GEOLGY, STRATIGRAPHY, AND SITE FORMATION PROCESSES OF THE UPPER PALAEO LITHIC AND LATER SEQUENCE IN KLISSEOURA CAVE 1

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Abstract

Klissoura Cave 1 is located in the northeastern edge of the Argive Plain, Peloponnese, at the entrance of the Berbadiotis river gorge. The cave comprises a collapsed cave chamber and a rockshelter area. The stratigraphic analysis and micromorphological study of the sediments elucidated the main processes involved in the formation of the site and its depositional history. The beginning of the Upper Palaeolithic sequence is characterized by the appearance of minor and major hiatuses. The Middle Palaeolithic layer VII is erosionally truncated by the Aurignacian layer IV, at the back of the rockshelter. In the middle area, layer V, characterized by an Early Upper Palaeolithic technology is also truncated by the Aurignacian layers. The sedimentary content of layer V is more similar to the overlying Aurignacian sequence and, in this respect the truncation can be considered as a minor hiatus. The underlying layer VI is the result of post-depositional mixture at the contact of the Upper and Middle Palaeolithic sequence. The deposits of the Aurignacian layers are mainly the result of anthropogenic processes including constructed clay hearths and dumped, raked-out and trampled ash remains. Geogenic processes in the form of shallow rain sheet wash and wall breakdown were more important in the beginning of the Upper Palaeolithic. The sequence that overlies the Aurignacian has an overall discrete ashy appearance in the field, but the contacts between the different layers are rather diffuse. The uppermost layers of this sequence are affected by geogenic processes. The Epigravettian and Mesolithic layers are disturbed by modern activities and present frequent truncations and diffused interfaces.

Key words: stratigraphy, site formation, micromorphology, cave sediment, hearths, Upper Palaeolithic.

INTRODUCTION

Klissoura Cave 1 is located in the northeastern edge of the Argive Plain, 4 km from the nearest village Prosymna and ca. 7 km from ancient Mycenae (Fig. 1). It lies at the entrance of the Berbadiotis river gorge (Figs 1, 2a) called Klissoura (narrows in greek). More than 30 caves and rockshelters are registered inside and around the gorge six of them containing archaeological remains (Koumouzelis et al., 1996, 2001a, 2001b, 2004). The gorge is 2 km long and up to 500 m wide and connects the Argive Plain with the Limnes plateau uplands through the Berbati valley. Klissoura Cave 1 lies at an elevation of 114 m above sea level, ca. 12 m above the Berbadiotis riverbed. Berbadiotis is an ephemeral stream entrenched into its gravelly deposits and thus forming a ca. 5 m high terrace above which the cave is found (Fig. 2b). The cave entrance faces southeast, overlooking the Argive Plain.

REGIONAL GEOLOGY

The Argive Plain is a Neogene graben filled with lacustrine, fluvial, alluvial fan and slope deposits. The hilly area around the cave is mostly made of Triassic to Jurassic limestones (IGME, 1970). The limestones are usually medium to thick bedded grayish and white, but they laterally pass to thin bedded hard limestones containing nodules and intercalations of radiolarian cherts.
Small outcrops of the Jurassic volcanosedimentary complex are found in several places (IGME, 1970). This complex comprises shales, sandstones, radiolarian cherts, limestones and volcanic bodies belonging to the ophiolitic group. Upper Jurassic, Cretaceous and Paleocene limestones are also found in the region. Some of them are reported to contain several types of chert and flint (IGME, 1970). Flysch is found further to the south and north of the Klissoura area. Alluvial cones
Fig. 2.  

a) The location of Klissoura Cave 1 at the entrance of the gorge;  
b) the front rockshelter of the cave (with arrow) above the Berbadiotis river terrace covered with orange trees.
and fans made of conglomerates are found along
the margins of the plain as well as inside the
Klissoura gorge.

On the basis of the study of Koumouzelis et
al. (1996) and the geology of the area it can be
safely assumed that most of the raw materials
distinguished in the archaeological findings can be
located in the broad area of Klissoura. Different
types of radiolarian chert and flint can be located
in the Triassic limestones and in the Jurassic vol-
canosedimentary complex within a 3–4 km radius
from the site (see Koumouzelis et al., 1996: fig.
13). Secondary flint and chert deposits are found
as pebbles in the Berbadiotis gravels as well as in
other stream deposits of the area. However, the
study of Koumouzelis et al. (1996) failed to locate
some types of black chert and flint within this ra-
dius. Nevertheless, these raw materials occur only
in trace quantities in the archaeological deposits.
The flints and cherts occurring in the Jurassic to
Cretaceous limestones around the Argive Plain
might be the source of the types of black chert and
flint that were not located close to the site. In any
case, further detailed studies of the geological oc-
currences of chert and flint, in comparison with
the artefacts found in the archaeological site is
needed for locating all the possible sources and
confirming the one proposed by Koumouzelis et
al. (1996).

