



Magura Cave, Bulgaria: A multidisciplinary study of Late Pleistocene human palaeoenvironment in the Balkans



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ABSTRACT

Two trenches excavated at Magura Cave, north-west Bulgaria, have provided Late Pleistocene lithic artefacts as well as environmental evidence in the form of large and small mammals, herpetofauna and pollen recovered from *Crocuta* coprolites. One of the trenches also has a visible tephra layer which has been confirmed as representing the major Campanian Ignimbrite eruption and is accurately dated at the source area to $39,280 \pm 55$ yrs and radiocarbon determinations have added to chronological resolution at the site. The palaeoenvironment of the region during the Late Pleistocene is discussed in the context of hominin presence and shows a mosaic landscape in a region considered a crucial refugium for both plants and mammals, including hominins.

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1. Introduction

Modern-day Bulgaria occupies a crucial geographical position between Asia and Europe, with potential routes to and from central and western Asia to the north or south of the Black Sea, the latter also ultimately providing a link to the African continent (Sirakov et al., 2010; Ivanova et al., 2012a). The Danube corridor has always been a critical route for early human migration (Mellars, 2006, 2011) as evidenced by the large number of Palaeolithic sites in the region and in Bulgaria in general, and the hills, river and

adjacent floodplains of the area provided early hominins with abundant raw materials of flint and quartzite for lithic tool manufacture, as well as considerable plant and animal resources. Pleistocene sites in Bulgaria with evidence of human activity range in chronology from the Lower Palaeolithic (e.g. Kozarnika at 1.4 Ma; Guadelli et al., 2005; Ivanova, 2009; Sirakov et al., 2010) through to the Epigravettian (e.g. Kozarnika, Bacho Kiro and Temnata Dupka) and include cave sites as well as inland and coastal open air sites (see Table S1 in Supplementary Information [SI]). The latter two sites are particularly relevant to the Middle to Upper Palaeolithic transitional period covered in this paper (Kozłowski, 1982; Kozłowski et al., 1992; Ginter et al., 1994, 2000). Many of the sites shown in Table S1 were investigated in older studies, although there is now an accumulation of more recent research and publications related to the better known Palaeolithic settlements.

Here we report on dating, environmental finds and some lithic tools from Late Pleistocene layers from excavations of two trenches in Magura Cave, undertaken during field seasons of 2011 and 2012,

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providing an environmental background for human occupation and dispersals in the region between about 60 ka and 30 ka. The Balkans are seen as a critical region for refugial populations of plant and animal taxa during the Late Pleistocene and as one of the three core centres for Neanderthal occupation and expansion at this time (Churchill, 2014). The main purpose of this paper consists in presenting a multidisciplinary study of one of the most interesting and promising Palaeolithic cave sites in Bulgaria, which is part of a larger project on Late Pleistocene environments and human adaptation in the Balkans. The data recovered (from lithic, faunal, aDNA, pollen and coprolite analyses, and chronological precision through ^{14}C and tephra dating) offer an opportunity for subsequent correlation with other sites on regional and supra-regional scales. The aim is to assess the influence of environmental factors in this region during the Late Pleistocene on dispersals of plants and mammals, including hominins.

2. Site location and history

Regionally, Magura Cave is situated in the western part of the Balkan Mountains (Stara Planina), a range which spans north-western to central Bulgaria, the Thracian plain lying to the south-east of the range, and the plain in turn fringed by the Rhodope Mountain range at its western edge (see Fig. 1). The River Danube lies about 25 km to the north-east of Magura, the Danube valley linking Central Europe and the Balkans with the Black sea coastal zone. Magura Cave is located on Rabisha Hill (461 m above sea level), with its entrance approximately 80 m below the peak at about 375 m a.s.l (43.7281, 22.5826 decimal degrees); it is 25 km north-west of the town of Belogradchik and 35 km south of the city of Vidin. The local geology is of Lower

Cretaceous, thick-layered limestones and cave formation started around 15 million years ago, with a Tortonian Stage (mid-Miocene) river creating, through phreatic action, impressive halls in three tectonic cracks as well as numerous galleries and unique natural formations. The total length of the cave exceeds 2500 m and consists of ten large halls and numerous smaller side galleries and branches (Fig. 2).

The first information about the cave appeared in the 1920s and 1930s in the publications of Mikov (1927) and Filkov (1936/7). The first systematic archaeological explorations in the cave were undertaken in 1961 in the entrance ("Triumphant") hall, at around 20 m from the main entrance (Dzhambazov and Katincharov, 1961). The length of this hall is 120 m, width 58 m and the highest point on its ceiling is 28 m. Investigations have revealed settlements in the cave dating back to the Neolithic, Chalcolithic and Bronze Age periods.

Magura Cave is now open to the public, with a path descending and winding through the "Triumphant" hall, a side gallery of which has been converted into a commercial winery. In the construction process, a large quantity of sediment was removed, but some bones (mainly from *Ursus spelaeus* s. lato) were taken for the collection of the Vidin Museum. Among these, several human bones were also found, but are now known to be from the Bronze Age. The cave has become famous for its prehistoric drawings in the so-called "Painting Gallery", located in a side branch off the main gallery around 300 m into the cave, which are established to be from the Chalcolithic and Bronze Ages (fifth to third millennia BC). At its entrance there is an image of a galloping horse, very different to the Holocene drawings and the only drawing made with a material other than guano; it is in poor condition, but is considered to be Palaeolithic/Mesolithic in style (Stoytchev, 1994).



Fig. 1. Location of Magura Cave within the Balkan context.

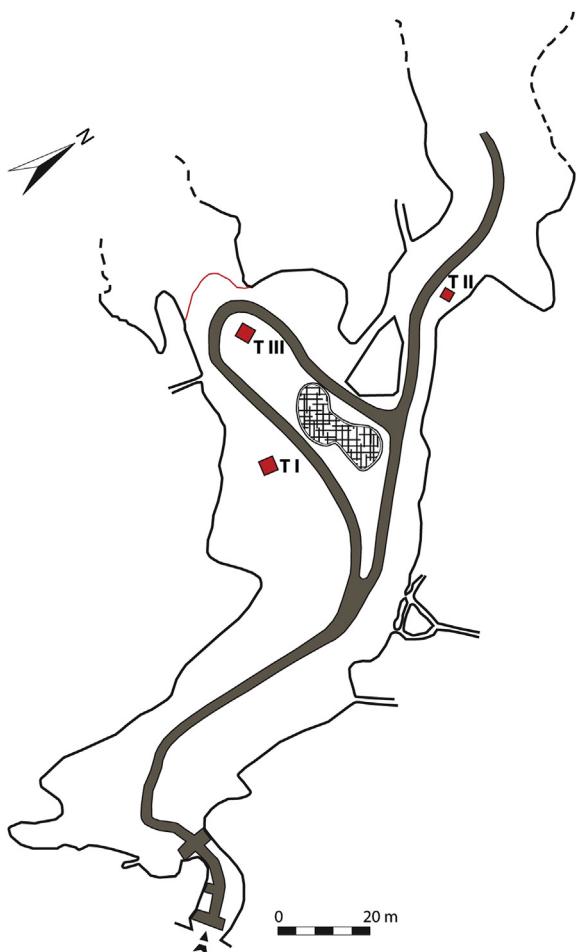


Fig. 2. Plan of the cave with location of Trenches I and III; the bold line is the current path of the showcave and the hatched area is a man-made water feature. The winery was constructed in the gallery adjacent to Trench III.

In 1994, S. Ivanova made two small trenches (Trench II and the start of Trench I) in areas where Holocene layers had been explored by the previous excavations (Dzhambazov and Katincharov, 1961, 1974). Remains of a Bronze Age wooden construction, hearth and animal bones were found in Trench II, but in Trench I no Holocene remains were found (Ivanova, 1995). In both trenches there were distinct Pleistocene sediments containing rich traces of fauna with the dominating presence of the *Ursus spelaeus*. Unfortunately, all fossil materials collected during the 1990s have since been lost. More recent archaeological excavations include the 2011 and 2012 seasons with an international team under the supervision of S. Ivanova and D. Strait with the sponsorship of the America for Bulgaria Foundation within the framework of the “Balkan Valley Project II: Excavations at the Magura Cave”, undertaken by the American Research Centre in Sofia (ARCS). The preliminary reports of the excavations published by Ivanova et al. (2012b, 2013) focused on two trenches (I and III) located in the “Triumphant” hall (Fig. 2).

3. Lithostratigraphy

3.1. Trench I

The excavations in Trench I reported here from 2011 to 2012 started at layer 13. The trench has dimensions of 3.5×3.0 m, the

floor surface area of which decreases with depth (reaching 7.5 m) and has revealed 45 distinctive lithostratigraphic layers (Fig. 3), scarce knapped lithic artefacts and rich faunal remains.

From the bottom of the trench at 7.50 m (layer 45) to layer 35 a sequence of rubble and clayey sand layers is evident, with presence of faunal remains. Sedimentation of layer 40, where microvertebrates were found, appears to have formed under normal conditions, without any influence of water. Layer 34 shows the formation of waterlogged deposits in that part of the cave. Layers 33–30 were formed under conditions of an active water regime and no bone remains were found. Layers 29–20 consist of clayey

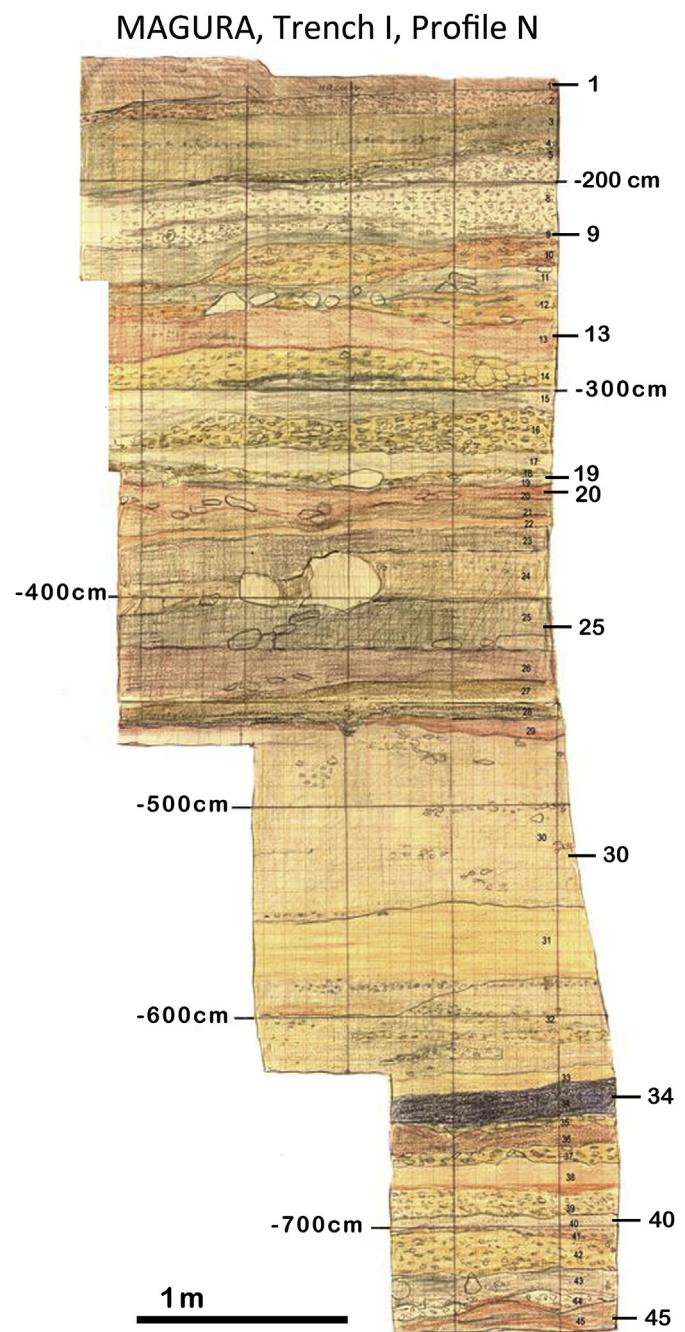


Fig. 3. Magura Cave: north profile of Trench I showing layer numbers and depths (Drawing by S. Ivanova).

