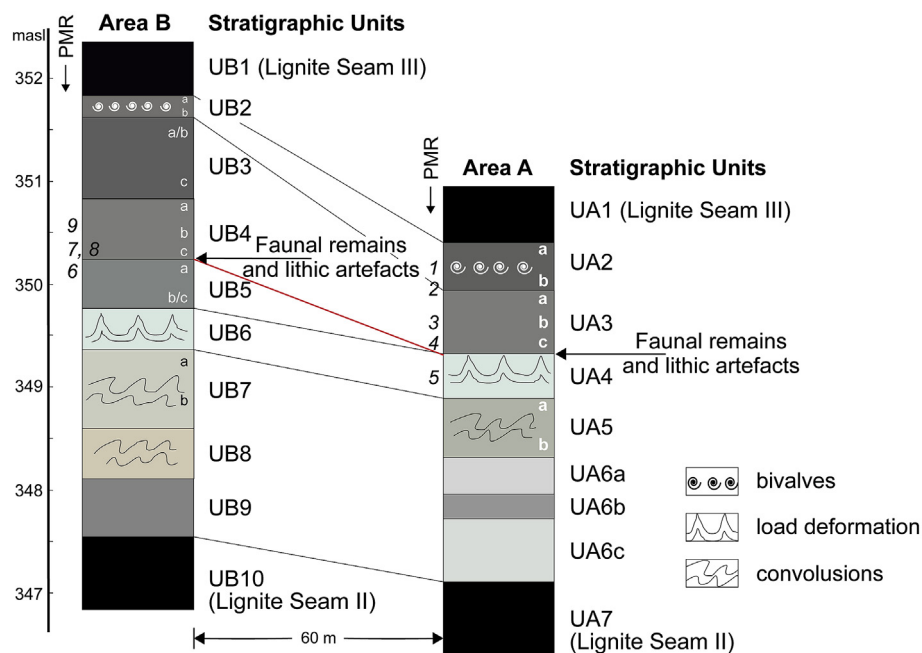


Fig. 2. Diagrammatic logs for Area A and Area B showing the correlation of the stratigraphic units, the level at which the elephant and lithic artefacts were found, and where the plant macrofossil samples were taken. PMR – plant macrofossil residues.

3. Fossil types and extraction methods

Plant macrofossils (carpological remains, wood and wood charcoal), phytoliths and diatoms were investigated. Different methods, which in part were dictated by the excavation procedure, were employed for the recovery of the different fossil types. Firstly, high concentrations of plant macrofossils (mostly carpological remains) became apparent during the processing of the sediments. For this reason, during the second excavation season in 2014 it was decided to extract the carpological remains from selected samples by a floatation method on site. In the following years all the excavated sediment samples were wet sieved. In this paper carpological and wood charcoal data are based on material recovered in 2014. Sorting and analysis of plant macrofossils from the following excavation seasons is in progress and data from this exercise will be presented at a later date.

The excavation exposed units UA3 and UB4 in which existed large surfaces with wood pieces of sizes ranging from a few centimetres to ca. 1 m long (Figs. 3 and 5). Individual large wood pieces as well as bulk wood samples (containing small wood fragments) were recorded and collected for study.

Sediment samples for phytoliths and diatom analyses were taken from all the geological units recorded in the sections between the lignite seams II and III at Marathousa 1.

3.1. Plant macrofossils

The plant macrofossils from Marathousa 1 include carpological, charcoal and wood remains. They are all exceptionally well-preserved presumably because of waterlogged and anaerobic conditions that occurred. Such conditions prevailed as a result of the existence of a high water table prior to pumping associated with the lignite extraction. Systematic sampling for plant macrofossil remains, especially those of a carpological nature, took place during the 2014 excavation campaign. Forty-four sediment samples from all the excavated layers were collected in Areas A and B. The average volume of the sediment samples was 7.3 L. All of these samples were processed in the field using a modified version of the floatation machine described by French (1971). The light fossils that floated were poured into a 0.3 mm mesh size sieve. The heavier fraction sank and was retained in a 1 mm mesh in the

interior of the floatation machine. All the flots and heavy residues were dried. Nine selected samples (Table 1) were investigated for carpological remains to provide data that would allow a reconstruction of the environment when the hominins were active in the area. Plant macrofossils (mainly carpological in nature) were picked from the dried residues and identified using reference material housed in the Archaeo- and Palaeo-botanical Laboratory, Faculty of Archaeology, Leiden, The Netherlands. Presence or absence of plant taxa is recorded from each sediment sample in Table 1. The nomenclature applied to the plant macrofossils follows Tutin et al. (1964–1993).

In Area A, wood charcoal from six water floatation samples and from another twenty-one wet sediment samples was analyzed (Table 2). In Area B, wood charcoal from twenty-one sediment samples processed with the water floatation technique and from another three wet during the excavation was analyzed (Table 2). The carbonized material was analyzed at the M.H. Wiener Laboratory for Archaeological Science using a metallurgical incident light microscope with dark/bright field and $\times 5$ to $\times 50$ magnification lenses. Each charcoal fragment was fractured by hand to expose cross, tangential and radial sections necessary for determination. Relevant literature (Schweingruber, 1990; Gale and Cutler, 2000) and the reference collection housed at the Wiener Laboratory allowed comparisons that lead to precise identifications of the fossil material. Presence or absence of plant taxa is presented by area and stratigraphic unit in Table 3.

Wood pieces were collected in Area A from stratigraphic unit UA3c and the UA3/UA4 contact, the dark grey massive organic silty sand and the bluish grey massive sand, respectively. In Area B, wood pieces were recovered from UB3c, UB4b and UB4c - all three units described as dark grey massive organic silty sand. In total, 83 large individual wood specimens were collected. Each wood specimen was identified, its dimensions measured, and any characteristics noted (presence of bark, knots and cut-marks). In addition, 40 bulk wood samples that were collected from Areas A and B (from stratigraphic units UA3c, UA4 and UB4c) have yet to be analyzed. Wood identification was achieved by examining thin sections under a transmission light microscope with $\times 10$ to $\times 50$ magnification lenses. In many cases anatomical features were difficult to observe, therefore, the method proposed by Figueiral et al. (1999: 241–242) for Miocene wood was used. This involves the carbonization of wood at 450 °C for 25–30 min. In general, compaction