DESCRIPTION AND FORMATION
OF THE CAVE

Klissoura Cave 1 is formed in highly kars-
tified grayish thick bedded Triassic limestones.
The excavation took place at the entrance of the
cave. At this area, the steeply inclined limestone
walls form a rockshelter (Figs 2b, 3). The rock-
shelter area behind the dripping line is ca 50 sq.
meters. The cave itself is blocked by limestone
boulders due to the collapse of a chimney located
close to the entrance of the cave. The cave interior
chamber can be seen also from the chimney open-
ing above the cave, and it seems that it does not
extend more than a few square meters.

The smoothly eroded and curved cliff of the
rockshelter is the result of undercutting erosion by
the running water of the Berbadiotis River, when
it was flowing at this level. The cave itself at the
back of the rockshelter is a karstic gallery made
by dissolution of the limestone. Through gradual
retreat of the cliff face by river erosion the rock-
shelter intersected the gallery itself.

THE ARCHAEOLOGICAL SEQUENCE

The Upper Palaeolithic sedimentary sequence of
Klissoura Cave 1 (Table 1 and Figs 4–8) com-
prises layers 6, 6a, 6/7, 7(a and b), II (a–d), III
(III’ III’’, IIIa–f), IV and V Koumouzelis et al.,
2001b; Kaczanowska et al., this issue ). Layers VI
is also included in this sequence having both Up-
per and Middle Palaeolithic cultural elements.
Layers 1 and 2 are surface layers containing
Bronze Age artifacts, and layers 3 to 5 are Mes-
olithic. The total thickness of this sequence in all
evacuated areas is between 190 and 210 cm. In
most areas the post Upper Palaeolithic sequence
is not thicker than 10–20 cm reaching in some pit
fills a ca. 60 cm thickness. Layers were defined in
the field during excavation and their identifica-
tions were based mainly on texture and color dif-
fences, but cultural content was also taken into
account. However, most of these layers are dis-

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<th>Sequence</th>
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<tr>
<td>A</td>
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<td>Mesolithic and modern</td>
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<td>B</td>
<td>IIa, IIb and IId</td>
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<tr>
<td>C</td>
<td>6, 6a and 6/7</td>
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<td>D</td>
<td>III, III’, IIIa, IIIb, IIIc, IIId, IIIe, IIIf and IIIg</td>
<td>MWA, HGB, RCS and LSS</td>
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<td>E</td>
<td>IV</td>
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<td>G</td>
<td>VI, VII and VIII</td>
<td>HCS, HGB and MWA</td>
<td>Middle Palaeolithic</td>
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Table 1
Layers, facies and cultural content of stratigraphic sequences in Klissoura Cave 1
continuous lensoid features with lateral variations that actually form interpenetrating wedges, causing the subdivisions of each major unit layer, particularly those of layers II and III in the study. The reason for these lateral variations is the spatial distribution of burnt features producing complex overlapping sequences of burnt remains. A discussion of these features will be presented below. It should be added that intact hearth complexes were excavated and separately labeled (Kaczanowska et al., this issue).

**METHODOLOGY**

Field descriptions provide a framework for the finer scale observations used in this study. For this purpose, information concerning the nature of the interfaces between adjacent layers, sedimentary texture, and degree of induration was recorded. For the study of the sediment in a finer scale a micromorphological analysis was employed.

Micromorphology is the study of undisturbed sediments and soils in thin section (Courty et al., 1989). By this technique the original integrity of the deposits is preserved, allowing for the observation of depositional and post-depositional features of natural or human origins.

Micromorphological samples were collected as intact blocks using different techniques depending on the consistency and degree of induration of the sediment. Excavated profiles preserving the maximum stratigraphic variability were selected for sampling (Figs 4–8). Continuous systematic

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**Fig. 3.** Plan view of Klissoura Cave 1 showing the excavation grid (survey made by Th. Chatzitheodorou). The dotted line marks the dripping line. The interior cave chamber is shown with dashed line. Heavy grey lines show the drawn profiles of Figures 4, 5b, 6, 7b and 8 where micromorphology sampling was conducted.
sampling was employed in most cases, in order to detect all variation within the sections. The top, relatively disturbed parts of the sequence were avoided. Five clay hearth structures were also selectively sampled. Sediments from the outside of the cave environment (e.g., modern soil and paleosols) were also sampled. The aim of the analysis was to document the site formation processes that operated at Klissoura.

The sampled intact blocks of sediment were impregnated with polyester resin under vacuum, following the methodology described by Murphy
Fig. 5. Photograph (a) and stratigraphic section (b) of north profile of square B1-A1 showing also the location of the micromorphology samples (numbered black rectangles). The sharp erosional contact between layers IV and VII is clearly seen in the photograph.
La rge for mat (75×50mm) thin sec tions were pre pared. Some 40 large for mat thin sec tions were stud ied in to tal, us ing a stereomicroscope at mag ni fi ca tions of 5 to 40× and a po lar iz ing mi croscope at mag ni fi ca tions rang ing from 50 to 400×. Thin sec tions were de scribed ac cord ing to Bull ock et al. (1985), as mod i fied by Stoops (2003) and Courty et al. (1989).