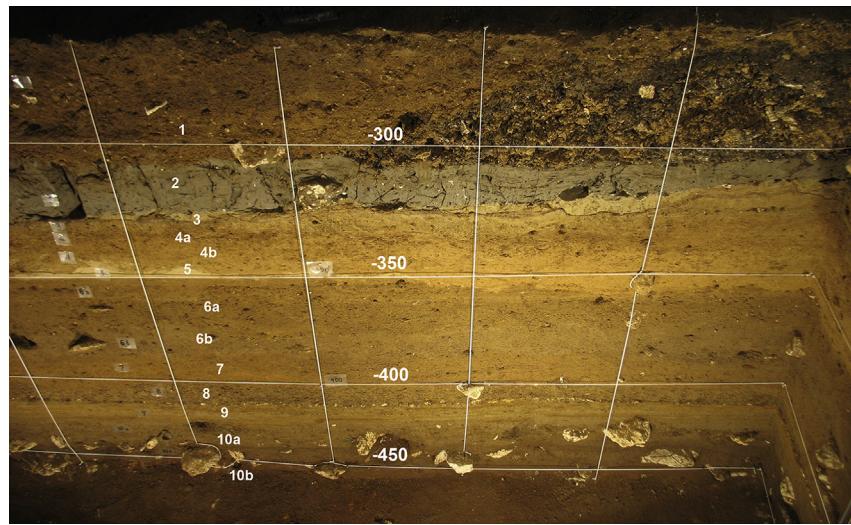


Fig. 4. Trench III: north-east profile with markers for depths and layers (Photo by M. Gurova).

sediments; limestone concretions with smooth edges and surfaces are also found. An accumulation of bones was found in layer 25 at the north-eastern corner of the trench, where the northern profile contained an *Ursus spelaeus* skull and under it, the jaw bone of a

juvenile bear. The eastern profile revealed a femur on top of the jaw of an old *Ursus* individual, several vertebrae and some teeth, all found on flat stones with smooth edges. It is likely that this extends into the unexcavated area. In layer 25 several artefacts

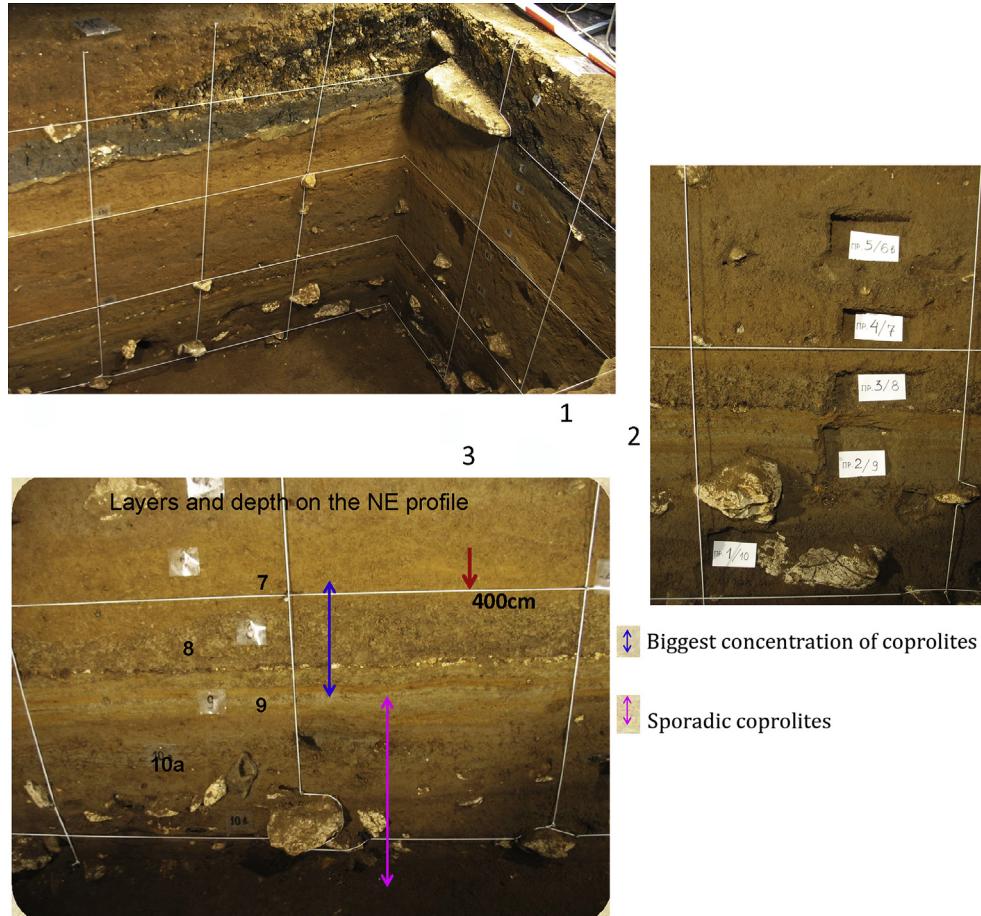


Fig. 5. Trench III: 1) east corner of the trench; 2) detail of the last column of the north-east profile with locations of samples taken for pollen analysis; 3) detail of the north-east profile with arrows showing coprolite concentrations (Photos by M. Gurova).

and pieces of charcoal were excavated, while some of the bones show traces of cut marks (Ivanova et al., 2013); cut-marked horse bones were also found in layer 26. In the sequence from layers 19 to 9, there are successive clay and gravel sediments; the gravels are larger in comparison with those from higher layers. The upper part of the sequence (layers 9 to 1) is composed of similar fine gravel and clayey sand layers, which probably arrived as a result of rockfall and other processes, due to the relative proximity of the trench to the entrance of the cave. Apart from layers 30–38 and 40–41, most other layers below layer 13 contain animal remains, although some are unidentifiable, with a predominance of cave bear bones.

3.2. Trench III

Trench III is slightly smaller (3×3 m) but has revealed very rich faunal remains, with 370 identifiable bones and fragments. The

4. Methods and results

4.1. Dating of Trenches I and III

4.1.1. ^{14}C dating

Trench I: Six samples were taken from Trench I for AMS ^{14}C dating at the Oxford Radiocarbon Accelerator Unit (ORAU) (Table 1; see SI for Methods). Samples OxA-29992 through to OxA-29995 were taken from the museum in Vidin and are clearly Holocene in age; the calibrated dates for these are given in Fig. S1 in the SI. There is no layer noted as they were not collected during archaeological excavations, but during the building of the winery. The two samples of relevance here are OxA-29785 (M/I/81) from layer 23 and OxA-29991 (M/I/151) from layer 25. They both give an infinite result but indicate that the archaeological material in layer 25, and therefore human presence, pre-date 50,000 BP.

Table 1
Showing all ^{14}C dating samples for Magura Trenches I & III.

OxA number	Layer	Site code	Sample/species	$\delta^{13}\text{C}$	Radiocarbon age BP
Trench I					
OxA-29785	23	M/I/81	Bone (unknown)	-21.25	>50,100
OxA-29991	25	M/I/151	Bone (unknown)	-18.85	>50,200
OxA-29992		Magura 8a:	Parietal (human)	-20.04	3303 ± 29
OxA-29993		Magura 8b	Frontal (human)	-19.54	3310 ± 28
OxA-29994		Magura 5a	Parietal (human)	-20.5	4453 ± 30
OxA-29995		Magura 2	Occipital (human)	-20.14	4474 ± 30
Trench III					
OxA-31009	4	Mag-1	Maxilla (<i>Crocuta</i> sp.)	-18.29	$32,750 \pm 500$
OxA-31115	8	Mag-5	Humerus (<i>Ursus</i> sp.)	-21.8	>50,000

depth reached during the excavations was 4.60 m with ten lithostratigraphic layers identified (Fig. 4). The Pleistocene layers (10–3) are characterized by a clayey sand fraction and varying quantities of coarse gravel-sized (20–60 mm) pieces of limestone. Layer 10 is a grey-beige clay sediment containing these limestone clasts. Layer 9 reveals a microsequence of grey clay and orange sand sediments. One of the most interesting discoveries in Trench III is a large number of *Crocuta* coprolites, with the highest concentration between 420 and 400 cm, corresponding to lithostratigraphic layers 9 and 8. Because of the significant coprolite concentration in these layers, we consider these as possibly being evidence of a hyaena den in this area of the cave, the layers being visually very distinct in relation to the vertical stratigraphy (Fig. 5). At the bottom of layer 8 is a seam of fine gravels but the main sediment fraction in layer 8 is a brownish clay with orange spots of weathered limestone and black manganese (Mn) particles. Layer 7 is a yellowish-brown sandy clay with gravel-sized limestone clasts. Layer 6 features a clearly observable stratum of small oval-shaped limestone clasts. Layer 5 is a visible tephra (volcanic ash) layer. The basal contact of the tephra layer is fairly planar and sharp, and the upper contact is erosional. The thickness is laterally variable on a decimeter scale, ranging from 1 cm to about 10 cm, and is completely eroded in places. The tephra is fine-grained with planar laminations that vary in colour (cream to dark grey) and thickness (a few mm to 1.5 cm). Layer 4 consists of a yellow-brown, loamy sand, more compact in the lower part and layer 3 of a beige-yellow compact clay. The sediment layers of the upper part of the sequence were destroyed during the building of the winery in the adjacent gallery (Fig. 2).

Trench III: A number of samples for ^{14}C dating were also taken from mammal bones from Trench III and so far two have been processed and provided results. They are OxA-31009, from a well-preserved *Crocuta* maxilla from layer 4, and OxA-31115, an *Ursus* humerus fragment from layer 8. The first of these has a calibrated date of between 38,341 and 35,765 cal BP (at 95.4% probability) using the IntCal13 dataset (Reimer et al., 2013; Fig. S2 in SI). The layer 8 sample has given an infinite date but, as with Trench I, it indicates a *terminus ante quem* for the lithic manufacture in layer 10 of at least 50,000 BP.

4.1.2. Tephra in layer 5, Trench III

As mentioned, much of layer 5 of Trench III consisted of a visible tephra horizon and samples were collected for geochemical analysis from the visually distinct upper and lower parts of this horizon (Fig. 6). The laboratory methods and electron microprobe analyses of the glass shards are given in the Supplementary Information (SI). The glass shards in the samples are typically up to 150 μm long and 40 μm wide (Fig. S3 a and b in SI). They are not very vesicular but the cuspatate shape suggests the shards are the quenched melt that surrounded large bubbles. Glass compositions range from phonolite to trachyte, with high alkali contents (12.80–14.34 wt.% Na₂O + K₂O). The glass shards in the two samples, OxA-31009 and OxA-31115, share the same geochemical range and 2 compositional populations are seen in both samples (Fig. 7). The dominant population ($n = 57$) has higher Na₂O and Cl, and lower K₂O, CaO, MgO and P₂O₅ contents, than the other K₂O-rich population ($n = 10$) (Table 2 and Fig. 7). The Al₂O₃ and SiO₂ ranges of both glass populations overlap, but the latter is lower in the K₂O-rich population (Table 2).

Table 2

Representative normalised glass compositions of visible tephra layer in Magura Cave ($\text{FeO}^T = \text{all Fe as FeO}$).

Analysis#	OxT9618_6	OxT9617_5	OxT9617_34	OxT9618_25	OxT9618_30	OxT9618_33	OxT9617_4	OxT9617_27	OxT9617_32	OxT9617_35
Population	High-K ₂ O	High-K ₂ O	High-K ₂ O	High-Na ₂ O						
SiO ₂	60.86	60.93	59.93	60.49	60.83	60.58	60.48	60.71	60.48	60.57
TiO ₂	0.39	0.32	0.39	0.40	0.41	0.40	0.45	0.40	0.47	0.43
Al ₂ O ₃	18.78	18.77	18.61	18.47	18.9	18.61	18.94	18.81	18.68	18.85
MnO	0.08	0.18	0.1	0.29	0.22	0.31	0.23	0.24	0.17	0.31
MgO	0.66	0.58	0.79	0.29	0.38	0.34	0.28	0.31	0.36	0.34
FeO ^T	3.17	3.08	3.36	3.08	2.85	3.14	2.95	3.15	2.97	2.67
CaO	2.4	2.17	2.74	1.8	1.69	1.66	1.66	1.62	1.77	1.71
Na ₂ O	3.27	4.07	3.26	6.7	6.41	6.89	6.72	6.51	6.75	6.55
K ₂ O	9.75	9.22	10.18	7.38	7.2	6.96	7.21	7.08	7.26	7.47
P ₂ O ₅	0.16	0.11	0.18	0.03	0.04	0.04	0.04	0.08	0.03	0.04
Cl	0.47	0.56	0.44	1.07	1.06	1.07	1.04	1.08	1.07	1.07
Analytical total	98.82	97.33	98.15	99.36	99.5	99.38	98.15	99.6	99.6	99.19
Na ₂ O + K ₂ O	13.03	13.29	13.44	14.08	13.62	13.85	13.93	13.6	14.01	14.02

The alkali-rich glass compositions of the visible tephra in Magura are typical of compositions erupted from Italy (Tomlinson et al., 2015). Furthermore, the glass chemistry of this layer is indistinguishable from the proximal units of the Campanian

Ignimbrite (CI) (Fig. 7; see Tomlinson et al., 2012). This indicates that the tephra at Magura is distal ash associated with the CI supereruption, which occurred from Campi Flegrei, Italy and has been dated by ⁴⁰Ar/³⁹Ar methods at sites close to the volcano at

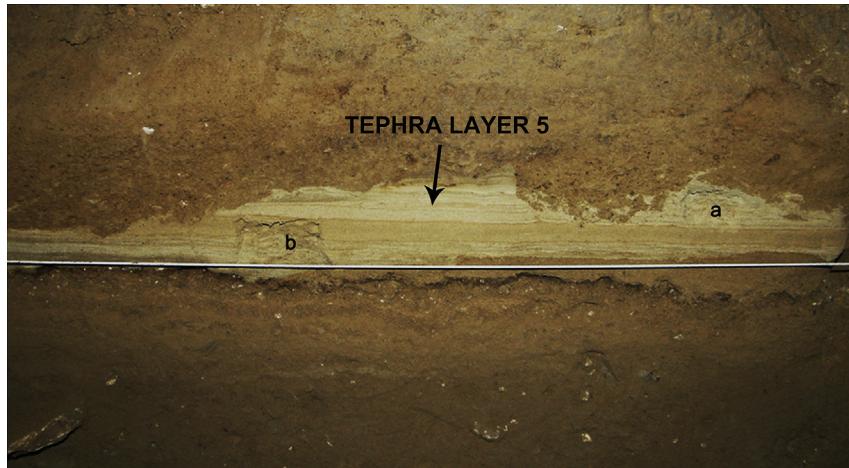


Fig. 6. Photograph of the visible tephra layer (5) in Magura Cave in Trench III. a (OxT9617) and b (OxT9618) refer to the samples taken for analysis (see text). The tephra is comprised of fine laminated ash that varies in colour. The basal contact and laminations are planar but erosion of the unit has led to considerable lateral variations in thickness and the tephra is absent in places.