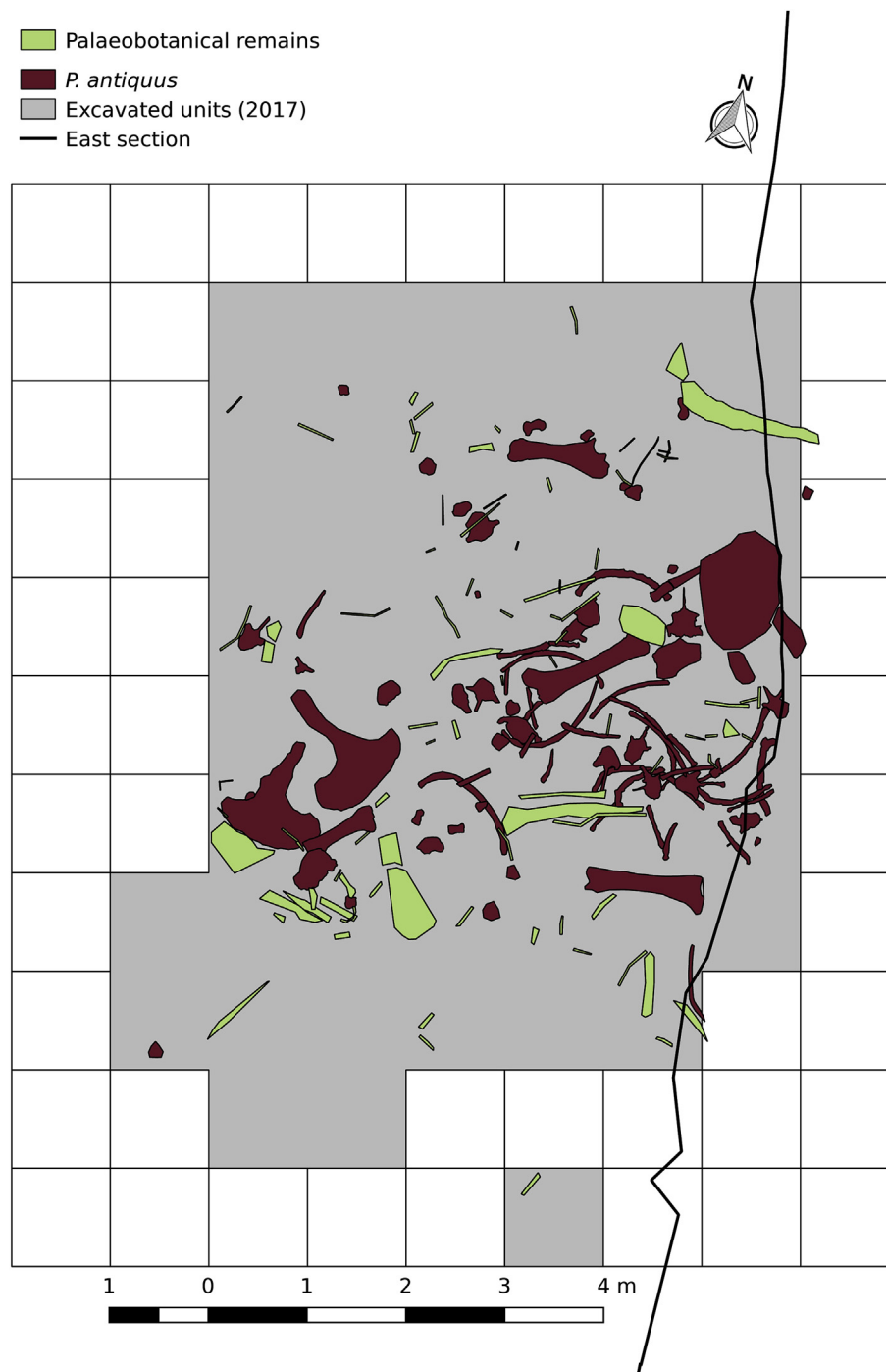


Fig. 3. Distribution of the elephant skeletal remains and the wood fragments in Area A at the UA3/UA4 contact.

made identification difficult (Fig. 6A). The results of the study of wood specimens are presented in Fig. 7.

3.2. Siliceous microfossils (phytoliths and diatoms)

3.2.1. Extraction of the siliceous microfossils (phytoliths and diatoms)

In total, nineteen sediment samples were analyzed; nine samples from sediments of Area A (UA3, UA4 and UA 6a, b, c) and ten from Area B (UB1 to UB9 (table) (Table 4). Unit UA4 was sampled twice to test the reproducibility of the method - samples UA4 (1) and UA4 (2). In thick formations, such as UA6 and UB6, samples were taken every 10 cm up through the sequence in order to detect changes.

A combination of phytolith and diatom standard techniques were

adopted for sample preparation (Tsartsidou et al., 2009; Battarbee, 1986). At first 1 gramme of dried sediment was analyzed from Area A. Samples yielded few microfossils so it was decided to analyze 3 grammes of dry sediment from Area B. Carbonates were removed using a 10% HCl. The residue was washed three times in distilled water by being placed in a centrifuge for 10 min at 3000 rpm. After this the residue was placed in a ceramic crucible containing H₂O₂ and left overnight. The next stage was to heat the residue to 80 °C for 5 hours in order to remove the organic matter. Clay particles were then removed by leaving the residue in ammonia overnight and decanting off the suspended clay particles. Distilled water was added and poured off after 2 hours. This process was repeated several times until the suspension was clear. Next, the residue was placed in a polypropylene centrifuge

Table 1
Plant macrofossil assemblages from selected samples taken during the 2014 excavation at Marathousa 1.

Sample location information	Area A	Area A	Area A	Area A	Area A	Area B	Area B	Area B	Area B
	939/674	939/674	939/674	940/674	940/675	934/610C	934/610C	934/610C	934/610C
	Geo2/Spit 1	Geo3/Spit1	Geo4/Spit1	Geo5/Spit4	Geo6/Spit2	Geo6/Spit3	Geo5/Spit5	Geo5/Spit3	Geo4/Spit3
	z350,13	z350,01	z349,94	z349,46	z349,27	z350,08	z350,15	z350,26	z350,54
	ID 10	ID 13	ID 15	ID 20	ID 49	ID 66	ID 62	ID 48	ID 37
Sample	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9
Stratigraphic unit	UA2b	UA2b/UA3a	UA3b	UA3c	UA4	UB5a	UB4c	UB4c	UB4b
Volume/litres	6	7	7	7	15	7	5	10	3

Woodland and shade tolerant

<i>Acer</i> sp(p).	fruit	X	-	-	-	-	-	-	-
<i>Alnus glutinosa</i>	seed	-	X	-	-	-	-	-	-
<i>Rubus fruticosus</i>	seed	X	X	X	X	X	-	X	X
<i>Sambucus nigra/racemosa</i>	seed	X	X	X	X	X	-	X	X
Vitaceae sp(p).	seed	X	-	-	-	-	-	-	-

Grassland and disturbed ground

<i>Euphorbia</i> cf. <i>exigua</i>	seed	-	X	X	-	-	X	X	X
<i>Linum perenne</i>	seed	-	-	X	-	-	-	-	-
<i>Polygonum minus</i>	nutlet	X	-	-	-	-	-	-	-
<i>Ranunculus</i> cf. <i>sardous</i>	achene	X	-	-	X	-	-	X	X
<i>Verbena officinalis</i>	seed	X	-	-	-	-	-	-	-

Waterside and damp ground

<i>Alismataceae</i> sp(p).	embryo	X	X	X	-	-	X	X	-
<i>Butomus umbellatus</i>	seed	-	X	X	-	-	X	X	X
<i>Cladium mariscus</i>	nutlet	X	-	X	X	X	-	X	-
<i>Damasonium alisma</i>	fruit	-	-	X	-	X	X	X	-
<i>Eleocharis palustris</i>	nutlet	-	X	-	-	-	-	-	X
<i>Lycopus europaeus</i>	nutlet	X	X	X	-	-	-	-	-
<i>Mentha</i> cf. <i>aquatica</i>	nutlet	X	X	X	X	X	X	-	-
<i>Menyanthes trifolata</i>	seed	-	-	-	-	-	-	X	X
<i>Montia fontana</i> subspecies <i>chondrosperma</i>	seed	X	-	X	X	X	-	X	X
<i>Oenanthe aquatica</i>	fruit	X	X	-	-	-	-	-	X
<i>Potentilla palustris</i>	achene	-	-	-	X	X	-	-	-
<i>Ranunculus scleratus</i>	achene	-	X	X	-	-	-	-	-
<i>Scirpus lacustris</i>	nutlet	X	X	X	X	X	X	X	X
<i>Sparganium erectum</i>	fruitstone	X	-	X	X	X	-	X	X
<i>Typha</i> sp(p).	seed	-	X	-	-	-	-	-	-

Aquatic

<i>Aldrovanda vesiculosa</i>	seed	X	-	-	-	-	-	-	-
<i>Azolla filiculoides</i>	megaspore	X	X	-	-	-	-	-	-
<i>Brasenia schreberi</i>	seed	X	-	-	-	-	-	-	-
<i>Ceratophyllum demersum</i>	fruit	-	-	-	X	X	X	X	X
Characeae sp(p).	oospore	-	X	-	-	-	-	-	-
<i>Elatine hydrodiper</i>	seed	-	X	-	-	-	-	-	-
<i>Euryale ferox</i>	seed	X	-	-	-	-	-	-	-
<i>Groenlandia densa</i>	endocarp	-	-	-	X	X	X	X	X
<i>Hippuris vulgaris</i>	fruit	-	-	-	X	X	X	X	X
<i>Myriophyllum spicatum</i>	fruit	X	-	X	X	X	-	-	-
<i>Nuphar lutea</i>	seed	X	X	X	-	X	X	X	X
<i>Nymphaea alba</i>	seed	X	-	X	X	X	-	X	X
<i>Potamogeton coloratus</i>	endocarp	X	X	-	-	X	-	-	-
<i>Potamogeton natans</i>	endocarp	-	-	X	X	X	X	X	X
<i>Potamogeton</i> sp(p).	endocarp	X	X	X	X	X	X	X	X
<i>Potamogeton</i> sp(p).	lid	X	-	X	X	X	-	X	-
<i>Ranunculus</i> subgenus <i>Batrachian</i> sp(p).	achene	X	X	X	X	X	X	X	X
<i>Sagittaria sagitifolia</i>	embryo	-	X	-	-	-	-	-	-
<i>Salvinia natans</i>	megaspore	X	X	X	-	-	-	-	-
<i>Zannichellia palustris</i>	fruit	-	X	-	-	-	-	-	-

(continued on next page)

Table 1 (continued)