STRA TIG RA PHY

In or der to ex am ine the se quence in a mean ing ful way, lay ers as de fined by the exca va tors have been combined to groups or facies (Table 1) that exhibit broadly the same sedimen tolo gical char acter is tics. These facies are combined into se quences (Table 1) by group ing sets of adja cent lay ers that due to a unique com bi na tion or oc cur rence of cer tain facies pres ent a dis crete field ap pear ance. The se quences are sep a rated by dis crete con tacts that rep re sent minor or major de pos itional hi a tuses (e.g., Fig. 5a). Some of the se quences com prise only one layer but for keep ing a se quen tial num ber ing they are also called se quences.

Fig. 6. Stratigraphic sec tion of west profile of squares B3-B2-B1 with the location of the micromorphology sam ples
Fig. 7. Photograph (a) and stratigraphic section (b) of east profile of squares CC1-CC2-CC3 with the location of the micromorphology samples.
**FACIES ANALYSIS**

Facies analysis is based on micromorphological analysis supported also by field observations.

*Facies MWA. Massive, firm, white ash complexes*

In the field it appears as relatively thick (usually 10–20 cm) massive and firm ash accumulations with diffuse boundaries and normally with a semi-circular shape with a diameter up to 1 m. Charcoals are often encountered, but they are usually small, friable and irregularly dispersed inside the ash. Under the microscope the sediment appears as consisting of micritic calcite, in a microscopic layered or massive form (Figs. 9–11). Calcite is predominately in the form of pseudomorphs after calcium oxalate crystals.

The ash crystals are rhombic or rectangular-shaped aggregates of micrite (Fig. 10). In addition, calcitic cellular pseudomorphs (Fig. 10), fine black charred compounds, fine charcoal, and fine reddened soil aggregates are frequent. Banding is defined by the arrangement of the clay aggregates, ash crystals and pseudomorphic cellular structures. Pockets and linear arrangements of horizontally bedded burnt bone were often observed. Some of them show signs of in situ fragmentation, possibly due to trampling (Fig. 12).

Internal erosional contacts between different increments of ash accumulations were also defined. In addition, the contacts with the surrounding sediment are always sharp.

It is clear that this facies represents mostly intact ashes. The frequent preservation of pseudomorphs and the layered appearance attest to this conclusion. However, signs of moderate tram-
pling and some minor reworking were also identified. It is obvious that the ash accumulations are the product of several burning episodes, with some of them being clearly separated in time. Burning was intense and almost complete, hence the lack of major amounts of charcoal.

**Facies RCS. Reddish clay structures**

Clay structures are easily defined in the field as discrete dark red compact features with a basin-like shape (Fig. 13). Their diameter is about 30 to 40 cm. Under the microscope the upper and lower boundaries of the clay structures appear mostly sharp. Nevertheless, there are cases where the upper boundary is diffuse at a microscopic scale and the overlying calcitic ashes impregnate the upper part of the hearth. The body of the structures is composed of reddish clay with large amounts of evenly distributed fine sand- and silt-sized chert fragments, quartz, subrounded limestone fine gravel, and rarely more exotic materials such as schist and basalt. The clay in some cases is decalcified and has a massive structure, but with frequent remnants of oriented fabrics that are attributed to soil forming processes. The pores are mainly vesicles and large vughs.

Karkanas et al. (2004) has presented the main evidence that supports the intentional preparation of the clay structures. In brief, they all have a constant shape and similar dimensions. Their lower boundaries are sharp, while the upper ones are microscopically diffused and calcined. They are made of distinct homogenous clay material that is similar to red alluvial soils found in the floodplain in front of the cave, and they lack signs of natural processes that can account for their formation, such as incorporation of any burnt component inside them that would imply colluvial or rain-wash processes. It is suggested that the clay material was brought to the site and after wetting it was carefully puddled and shaped in place. In addition, mineralogical analysis with Fourier Transform Infra-red spectrometry (FTIR) and Differential Thermal Analysis of the clay structures as well as of experimentally heated soils that are thought to be the raw material, suggest that the clay structures were heated to temperatures of 400 to 600 °C. In addition to the low temperature of heating, the association of the clay structures with undisturbed, microscopically intact wood ashes and food remains implies that they were used as hearth structures, perhaps for cooking purposes (Karkanas et al., 2004).
Facies HGB. Heterogeneous gray to brownish gray burnt remains

In the field it comprises tabular to lensoid layers of mainly silty material, and varying colors from pale to dark gray with or without a brownish tint. Its induration degree varies from loose to firm. They often contain fluctuating quantities of angular limestone gravel irregularly dispersed inside the matrix. Its interfaces vary from sharp erosional to diffuse. Under the microscope it consists of a chaotic mixture of micritic calcite, burnt bone, soil aggregates, coarse limestone, chert fragments, and fine charcoal pieces (Figs 11, 12, 14, 15). Calcite is predominantly in the form of ash crystals, which do not retain any cellular structure but are intimately mixed with the other components of the sediment. Soil aggregates have varying sizes, shapes and roundness. When in large amounts, they give a brownish tint to the sediment (Fig. 11). They are irregularly distributed in the sediment matrix. Bioturbation is frequent, forming loose porous pockets inside generally compact sediment (Fig. 11).