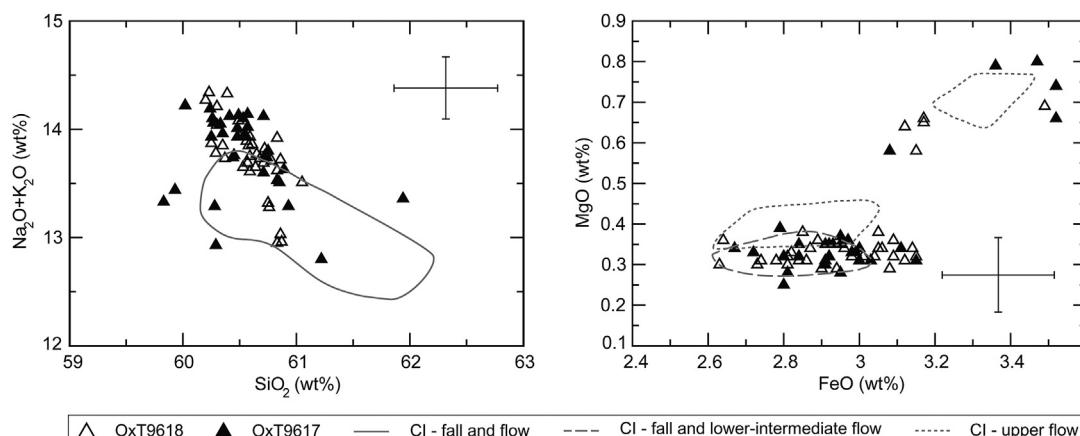


Fig. 7. Glass shard compositions of the visible tephra, layer 5, in Magura Cave: OxT9617 (sample a in Fig. 6) and OxT9618 (sample b in Fig. 6) and the Campanian Ignimbrite (CI) data from Tomlinson et al. (2012) (plotted as fields). The glass compositions of the visible tephra layer are the same as the CI, and there are some shards in both the lower and upper parts of the distal tephra that have the distinct FeO and MgO compositions that are characteristic of the CI upper flow. Error bars are $\pm 1\sigma$ and based on precision on the secondary glass standards.

$39,280 \pm 55$ yrs (De Vivo et al., 2001). The tephra associated with this eruption is incredibly widespread across the eastern Mediterranean (Pyle et al., 2006; Costa et al., 2012) and has been found in many other sedimentary archives (e.g., Lowe et al., 2012; Davies et al., 2015). This correlation of the Magura tephra to the CI eruption provides an excellent marker and allows the precise age of the eruption to be used for Layer 5 at the Magura site. Furthermore, it allows this site to be directly compared to other sites around the Mediterranean Sea and southeastern Europe, including palaeoenvironmental records and other archaeological sites.

4.2. Lithics

4.2.1. Trench I

Whilst cleaning and smoothing the profile of Trench I an Upper Palaeolithic blade (Fig. 8.4) from a single platform core was found in layer 8 but, apart from this, all other artefacts were found in layer 25.

The assemblage consists of the following artefacts: one quartzite core with oval, plate removal surface with multidirectional negatives — an atypical discoid core (Fig. 8.1); a side-scraper on flint

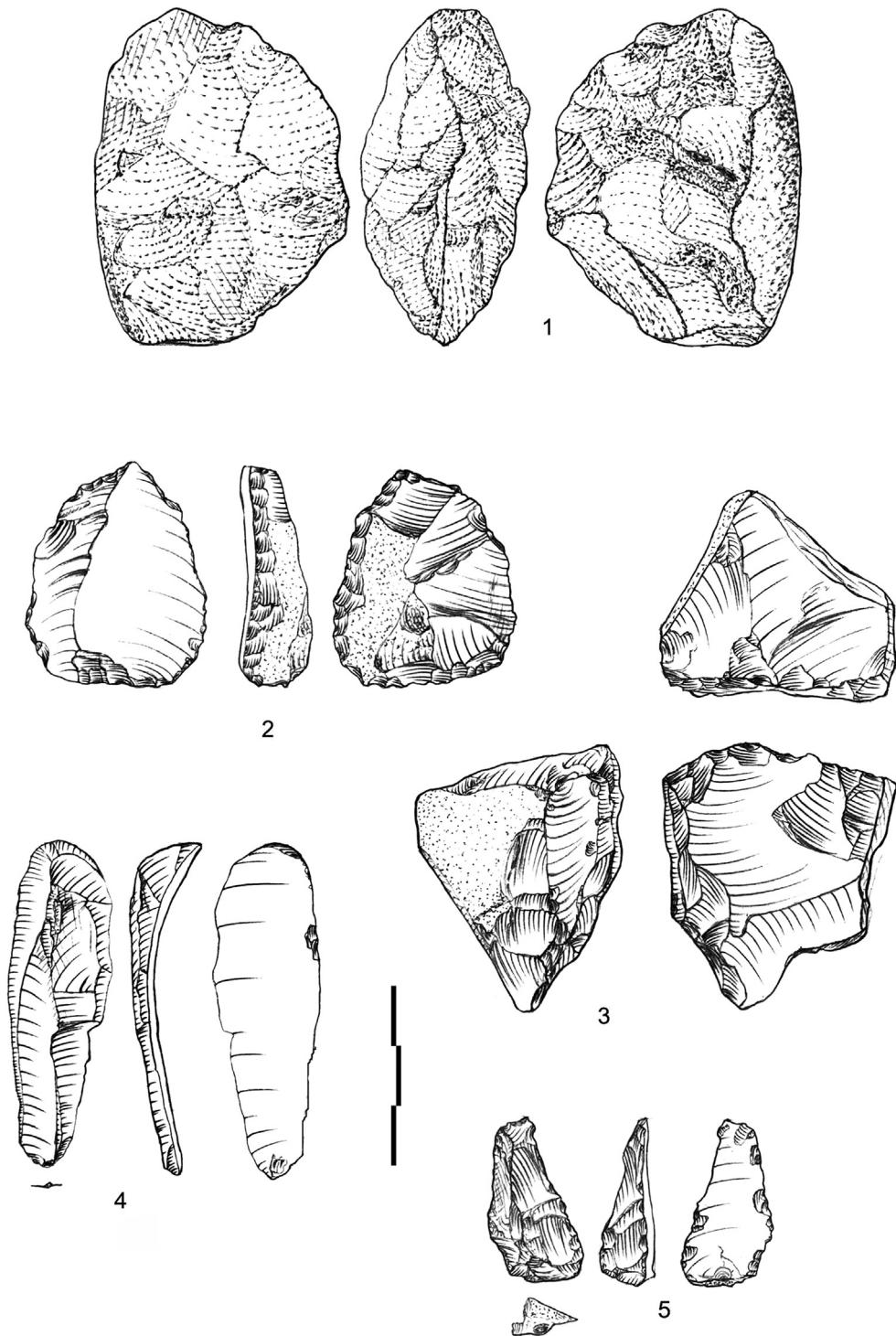


Fig. 8. Trench I. Artefacts: 1–3 and 5 (layer 25); 4 (layer 8); 1 and 3 – cores; 2 – side-scraper; 4 – blade; 5 – flake (drawings by E. Anastassova). Scale = 30 mm.

flake with semi-abrupt denticulate retouch — a negative on its ventral surface is either intended thinning of the artefact or an attempt for its exploitation as a core (Fig. 8.2); a core for removal of flakes and blade-like flakes — the striking platform has been prepared and negatives on the removal surface suggest changing of the direction during exploitation of the core, and the raw material is local and of good quality (Fig. 8.3); three small (2.5–3.0 cm) flakes from the same raw material; a small elongate flake with natural

butt (Fig. 8.5). In this layer (25), twelve amorphous quartzite pieces were found, one of which is a small scraper on a flake. Some of the pieces bear traces of testing or attempts at exploitation as a core. Microscopic observation of the artefacts revealed two pieces with post-depositional surface modifications (PDSM) (Fig. 10.1). Only one artefact, the Upper Palaeolithic blade, revealed diagnostic use-wear traces related to the cutting of soft material (meat/fresh hide) (Fig. 10.2 a, b). This detected activity could be attributed to butchery

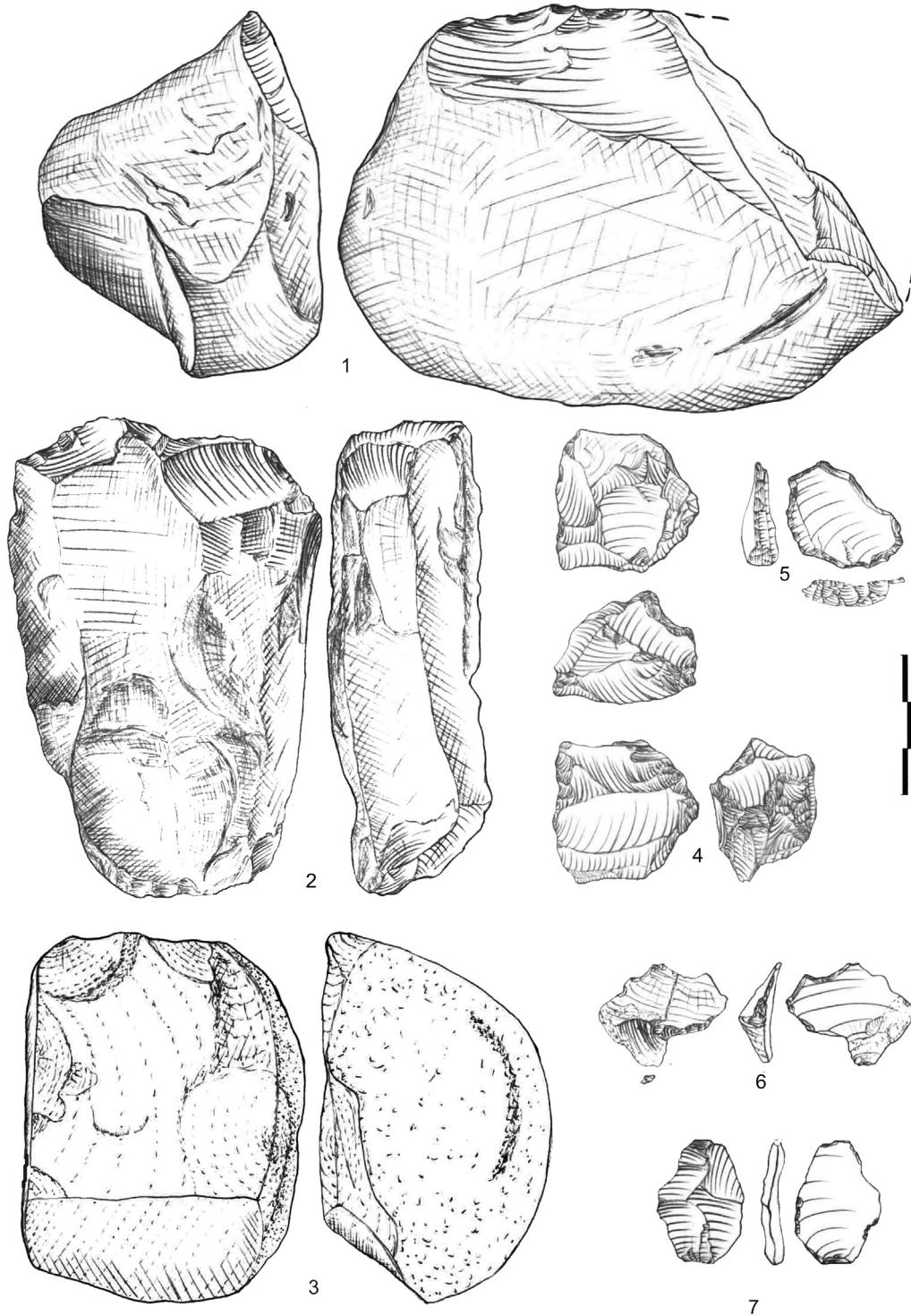


Fig. 9. Trench III. Artefacts from layer 10: 1) chopper-like tools on pebble; 2) large implement of quartzite pebble; 3) large quartzite pebble with traces of removal of flakes; 4) core with changed orientation of removal surfaces; 5) and 6) retouched flakes; 7) flake (drawings by E. Anastassova). Scale = 30 mm.

practices by the human visitors to the cave. The lithic assemblage from layer 25 can be generally defined as belonging to the final part of the Middle Palaeolithic, this evidence supporting hominin presence in the cave during this period.

4.2.2. Trench III

The lithic finds in this trench are few and are all from layer 10. The artefacts consist of a small core for flakes with unipolar multidirectional removals (Fig. 9.4), two small flakes with

transversal retouch (Figs. 9.5 and 9.6) and a few smaller flakes (Fig. 9.7). Another group of larger pieces includes a pebble tool of chopper type (Fig. 9.1), an elongate quartzite implement (Fig. 9.2) and a large quartzite pebble with flat negatives on the cleavage surface (Fig. 9.3). There is no evidence for a complete *chaîne opératoire*, but it is probable that the core exploitation and artefact manufacture took place in the cave. The artefacts reveal general features which can be assigned to the final Middle Palaeolithic.



Fig. 10. Trench I. Artefacts with wear traces: 1) postdepositional surface modification (PDSM), in this case polishing and striation, on the ventral part of the side-scaper on flake; 2) Upper Palaeolithic blade from Trench I with (a) spots of PDSM on the dorsal ridge and (b) use-wear traces of cutting soft material (meat/fresh hide); photomicrographs in both 1 and 2) are x75. Scale = 50 mm. (Photos by M. Gurova).