Sample location information	Area A	Area A	Area A	Area A	Area A	Area B	Area B	Area B	Area B
	939/674	939/674	939/674	940/674	940/675	934/610C	934/610C	934/610C	934/610C
	Geo2/Spit 1	Geo3/Spit1	Geo4/Spit1	Geo5/Spit4	Geo6/Spit2	Geo6/Spit3	Geo5/Spit5	Geo5/Spit3	Geo4/Spit3
	z350,13	z350,01	z349,94	z349,46	z349,27	z350,08	z350,15	z350,26	z350,54
	ID 10	ID 13	ID 15	ID 20	ID 49	ID 66	ID 62	ID 48	ID 37
Sample	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9
Stratigraphic unit	UA2b	UA2b/UA3a	UA3b	UA3c	UA4	UB5a	UB4c	UB4c	UB4b
Volume/litres	6	7	7	7	15	7	5	10	3

Unclassified

<i>Atriplex</i> sp(p).	seed	-	X	X	-	-	-	X	-
<i>Carex</i> sp(p).	trigonous nutlet	X	X	X	X	X	X	X	X
<i>Carduus/Cirsium</i> sp(p).	achene	-	-	X	-	-	-	-	-
<i>Hypericum</i> sp(p).	seed	-	X	-	-	-	-	-	-
Gramineae sp(p).	caryopsis	-	-	-	X	-	-	X	-
<i>Ranunculus</i> subgenus	achene	X	X	X	X	X	X	X	X
<i>Ranunculus</i> sp(p).									
<i>Rumex</i> sp(p).	nutlet	-	-	-	-	-	X	-	-
<i>Solanum cf. dulcamara</i>	seed fragment	-	-	-	-	-	-	-	X
Undetermined charcoal	charcoal	X	-	-	X	X	X	X	X
<i>Urtica dioica</i>	achene	X	X	-	-	-	-	-	-

tube with 5 ml of heavy liquid solution (Sodium polytungstate) calibrated at 2.4 specific gravity and 1 ml distilled water which was centrifuged for 15 min at 3000 rpm. The residue was centrifuged after being placed in a clean tube with 1 ml of distilled water. More water was added after this before the residue containing phytoliths, sponges and diatoms was dried. Finally, 1 mg of dried residue was mounted on microscope slides (2 slides per sample).

3.2.2. Counting and determining the siliceous microfossils

3.2.2.1. *Phytoliths*. The phytoliths were identified and counted by type. When possible 200 phytoliths were counted on each slide (400 phytoliths per sample). The total number of phytoliths on the slide was then estimated. Samples in which less than 100 phytoliths were counted were ignored because of large statistical error.

Phytoliths were described following the International Code for Phytolith Nomenclature (Madella et al., 2005). They were separated into two major categories: those with consistent morphology that could be observed in more than one sample, and those with variable, irregular or unidentifiable morphology. Phytoliths with consistent morphology were classified into families, genera, and part of the plant. Then the relative proportion of each classification was determined.

The main categories of phytoliths encountered were monocotyledons or monocots (grasses, sedges, reeds and palms) and dicotyledons or dicots. The type of plant part was identified based on phytolith type: dicot woody parts (spheroids and irregular shape phytoliths), dicot fruits and leaves (polygons and polyhedral or honeycomb leaf cells), grass inflorescence (dendritics, echinates, papillae) and grass stem/leaf (long cells sinuate and wavy). Dicot fruit genera (e.g. *Celtis* sp.) and palm tree phytoliths (spiny spheroids) were also recognized. Grass phytoliths were determined to the sub-family level based on cell morphology i.e. Pooideae (rondels and trapeziforms), Chloridoideae (saddles) and Panicoideae (bilobates, polylobates).

3.2.2.2. *Diatom frustules*. Whole diatom frustules were counted as 1. Fragments containing the central part were also counted as 1. Four broken pieces were counted as 1. In most samples less than 100 whole diatom frustules were counted leading to potential bias and error in the

interpretations made. The species were identified using Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b).

Sponges were counted as 1 irrespective of size.

4. Results of the carpological investigation of sediment samples from Marathousa site 1

4.1. Carpological results from excavation Area A

The assemblages recovered from Area A are diverse and are dominated by aquatic, waterside and damp ground plant taxa (Table 1). Submergent (e.g. *Zannichellia palustris*), emergent (e.g. *Brasenia schreberi*, *Euryale ferox*, *Nuphar lutea* and *Nymphaea alba*) and floating (e.g. *Aldrovanda vesiculosa*, *Azolla filiculoides* and *Salvinia natans*) aquatic taxa are recorded. Large concentrations of *Potamogeton* (pondweed) fruits were encountered in all the samples analyzed. The marginal reedswamp was inhabited by tall plants, such as *Butomus umbellatus*, *Cladium mariscus*, *Oenanthe aquatica*, *Scirpus lacustris*, *Sparganium erectum* and *Typha* sp. In addition, some woodland and shade tolerant taxa are represented that would have probably grown in the vicinity on drier ground (e.g. *Acer* sp., *Rubus fruticosus*, and *Sambucus cf. nigra*). Mädlar (1971) identified fruitstones of the liane *Vitis parasilvestris* Kirchheimer from the Megalopolis basin. One Vitaceae fruitstone has been recovered from the Marathousa 1 Area A sediments, but its morphological characteristics most closely match those of the North American climber *Parthenocissus quinquefolia*. More specimens are required before a definite species identification can be made.

The presence or absence data obtained from the Area A dried residues shows no significant differences in the composition of the vegetation before the elephant's death (Unit UA4), at the time of the elephant's death (Unit UA3c) or after the elephant's death (Units UA2a/b, UA3a and UA3b). This may reflect a short period of time being represented in the sediment profile studied.

Of note is that a number of the taxa recorded are exotic to Europe today (e.g. *Brasenia schreberi* and *Euryale ferox*) (Fig. 4).

Table 2

Provenance of the wood charcoal material analyzed and presented in this paper.

AREA	Square	Archaeological layer (GEO)	Spit	z	Stratigraphic Unit	Volume (in l)	Method
A	942/677	3	2	349.83	UA2b + 3a	min. 12	wet sieve
A	942/677	3	1	349.92	UA2b + 3a	min. 12	wet sieve
A	942/677	3	3	349.75	UA2b + 3a	min. 12	wet sieve
A	942/672	3	4	349.6	UA2b + 3a	min. 12	wet sieve
A	942/672	3	5	349.57	UA2b + 3a	min. 12	wet sieve
A	942/672	3	6	349.51	UA2b + 3a	min. 12	wet sieve
A	942/674	4	1	349.58	UA3b	min. 12	wet sieve
A	942/674	4	2	349.53	UA3b	min. 12	wet sieve
A	941/673	5	1	349.45	UA3c	min. 12	wet sieve
A	941/673	5	2	349.34	UA3c	min. 12	wet sieve
A	940/673	5	6	349.16	UA3c	min. 12	wet sieve
A	940/673	5	4	349.39	UA3c	min. 12	wet sieve
A	940/673	5	3	349.49	UA3c	min. 12	wet sieve
A	940/673	5	5	349.32	UA3c	min. 12	wet sieve
A	938/674	6	2	349.06	UA4	min. 12	wet sieve
A	939/674	6	3	349.07	UA4	min. 12	wet sieve
A	939/673	6	1	349.05	UA4	min. 12	wet sieve
A	942/674	7	1	349.15	UA5b	min. 12	wet sieve
A	942/674	6	3	349.21	UA3c	min. 12	wet sieve
A	941/677	5	2	349.67	UA3c	min. 12	wet sieve
A	937/674	5	2	349.33	UA3c	min. 12	wet sieve
A	942/677	1	5	350.05	UA2a	8	water flotation
A	939/674	1	4	350.19	UA2a	7	water flotation
A	939/674	1	3	350.24	UA2a	5	water flotation
A	939/674	2	3	350.13	UA2b	6	water flotation
A	942/677	2	3	349.95	UA2b	12	water flotation
A	939/674	5	2	349.69	UA3c	12	water flotation
B	934/594 A	1	3	350.84	UB4a	7	water flotation
B	934/594A	2	1	350.79	UB4b	7	water flotation
B	934/594A	2	2	350.73	UB4b	7	water flotation
B	934/594	3	1	350.62	UB4c	5	water flotation
B	934/594 A	3	2	350.55	UB4c	7	water flotation
B	934/594 A	3	3	350.49	UB4c	7	water flotation
B	934/594 A	3	4	350.43	UB4c	7	water flotation
B	934/594 A	4	2	350.23	UB5a	6	water flotation
B	934/610C	1	2	351.28	UB3a/3b	5	water flotation
B	934/610C	1	4	351.13	UB3a/3b	7	water flotation
B	934/610C	1	5	351.03	UB3a/3b	5	water flotation
B	934/610C	2	1	350.91	UB3c	8	water flotation
B	934/610C	3	1	350.79	UB4c	8	water flotation
B	934/610C	4	1	350.7	UB4b	8	water flotation
B	934/610C	4	2	350.6	UB4b	7	water flotation
B	934/610C	4	3	350.54	UB4b	3	water flotation
B	934/610C	5	1	350.49	UB4c	9	water flotation
B	934/610C	5	2	350.37	UB4c	8	water flotation
B	934/610C	5	3	350.26	UB4c	10	water flotation
B	934/610C	5	4	350.19	UB4c	7	water flotation
B	934/610C	5	5	350.14	UB4c	5	water flotation
B	932/599B	1	4	350.55	UB4c	min. 12	wet sieve
B	932/595D	4b	8	350.44	UB4c	min. 12	wet sieve
B	933/594	4	5	350.35	UB4c	min. 12	wet sieve