Facies HGB is interpreted as ash remains disturbed mainly by anthropogenic activities such as trampling, scooping and cleaning of the hearth remains. The content of this facies does not differ from the previously described facies MWA, but
lacks any in situ feature as described above. Most of the soil aggregates have been incorporated by natural processes, their nature being more obvious in other facies discussed below. The limestone gravel component of this facies is the product of the gradual breaking down of the cave walls due also to natural processes (see below).

**Facies LHW. Loose homogeneous whitish ash remains with a high content of snail shells and some angular gravel**

Its content is not much different from that of the previous ashy facies, albeit with less soil aggregates and with a high amount of whole and or fragments of snail shells and some enrichment in angular limestone gravel. In the field it appears loose and very silty. However, its microscopic fabric is completely different from the previous facies (Fig. 16). It is finely aggregated and spongy. It is also quite homogenous in a meso-scale, with soil aggregates and fine bone fragments evenly distributed. Some elongate coarse fragments show inclined or vertical orientations. Bioturbation is also evident and probably partly responsible the porous loose nature of the sediment. On the basis of the above features this facies is interpreted as rather dumped ashes.

**Facies LSS. Laminated and sorted sediment**

This facies occur as fine lamina and rarely as a thicker layer interspersed inside the other deposits. Only in the lower part of the studied sequence can be discerned in the field as distinct depositional laminae. However, under the microscope it is observed more often, but with different degrees of integrity (Figs 17, 18). The sediment of these facies consists of crudely sorted and bedded deposits. The content can be from a mixture of rounded silt and sand-sized soils aggregates and other material (quartz, bone, chert, limestone etc), clean and elutriated, to gravel clast-supported layers composed mainly of subangular to subrounded limestone and bone fragments.

Presumably facies LSS is the result of rain sheet wash with increasing intensity of flow producing more sorted and laminated sediment.

*Fig. 13.* Detail of the north profile of square BB1 showing clay hearth structures (some with arrows) inside grey ashy sediment of layer IV (Aurignacian). Note the difference with the underlying Middle Palaeolithic layers that have a brownish color (darker grey in the photo) due to the large amount of geogenic sediment
Facies HCS. Heterogeneous clay-rich sediments

It comprises layers with a brownish clayey and firm appearance. A subfacies of it contains amounts of gravel-sized angular limestone fragments. In a microscopic scale these layers appear as a chaotic mixture of burnt remains and soil aggregates. The soil aggregates predominate and occasionally make bands and stringers. They also have different grains sizes and forms, but the rounded aggregates predominate (Fig. 18). Micritic calcite makes the matrix and is partially recrystallized.

This facies is probably the result of colluvial accumulation of soil material inside the cave, intermixed with anthropogenic burnt remains. However, trampling and probably aeolian reworking have eliminated some of the features that would indicate the specific type of the natural processes that are responsible for the formation of the main content of this facies. Nevertheless, the survival of the friable soil aggregates points out to rain sheet wash and generally a mixture of gravity and runoff processes.

SEQUENCE DESCRIPTION

Sequence A

It is the upper part of the sedimentary sequence ca. 20–30 cm thick. It is found in all excavated areas, but not all of its layers are found everywhere (Figs 4–8). In the field it appears as light brownish gravelly loam with locally gray tints and silty content. An organic-rich layer (mostly sheep and goat dung) is found on its top. It is of importance to note that as the layers of this sequence are actually the surface layers, they are frequently dissected by recent pits filled with animal dung, stones and elasic sediments rich in clay. These pits, together with modern surface trampling and biological activity (roots, earthworms) obscure detail observation of their sedimentary features. Layer 1 is the top recent humus and dung (not described as specific facies). Layers 2 and 3 comprise mainly heterogenous clay-rich deposits (facies HCS). Layers 5 and 5a consist also of facies HSC, with intermixtures of loose ash and shell rich deposits (facies LHW), and natural laminated deposits (facies LSS). In the text below, only part of Sequence A, i.e. layers 3 and 5, regarded as of the early Holocene (Mesolithic), will be discussed.

Sequence B

Natural elastic sediments dominate this sequence. It has a brownish color characterized by the presence of clay rich layers (facies HSC), but facies HGB (reworked burnt remains) and LSS (laminated and sorted sediment) also occur locally. It comprises layers IIa, IIb, and IID (Table 1; Figs 4, 6, 8). It is also characterized by frequent
clusters or lines of rocks. Rock lines most likely represent deflation surfaces also implying depositional hiatuses. They are distinguished between different layers and one of these defines in places the contact between this sequence and the underlying one.

**Sequence C**

It comprises facies LHW (dumped, loose homogeneous whitish ash remains), but occasionally some intact burnt features are observed in it (facies MWA: e.g. Hearth 2; Fig. 11). It includes layers 6/7 and 6 and 6a (Table 1; Figs 4–6). At some spots layers 6a and 7 are reworked and disturbed by later activities related to the formation of Sequences A and B (Fig. 11). Thus layers 6a and 6/7 of Sequence C have very diffuse contacts with the overlain layers and locally it is hard to differentiate them.