The typology of the artefacts from layer 25 (Trench I) and layer 10 (Trench III), as well as dating results, lead us to assume that the sedimentation of these layers was broadly coeval. The lithic artefacts from both trenches suggest some human activity in the cave at the end of the Middle Palaeolithic; the blade from Trench I indicates a human presence in the cave during the Upper Palaeolithic also.

4.3. Fauna and taphonomy: taxonomic, biochronological and palaeoecological context

The study of the fossil bone remains from Trenches I and III shows that the deposits present to date only Late Pleistocene fauna. The preliminary list of the large mammal fauna is: *Lepus* sp. (hare), *Canis lupus* Linnaeus, 1758 (wolf), ? *Cuon* sp. (dhole), cf. *Vulpes vulpes* Linnaeus, 1758 (fox), *Ursus spelaeus* Rosenmüller, 1794 s. lato (cave bear), *Crocuta crocuta spelaea* Goldfuss, 1823 (cave hyaena; bones and coprolites), *Panthera spelaea* Goldfuss, 1810 (cave lion), *Equis germanicus* Nehring, 1884 (horse), *Equus hydruntinus* Regalia, 1907 (European ass), Rhinocerotidae indet. (rhinoceros), *Cervus elaphus* Linnaeus, 1758 (red deer), *Megaloceros giganteus* Blumenbach, 1799 (giant deer), cf. *Bos primigenius* Bojanus, 1827 (aurochs), cf. *Bison priscus* Bojanus, 1827 (steppe wisent), aff. *Rupicapra rupicapra* Linnaeus, 1758 (chamois), Aves indet. (birds).

4.3.1. The large vertebrate faunal remains and taphonomic peculiarities

More than 1400 animal remains (including a high percentage of unidentified bone fragments) were excavated during the field seasons 2011–2012, with about 563 bones identified (Table 3; Fig. S4 a and b and Table S3 in SI). Birds, hares, rhinoceros and giant deer are represented by a few bones only. The finds of giant deer, *Megaloceros giganteus*, are a metapodial from Trench I, layer 25, and a fragment of maxilla in Trench III, layer 4. The carnivores (excluding the dominant cave bear remains) are better represented, especially *Canis lupus*. The hyaena remains (6 specimens) were found mainly in Trench III, layers 4, 7, and 10. A large number of hyaena coprolites were also found, especially in layer 8, but also in layers 7, 9 and 10. A partial mandible of *Panthera spealaea* (Fig. 11c) was also found in layer 10, the only evidence of this taxon found so far. For Trench I the most numerous finds overall are those of cave bears, followed by horses (Equidae (see Table 3 and Fig. S4a in SI)). In Trench III, again the most numerous finds are those of cave bears; among the remaining fauna, the carnivores, red deer, bovids and horses are most abundant (Fig. S4b in SI). The finds of large cervids and bovids are in different proportions for each trench, with the bovids predominant in Trench I, but the remains of neither group allow for any generic identification. In Trench III the cervids are more abundant and the finds of some characteristic bones determine the presence of *Cervus elaphus*, as well as some *Bos* or *Bison*.

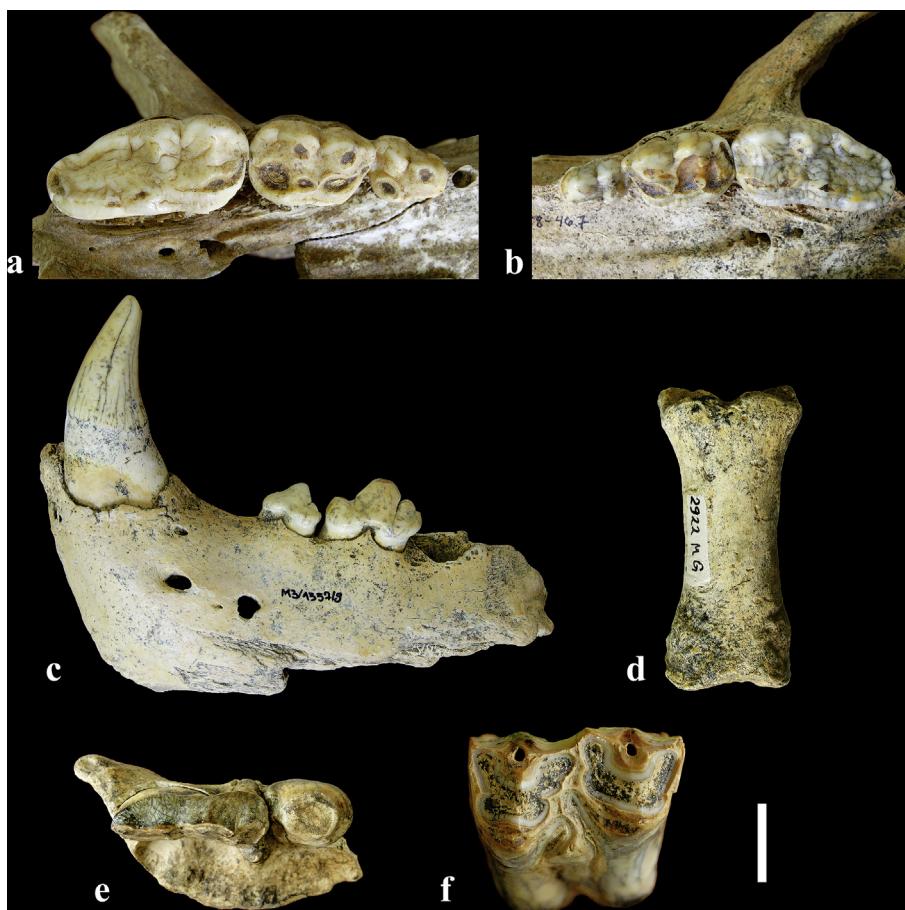


Fig. 11. Large mammal specimens from Magura Cave, Trenches I and III. (a) FM3118 – *U. spelaeus* s.l., maxillary fragment, Trench III, layer 4; (b) FM3116 – *U. spelaeus* s.l., maxillary fragment, Trench I, layer 25; (c) FM3119 – *Panthera spelaea*, mandibular fragment, Trench III, layer 10; (d) FM2922 – *E. hydruntinus*, first phalanx, Trench I, layer 14; (e) FM3122 – *Crocuta crocuta spelaea*, maxillary fragment, Trench III, layer 4; (f) FM3117 – cf. *Bos primigenius*, upper molar, Trench III, layer 4. Scale bar: a – e = 20 mm; f = 10 mm (Photos by L. Hristova).

An upper molar with very high entostyle, a feature mostly typical for aurochs and not for bison, gives ground to refer this tooth to cf. *Bos primigenius* (see Delpech, 1984). Fig. 11 shows some of the recovered specimens from both trenches.

significant numbers of ribs and vertebrae, indicating the presence of once whole skeletons; however, these are mostly remains of cave bears, which could have died in the cave during hibernation or on other occasions.

Table 3
Total of identified animal remains excavated from Trenches I & III.

Species/layers	Trench I						Trench III						
	13–23	24	25	26	29	39	43	4	6	7	8	9	10
<i>Ursus spelaeus s. lato</i>	28	14	72			8	5	27	93	19	50	30	99
<i>Carnivora</i> indet.			2				1		1	1	1	2	1
<i>Canis lupus</i>		1	3						2			1	
? <i>Cuon</i> sp.												1	
cf. <i>Vulpes vulpes</i>							1			1			
<i>Crocuta spelaea</i>			1						3		1		1
<i>Panthera spelaea</i>													1
Rhinocerotidae										1			
<i>Equus germanicus</i>		2	2	34	4				1	4	1		4
<i>Equus hydruntinus</i>	1									1			1
Artiodactyla indet.	1		6	1		1	1	1	1	1	1		
<i>Megaloceros giganteus</i>			1						1				
<i>Cervus elaphus</i>	1		2	1				5	9				
? <i>Bos primigenius</i>								1					
cf. <i>Bison priscus</i>									1	2			
aff. <i>Rupicapra rupicapra</i>													1
Aves indet						2						1	1
<i>Lepus</i> sp.								1					

The numerous gnawed bones of bears, large bovids and cervids, as well as the finds of hyaena bones and coprolites, demonstrate that at some point the cave was a hyaena den, where they also brought the remains of their prey. Of interest is the concentration of horse remains in layer 26 of Trench I. Most of the bones are from the distal part of the extremities – tarsals, metapodials and phalanges. Cut marks have been observed on a few *Equus* tarsal bones – a talus (astragalus), two third tarsals and a fourth tarsal. On the astragalus (Fig. 12a), the cut marks are on its medial surface, starting above the tuberculum, close to the facet for the navicular, and ending on the protuberance close to the top of the bone. The cut marks on both third tarsals are situated along the cranial side (Fig. 12b). On the fourth tarsal, the cut marks are on the medial wall close to, or over, the tuberosities for the ligaments. They are all on the outer surface of the ankle joint and are most likely associated with the disarticulation of the foot during butchery. These cut marks suggest that this accumulation may be the result of horse hunting by hominins. There is no explanation for the abundant bear fibulae in layer 25 of Trench I (usually a rare find because they are fragile bones) compared to the less numerous and broken tibiae (one of the strongest bones). It is possible this also is the result of human activity. The distribution of the bones of different skeletal parts shows

4.3.2. Cave bear sample

4.3.2.1. Ancient DNA analysis of Magura Cave bears. To establish a more precise taxonomic status of the cave bears from Magura, ancient DNA (aDNA) analyses were performed on three teeth and on a metapodial sample from Trench III, following precautions and authentication criteria commonly described in the literature. Amplification in singleplex of two short fragments (fragment 1 and 5) of the mitochondrial DNA (mtDNA) control region was set up with primer pairs and PCR conditions described in Stiller et al. (2014). Phylogenetic analyses were carried out by comparing the sequences of the mtDNA fragments successfully amplified with those of cave bear analysed in previous studies and deposited in GenBank. More details about the methods and contamination precautions adopted in this study are given in the SI.

Amplification and sequencing of DNA across multiple independent experiments of the two fragments of the mtDNA control region were successful and met the authentication criteria in the metapodial sample (sample M3, specimen M3/1359, layer 8) and in one molar tooth (sample MG1, specimen M3/1085–1086, layer 6). A phylogenetic tree of 61 unique haplotypes of the two concatenated fragments from sequences deposited in GenBank was constructed with MrBayes and showed that the genetic distinctiveness of the

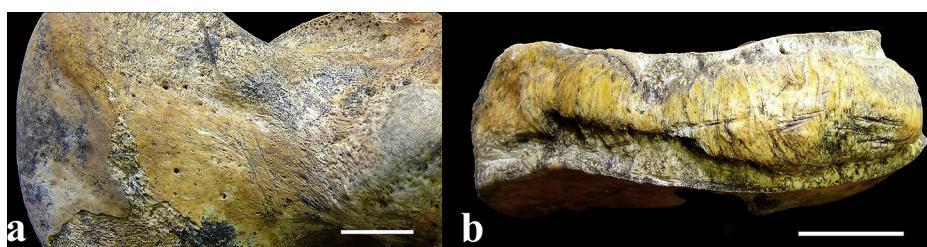


Fig. 12. *Equus* tarsal bones from layer 26 showing cut marks on (a, left) the medial surface of an astragalus and (b) the cranial side of a third tarsal. Scale bars = 10 mm. (Photos by L. Hristova).

main taxonomic units described previously with longer sequences – *U. spelaeus*, *U. ingressus*, *U. kudarensis*, *U. rossicus* and *U. ladinicus* – was preserved with fairly high support in the two fragments analysed (Fig. S5 in SI). The sequence read from the two amplicons of the samples M3 and MG1 revealed two different haplotypes that could both be assigned to the *Ursus ingressus* clade.

The two haplotypes showed an overall eastern European distribution. The mtDNA haplotype found in the sample M3 from Magura did not match any of the haplotypes described before and it was one mutational step distant from sequences found in cave bears from Austria (Gamssulzen, Herdengel and Nixloch), Croatia (Vindija), Romania (Peștera cu Oase), Slovakia (Medvedia jaskyna), Slovenia (Potocka Zijalka) and Ukraine (Payjma cave). The haplotype observed in the molar sample (MG1) has been previously found in two bears from Romania (Peștera cu Oase) and in one from Ukraine (Molochnyi Kamin cave).

4.3.2.2. Cave bear tooth and metapodial morphology. Materials, methods and taxonomic conclusions. The methodology of Rabeder (Rabeder, 1983, 1989; Rabeder and Tsoukala, 1990) was applied for the analysis of tooth morphology of the bears. The results from the morphotype study of the upper and lower fourth premolars (P^4 and P_4 respectively) for both trenches are presented in Tables 4 and 5.

Table 4
Showing morphotypes of P^4 and P_4 , following Rabeder and Tsoukala (1990).

Trench I		
Layer	P^4	P_4
14	E	D2, E3
17	F	
24	D	
25	C	C3, D3

Table 5
Showing morphotypes of P^4 and P_4 , following Rabeder and Tsoukala (1990).

Trench III		
Layer	P^4	P_4
4 and 5	D, F	
6	D	C2, D3
7	E3	
8		C2, E3
9	C, D	C1
10	5 C	B3, 2 C3, 2 D2

The spectrum of morphotypes at Magura is quite wide, and it seems to cover the morphological features of the premolars for both *U. spelaeus* (B to D) and *U. ingressus* (E and F). As the sample is very small, we would suggest that the observed intraspecific variability of the teeth does not sufficiently reflect the real picture. Therefore, the attribution of the Magura Cave teeth to several different discrete groups means it is inconclusive as to which species the samples should be referred, *U. spelaeus* or *U. ingressus*.