4.2. Carpological results from excavation Area B

All the assemblages from Area B are dominated by waterside and damp ground, and aquatic taxa and are of a similar composition to those recovered from samples collected in Area A (Table 1). Woodland and shade tolerant taxa are present in Units UB4b and UB4c (i.e. at or just above the horizon that contained the lithic artefacts). However, Unit UB5 (located below the horizon containing the lithic artefacts) contained no fossils from woodland and shade tolerant taxa. There is no equivalent stratigraphic unit in Area A and, therefore, no comparison is possible. An assessment of the position of the shoreline during the hominin activity episode is difficult to make based on the carpological data alone because of the method used to extract the carpological fossils from the sediment subsamples. Extraction of all carpological fossils from known volumes of sediment would lead to the production of quantitative concentration data that could allow a more confident assessment of the proximity of the woodland. This approach is being applied in ongoing investigations. There is sedimentological evidence

that suggests that Unit UB5 may represent a period of sedimentation immediately after a significant depositional hiatus (Karkanas et al., this issue).

5. Wood and wood charcoal remains from the Marathousa site 1 sediments

5.1. Wood

Wood remains at Marathousa 1 are present in varying amounts in all the excavated stratigraphic units from Areas A and B (Fig. 7). The sorting of wet-screened sediment residue is in progress and will allow wood concentration to be established in the stratigraphic units. At this stage, on the basis of observations made in the field and laboratory, it is apparent that small size wood fragments (< 5 cm) are present in all the excavated units above UA5 and UB6. Of note, is that in Units UA3c and at the UA3/4 contact in Area A there are not only small size wood fragments, but extensive surfaces composed of large branch/trunk

Table 3
The results of the analysis of wood charcoal specimens from selected sediment samples.

Taxon	Area A						Area B						
	UA5b	UA4	UA3c	UA3b	UA2b/3a	UA2b	UA2a	UB5a	UB4c	UB4b	UB4a	UB3c	UB 3a/3b
Acer sp.			*		*								
Alnus sp.	*	*	*	*	*					*		*	*
<i>Alnus/Corylus</i>				*	*				*				
cf. <i>Corylus</i>									*				
cf. <i>Laurus</i>					*								
Pomoideae			*										
<i>Quercus</i> sp. deciduous			*	*		*			*				
<i>Quercus/Castanea</i>			*		*								
<i>Salix</i> sp.		*	*	*	*	*	*		*	*			*
<i>Salix/Populus</i>									*			*	
<i>Ulmus/Celtis/Zelkova</i>		*	*		*				*	*			
<i>Phragmites/Arundo</i>		*	*	*	*		*						
cf. <i>Palmae</i> type 1	*			*									*
cf. <i>Palmae</i> type 2		*	*			*			*				
Monocot type 1			*	*		*							
Monocot type 2			*										
Monocot (lignified)		*	*		*								
Angiosperm	*		*	*			*	*	*	*	*	*	*
Indeterminate			*										
cf. <i>Fern</i>			*			*							

Table 4
Total number of phytoliths, diatoms and sponges per gramme of dry sediment.

Unit	Phytoliths/gramme sediment	Diatoms/gramme sediment	Sponges/gramme sediment
UA 3 c	5634	96	37091
UA 4 (1)	3742	145	42552
UA 4 (2)	2675	572	37762
UA 6a	99	0	236
UA 6b	384	0	238
UA 6c (1)	8	0	0
UA 6c (2)	11	0	0
UA 6c (3)	61	6	126
UA 7	383	18	5465
UB 1	30194	14347	432127
UB 2	141242	4765	265837
UB 3	92549	4808	138921
UB 4b	27847	781	25967
UB 5	20363	3973	77539
UB 6 Lo	27465	1962	98761
UB 6 Up	75116	13180	14713
UB 7	3065	166	9986
UB 8	2676	282	7026
UB 9	47401	2419	246051

wood pieces (> 5 cm and up to ca. 100 cm). In Area B, Units UB3c and UB4c also contained large wood surfaces but not as large as those recovered from Area A. In both Areas A and B the large wood surfaces occur primarily in the organic rich silty sands with the elephant remains and lithic artefacts (Units UA3c, UB4b and UB4c) as well as at the erosional contact with the underlying bluish grey muddy clays (UA4) in Area A and the overlying organic rich silty sands (UB3c) in Area B.

Fig. 7 summarizes the results of the study of the 82 wood specimens from the afore-mentioned units from Areas A and B. Microscopic identification has been carried out for all wood specimens. Compression of the woody tissue has severely affected the cross section in all cases (e.g. Fig. 6A). The anatomical characteristics were less affected in the longitudinal sections and allowed the identification of the following taxa: *Alnus*, *Alnus/Corylus*, *Salix*, *Salix/Populus*, Ulmaceae (*Ulmus/Zelkova/Celtis*), *Quercus* deciduous, cf. *Quercus* and angiosperm. On 64.7% of the wood pieces bark is preserved, while 76.8% wood fragments had knots and/or scars. No anthropogenic modification has been observed in any of the wood specimens examined.

The woody assemblages from Units UA3c, UA3/4 contact, UB4c and

UB3c are characterized by low taxa diversity and are dominated by *Salix* and *Alnus*. *Ulmus* type and *Quercus* are rare (Fig. 7). Many specimens could only be determined as angiosperms. It is interesting to note that conifers are absent from the assemblages. The size of wood remains in these units ranges between 5 and > 100 cm in length, and therefore, no sorting by size occurred. This indicates that pieces of wood were rapidly dumped on inundated ground by mudflows as suggested by the sedimentological analysis (Karkanis et al., this issue). This contrasts with the situation observed in all other units above UA3c and UB4b/c where small wood fragments (< 5 cm) were predominantly deposited. These smaller wood fragments were probably deposited by fluvial activity and concentrated by wave action.

The predominance of *Salix* and *Alnus* in the wood assemblage of UA3c, UA3/4 contact, UB3c and UB4c indicates the existence of alluvial forests growing on the flat, less well-drained ground bordering the lake. Such vegetation would require periodical surface inundation. In the vicinity, on better drained ground, hardwood alluvial woodland with *Ulmus* and deciduous *Quercus* existed. The presence of Ulmaceae and deciduous *Quercus* indicates temperate conditions.

5.2. Wood charcoal

Wood charcoal remains were present in the majority of the sediment samples investigated from both Areas A and B (Table 2). Natural fires around the lake probably produced this material. Wood charcoal fragments are light and may have been transported over long distances before being washed into the lake.

Quantitative analysis of the assemblages is still in progress and will be published at a later date. The qualitative results of the analysis of wood charcoal remains from the upper part of the sequence in Area A are presented in Table 3. The taxa that are found in most of the assemblages are *Salix*, *Alnus* and *Phragmites/Arundo* (Fig. 6). Similar to the wood remains presented in the previous section, the presence of these taxa testifies to the existence of alluvial woodlands and reed swamps growing on the less well drained flat areas surrounding the lake. The stems of monocotyledon plants are frequent in the samples and their diverse anatomy implies that different taxa may have been present. cf. *Palmae* charcoal fragments (Fig. 8A–E) are present in UA5, in UA4 and UA3 (Table 3) and there is evidence of ferns in UA3c (Fig. 6L and Table 3). Additional woody taxa are present; the commonest being *Quercus* and *Ulmus*, but *Acer*, Pomoideae and cf. *Laurus* are present in UA3 and UA2.