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**Fig. 16.** Photograph of thin section KL5c showing dumped burnt remains of sequence C. The light grey matrix represents ash aggregates in a loose arrangement containing also burnt (BB) and not burnt bone (B), shell fragments (S) and soil aggregates (T).

**Fig. 17.** Photograph of thin section KL17b showing laminated and sorted sediment as a result of shallow rain sheet wash.

**Fig. 18.** Photomicrograph of sample KL3a showing rounded soil aggregates (T), rounded bone (B) and limestone (L) with clay coatings overall attaining a rounded shape. Sorting is rather poor and the fabric is dense with relatively few packing voids. However, the roundness of the aggregates and the restricted range of the grain sizes between silt and sand should be attributed to very low energy water flow. Post-depositional reworking and compaction is probably due to trampling.
The deposits of this sequence are quite homogeneous with a maximum thickness of 50 cm. They are silty, loose, light gray but with lighter and darker parts, and a high amount of whole and fragmented snail shells and dispersed angular limestone fragments. The sequence forms a large pit-like feature on the back (northern) excavated part of the cave with a sharp erosional lower contact. In the profile of square A1-A2 line, it clearly truncates layers III and III’ and starting from the middle of square A2, as lateral differentiation of layers IIb and IId, it deeps towards A1 (Fig. 4). However, the relation of layer 6a with the layer II is obscure, although the latter seem to be younger in terms of its cultural content.

Sequence D

It is dominated by burnt features (facies MWA, RCS and HGB and LSS). It comprises layers III, III’, III” and IIIa–g (Table 1; Figs 4–8). It forms a complex of interfingering gray, whitish, and brownish gray silty lensoid layers, loose to lightly cemented, with some gravelly clusters. Undisturbed (facies MWA) and reworked burnt remains (facies HGB) form the main part of the sequence. In places it contains clusters of reddish clay structures (clay hearths) that were already discussed in detail (facies RCS). Some heterogeneous clay- and gravel-rich areas (facies LSS) are also present. The contacts of the different layers are in places sharp, but they change laterally to diffuse (e.g. Fig. 7a). In some of the excavated squares, it is clear that they truncate each other, but laterally this feature is obscured by secondary or post-depositional processes (bioturbation, trampling etc.). It is of major importance to note that some of the layers defined as such are in reality discontinuous, but as they exhibited the same field appearance they were labeled as the same layer by the excavators. However, they do not strictly belong to the same stratigraphic unit, because laterally what are considered parts of the same layer are not found in exactly the same stratigraphic position (i.e., they do not share the same boundaries with the other layers). In fact, the different layers of Sequence D can be considered as representing the spectrum of different facies found in this sequence, rather than chronostratigraphic entities. That is, each particular layer was not deposited during a certain time period, but represents a unique combination of natural and anthropogenic processes deposited in different times. Nevertheless, ensemble of layers can be put in a general stratigraphic order. This way, the sequence of layers III, III’ and III” overlie layers IIIb–d and these in turn overlie layers IIIe–g. Furthermore, in places, the uppermost part of the sequence, e.g. layer III’ in the southern profiles (squares AA3, BB3, CC3), has diffuse contacts with the overlying Sequence B (layers II) suggesting reworking and mixing of cultural contents.

Sequence E

It contains a mixture of almost all the facies (MWA, RCS, HGB, LSS and HCS), but burnt remains in different forms and particularly clay hearth structures of facies RCS predominate. It comprises layer IV sensu stricto (Table 1; Figs 4–8), and a lateral variation of it in the southern entrance area (see below). It consists of gray to whitish, moderately firm, gravelly silts with a high amount of discrete reddish clay structures (facies RCS), and several big dispersed stones, that in overall give a unique appearance to this sequence (Fig. 13). However, clay structures are not found in the southern part of the excavation, beyond the dripping line and close to the entrance of the rockshelter. In this area the sediment attains a more reddish brown clayey homogeneous texture (facies HCS), presumably due to the contribution of sediment from the decay of the clay structures. In the same area, layer IV is characterized by large stones in a linear or clustered arrangement. The contacts with the underlying and overlying sequences are mostly undulating, sharp or diffuse, attributed most likely to anthropogenic activities (trampling, scooping out of cultural deposits, etc.), but natural erosional processes cannot be ruled out, particularly for the lower contact (see below for details).

Sequence F

This sequence is of special interest and consists of layer V (Table 1; Figs 4, 6, 8). It contains the Early Upper Palaeolithic (EUP) lithic industry. Layer V is a dark gray clayey silty layer and comprises mainly reworked (facies HGB) and in situ burnt remains (facies MWA) at places. It is found only in the middle and southern part (en-
trance area) of the excavation. In the southern area it comprises several overlapping lensoid features. In the northern (back) area, layer IV of Sequence E truncates the underlying deposits and through a sharp erosional contact sits directly on layer VII of Sequence G; hence layer V is not present in this area (Figs 5a, b). In the middle area layer IV appears to truncate both layers V and VI (Figs 6, 8). Therefore, layers IV and V (Sequences E and F respectively) seem to be separated by a hiatus (IV covers unconformably all layers below). However, in the entrance area this unconformity is not so obvious. The contact between layer IV and V is rather diffuse and in fact layer V might be regarded in places as a vertical or lateral variation of layer IV. But taking under consideration that layer IV in the entrance area is reworked, the diffuse contact might be due to this secondary process. In any case, it is clear that layer IV (Sequence E) and or V (Sequence F) rests through a clear erosional contact on the underlying Sequence G, which is totally different on sedimentological grounds (Fig. 13).