The observation above suggests that both *U. spelaeus* and *U. ingressus* could be present, but that several morphological tooth characters of these close forms could overlap to some extent, having a mosaic distribution of features (see also Rabeder, 1999). It should be noted, in relation to this, that following some opinions (Baryshnikov, 2007; Baryshnikov and Puzachenko, 2011), the morphological and genetic differences between these "Eastern" (*U. ingressus*) and "Western" (*U. spelaeus* sensu stricto) cave bear forms are not considerable and do not exceed the known differences amongst recent brown bear populations, in spite of the fact that the molecular data distribute them into different haplogroups,

regarding these taxa as separate species (Rabeder et al., 2004, 2009). Primitive and evolved morphotypes could be observed in one and the same layer but, to some degree, the premolar morphotypes in the lowermost layer 10 (Trench III) are more primitive (P^4 – 5C; P_4 – B3, 2 C3, 2 D2), if compared with the upper layers 4 to 6 (P^4 – 2 D, F; P_4 – C2, D3). The DNA-sampled specimen M3/1085-1086 is an M^1 from a left mandible. It has P^4 and all molars preserved, its age cohort is V (sensu Stiner, 1998) and the teeth are medium-worn. The P^4 morphotype is C2. The presence of *U. ingressus* coincides with the presence of jaws with an additional alveolus in front of the fourth premolar (specimen FM3118). On the other hand the absence of *U. spelaeus* DNA in the limited sample investigated is not a reason to exclude the presence of this species among the Magura bear sample. Bearing in mind the close relationships between the two cave bear forms, it would not be logical to expect the presence of both species (subspecies?) in one and the same layer, but it is possible that in some of the layers, for example in layer 10, where the more primitive tooth morphology has been observed, the bear taxon is *Ursus spelaeus*. On the other hand, this primitive morphology of the premolars could be related to an earlier stage of *U. ingressus* evolution.

There are four small, strongly convex metapodials from Magura Cave (layer 24, Trench I and layer 8, Trench III) that differ in general shape and size from cave bears, but they are comparable with the known smallest ones of *U. spelaeus* and *U. ingressus*. This is supported by the positive DNA results for one of the specimens, M3/1359, which assigns it to the *Ursus ingressus* clade.

4.3.2.3. Cave bear sexual dimorphism and age distribution. Materials, methods and conclusions. Although the fossils of cave bears at Magura are the most abundant of all the mammalian taxa, well-preserved cave bear bones are few, which strongly reduces the use of some statistical methods when studying the cave bear sample. The most significant material from the limited sample of Trench I and Trench III are the canines.

The results show almost equal representation of both sexes (Table 6), with a slight prevalence of males (using data from the lower canines for Trench I and upper canines from Trench III), except in the upper canine sample from Trench I, which shows a prevalence of females.

Table 6
Representation of sexes of the *Ursus spelaeus* sample from Trenches I & III, using canine teeth.

	Trench I			Trench III		
	Male	Female	n	Male	Female	n
Upper canines	1	4	5	7	6	13
Lower canines	4	3	7	5	5	10
Upper canines – %	20	80	5	53.8	46.2	13
Lower canines – %	57.1	42.9	7	50	50	10

As for the other teeth from both trenches, the most abundant are the upper and lower cheek teeth which allows detection of all ontogenetic stages – from cubs a few months old to senile individuals. The age scoring technique of Stiner (1998) was applied for the study of the age distribution. To increase the numbers of teeth in the sample, each tooth position on the maxillae and mandibles was counted as a separate tooth, even if the tooth itself was missing. The cheek teeth were separated into 9 consecutive cohorts, depending on the root formation and the wear of the occlusal surface. The MNI (minimum number of individuals) was not calculated because of the small sample. All available cheek teeth from current tooth position have been compared and the size, morphology and degree of attrition were checked carefully for similarities.

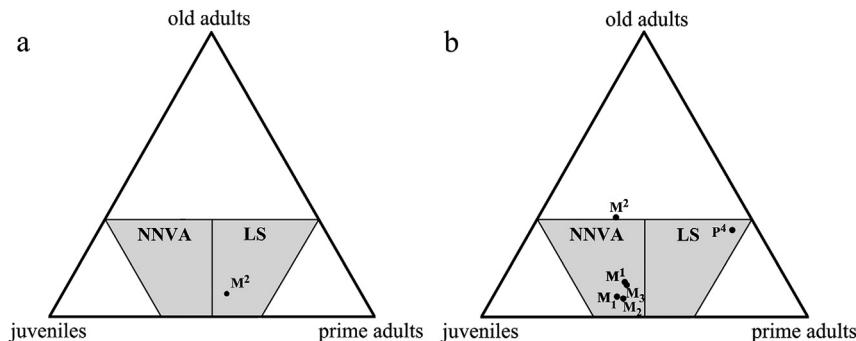


Fig. 13. (a) NNVA – normal nonviolent attrition pattern family; LS – living age structure pattern family; M₂ – second lower molar of the sample from Trench III, layer 10. (b) NNVA – normal nonviolent attrition pattern family; LS – living age structure pattern family; P⁴, M¹, M², M₁, M₂ and M₃ – the tooth positions from the whole sample of Trench III.

The results show that all teeth belong to different individuals; therefore the number of specimens is equivalent to NISP (number of identified specimens). Then the 9 cohorts were united in 3 main groups (juveniles, prime adults and old adults) and were built into tripolar diagrams, following Hammer et al. (2001). The result is presented in Fig. 13.

The small sample size would make the study of the age structure layer by layer inefficient and would give a false result. Only the sample of M₂ (Trench III, layer 10) has an adequate number of specimens at about the minimum threshold for this analysis – 12 specimens (Stiner, 1998), and it falls in the LS (living structure) zone (Fig. 13a).

In order to increase the number of specimens involved in the analysis, the method of Stiner (1998) was followed: the cheek teeth from all layers of Trench III are combined (see Table 7). In this way the “net consequences of multiple bear occupation and death events” is expected to be evaluated. The results are presented in a tripolar diagram, Fig. 13b.

Table 7
Total cheek teeth from all layers of Trench III.

Tooth position	Juveniles	Prime adults	Old adults	NISP
P ⁴	1	7	4	12
M ¹	8	6	2	16
M ²	7	4	6	17
M ₁	16	11	2	29
M ₂	16	12	2	30
M ₃	9	7	2	18

With the exception of the P⁴ and M², all other cheek teeth mortality data fall into the normal non-violent attrition zone on the diagram. The M² is at the boundary of NNVA, while P⁴ is situated in the zone representing living age structure (LS). The results related to P⁴ could be explained by their small number, at the limit of the analysis. As a whole, the results of the age groups in Trench III are suggestive of a hibernation mortality pattern (NNVA), but cannot be considered conclusive. The collected teeth do not show the distribution of the cave bear remains throughout the whole cave, but only in one small, randomly chosen place.

4.4. Small mammals (mammalia: eulipotyphla, chiroptera, lagomorpha, rodentia) from Trench 1

Small mammal bone fragments and isolated teeth were retrieved during wet-sieving of excavated sediments through mesh size of 1 mm. Scarce determinable remains were found in three samples from Trench I, layers 26, 27 and 40. The material was examined and identified using a binocular microscope. In total, 21

taxa (insectivores, bats, lagomorphs, and rodents) were recorded (Table 8), many to species level. The considerable fragmentation of all specimens and signs of corrosion by the predators' digestive acids indicate that pellets of birds of prey were possibly a significant source of the fossil material.

Table 8
Species composition of small mammals from Trench I of Magura Cave.

Species	Layer (Depth cm)			Habitat
	26 (455–460)	27 (460–465)	40 (694–698)	
<i>Sorex araneus</i>			+	Forest
<i>Crocidura leucodon</i>	+			Forest
<i>Talpa sp.</i>	+			Forest-meadow
<i>Rhinolophus sp.</i>	+			Forest
<i>Myotis blythii</i>	+			Forest
<i>Barbastella barbastellus</i>	+			Forest
<i>Miniopterus cf. schreibersii</i>	+			Forest
<i>Ochotona sp.</i>	+			Steppe
<i>Spermophilus sp.</i>			+	Steppe
<i>Glis glis</i>	+			Forest
<i>Apodemus sp.1</i>	+		+	Forest
<i>Apodemus sp. 2</i>	+			Forest
<i>Mus sp.</i>		+		Forest-steppe
<i>Nannospalax sp.</i>	+			Steppe
<i>Cricetus cricetus</i>		+	+	Steppe
<i>Mesocricetus newtoni</i>		+		Steppe
<i>Clethrionomys glareolus</i>	+			Forest
<i>Lagurus lagurus</i>		+	+	Steppe
<i>Microtus subterraneus</i>	+			Forest-meadow
<i>Microtus ex gr. arvalis</i>	+	+	+	Meadow-steppe
<i>Chionomys nivalis</i>	+	+		Rocks

As concerns the species composition and structural characteristics of the fossil assemblages, the whole set clearly splits into two markedly different stratigraphic units:

- (i). The faunal assemblage from layer 26 is characterized by a considerable taxonomic richness and includes taxa characteristic of temperate and more or less humid climates, inhabiting forests and meadows, such as *Crocidura leucodon*, *Talpa sp.*, *Rhinolophus sp.*, *Myotis blythii*, *Barbastella barbastellus*, *Miniopterus schreibersii*, *Glis glis*, *Apodemus spp.*, *Clethrionomys glareolus*, *Microtus subterraneus*.
- (ii). The faunal assemblages from layers 27 and 40 yielded a small mammal fauna that is poorer both in abundance and species number. It also differs by the absence of the majority of the above mentioned taxa and includes taxa associated with cool and relatively arid climate with predominance of open

vegetation such as *Spermophilus* sp., *Cricetus cricetus*, *Mesocricetus newtoni*, *Lagurus lagurus*.

Taxa common to both assemblage types are few. Unfortunately, the material is too scarce to allow a more detailed statistical analysis of the observed differences. It should be mentioned however that bat remains were found only in the first assemblage type, indicating a relatively warm climate. The species composition of bat remains agrees with this interpretation, with presence of thermophilous taxa, such as *Rhinolophus* sp., *Myotis blythii* and *Miniopterus schreibersii*.

The above data show that samples of layers 26 and 40 reflect completely different environmental conditions. Layer 26 is probably deposited in a relatively warm/temperate and humid climate, with forest vegetation in the vicinity of the cave. Layer 40 presents a cool, dry continental climate and herbaceous vegetation (steppes) in the vicinity of the cave.

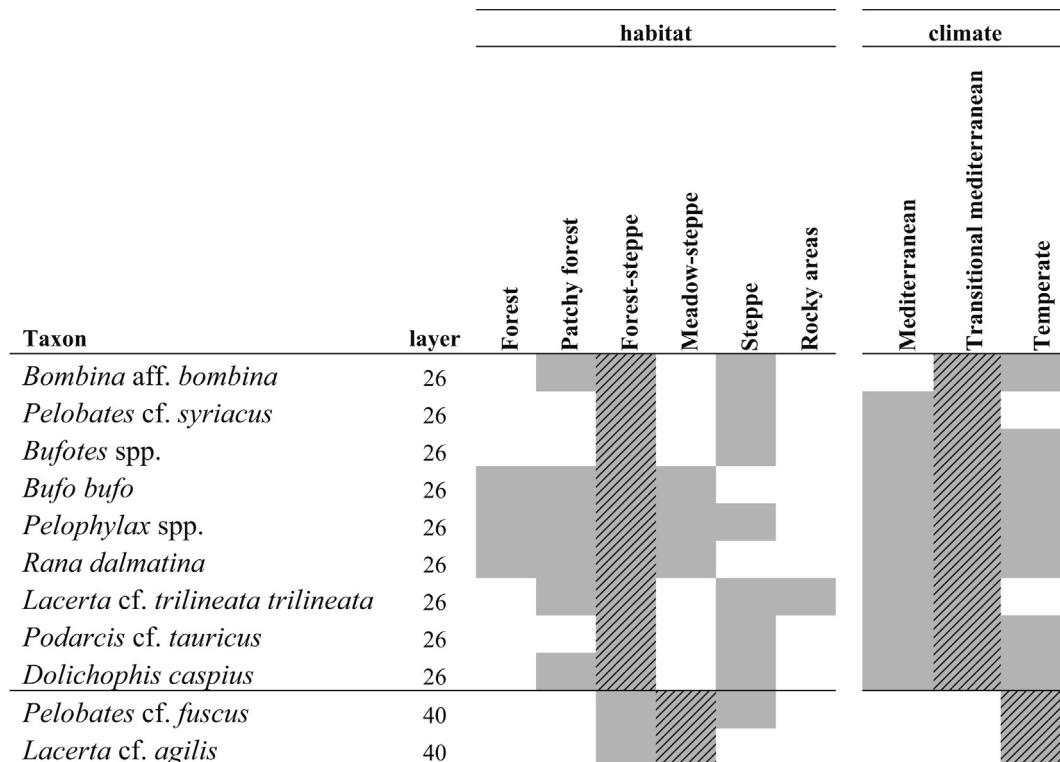
4.5. Amphibians and reptiles from Trench 1

Small numbers of herpetofaunal remains belonging to currently known groups were recovered from Trench I, layers 26 and 40.