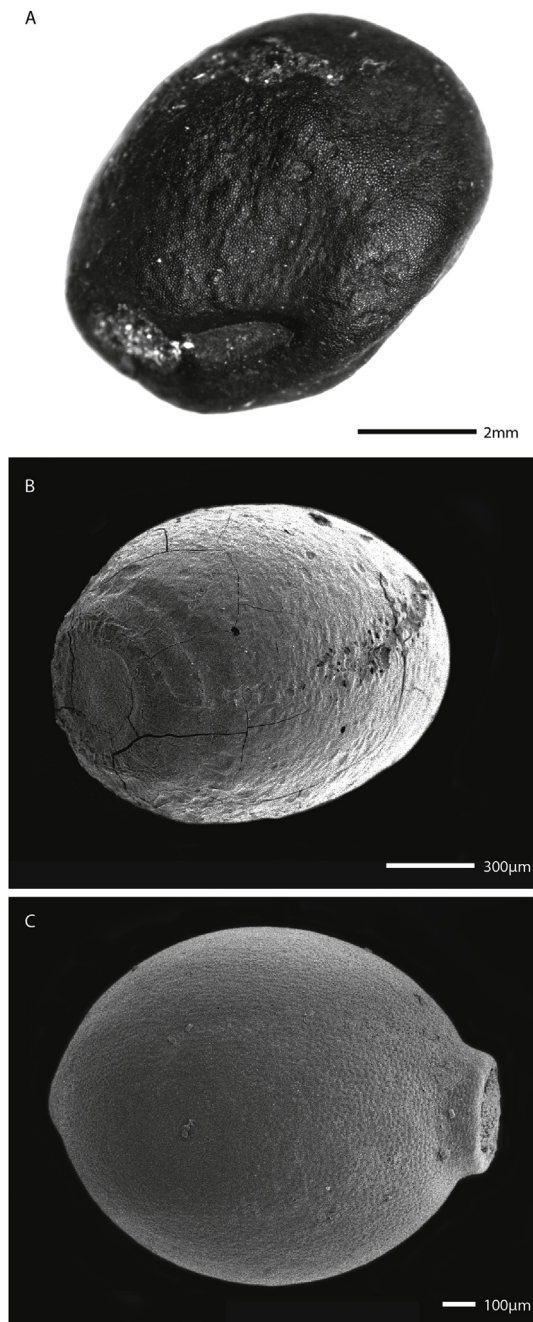


Fig. 4. A: Image of a seed of *Euryale ferox* from UA2b in Area A. B: SEM image of *Brasenia schreberi* from UA2b in Area A. C: SEM image of *Aldrovanda vesiculosa* from UA2b in Area A.

Differences in the composition of the assemblages between the stratigraphic units cannot be identified at this preliminary stage of analysis especially since the number of studied samples is low and quantification has not been attempted. Overall, Unit UA3 is the richest in terms of taxa and includes plants from the azonal vegetation (the damp woodland and the reed swamp) and temperate woodland (such as *Acer*, *Quercus*, *Ulmus*) as well as other taxa such as cf. *Palmae* (Fig. 8A–E) indicating warm conditions.

The results of the study on wood charcoal remains from the upper part of the sequence in Area B are presented in Table 3. Similar to Area A, the woody taxa that are well represented in most of the assemblages in Area B are *Salix* and *Alnus*, thus suggesting the presence of damp woodland nearby. A greater variety of taxa are recorded in UB4 where the temperate taxa *Ulmus* and *Quercus* are present along with cf. *Palmae*

(Fig. 8A–E). These data are in agreement with those from UA3.

6. Phytolith results

6.1. Quantitative results

Despite poor phytolith preservation reproducibility of the method is good. However, the limited information from the phytolith assemblages does add some added value to the palaeoenvironmental reconstructions.

Sediments from Area A contained low concentrations of phytoliths (Table 4). To check that this was not an artefact of processing in the laboratory an examination of the poorest sediments was conducted prior to analysis. There were no phytoliths or diatoms observed. The pH of the bluish clays (UA6a–c) was measured and it was almost neutral (7–8). This suggests that the lake was not very alkaline and the poor preservation is probably not due to dissolution.

Most of the samples that come from the lower bluish clays (UA6) contain almost no phytoliths and diatoms. The rest of the units such as the upper bluish clays (UA4) as well as lower lignite UA7 and the mudflow (UA3c) that covers the elephant layer contain low concentrations of phytoliths (less than 6000 phytoliths per gramme of sediment).

The two samples collected from Unit UA4 (1 and 2) contain similar concentrations of phytoliths (both approximately 4000 phytoliths per gramme of sediment). This shows that the reproducibility of the method is good.

Area B is much richer in phytoliths and diatoms than Area A. Apart from the lower units in the sequence with low organic content (i.e. Units UB7 and UB8) the rest of the units in Area B preserve between 20,000 and 140,000 phytoliths per gramme of sediment. The richest samples are from the organic rich UB2 and UB3 with 140,000 and 93,000 phytoliths per gramme of sediment respectively. The organic poor UB6, the equivalent layer of UA4, was split into two samples, the upper part and the lower part. Comparison of these show that the upper part of UB6 is richer than the lower part preserving 75,000 and 27,000 diatoms and phytoliths per gramme of sediment respectively.

6.2. Qualitative results

Fig. 9 shows that grass phytoliths are well represented in all the samples analyzed. The lowest frequencies are shown in the samples from Unit UA4 (80–88%) as well as those from Unit UB3 (76%). By contrast the Unit UA4 samples contain the largest frequencies of phytoliths produced by dicotyledonous plants, leaves of trees (6–7%) and woody parts (up to 15%) (Fig. 9). The Pooideae subfamily is represented in varying degrees (Fig. 9). The Chloridoideae short grasses, that grow in warm open grasslands, are common (10%) in samples from UB1 (the upper lignite) and UB2 indicating warm climatic conditions (Fig. 9). They show a dramatic raise from the lower part (3%) to the upper part (19%) of UB6. The cooler climate Pooideae grasses show a decline from the bottom to the top of layer UB6 (they decline from 80% to 48%) (Fig. 9).

Phytoliths of damp ground plants are present in all the samples analyzed indicating swampy areas. The highest frequency of reed phytoliths has been recorded in the sample from UB3 (18.5%). Reed phytoliths are also recorded in the upper part of UB6 (6%). Sedges phytoliths have been recovered in the same sample but in smaller amounts. This could be due to poor preservation. The sedges are plants that produce fragile morphotypes. By contrast the lower part of UB6 shows absence of both sedges and reeds.

Dicot fruit phytoliths occur in low frequencies in many samples (below 1%). Therefore, it is not possible to comment about fruit exploitation or consumption by hominins. Some of the fruits belong to *Celtis*, a tree also recorded in the wood assemblages. Two spinny spheroid phytoliths attributed to *Palmae* have been identified in UB6



Fig. 5. Wood specimens from Area A (UA3 and UA3/UA4 contact). Note variable sizes and also compression on their traverse section. A. UA3c/U4 contact: *Alnus* sp., B. UA3/UA4 contact: *Alnus* sp., C. UA3/UA4 contact: *Salix* sp., D. UA3c: *Salix* sp., E. UA3c: angiosperm.

and UB4 (Fig. 8F) pointing to warm climatic conditions. It should be noted that UB6 has been deformed after deposition and reworked, therefore, this assemblage should be treated with caution as it might contain some material originating from unit UB5.

7. Diatoms and sponges

7.1. Results of the diatom and sponge investigations of the sediments from Marathousa site 1

Sponges have been recovered from many of the samples. The occurrence of sponges generally follows the same pattern as with phytoliths and diatoms; Area B samples have larger concentrations ranging from 10,000 to 400,000 sponge spicules per gramme of sediment. In contrast, Area A has poor preservation of sponges with the richest three samples found in UA3c and UA4. Nevertheless, it is worth mentioning that they are fragmented and, therefore, no reliable conclusions can be made regarding their abundance.

Samples from Area A yielded low concentrations of diatoms (no more than 600 diatoms per gramme of sediment) with a sample from UA6c being almost devoid of diatoms (Table 4). The assemblages are very weathered and broken permitting the identification of very few taxa. The numbers of identifiable taxa counted on a slide is low (less than 11) and, therefore, the statistical error is large (Table 5). The preservation of diatoms in Area B is slightly better but the recovery is still poor ranging from 166 to just over 14,000 diatoms per gramme of sediment (Table 4). In all the samples the number of diatom taxa identified was less than 100. A sample from the lower part of UB6 was the only one where 96 diatoms were counted on one slide, 87 of which were identifiable (Table 5).

The richest unit is the lower part of UB6 in which less than 100 diatoms have been classified to genera and species (Table 5). Many taxa identified belong to benthic diatoms with *Cymbella* spp. being the

commonest represented. Species providing climate and lake regime information have been identified in both the upper and lower parts of UB6. *Epithemia turgida* has been recorded in the lower part of UB6; a species that tolerates salinity and high nutrient levels pointing most probably towards shallow water conditions. *Cymbella erhenberghii* is recorded, a species that prefers freshwater conditions and high carbonate concentrations (Round, 1953; Momeu et al., 2015). In contrast, the upper part of UB6 contains *Aulacoseira ambigua* frustules, a planktonic species that requires deeper water to thrive. Although the taxa counted are few it is evident that benthic taxa are richer in the lower part of UB6 (e.g. *Fragilaria construens* and *Cymbella* spp.) while planktonic taxa are better represented in the upper part of UB6. This could point to deeper water in the upper part and shallower water in the lower part of UB6.