Sequence G
Layers VI–VIII belong to this sequence (Table 1; Figs 4–8) which is dominated mostly by reddish brown firm layers rich in clay and angular limestone fragments (facies HCS). Locally brownish gray lenses of reworked burnt remains (facies HGB) and some in situ burnt remains (facies MWA) occur. The sediments are also weakly cemented mainly by re-crystallization of calcitic ashes. Nevertheless, this feature differentiates them clearly from the overlying non-cemented sequences, implying also some considerable time lapse for the cementation to complete before being buried by the sediments of layer V.

Although it is a very distinctive sequence in the field, its upper part (layer VI) appears to be a mixture of MPL and EUP cultural components. This is to be expected given the intensity of reworking as defined for the origin of facies HCS (natural reworking) and HGB (mainly anthropogenic reworking) that build the sequence. As discussed above, its upper contact is erosional. The contacts with the underlying main Middle Palaeolithic sequence are also sharp and erosional. In profile A1–A4 layer VI seems to attain also an erosional contact with VII.

DISCUSSION OF THE SITE FORMATION PROCESSES

Natural formation processes
The presence of clastic material in Klissoura Cave 1 has to be assigned at least partly to natural processes. It is probable that some of the bigger stones could have been brought in by humans. It is also probable that some of the interspersed clay in the sediment might have been brought in on their feet, or when they constructed the clay fireplaces. This should account however, for a small portion of the clastic sediments that only in some layers, consisting the facies LSS and HCS, dominate the deposit. In most cases post depositional alterations have blurred the original features that could reveal the details of the sedimentary processes responsible for their accumulation (Fig. 18). Nevertheless, the scant presence of some original sedimentary structures as described in facies LSS (Fig. 17) probably account for the deposition of most of the finer clastic component. They are mainly the product of shallow rain sheet wash. On the other hand coarse pebbles and fine cobbles of limestone are most likely the product of the breaking down of the cave walls by solution, freeze thaw, earthquakes etc. (cf. Farrand, 2000). In a later time they were probably spread by sheet wash or by trampling on the surface of the cave. The fact that the chamber which is at the back of the rockshelter has an open chimney (Fig. 3) has resulted in frequent transportation of soil material (mainly terra rossa) from above the hills and limestone fragments of all sizes. (Note: The time of the opening of the chimney in the back of the cave is well recorded in the Middle Palaeolithic sedimentary sequence). This actually can be seen even today, in that mudflows or rockfalls originated from the chimney at the back of the cave are the main processes bringing sediment onto the site.

Aeolian activity has not produced any recognizable features in the sediments. However, given the dry conditions that prevailed in the past (see below) some reworking by the wind is expected. In fact some rounded soil aggregates of sand sizes could be the result of rolling by the wind.

In general, most of the natural processes are of low energy and have probably resulted in slight modification of the original position of the ar-
archaeological material, particularly in layers that are dominated by facies LSS and HCS. We should note, though, that anthropogenic activities like cleaning, scooping out of ashes, and trampling might have had a greater effect on the modification of the original discard pattern, but, this new pattern nevertheless, is informative of cultural transformations, albeit secondary or tertiary (cf. Schiffer, 1972, 1983).

It is also of interest to comment on the trend of the rate of accumulation of clastic sediment in the cave. In Sequences D and E it is minimum, even if in E sequence there are more discrete depositional increments clearly deposited by sheet wash. However, there is no particular mixing of the underlying sediment by natural processes and the overall anthropogenic character of Sequence E is not altered. On the contrary, the cases of Sequences A, B and G are different, since they dominated by clastic sediment (Figs 11, 13, 17, 18). There are two possibilities for this difference. Either there is a substantial increase in the rate of clastic sediment input or a decrease in the rate of anthropogenic input. An estimation of the rate of anthropogenic versus natural input can be made by the analysis of the proportion of the different mineralogical fractions of the Klissoura deposits as reported in Koumouzelis et al. (2001b). The ratio of calcite to quartz is particularly informative. In Koumouzelis et al. (2001b) it is erroneously reported that fine-grained calcite is not related to anthropogenic activities but to autogenic crystallization, presumably by pore-water precipitation. In fact, as has been shown above, the major part of calcite is in the form of calcitic ash derived from burning activities (cf. Canti, 2003). Some minor input of fine clastic calcite certainly exists, but not to the point to distort the overall picture. From the plot of the ratio of calcite to quartz (Koumouzelis et al., 2001b: fig. 4) it is shown that the autochthonous ash component (calcite) predominates over the allochthonous quartz in Sequence D and partly in Sequence E (upper part), but drops considerably in Sequences A and B and particularly layers II and 5, and in Sequences F and G. In the same figure the ratio of calcitic ash to apatite (derived mainly from bone) can account for changes in the activities (burning versus food byproducts) since both variables indicate anthropogenic inputs. The ratio generally follows the same trend as the previous ratio with the exception of the top of layer III’ which shows a very high bone contribution (although ash in relation to natural components remains high). The same picture emerges for the ratio of quartz plus clay (allochthonous material) to apatite (anthropogenic input). It shows slightly higher values constantly in Sequences A, B and gradually increasing values from the lower part of E to F and G, and lower values in Sequence D and the upper part of Sequence E. [Note that in fig. 4 of Koumouzelis et al. (2001b) the trend appears reverse, because the ratio is between allochthonous versus anthropogenic, whereas in the case of the ratio of calcite to quartz it is the opposite]. In summary, it appears that at the end of the Middle Palaeolithic (beginning of Sequence G) and up to the very beginning of the Aurignacian (lower part of Sequence E) and in the Epigravettian and Mesolithic layers (Sequences A and B) the rate of natural input was higher that that of the main part of the Aurignacian layers (Sequences D and upper part of E). In addition, during intensive occupation the increase in the input of ashes is generally greater than the input of bone with a pronounced exception of the upper part of layer III’.

