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The Neolithic tell as a multi-species monument: Human, animal, and plant relationships through a micro-contextual study of animal dung remains at Koutroulou Magoula, central Greece

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ABSTRACT

Neolithic tells are traditionally considered synonymous to prolonged and persistent human activity. In this paper, micro-contextual examination of dung-related evidence at the Neolithic tell of Koutroulou Magoula, central Greece challenges this anthropocentric view. Thin section analysis demonstrates the abundance of dung indicators – including faecal spherulites, phytoliths, phosphatic impregnative features, and microlaminated fabrics – within a range of deposits and contexts across the site; such evidence was observed in built and unbuilt spaces, and enabled identification of possible penning areas and documentation of the use of dung as fuel source. Targeted archaeobotanical and phytolith analyses of dung-rich deposits point to diverse animal feeding practices and joint human-animal engagement with a range of ecological resources. Based on this integrated evidence which illustrates the significance of animals in co-creating and sharing living environments with humans at Koutroulou Magoula, we argue for the value of a multi-species perspective in Neolithic research.

1. Introduction

The archaeological significance of animal dung is widely recognised, as it comprises an important resource for pre-industrial societies, e.g. used as fertiliser, fuel, and construction material, and can provide direct evidence on animal diet and husbandry practices (e.g. Anderson and Ertug-Yaras, 1998; Jones, 2012; Shahack-Gross, 2011). In particular, dung has become a key subject of investigation in current Neolithic research. Recent decades have seen a proliferation of dung-related studies that cover a range of methodological approaches and analytical perspectives, and have greatly contributed to our understanding of Neolithic life. Some studies have highlighted the use of manure in crop cultivation, evidenced through isotopic signatures of plant remains, with implications for the inferred extent and intensity of agricultural practices (e.g. Bogaard, 2012; Vaiglova et al., 2014). Ethnoarchaeological and experimental research has explored the potential of dung as fuel resource, including its firing properties, the range of activities associated with dung fuel, the seasonality of its use, and the different types of its preparation and storage (e.g. Anderson and Ertug-Yaras, 1998; Gur-Arieh et al., 2014, 2013). Other ethnoarchaeological investigations have provided insights into recent agro-pastoral practices and their spatial configurations, and highlighted issues of preservation and taphonomy of dung remains (e.g. Elliott et al., 2015; Shahack-Gross et al., 2004, 2003). Biomolecular analyses of faecal remains have provided evidence on dung provenience, distinguishing between herbivore and omnivore species in order to build a clearer picture of animal presence and on patterns of dung distribution in archaeological sites (e.g. Shillito et al., 2011). Finally, integrated plant and microstratigraphic approaches have examined dung remains as evidence of animal management and feeding/herding practices through the analysis of ingested plant material, providing insights into animal diet, ecology, and resource strategies (e.g. Portillo et al., 2012; Portillo and Albert, 2011; Portillo et al., 2009; Shillito et al., 2013).

This paper examines dung evidence at the Neolithic tell settlement of Koutroulou Magoula, central Greece, where thin section analysis identified dung as a major constituent of the sediments comprising the

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site's stratigraphy. This observation is similar to other tell sites where micromorphology has been used for micro-stratigraphic investigation; the best-known example is the Neolithic tell of Çatalhöyük, Turkey, where Matthews (2005) and Shillito (2011) identified ample evidence of different types of herbivore and omnivore dung, e.g. in middens and in primary penning contexts. Later tell sites have also been shown to comprise high concentrations of dung-derived deposits, such as the Late Bronze Age and Iron Age urban layers of Tel Dor, Israel (Albert et al., 2008). Within this research context, in this article we take the opportunity to examine the abundant and well-preserved dung remains at Koutroulou Magoula with the aim of providing insights into the role of animals within the community and, more broadly, exploring the multiple human-animal interactions. In particular, we explore the following interlinked questions:

- What evidence can we provide on animal diet by examining plant-derived dung content? Based on this evidence what can we learn about the availability and use of ecological resources, and the patterns of animal (and human) mobility through the landscape?
- Was dung perceived and employed as a resource by the inhabitants of Koutroulou Magoula? What uses of dung can be documented in examining the histories of deposition and preservation of dung deposits, in their contextual associations? Can we discern any patterns of use and final deposition that may be linked to seasonal or environmental factors?
- What are the implications of dung evidence for the human-animal day-to-day experience in the settlement? What could be inferred on the nature of human-animal relationships that would have been built and maintained through routine practice, cohabitation and close physical interaction? How can the study of dung remains contribute to current theoretical debates on the co-constitution of human/animal worlds, in archaeology as well as in animal studies?
- What are the implications of these findings for the Greek Neolithic, and the study of the Neolithic more broadly?

2. The site

Koutroulou Magoula is a mound located at the south-east edge of the Thessalian plain, central Greece (Fig. 1), where it rises c. 6.6 m above the modern surface and constitutes a prominent landscape feature. The main archaeological phase is the Middle Neolithic when a large and thriving village was established. AMS radiocarbon dating places the Neolithic occupation of the site within the first two centuries of the 6th millennium B.C.E. (Hamilakis et al., 2017). The site was also used as a burial ground in the Late Bronze Age (c. 1200 BCE), and the Medieval times (12 c. CE). Archaeological work on the mound started in 2001 by the 14thEphorate of Prehistoric and Classical Antiquities (now Ephorate of Antiquities of Phthiotida and Evrytania), directed by Dr. N. Kyparissi-Apostolika (Kyparissi-Apostolika, 2003). Since 2009 (formally since 2010) the investigation of the site became part of the Koutroulou Magoula Archaeology and Archaeological Ethnography Project, a collaboration between the Greek Archaeological Service and the University of Southampton under the auspices of the British School at Athens (Hamilakis and Kyparissi-Apostolika, 2012; Hamilakis et al., 2017; Morgan, 2011, 2012, 2013). In 2017, and following the move of one of the two co-directors to Brown University, a new collaboration framework was established, involving the Ephorate of Phthiotida and Evrytania, the Brown University, and the Universities of Liverpool (for the 2017 season), and University College London (2018–).