7.2. Taphonomic issues

Interpretation of the Marathousa 1 assemblages should be conducted with caution because of the nature of preservation. The monocot stem phytoliths dominate the assemblages whereas the husk phytoliths are almost absent. The husk phytoliths, specifically dendritics and papillae forms, are poorly represented (Fig. 9). As has been shown previously (Cabanes et al., 2011) these morphotypes are fragile and, therefore, are the first to dissolve in unsuitable conditions. Cabanes et al. (2011) claim that the dissolution is higher when assemblages are fossilized without having been first burnt. Although their study focussed on *Triticum* the results are applied to wild grasses here. The low recovery of dendritics and papillae phytoliths (Fig. 9) probably points to poor preservation. In addition, the morphotypes recorded in the Marathousa 1 assemblages from all taxa represented have etched endings together with pitted and verrucate surfaces indicative of severe weathering.

Diatom preservation is also poor and, therefore, data are only interpreted in combination with the other proxy datasets. Low taxa

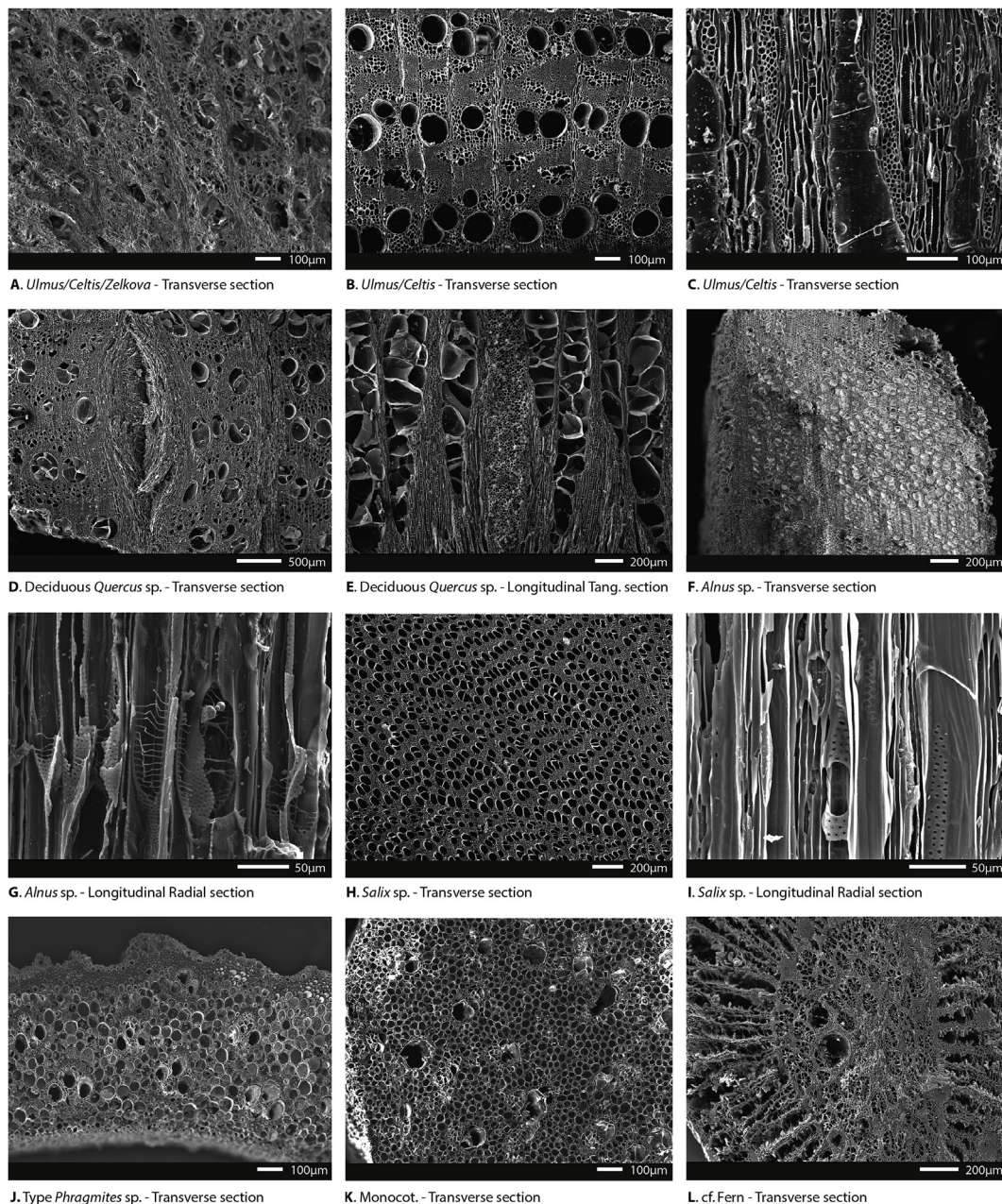


Fig. 6. SEM photographs of the anatomy of woody taxa identified in the MAR-1 sediments. Specimen A is wood and shows signs of compaction in the transverse section. All other specimens are wood charcoals (note their excellent preservation). Tang. = tangential.

diversity might be the result of disturbance of the lake water body and bottom sediment by mudflows entering the lake margin.

Phytoliths, diatoms and sponge spicules are three times more abundant in Area B than in Area A. This probably reflects the starting weight of samples from UB2-UB9 which was 3 times more than the rest of the samples. Nevertheless, even with a starting weight of 3 g samples UB7 and UB8 yielded no diatom frustules and extremely low numbers of phytoliths.

8. Discussion of the local palaeoenvironmental and climatic reconstruction based on the archaeobotanical data and diatoms

The composition of the carpological assemblages identified from sediments collected from excavation Areas A and B at Marathousa 1 are remarkably similar to those recognized by Mädlér (1971). The plant taxa represented in the carpological assemblages from UA4, UA3 and

UB4 indicate that sediment deposition took place in slow moving or still water which was basic, mesotrophic to eutrophic, with low suspended sediment, and probably a metre or two deep. Nevertheless, these sediments have experienced mudflow disturbance on occasion. The composition of the assemblages suggest that deposition could have taken place just offshore in front of the marginal reed swamp where such mudflow activity may be expected.

The combined data from the wood and wood charcoal study show that overall the tree component of the vegetation from UA5 to UA2 and UB4 to UB3 was dominated by *Salix/Populus* and *Alnus*, while *Phragmites* is the best represented of the monocotyledons. These taxa indicate the presence of marginal reed swamp and damp forests around the lake. The presence of deciduous hardwood woodland preferring better drained areas is shown by the presence of deciduous *Quercus* and *Ulmus/Celtis/Zelkova*.

The presence of large and small size wood concentrations in UA3c,

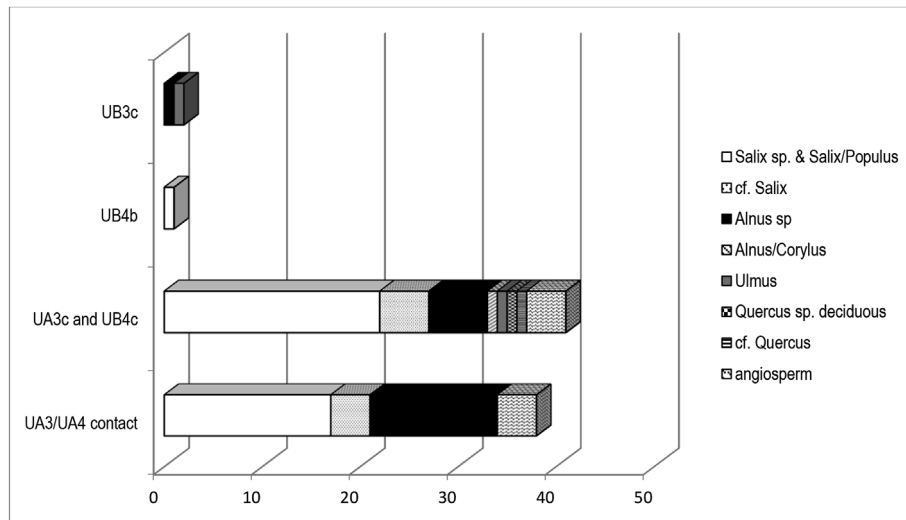


Fig. 7. The composition of the wood assemblages from the unit containing the elephant and lithic remains and the units above in Areas A and B (expressed as the actual number of wood pieces for each taxon).