The environmental conditions prevailing during the deposition of Sequences D and E might be totally different from those in Sequences A and B. Sequences D and E have been accumulated during the later stages of marine isotopic stage 3 (MIS3) whereas Sequence B during the deglaciation (post last glacial maximum) and Sequence A during the early Holocene (Kuhn et al., this issue). So it might be postulated that the precipitation was higher during the deglaciation and early Holocene leading to an increase in runoff and washing in of clastic material from the hills above. However, the results of both charcoal and phytolith analysis supported also by the fauna data agree that the climate during the deposition of sequence B was cold and dry (Albert, this issue; Ntinou, this issue; Starkovitch et al., this issue). In this respect, the enhanced clastic sedimentation recorded in Klissoura during that time could be explained by the existence of a treeless environment vulnerable to erosion probably by infrequent storms. As precipitation levels were rising during the beginning of Holocene the increasing plant cover could not totally compensate
for this and the still vulnerable to erosion environment continued to occasionally feed the cave with clastic sediments.

On the other hand, Sequence G has been deposited in the earlier stages of MIS3. In general MIS3 is characterized by fluctuating climatic conditions with stadials and interstadials regularly alternating (Bond et al., 1993; Bar-Matthews et al., 1999; Geraga et al., 2005). However, the age resolution of the Klissoura sequence is not sufficient for such a detailed correlation, although all the evidence point to that the formation of the Aurignacian sequence (corresponding with sequences D and E) coincides with an interstadial (Ntinou, this issue). In addition, sequences E and D are characterized mostly by loose sediments with an almost dusty appearance that could be only explained by low humidity values preventing any re-crystallization and cementation of the otherwise fragile calcitic wood ashes. So for the moment, it suffices to suggest that during most part of the Aurignacian period the climatic condition was quite dry in Klissoura but with sufficient precipitation to allow temperate trees to grow (Ntinou, this issue) and generally more humid in respect to the late glacial period that is presented in the cave.

**Anthropogenic formation processes**

It is more than clear that the majority of the sediments that make the Upper Palaeolithic sequence of Klissoura are burnt remains. The burnt remains in Klissoura comprise intact flat hearths (facies MWA), clay hearth structures (facies RCS), re-deposited, probably raked-out hearth remains (facies HGB), and dumped ashes (facies LHW) (Figs 5a, 7a, 9–16). It is of importance to repeat that they are mostly loose ashes with meager quantities of fine charcoal. Complete burning due to repeat use of the site and the same hearths for long times is probably the best explanation for this. In addition, the loose unconsolidated nature of most of the deposits points to the persistence of dry conditions that prevented cementation by pore water circulation. This might be an additional reason for the complete burning of the fuel used, because a moist substrate could have trapped and preserved some charcoal pieces. Nevertheless, the absence of major clastic inputs into the cave is another reason for complete burning, as clay and other clastic sediments have better potential to trap and prevent previously deposited charcoal from complete burning down to ashes in a later burning activity. However, although the latter interpretation may be valid for the sequences dominated by burnt remains (i.e. D–E), it cannot account for Sequences A and B that are very rich in clay content. For these sequences a combination of complete burning and a dry environment during occupation may better explain the absence of large charcoal pieces. On the other hand, severe trampling and reworking by natural processes during non-occupational periods may have fragmented and finely comminuted the charcoal. This may also account for the general lack of intact combustion features in Sequences A and B.

The high content of wood ash crystals in the sediment and the lack of major quantities of phytoliths (see Albert, this issue) suggest that wood was probably the major fuel used in the site. In any case, the high degree of calcination of the ash components and their light gray to white colors are features that can classify the burnt remains as anthropogenic combustion structures of high intensity, such as open-air communal cooking fires (Mallol et al., 2007).