Predominant amphibian taxa indicate the existence of a seasonal or permanent water body in relatively close proximity to the bone accumulation area, as *Pelobates* spp. larvae need at least 1.5 months for metamorphosis but under optimal conditions this period may be prolonged to 3–4 months (Székely et al., 2010; Nöllert et al., 2012). The presence of green frogs (*Pelophylax* spp.) is also consistent with a permanent water body being present. It must be pointed out that some of the reported species (*Bombina cf. bombina*, *Bufo* spp., *Rana dalmatina*) are able to reproduce in relatively small lentic water bodies, and that only *Bufo bufo* is also able to reproduce in lotic ecosystems. The co-occurrence of species confined to open habitats with species partly associated with forests indicates the mosaic character of the presented habitats. Taxa such as *R. dalmatina* and *B. bufo* indicate the presence of at least small patches of forest or riparian woodland. One taxon, *Pelobates cf. syriacus*, could be categorized as thermophilous. Most of the determined taxa currently have relatively broad ecological niches; however, based on the cross-analysis of their habitat preferences, it could be postulated that the forest-steppe characteristics of the landscape, under a transitional-mediterranean climate, is the habitat-climate combination that best suits all the taxa presented here (Table 9).

Table 9

Herpetofaunal list from Trench I and the associated habitats and general climatic conditions in the study area: light grey indicates present-day habitat and climatic preferences; the diagonal shading over the grey indicates the preference zone mutual to all taxa, and therefore the projected optimal habitat type and climatic zone, at time of deposition, for the respective layer.



Comparative material (housed at the National Museum of Natural History, Sofia), including a full set of recent regional herpetofaunal taxa, was used for taxonomic determination. The fossil remains were highly fragmented, which may indicate their accumulation by predators. Most of the taxa identified currently inhabit the study region. Layer 26 provided the richer herpetofaunal assemblage. The

Determined reptile taxa support the interpretation of the mosaic characteristics of the landscape and also indicate a warmer climate in the study area in the past compared to the present. Taxa such as *Podarcis cf. tauricus*, *Dolichophis caspius* and especially *Lacerta cf. trilineata trilineata* have been categorized as thermophilous, and the latter indicates the presence of rocky areas. Taxa that

were found in layer 40 define the climate as temperate and more humid than the present day, as well as suggesting a landscape with more open habitats.

4.6. Hyaenas and coprolites

Evidence for the presence of spotted hyaenas (*Crocuta crocuta* RXLEBEN 1777) at Magura Cave is confirmed by finds of a few *Crocuta* bones, as well as a large number of well-preserved coprolites from layers 7–10 in Trench III. Initially, ten coprolites (Fig. S6 in SI) were measured and sampled for palynology and mineralogy (see Table S4 in SI); five more were later processed for further pollen analysis.

The genus *Crocuta*, although having its phylogenetic roots in Africa (Rohland et al., 2005; Kahlke, 2014), is known from a large number of sites throughout Eurasia during the Pleistocene, reaching to Britain in the north-west, and as far east as Zhoukoudian in modern day China. Eurasian members of the genus *Crocuta* are often described as 'cave hyaenas' (*C. crocuta spelaea* GOLDFUSS 1823) and although recent research suggests that there is little or no phylogenetic separation between these two forms (Rohland et al., 2005; Bon et al., 2012), there are several morphological characteristics that distinguish Eurasian spotted hyaenas from African ones. These include different body proportions (Kahlke, 1994), a slightly differing cranial morphology, and some variations in jaw and teeth morphology (Doris Nagel, pers. comm.).

Phylogenetic analysis suggests that the most recent spotted hyaena migration into Europe and Asia took place after about 360 ka, starting from a northern African refugial population (Rohland et al., 2005; see Stuart and Lister, 2014 for further phylogenetic discussion and references). Layer 8 of Trench III at Magura, from where a significant number of coprolites were recovered, has an infinite ^{14}C date (OxA-31115) on an *Ursus* humerus of >50,000 ka, but gives us a *terminus ante quem* for the deposition of at least some of these coprolites; there are a few from layer 7 above. The layer 4 *Crocuta* maxilla already mentioned has a calibrated date of 38,341–35,765 cal BP (OxA-31009), and this concurs with Stuart and Lister (2014) regarding the most recent presence of *Crocuta* in Europe, who report a direct date of

30,813–30,328 cal BP (OxA-10523) from Grotta Paglicci, Italy. Of additional relevance here is a slightly later record from Kozarnika Cave, Bulgaria (levels 4b and 5b) dated to ca 26,000 BP (ca 31–30,000 cal BP) (Guadelli et al., 2005), but this still requires direct dating for confirmation.

4.6.1. *Hyaena* coprolite analysis

Over the past few decades, coprolite analysis has been recognised as an excellent source of data in archaeology and palaeontology, providing a range of proxies concerning both the individual producer and its environment (e.g. Sobolik et al., 1996; Carrión et al., 1999, 2005; Gil-Romera et al., 2014; see Reinhard and Bryant (1992) and Lewis (2011) for extensive bibliographies). Depending on the species producing the coprolite, there is a wide range of potential components to be found, including vertebrate and invertebrate remains, plant macrofossils, pollen, phytoliths, and parasite remains as well as the chemical constituents of the coprolite itself. Much past focus has been on human coprolites (Martin and Sharrock, 1964; Callen, 1965; Bryant and Larson, 1968; Trevor-Deutsch and Bryant, 1978; Reinhard et al., 1991, 2006; Chaves and Reinhard, 2006) but more recently analyses of the coprolites of spotted hyaenas have also been shown to provide excellent results for reasons pertaining to its diet and behavioural ecology (e.g. Scott et al., 1995, 2003; Carrión et al., 2000, 2001, 2007, 2008; Yil et al., 2006; Lewis, 2011).

4.6.2. Metrical analysis of coprolites

Crocuta coprolite morphology is quite distinctive due to peristaltic movement of the digestive tract (Horwitz and Goldberg, 1989), which produces segmented scats, often almost spherical with one concave end and the other more convex (see Fig. S6), although there is some variation. The size of these segments is also variable within and between hyaena individuals.

Coprolite measurements have been used in past studies to separate hyaenid taxa (Horwitz and Goldberg, 1989; Parfitt and Larkin, 2010) and have been used for other vertebrates to infer body size of individuals. The maximum width, the most reliable measurement for providing a distinction between hyaenid taxa and for comparison with other studies (see Parfitt and Larkin, 2010), of

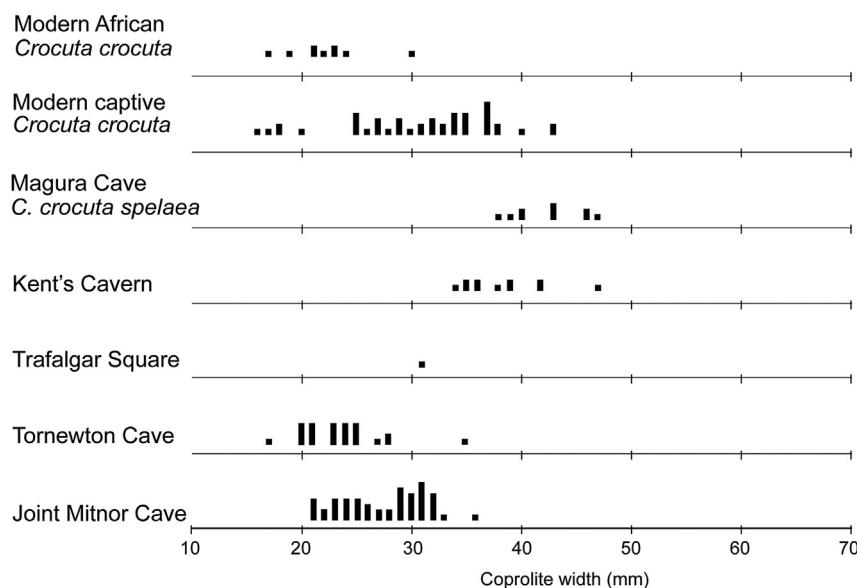


Fig. 14. Histograms showing the maximum width (in mm) of the Magura coprolites in comparison with modern spotted hyaena scats and coprolites of *Crocuta crocuta* from British Late Pleistocene sites: Kent's Cavern (Last Cold Stage, MIS 3), Trafalgar Square, Tornewton Cave, Joint Mitnor Cave (Last Interglacial, MIS 5 *sensu lato*). After Parfitt and Larkin (2010).

the ten coprolites used for mineralogy and palynology was measured here and compared with other Late Pleistocene and modern data sets (see Fig. 14).

Although *Crocuta* remains are known from Late Pleistocene sites in central Europe (Diedrich and Zák, 2006; Stuart and Lister, 2014) there appear to be no data on coprolite size, and consequently the comparative sites used here are all British. Both European and British Last Cold Stage *Crocuta* are known from bone remains to have been larger than other Eurasian Pleistocene interglacial and modern East African members of the genus (Klein and Scott, 1989; Turner, 1995; Parfitt and Larkin, 2010). This is possibly as an adaptation to temperature regulation following 'Bergmann's Rule', and the large width of coprolites from the A2 Cave Earth layer at Kents Cavern (see Fig. 14) is consistent with this, being thought to belong broadly to the Last Cold Stage MIS 3 period. The range of coprolite widths seen at Magura is very similar to that of Kents Cavern, the three sites below it in the graph (Trafalgar Square, Joint Mitnor and Tornewton) all belonging to the more temperate MIS 5. Anatomical observations of jaws and teeth at Magura suggest that the *Crocuta* remains should be referred to *C. crocuta spelaea*, and the coprolite size similarity supports this.

4.6.3. Mineralogy

The main aims of mineralogical analyses, along with observations on size and morphology, are to identify with certainty that the coprolite has been produced by *Crocuta*. Coprolites of *Crocuta* are distinguishable from those of other carnivores through their chemical composition, being largely composed of apatite ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$), a complex mineral form of calcium phosphate, which is a product of the high bone content of *Crocuta* diet (Kruuk, 1972, 1976; Horwitz and Goldberg, 1989; Larkin et al., 2000). Their powerful jaws and teeth have evolved for specialized bone crushing, allowing the maximum nutrition to be extracted from their prey (Stuart and Lister, 2014), and the amorphous nature of the white interior of the coprolites suggests digestion of all the organic constituents of the bone, leaving only the inorganic fraction in a reconstituted form. The high inorganic content makes the coprolites extremely durable, which undoubtedly aids their preservation in the fossil record (Larkin et al., 2000).

The methods and a detailed table of results of the wet chemistry can be seen in Table S5 of the SI, with the mean percentages of calcium (Ca) and phosphorus (P) shown in Table 10. The results show values very similar to the *Crocuta* comparative samples and overall, the Ca to P ratio is constant within analytical error, suggesting almost identical mineral composition; this in turn points to the same species being responsible, with a bone-rich diet in this case. In contrast, the more omnivorous brown hyaena (*H. hyaena*) has Ca values less than half of those of *Crocuta* (Table 10). Concentrations for a number of other elements were also quantified (see SI), all coprolite samples showing similar values within each element analysed. Finally, values of rare earth elements were very low in all samples (0.8–8 ppm of total of 14 lanthanoids), which suggests very little diagenetic alteration.

X-ray diffraction showed, in all ten coprolites sampled, that the only apparent mineral phase is apatite with all of the major peaks corresponding to those generated by an apatite mineral, in this case hydroxyapatite. X-ray diffractograms (Fig. S7 in SI) of three of the coprolites (2, 5 and 9) clearly show hydroxyapatite peaks; the pattern was the same for all ten coprolites analysed. The peaks for coprolite 9 are also shown in slightly more detail. Peaks of quartz were also notably present, which probably represent sediment ingested along with the prey animal. A range of apatite mineral phases exist, other phases such as fluorapatite suggesting diagenetic alteration, but the absence here of any other phase concurs with the wet chemistry evidence that there has been little or no diagenetic alteration in this case.

Diagenetic change in coprolites may be related to period of burial in the ground, and possibly also burial environment (Lewis, 2011), and the mineralogy results here suggest that little or no diagenesis has taken place. This is consistent with the Late Pleistocene age provided by the ^{14}C and tephra dates and has positive implications for the palynology also, suggesting integrity of the coprolite as a sealed context for pollen.

4.7. *Hyaena* coprolite palynology

Pollen analysis from hyaena coprolites is now well-established, and can be seen as a useful tool where conventional pollen sources may be absent, particularly cave sites where taphonomic biases or poor preservation often occur within pollen assemblages from cave-floor deposits (Dimbleby, 1985; Turner, 1985; Carrión et al., 2008; Gil-Romera et al., 2014). A large number of *Crocuta* coprolites are present in Trench III here, the highest concentration found between 400 and 420 cm, corresponding to lithostratigraphic layers 8 and 9, with coprolites also present in layers 7 and 10. Hyaena coprolite pollen assemblages are likely to give relatively unbiased reflections of vegetation of the wider surroundings in which hyaenas are active (Scott et al., 2003). Recent modern observations of pollen from hyaena coprolites and surface samples have shown their potential to detect local occurrences of plant species that are seldom registered in pollen analysis of lacustrine, peaty and similar sediments and provide valuable information on the past biodiversity in the area where the hyaenas have roamed (Gil-Romera et al., 2014); the same study has shown the inner section of the coprolites to have a significantly larger number of taxa than the outer fraction. Pollen content of coprolites (including those of hyaenas) from cave deposits can be a valuable source of information on past vegetation and landscapes in arid and semi-arid environments, especially when crosschecked with regional pollen records (Linseele et al., 2013). Palynology of well-stratified coprolites, in association with other mammal remains from the same layers as here at Magura, has the further advantage of enhancing palaeoecological interpretation by providing evidence from two associated proxies.