UA3/4 contact and UB4 contrasts with the assemblage characteristics of the overlying units in which only small size wood remains are recorded. This could suggest differences between the depositional environment of the archaeological horizon and that of the overlying strata. The presence of unsorted wood remains in the sediment of the above-mentioned units supports deposition by locally originated mudflows under shallow water and/or swampy conditions (Karkanis et al., this issue). Thus, the wood remains would have been deposited close to their source and, therefore, represent plant taxa growing nearby. The above observation implies that the surrounding area was composed of mudflats occupied by *Salix-Alnus* woodland. In contrast, the presence of only small size wood pieces in all the overlying units (UA2, UB3) is probably a result of sorting by fluvial activity and wave action possibly suggesting a near shore environment.

No significant change in the composition of waterside and damp ground, and aquatic component of the carpological assemblages up through the sediment sequence investigated from Areas A and B indicate that the vegetation and environment remained stable while the sediments studied were deposited. Nevertheless, there is a difference recorded between UB4 and UB5 - woodland and shade tolerant taxa are present in UB4b and UB4c, but not in UB5 where more open area taxa are present. This may hint that in UB5 (below the presence of the hominins level) the woodland was more distant from the point of sampling. Phytolith assemblages support this argument pointing to tree vegetation at the time of the elephant death (UA4/UA3 contact) with tall Pooidae grasses and absence of sun loving Chloridoids. By contrast the upper part of Unit UB6 provides evidence of fewer trees and many short Chloridoid grasses indicating a more open area.

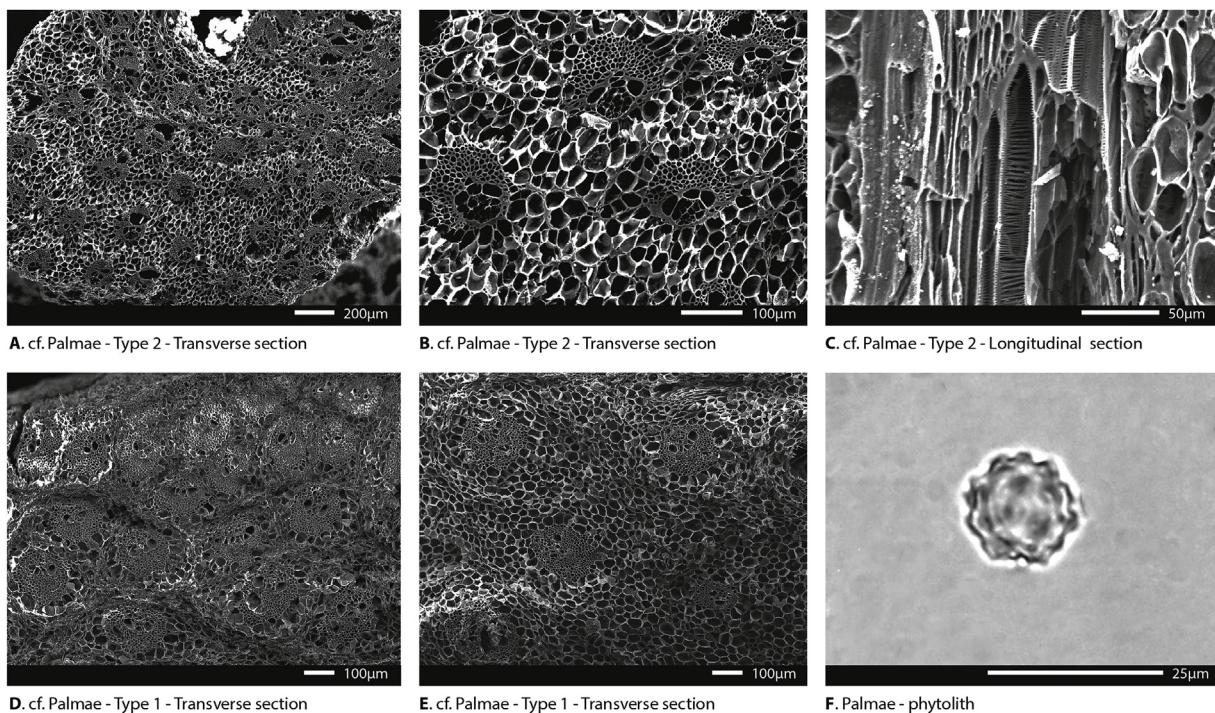


Fig. 8. A–E: SEM photographs of the anatomy of charcoal specimens identified as cf. Palmae. F: Image of a spiny spheroid phytolith attributed to Palmae and identified from UB4 in Area B.

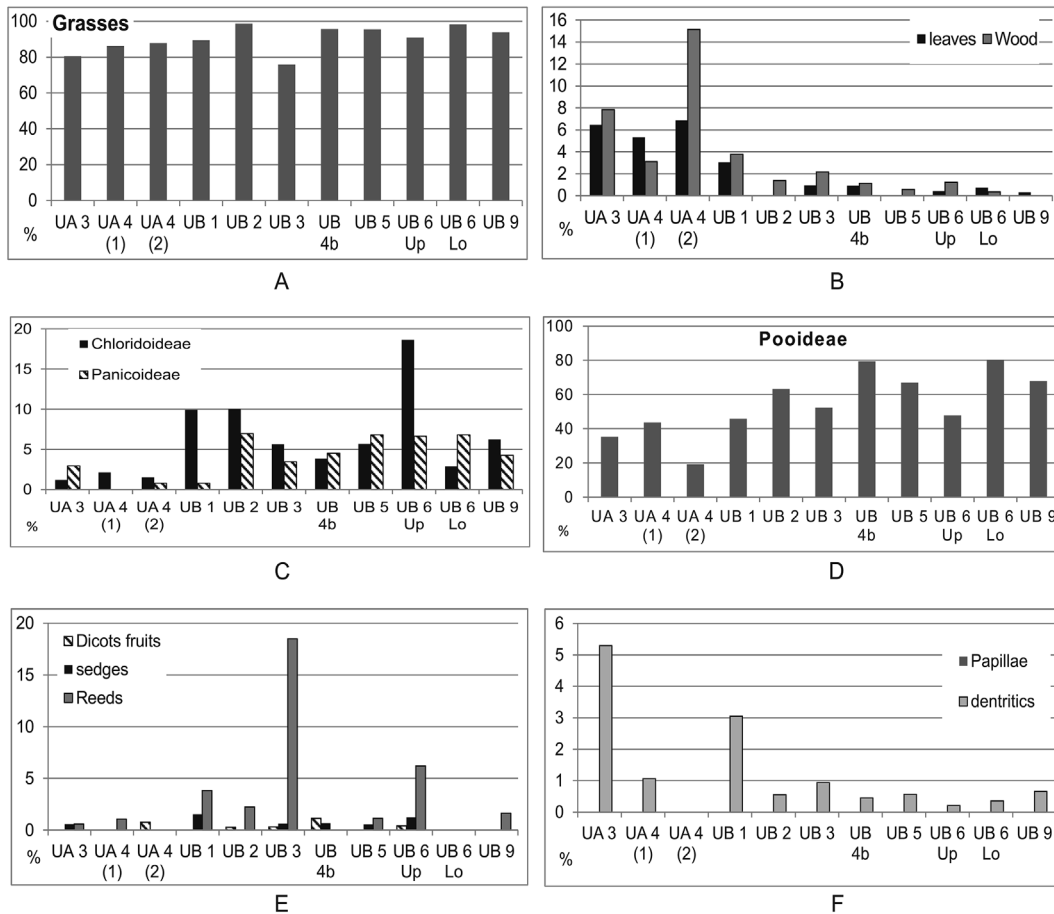


Fig. 9. Frequencies of phytoliths identified in the sediment assemblages. A: Grasses. B: Leaves and wood phytoliths from dicotyledonous plants. C: Chloridoideae and Panicoideae subfamilies. D: Pooideae subfamily. E: Reeds, sedges and fruits of dicotyledonous plants. F: Dendritics and papillae phytolith morphotypes.

Table 5
The number of diatoms taxa identified in each sample examined.