Karkanas et al. (2004) have suggested that the clay structures might have been used as satellite fireplaces with the fuel actually brought in the incandescent stage from the principal flat fireplaces (see also Meignen et al., 2001). In any case, it is evident that people were bringing clay materials to the site and after wetting they carefully puddled and shaped them in place. Some of the clay aggregates found interspersed within the deposits are probably byproduct of this activity. Frequent re-arrangement and modification of the fire places with cleaning and scooping out the top ashes, as well as frequent trampling, have produced thick heterogeneous accumulations of ashes (facies HGB). Signs of trampling are particularly evident in situ or slightly modified hearth remains where bones are crushed on place (Fig. 12).

In the upper part of the Aurignacian sequence a thick accumulation of dumped ashes are found towards the back of the cave in the form of an elongated shallow pit fill (Sequence C: mainly facies LHW) (Figs 4–6, 16). They are accompanied by large amounts of land snail shells dominated by *Helix figulina* exploited as food (Steiner, this
issue). The way the pit was originally formed (before filling) is unclear, but any water intruded into the cave through the back chimney should have been impounded at this area, probably leading to soil dissolution and subsidence. In addition, rock falls from the chimney should accumulate at this area, and if people were using these stones as hearthstones or for other structures, an empty space could have been formed. The time of the filling seems to post-date the rest of the Aurignacian sequence as already discussed.

Dumping of ash remains on the back of the cave has been reported already from the Middle Palaeolithic in Kebara Cave (Goldberg and Sherwood, 2006; Meignen et al., 1989, 2007). In the same site the presence of in situ burning, dumping and cleaning of ashes are interpreted as different activities associated with the occupants. In Klissoura, the frequent modification of the living area is particularly well depicted in the complex stratigraphy of Sequence D.

Post-depositional modifications

Post depositional modifications are restricted mainly to light cementation, moderate to strong bioturbation (Fig. 11) and very faint indications of freeze thaw activity. Cementation is in the form of precipitated calcite in the pores of the sediment and/or recrystallization of mainly ash calcite. It is observed only locally, in all sequences and probably is the result of water dripping or ponding.

Bioturbation is more frequent and some times it leads to obliteration of the primary sedimentary structures and to the formation of porous fine granular sediment. Earthworms and insects are most likely the major agent. The intensity of bioturbation is not related to any particular time period or sequences but the uppermost Sequences A and B, as being closer to the present surface are particularly affected.

Freeze thaw activity in the form of incipient local platy structure is observed only locally in the upper parts of Sequence D, i.e. layer III’. There are two possibilities that such features are not widely observed in Klissoura during the last glacial, in contrast to what is observed in other caves in Greece [e.g. Theopetra in central Greece: Karkanas (2001)]. The Klissoura Upper Palaeolithic sedimentary sequence corresponds to marine isotopic stages 3 and 2. As already mentioned, it is suggested that generally arid conditions prevailed during most of this time in Klissoura. This in turn, should have impeded the formation of ice in the soil pores due to the lack of sufficient moisture. It is also true that Klissoura located in southern Greece is part of a different climatic regime. Southern Greece is more arid and warmer than the rest of Greece. Thus the temperature is not expected to be so low frequently in order for ice to form inside the sediment. In any case, it seems that both explanations might be equally valid.

CONCLUSIONS

The Upper Palaeolithic sequence of Klissoura Cave 1 is mainly the result of anthropogenic processes in the form of constructed hearths and dumped, raked-out and trampled ash remains. This contrasts with the Middle Palaeolithic sequence immediately underlying the Upper Palaeolithic one. The former is a combined result of geogenic and anthropogenic processes in fluctuating proportions. However the change is not abrupt and geogenic processes are also important in the beginning of the Upper Palaeolithic. Shallow rain sheet wash and wall breakdown was the dominant geogenic sedimentation. The same trend is also visible in the upper part of the sequence towards the end of the last glacial and the beginning of the Holocene. It is suggested that a relatively arid climate prevailed during the formation of the Aurignacian sequence, but the precipitation was sufficient to produce a plant cover that resulted in a generally stable landscape. This period was followed and preceded by even drier and probably cold periods (except for the Holocene), when the almost treeless environment was vulnerable to erosion. Nevertheless, some geogenic materials continued to accumulate in the cave during the entire Upper Palaeolithic. They are more prominent towards the entrance of the cave and have resulted in mixing anthropogenic remains and obliterating some of the stratigraphic contacts.

It is conceivable that the nature of the contacts between the different cultural phases is of major importance. The Aurignacian, starting with layer IV clearly truncates the underlying layers at the back of the rockshelter and rests through an erosional contact on the Middle Palaeolithic layer VII. In the middle area, the layer V characterized
by an EUP technology is also truncated by the Aurignacian layers. The nature of this truncation is not so clear. From the aspect of site formation processes layer V is more similar to the overlying Aurignacian sequence, and in that respect the truncation can be considered as a minor hiatus. The underlying layer VI is probably the result of post-depositional mixture of layers V and VII.

The layers that overly the Aurignacian have in overall a discrete appearance in the field, but the contacts are rather diffused. Their sediments are more affected by geogenic processes. Modern disturbances, frequent truncations and diffuse interfaces characterize the contacts of the Epigravetian and Mesolithic layers.

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