Previous Quaternary hyaena coprolite palynological studies have mainly been undertaken in Southern Africa (e.g. Scott, 1987; Scott et al., 2003; Gil-Romera et al., 2014), the Iberian Peninsula

Table 10

Results of calcium (Ca) and phosphorus (P) percentages for Magura *Crocuta* coprolites, as well as some modern (Col = Colchester Zoo) and Pleistocene samples (WR = West Runton, TN = Tornewton, both UK). \pm = S.D. Also shown for comparison are Kruuk's (1976) values, including those of brown hyaena (*H. hyaena*).

	Col 01	Col 02	WR 01	TN 01	Magura <i>Crocuta</i> n = 10	Kruuk (1976) <i>Crocuta</i> n = 20	Kruuk (1976) <i>H. hyaena</i> n = 20
% Ca	26.93	26.56	28.71	28.41	27.65 \pm 3.67	25.54 \pm 10.76	12.07 \pm 7.2
% P	11.34	11.95	10.94	13.36	13.48 \pm 5.00		

(e.g. Carrión et al., 2007, 2008), a few British sites (Lewis, 2011) and the Irano-Turanian region (Djamali et al., 2011), but we are currently unaware of any studies from central or eastern Europe. The coprolite investigation presented here provides the opportunity to fill this gap and to deliver information on pollen deposition in this region using hyaena coprolites; this allows an insight into the local vegetation and environmental conditions during the Late Pleistocene in an area where, until now, such information is scarce and continuous lake and mire sediments covering the period are missing. By providing a chronological framework of the finds and integrating them with the archaeological and megafaunal evidence, it is possible to obtain a detailed reconstruction and interpretation of the palaeoenvironmental conditions and human adaptations to them during the period in question.

4.7.1. Palynological method

Sample preparation, laboratory and microscopy methods can be found in the Supplementary Information.

4.7.2. Results

The pollen results are presented in percentage values of the pollen sum used for calculation – total land pollen and spores (TLP) identified excluding the aquatics. The pollen diagram represents the relative proportions of the pollen in each of the studied coprolites and the TLP sum is also given (Fig. 15). Some plant macrofossils identified on the pollen slides are given in a separate diagram as absolute values (Fig. 16).

The coprolite pollen generally shows good preservation and diversity (61 land pollen taxa represented overall, 38 taxa/sample

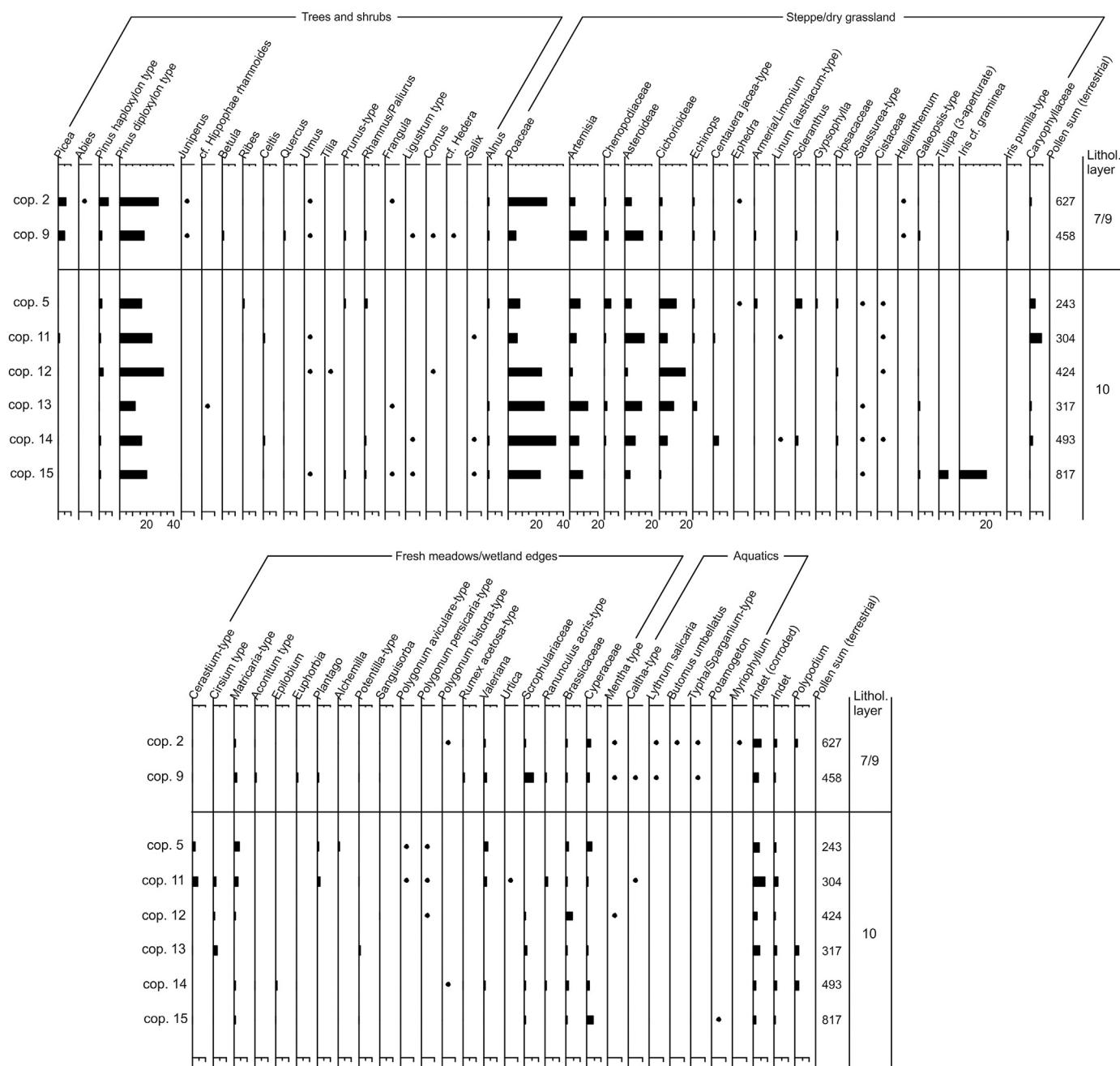


Fig. 15. Percentage pollen diagram from coprolites in Trench III.

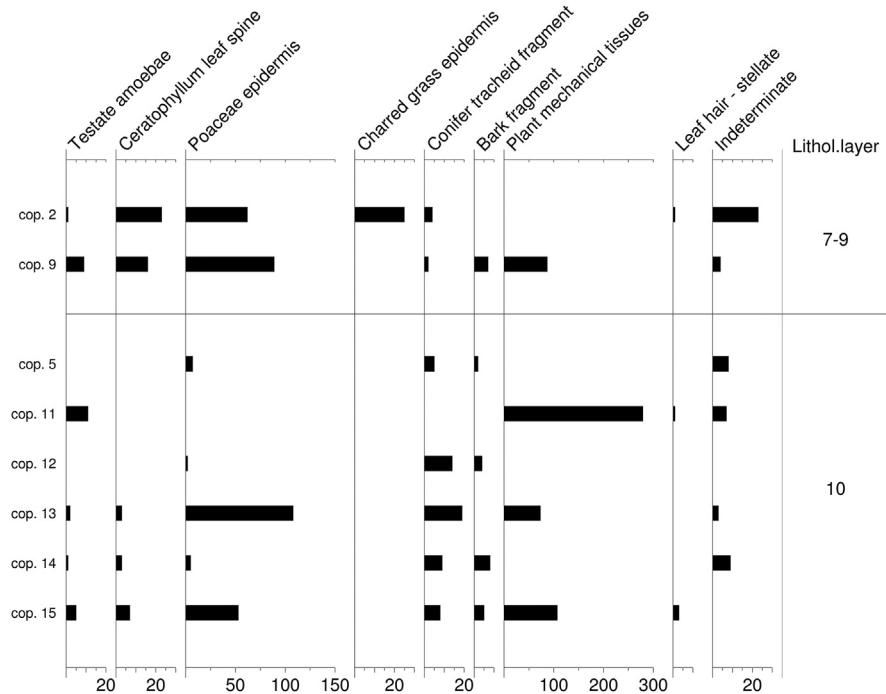


Fig. 16. Absolute values of recovered non-pollen palynomorphs (NPP) and plant tissues from the Trench III coprolites.

mean) The presence of corroded, unidentifiable pollen is low apart from in two of the samples – coprolites 2 and 11, up to 9% – with a mean pollen sum of 460 grains per sample, therefore sufficiently representative in diversity and number to provide a good basis for inferring the main vegetation types in the local area.

The general palynological composition of the coprolites is fairly similar in all samples, the dominating pollen taxa being pine (*Pinus*), grasses (Poaceae) and representatives of the Asteraceae (*Artemisia*, Asteroideae and Cichorioideae). Apart from pine, arboreal pollen (AP) is very scarce (Fig. 15) and is dominated mainly by shrubs or smaller heliophilous trees, such as *Betula*, *Celtis*, *Cornus*, *Juniperus*, *Ligustrum*-type, *Prunus*-type. The assemblages contain pollen of herbs from a variety of habitats, such as open steppe (several indicators including *Artemisia*, *Echinops*, *Ephedra fragilis*-type, *Linum* sp., *Armeria/Limonium*) and also of damp and wet habitats including some obligate aquatics. The presence of coniferous tracheid fragments in the samples suggests local presence of conifers, which include pine but also *Juniperus*.

The two coprolites from lithological layers 7–9 show slightly higher proportions of *Picea* and single grains of *Abies*, probably reflecting presence of more humid woodland habitats visited by the hyaenas or their prey. The higher abundance of damp meadow and wetland pollen types in these two samples is also consistent with this. One of these coprolites (coprolite 2) also contains numerous charred particles, most of which could be identified as coming from grass epidermis (Fig. S8 in SI).

In two of the hyaena coprolites (9 [layer 7/9] and 15 [layer 10]) there are increased proportions of pollen of *Iris cf. gramminea*, *Iris pumila*-type and *Tulipa* (see SI Fig. S8), all taxa that flower in spring and early summer. This could be indicative for the period of deposition of those coprolites with the spring time. Similar observations of seasonality were also made for some of the hyaena coprolites of last glacial age from the central Zagros Mountains (Djamali et al., 2011).

Studies of the complex taphonomy of the pollen preserved in hyaena coprolites can help to test the validity of vegetation

reconstructions based on coprolite pollen analysis. According to the model proposed by Lewis (2011) there are a number of taphonomic pathways by which pollen may enter hyaena coprolites including inhalation of atmospheric pollen, through drinking water or probably most importantly as part of the diet (ingestion of vegetable matter); with *Crocuta* this is most likely through ingestion of the hide or stomach of their prey. The palynological samples and recognisable fragments of plant tissues and non-pollen palynomorphs (NPP; Fig. S8) on the slides can help provide evidence of some of the possible pathways by which pollen has become incorporated into the coprolites. The abundant presence in the samples of bark fragments, mechanical tissues, conifer wood-tracheid fragments and grass epidermis parts suggest contribution of herbivore diet to the pollen assemblages through the prey. Pollen ingested through drinking water, by the hyaena or its prey, is suggested by the presence of aquatics (*Myriophyllum*, *Potamogeton*, *Typha/Sparagnum* type), as well as *Ceratophyllum*-spines and testate amoebae.

4.7.3. Local vegetation inferred by the coprolite pollen

The majority of the pollen types in the coprolites indicate an open landscape vegetation indicative of steppe or dry grassland. This steppe vegetation is dominated by grasses (Poaceae), followed by *Artemisia* and Chenopodiaceae, which are less abundant. This composition indicates a more productive steppe community and better moisture availability compared with a shrub-type steppe (with *Artemisia* and Chenopodiaceae as the main components). Pollen of pine, spruce and some fir indicate presence of boreal woodland patches in the area and local presence of coniferous woodlands is confirmed by fragments of conifer wood tissues in the pollen slides. Additionally, pollen of plants from wet and aquatic environments present in the assemblage show the diversity of the azonal vegetation related with moist habitats in the site surroundings.

Period	Lithostratigraphy		Absolute chronology	Lithic assemblages	Megafaunal assemblages	Flora	Microfauna
	Trench I	Trench III					
Upper Palaeolithic	layers 9 - 1				Trench I, layer 8: Upper Palaeolithic blade		
	layers 19 - 10	layers 9 - 3	Trench III, Layer 4: 14C Age: ca.33,000 BP (38,341 – 35,765 cal BP) Trench III, Layer 5: Tephra 39,300 ± 50 ka		Trench III, layers 10 - 4: dominated by Ursus and other carnivores, mainly <i>Canis lupus</i> , and <i>Crocuta</i> . <i>Equus</i> in layers 10, 7, 6 and 4		
Middle-Upper Pal transition			Trench III, Layer 8: 14C Age: >50,000 BP		Trench III, layers 10 - 7: pollen from <i>Crocuta</i> coprolites indicates mainly steppe vegetation with some temperate trees/shrubs and conifer woodland		
	layers 29 - 20	layer 10	Trench I, Layer 23: 14C Age: >50,000 BP Trench I, Layer 25: 14C Age: >50,000 BP	Trench I, layer 25 and Trench III layer 10, final Middle Palaeolithic	Trench I, layers 26 & 25 dominated by Ursus followed by large herbivores such as bovids, <i>Cervus elaphus</i> and <i>Equus</i> , the latter found in layers 29 to 24		Small mammals in Trench I layers 40, 27 & 26: Layer 26: warm, humid, temperate conditions. Layers 27 and 40: cool, dry, continental conditions Herpetofauna: layers 40 & 26
Middle Palaeolithic	layers 33 - 30						
	layers 45 - 34						

Fig. 17. Chart showing proxies, dates and tentative stratigraphic correlations between Trenches I and III.