Diatom taxa	UA 7	UA 6c 3	UA 4	UA4	UA3	UB 9	UB 8	UB 7	UB 6 lower	UB 6 upper	UB 5	UB 4b	UB 3	UB 2	UB 1
Aulacoseira ambigua	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0
Aulacoseira granulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira sp.	0	0	0	0	0	0	1	0	3	4	1	0	0	0	6
Centrales	1	1	0	0	0	0	0	0	0	3	0	2	0	2	0
Coconeis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cymbella aspera	0	0	0	0	0	0	1	0	2	0	0	0	2	0	0
Cymbella Ehrebergii	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Cymbella sp.	0	0	2	3	2	10	2	3	25	1	19	6	10	7	18
Diploneis interrupta	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Epithemia adnata	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Epithemia sp.	0	0	0	7	0	0	0	0	15	1	2	0	2	1	0
Epithemia turgida	0	0	0	0	0	0	0	0	9	0	0	0	0	0	2
Fragilaria	0	0	0	0	0	0	0	2	4	1	2	0	0	0	0
Fragilaria brevistriata	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Fragilaria construens	0	0	0	0	0	0	0	0	12	1	5	2	0	0	0
Fragilaria ulna	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Gomphonema	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Navicula cari	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0
Navicula cospitata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula sp.	0	0	0	0	1	0	0	0	2	0	0	1	0	0	17
Stauroneis sp.	0	0	0	1	1	1	2	0	2	0	5	0	1	0	1
Suirella	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0
Total determined	1	1	2	11	4	11	7	5	87	15	38	13	15	10	45
Undetermined whole	0	0	3	2	4	2	1	0	4	6	1	0	0	0	3
Broken	0	1	0	2	0	0	1	0	5	0	0	0	6	2	43

The prevailing climate when units UA4 and UA3 and UB4 were deposited was warm as indicated by all proxies. For example, the presence in these units of cf. *Palmae* in charcoal and of *Palmae* in phytolith assemblages, the records of temperate taxa such as *Quercus*, *Ulmus* and *Acer* in the charcoal assemblages, and *Brasenia schreberi*, *Euryale ferox* and *Salvinia natans* in the carpological assemblages. Drzymulska (2018) has commented that the *Brasenia schreberi*, *Euryale ferox* and *Aldrovanda vesiculosa* association is typical for the climatic optima of European interglacial stages. It should be noted that these finds belong to the organic-rich transitional units below Lignite Seam III suggesting that they were deposited during a period of climatic amelioration. These units contrast with those found below (that are composed of organic-poor sediments) which are thought to be deposited during a cold climatic period (Karkanas et al., this issue). Phytoliths also suggest a colder climate during the deposition of the lower sediments. Previous investigations undertaken on sediments and fossils from the Megalopolis basin suggest that the peat (which eventually formed the lignite) was deposited during warm and humid periods, while the lacustrine and fluvio-lacustrine clastic sediments were deposited under cold, dry climate conditions (e.g. van Vugt, 2000 and Okuda et al., 2002). The data presented in this paper shows not an abrupt change from cold to warm at the clastic sediment/lignite boundary, but a longer transition towards warmer conditions that began before the deposition of the peat.

The warm, temperate conditions supported by the presence of several plant taxa could either be a result of global climatic change or conditioned locally by the microenvironment found on the flat swampy areas around the lake where damp sediments rich in nutrients could have balanced out the effects of cold, arid conditions in the catchment and further afield. However, the azonal vegetation that characterizes the assemblages of all the stratigraphic units above UA5 and UB4 does not allow any climatic changes to be recognized. Ongoing palynological investigations of the sediments may provide more information about the regional vegetation changes taking place during the deposition of these sediment units and give a better understanding of whether or not any changes were prompted by climate change.

The phytolith and diatom record from the part of the sequence below where the elephant and lithic artefacts were found shows progressive climate amelioration. The diatom data indicates deep lake water while the Chloridoid grass phytoliths point to warm and dry climate in the upper part of UB6. This is in accordance with the carpological data from the next unit (UB5) where no fossils of woodland and shade tolerant taxa were recorded pointing to an open ground and maybe to a shoreline more distant from any woodland. Diatom data show cold and arid climate with shallow water during the lower part of UB6 (with *Epithemia turgida* present) as opposed to the upper part where *Aulacoseira ambigua* (a planktonic species) indicates most probably warm climate with deeper water. It has been shown with batch culture experiments (Poister et al., 2012) that *A. ambigua* prefers higher temperature and light intensity relative to other members of the genus. Climatic oscillations reflected in lake regime have been reported in the study of Pleistocene layers of Lake Prespa where extreme aridity and cold result in low lake level during the glacial periods as opposed to deeper water during the interglacial times due to warm climate and higher precipitation (Cvetkoska et al., 2015).

The habitat diversity (dry and damp woodland, reed swamp, open damp ground, and open water) at the margins of the lake and the large number of plant species growing in these habitats offered the hominins active at the time of sediment deposition great opportunity. It is possible, and perhaps probable, that they were exploiting a range of plant species for different purposes. Food and tools may have been the more obvious uses for plant material harvested at the lake's edge. However, there is no direct evidence from the carpological assemblages that such exploitation was taking place. It would be unwise to be tempted to suggest that the hominins were eating parts of *Celtis* sp. or *Euryale ferox*, for example, just because these taxa are recorded. Even taking into

account modern utilization of *Euryale ferox* in India (Jha et al., 1991) and suggestions of Pleistocene exploitation of this species from a site in Israel (Goren-Inbar et al., 2000). *Celtis* sp. is a widely grown edible plant recorded in ash deposits from Choukoutien cave in China (Brothwell and Brothwell, 1969) as well as in from Middle Palaeolithic deposits from Douara cave in Syria (Matsutani, 1987).

Wood charcoal fragments are present in all units above UA5 and UB5. The lack of evidence for any anthropogenic use of fire would suggest that such material was derived from natural forest fires and was eventually transported and deposited by fluvial or wave action. Interestingly, taxa from both the azonal and the hardwood lake margin vegetation are represented, thus implying that forest fires affected the entire flat plain and swampy areas bordering the lake. The possible presence of ferns could be associated with colonization of burnt areas by these pioneer plants.

The aquatic fern *Azolla filiculoides* disappears from the fossil record at the end of the Middle Pleistocene in western and central Europe (Field, 1999). Its presence at Marathousa 1 supports at Middle Pleistocene or older age determination.

9. Conclusions

The four proxies analyzed in this study allow a reconstruction of the environment when the elephant was butchered as well as before and after this event. The plant macrofossil assemblages recovered from Areas A and B just below, at the level of the elephant remains and lithic artefacts, and just above these finds are diverse and are dominated by aquatic, and waterside and damp ground plant taxa. They show that sediment deposition took place in still water with low suspended sediment. The composition of the assemblages suggests that deposition took place just offshore in front of the marginal reed swamp. Lithological evidence suggests periodic mudflows into the lake, but the carpological assemblages indicate that deposition took place predominantly under water at the point of sampling in Areas A and B. A flat damp area (mudflat) at the margins of the lake is supported by the dominance of *Alnus* and *Salix* in the wood assemblages. Charcoal of *Alnus*, *Salix* and *Phragmites/Arundo* suggest that natural fires occurred occasionally on the damp floodplain. Some other trees that probably preferred better drained areas are represented but it is interesting to note that no coniferous taxa are recorded. The presence of cf. *Palmae* in charcoal and *Palmae* in phytolith records as well as carpological remains of certain taxa, such as *Brasenia schreberi*, *Euryale ferox* and *Salvinia natans*, indicate that the prevailing climate at the time of the elephant's death and butchery was warm. Previous depositional phases took place under colder climate conditions with associated lake level fluctuations. The climatic amelioration recorded in the palaeobotanical and diatom data retrieved from the younger organic-rich units is compatible with previous palynological studies and the interpretation of the sedimentological formation of the units which correspond to the warming episode. The environment at the time of the butchery event was warm and probably favourable for the hominins with open grassland and woodland at the lake side offering opportunities to exploit a range of plant species. Nevertheless, despite the presence of lithic artefacts and cut-marks on the elephant bones indicating that the hominins were butchering this animal there is no direct evidence to suggest that hominins were exploiting the plants growing in the local vegetation.

Long and continuous terrestrial sedimentary records, such as that found at Megalopolis, are rare in the geological archive and especially so in the Mediterranean region. They are significant because they can offer unique insights into past climate, climate fluctuations and how ecosystems changed in response. Studies of such sediment sequences, which combine analysis of high-resolution lithostratigraphic, palaeontological and sedimentological data to understand the stratigraphic and environmental context of in situ archaeology, are even more exceptional and, therefore, are crucial for assessing hominin

adaptations to different environmental conditions. The work presented in this paper adopted a site-scale approach and focused on reconstructing the palaeoenvironment during and around the time of hominin presence at Marathousa 1. Future investigations plan to complement this work with an ‘off-site’, basin-scale approach, in order to investigate broader spatial and temporal palaeoenvironmental changes and landscape dynamics within the Megalopolis basin.

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