5. Stratigraphy and environmental proxies

The aim here is to interpret environmental change at Magura over the time period represented, from the different proxies available, and to place the archaeology and hominin presence within this context. Information comes from two different trenches with different sedimentary sequences and scarce archaeology and it is not possible to establish direct stratigraphical correlations on a layer by layer basis. Correlation relies instead on absolute dates but the potential exists, when excavation on these trenches continues, for further ¹⁴C dates on higher levels of Trench I or on archived bone material, as well as searches at higher resolution for the CI tephra in cryptic form, if present, to help elucidate stratigraphical relationships between the trenches. The ¹⁴C and tephrochronology indicate the time span of this accumulation from more than 50,000 BP to at least ~36,000 cal BP, spanning the late Middle Palaeolithic to Upper Palaeolithic transition. Dating results and typology of the artefacts suggest that the sedimentation of layer 25 (Trench I) and layer 10 (Trench III) are broadly coeval. The trenches both present important but differing strands of evidence and first need to be treated separately. Fig. 17 provides a tentative correlation of the lithics, fauna and vegetation from both trenches.

Trench I, at 7.5 m and not yet bottomed, is the deeper of the two sequences and will be presented first. From the lowest layer 45 up to layer 34 is a sequence of rubble and clayey sand layers; a few unidentifiable fragments of large mammals are found in the lowest layers. In layer 43, apart from *Ursus*, there are two carnivore bones and one artiodactyl bone. Small mammal and herpetofauna assemblages were recovered from layer 40. Here, these two assemblages differ in that the small mammals, although scarce in numbers, include taxa of cool climate and open environments; the herpetofauna are also characteristic of open environments but suggest a climate as temperate as the present day. Layer 39 provides evidence of possible hominin presence from a burnt and possibly cut-marked *Cervus* humerus.

Higher in the Trench I sequence, a series of layers shows the influence of water in that part of the cave, with layer 34 showing the formation of waterlogged deposits and layers 33–30 formed under conditions of an active water regime; no bone remains were found from these layers. Above, layers 29–20 consist of clayey sediments with limestone concretions with smooth edges and

surfaces. Within these layers, the small mammal assemblages indicate a change of climate between cold, arid conditions (layer 27) and warm, humid, mainly forested landscapes (layer 26). There is no herpetofauna from layer 27, but the taxa found in layer 26 currently have relatively broad ecological requirements with some categorized as thermophilous. The co-occurrence in this layer of species confined to open habitats with species partly associated with forests indicates the mosaic character of the habitats. The microfaunal data show that samples from layers 26 and 27 reflect completely different environmental conditions and this could be seen as representing one of the well pronounced climatic variations of the Late Pleistocene (Rasmussen et al., 2014). In the context of determined radiocarbon dates it can be said that layers 26, and 27 are older than 50,000 years BP. Layer 26 also provided significant numbers of cut-marked horse bones, mainly tarsals, and this concentration of horses would also confirm the spread of open but mosaic landscapes as well as a hominin presence.

All artefacts from Trench I (apart from an Upper Palaeolithic blade in layer 8) were found in layer 25 and can be attributed to the final part of the Middle Palaeolithic; some charcoal was also found here, as were the only *Crocuta* remains from Trench I and some further cut-marked bones. As mentioned, it is considered that this layer can be stratigraphically correlated with layer 10 of Trench III, from where there is also a good palynological signal. Large mammal taxa present in layer 25 include Artiodactyla, Carnivora, (including wolf and hyaena), Bovidae, Cervidae, *Equus* and *Megaloceros* and most abundantly *Ursus* (see Table S3 in SI). From layers 24 to 13, *U. spelaeus* (sensu lato) remains dominate, with other taxa present only very occasionally; in Trench I overall, there are 127 *Ursus* specimens (about 66% of large mammals) which is a typical feature of the Late Pleistocene mountain caves of Bulgaria (Spassov and Popov, 2007). Bear mortality, from taphonomic and morphological investigations, could be related mainly to unsuccessful hibernation.

Trench III, although smaller in area and depth, has revealed rich faunal remains, with ten lithostratigraphic layers identified over 4.6 m and 370 identifiable large mammal bones and fragments. Pleistocene deposits, layers 10–3, are generally characterized by a clayey sand fraction with varying quantities of limestone clasts. Layer 10 is a grey clay with gravel-sized limestone pieces and contains *Crocuta* remains, along with sparse bones of *Equus* and

bovidae; a partial *Panthera spelaea* mandible, the only evidence of this taxon, was also found here, and the layer is otherwise dominated by *Ursus* remains. *Crocuta* coprolites are found from layer 10 up to layer 7 and six coprolites with countable pollen assemblages came from layer 10, showing an open landscape dominated by steppe vegetation, interspersed with temperate and boreal woodland habitats. The only lithic artefacts from Trench III are also found here, their typology suggesting correlation with layer 25 of Trench I. The infinite date on the *Ursus* humerus from higher in layer 8 gives a date for the lithic manufacture in layer 10 of at least 50,000 BP. Layer 9 is composed of grey clay and orange sand and, along with layer 8 above, has the largest concentration of coprolites. This is probable evidence of a hyaena den in the cave although the low number of bone remains of *Crocuta* and of other taxa apart from *Ursus spelaeus* in any of the coprolite-rich layers (10–7) could also suggest, in this area of the cave at least, a possible latrine area. Layer 8 comprises a brownish clay with orange spots of weathered limestone and black manganese particles and layer 7 is a yellowish-brown sandy clay with gravel-sized limestone clasts. The pollen found in coprolites from layers 9–7 (Fig. 16) suggest a change in environmental conditions from those in layer 10 to more humid conditions, some tree taxa (*Abies* and *Picea*) reflecting this as well as higher pollen numbers of damp meadow, wetland edge and aquatic plant taxa. Apart from *Ursus*, layers 7–9 provide few other large mammal remains although notably the only bird remains from this trench are found in layers 9 and 8. Layer 6 includes a stratum of small oval-shaped limestone clasts and includes most large mammal taxonomic groups represented at Magura; along with layer 4 it provides the only identified *Cervus elaphus* remains from either trench. The DNA results from two specimens determine the presence of *Ursus ingens* in layers 8 and 6.

The visible tephra layer 5 gives a date in calendar years of $39,280 \pm 55$ providing a valid and precise correlation marker with other events and sites across Europe. In the most complete archaeological sections of Temnata Dupka, the CI tephra separates the Early Aurignacian layers from the other Upper Palaeolithic ones (Giaccio et al., 2008) while at Kozarnika it overlies the early Upper Palaeolithic levels (Lowe et al., 2012). Layer 4 is a yellow-brown, loamy sand and a well-preserved *Crocuta* maxilla from here gave a ^{14}C date of between 38,341 and 35,765 cal BP, both dates providing a chronological context for these upper layers. Apart from *Ursus*, there are few other large mammal taxa present in layer 4.

6. Magura Cave in a regional palaeoenvironmental context

The Balkan and Carpathian regions are seen as two of the most important glacial refugial areas for mammals in Europe during the last cold stage (Sommer and Nadachowski, 2006) up to and including the Last Glacial Maximum, providing centres for the recolonization of Europe by a large number of different mammal taxa. Vegetational studies by Willis et al. (2000) concluded that central and south-eastern Europe provided an important cold-stage refugium for flora (and fauna) from late MIS 3 up to and during the pleniglacial and in general there is little doubt that this part of the Balkan region during the period roughly coinciding with the deposits at Magura should be seen as a refugial area, temperature and precipitation fluctuations being of relatively low magnitude compared to northern Europe (Feurdean et al., 2014). Stable isotope records from speleothem from SW Romania (Constantin et al., 2007) indicate the climatic fluctuations for this period, suggesting warming from 60 to 57 ka, a subsequent overall cooling trend up to 42 ka, followed by a cold phase between 38 and 35 ka (Constantin et al., 2007).

The vegetation in central and eastern Europe during the period covering Marine Isotope Stage 3 (MIS 3, ~57 ka–29 ka) was dominated by warm steppe communities (Feurdean et al., 2014) with presence of small-scale xeric woodland, as reported in the south eastern part of the Carpathian region (Markovic et al., 2007, 2008; Zech et al., 2013). Palaeobotanical research has shown a wide diversity of tree types present in the region with both boreal (*Abies alba*, *Alnus*, *Betula nana*, *B. pubescens*, *Juniperus communis*, *Larix*, *Pinus*, *Picea*, *Salix* and *Sorbus aucuparia*) and temperate taxa represented (*Carpinus betulus*, *Corylus*, *Fagus sylvatica*, *Fraxinus*, *Quercus*, *Ulmus*) (Opravil, 1994; Culiberg and Sercelj, 1995; Damblon, 1997; Willis et al., 2000; Rudner and Sümegi, 2001; Haesaerts et al., 2010). The vegetation at Magura fits well into this regional environmental picture, with the majority of the pollen types indicating a similar open landscape dominated by steppe vegetation, but the overall taxonomic composition, with high Poaceae values, suggesting better moisture availability compared with a shrub-type steppe. There is local presence also of coniferous woodland, as well as light-demanding temperate deciduous taxa; in layers 9–7 of Trench III conditions become slightly more humid than in layer 10, but with the continuation of this mosaic landscape.

The mammal evidence at Magura generally concurs with the vegetation signal, although with some inconsistencies. Large mammal bones were more numerous in Trench III than in Trench I, but this difference is mainly made up by more *Ursus* remains and both trenches overall present a broadly similar large mammal fauna. In Trench I the fauna from layer 23 to the bottom of the trench suggests an open/mosaic landscape with some forests. However, a cold stage microfauna in layer 27, possibly representing a Greenland Stadial (GS) event (Rasmussen et al., 2014) followed by a fauna of more humid, forested landscapes in layer 26, is not supported by the large mammal evidence, horses being abundant in this layer. The presence of horses and the absence of the ibex is possibly a feature related to the local environment and relief, i.e. relatively low, hilly terrains and foothills, with considerable open spaces. Horses would normally indicate a relatively cold climate but the Magura fauna does not include taxa normally found in the cold-resistant faunal complexes of the Late Pleistocene, such as reindeer, saiga, musk ox, and wolverine, which are characteristic of the climatic minima in central and western Europe as well as for the eastern European steppes. It in fact demonstrates the typical Balkan Late Pleistocene faunal composition, which does not suggest very cold climatic conditions (Spassov and Popov, 2007). This relatively mild climate is confirmed by the presence of *Megaloceros* and the probable presence of aurochs, the fauna in general indicating open/mosaic landscape with some forests, consistent with the pollen evidence.

7. Hominin presence at Magura Cave

It has been noted (Verpoorte, 2006) that constraints on Neanderthal physiology would have made their mobility in the landscape costly and that areas of persistent Neanderthal occupation were located in regions with mosaics of different biomes (Davies et al., 2015) thus enabling them to minimise costly mobility and maximise access to resources. Ecotones within this mosaic landscape, for instance the woodland-steppe boundary, may even have been advantageous to Neanderthals using ambush hunting strategies. The mosaic of habitats presented at Magura would undoubtedly fit this description. Furthermore, Churchill (2014) points out that the Balkan region probably represented one of the three core Neanderthal populations that, through migration, supported populations in other parts of Europe.

Two small Middle Palaeolithic assemblages have been recovered from Magura so far, and butchery was certainly taking place in the

cave, with clear evidence of cut marks, particularly on horse bones; it is also probable that artefact manufacture took place in the cave. The lack of Levalloisian forms and the typological characteristics of the cores allow us to assign the lithics so far recovered to the typical Mousterian non-Levallois. But the low number of artefacts at Magura makes precise comparisons with other assemblages and sites difficult and these low numbers could be used to infer rare occupation of the cave or low population sizes. Modelling of Neanderthal demography has been attempted in a number of ways, the most accepted probably being the genomic approach, and some studies suggest populations were small with low population densities and that in some regions of Eurasia there were certainly problems in maintaining viability (Churchill, 2014; Davies et al., 2015). Additionally, high adult mortality and other sociobiological constraints added extra pressure on maintaining an effective group size.

Other sites in north-west Bulgaria, such as Temnata Dupka (Ginter and Kozłowski, 1992) and Bacho Kiro (Kozłowski, 1982), have produced more abundant Middle Palaeolithic material, but we consider that the low density of lithics found at Magura is quite possibly related to the size of the cave and the area excavated. It is notable that the floor surface area of both trenches covers only 20 m² and decreases with depth, yet the total area of the main gallery is approximately 5,720 m². The presence of definite cut-marked horse tarsals in a layer where no artefacts have been found so far would support this and it is possible, with such a large available cave area, that there was some separation of space for different tasks. It is hoped that further excavation in adjacent areas will provide more artefacts and cut-marked material, and consequently provide finer resolution on patterns of Neanderthal occupation at Magura Cave.

8. Conclusions

The interdisciplinary investigations at Magura Cave have recovered evidence of human presence as well as a rich mammal bone accumulation and other biological remains revealing the picture of the fauna, vegetation, climate and Palaeolithic culture of that time (Ivanova et al., 2012b, 2013). The ¹⁴C and tephra dating determines the time span of this accumulation from before 50,000 BP to at least ~36,000 cal BP, which is in concordance with the faunal data. The taphonomic evidence from both trenches suggests that the mammal bone accumulation is related to both human and carnivore (*Crocuta crocuta* and *Panthera spelaea*) activities as well as to natural perishing of a number of individual animals, especially bears. Palynology indicates some variation of climate and vegetation in the time span investigated, but where a mosaic landscape was present in general, with domination of open landscapes with meadow-steppe herbs, some deciduous trees and patches of coniferous woodland in the foothills of the western Stara Planina. Future excavation, dating and taphonomic investigation should further enhance the results presented here.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.quaint.2015.11.082>.

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