Fig. 1. Map of Greece indicating the location of Koutroulou Magoula.

The location of Koutroulou Magoula at the edge of the alluvial plain of the Trikala Basin and near the foot of mountainous formations to the south-east indicates proximity and access to diverse geomorphological and ecological niches, including lower and higher altitude vegetational zones, such as mixed woodland, semi-open grasslands, and patches of wetland, that would have provided a range of options and potential resource strategies for the Neolithic community (Bottema, 1979, 1982; Koromila et al., 2017; Van Andel and Runnels, 1995).

The anthropogenic character of the investigated deposits indicates that the formation of the mound was the result of spatially focused human activity and accumulation, and more specifically the successive building and rebuilding activity on the same spot. The excavation thus far has exposed stratigraphic sequences down to 2.5 m from the surface of the tell, without any evidence of hiatus.

The built environment of the settlement seems to have been characterised by free-standing rectilinear buildings. Two well preserved examples have been fully excavated to date, as remains of stone wall foundations and cobbled under-floor layers on top of which clay floors seemed to have been laid; a number of other, partially preserved rectilinear buildings have been also unearthed. In one of the two fully excavated buildings, two or three earlier building phases, of the same position and orientation, have been revealed. This evidence is corroborated by the geophysical surveys, which suggest the presence of more similar features throughout the settlement. The outdoor spaces between buildings were places of intensive accumulation and activity, as indicated by finely stratified midden-like deposits, and charred and ash residues; by the presence of spatial features such as fire installations, stake holes and paved surfaces; and by densely deposited anthropogenic remains, including high amounts of pottery, animal bones, ground stones, lithics, and clay figurines (Hamilakis and Kyparissi-Apostolika, 2012; Hamilakis et al., 2017; Kyparissi-Apostolika and Hamilakis, 2012).

The geophysical and topographical surveys have also shown the existence of terracing, most probably to facilitate building activity, and the presence of con-centric curvilinear features surrounding the occupation area; these features have been interpreted as ditches defining the habitational area, which may have also served other purposes (Hamilakis and Kyparissi-Apostolika, 2012; Hamilakis et al., 2017; Kyparissi-Apostolika and Hamilakis, 2012).

3. Methodology

In our research approach we integrate data produced by thin section analysis of sedimentary sequences with bioarchaeological data, namely phytoliths, plant macroremains, and animal bones. This interdisciplinary approach enables us to piece together a dataset with broad interpretational potential. Furthermore, using multiple analytical lenses allows us to identify and address key methodological limitations and develop an improved integrative research strategy for future work on site and beyond.

We used soil micromorphology as our key analytical method, as it enables the identification of microscopic sedimentary components and the observation of these in their depositional and contextual associations. We were thus able to identify the presence and abundance of dung remains at the site, and to provide a comprehensive record of the depositional histories of these remains, their spatial, temporal, and contextual patterning, and their post-burial alterations and final preservation (e.g. Akeret and Rentzel, 2001; Angelucci et al., 2009; Boschian and Montagniari-Kokelj, 2000; Courty et al., 1989, 1991; Karkanas, 2006; Macphail et al., 1997; Matthews, 2010; Matthews et al., 1997; Shahack-Gross and Finkelstein, 2008). This evidence provided us with the opportunity to establish the range of types and contexts of dung deposits, and develop a dynamic view of the formation of the archaeological record at the site with reference to the activities and processes involved. Understanding the formation of deposits is fundamental for interpreting all evidence originating from these: in this study, the observed concentrations of dung content formed the main criterion for the selection of plant samples examined (Van der Veen, 2007). In addition, thin section analysis comprises a window to the microscale and enables us to develop an understanding of the past as lived experience (Boivin, 2001).

The analysis of plant evidence, phytoliths and macroremains, is employed to identify the types, degree of diversity, and composition of herbivore diet, which informs on practices of animal feeding strategies, mobility, and interrelationships with available ecological resources and landscape features (e.g. Portillo et al., 2012; Portillo and Albert, 2011; Portillo et al., 2009; Shillito et al., 2013; Valamoti, 2007, 2006, 2004). By combining the results of the two methods, we were able to identify the presence and relative abundance of a wide range of plants and establish an integrated archaeobotanical dataset of dung-rich deposits.

Soil micro-morphological and archaeo-botanical data were also integrated with the preliminary results of our faunal (large mammal) analysis in order to understand the make-up and character of the animal community, and more generally the role of the primary agents in the accumulation of dung on the site. It must be stressed, however, that of the three lines of evidence integrated here, the analysis of the faunal record is the least developed to date, and we will be able to say much more on the role of animals in the years to come, as the analysis proceeds further.

3.1. Field, laboratory and analytical processes

3.1.1. Micromorphology

Sampling for micromorphology targeted all types of contexts and sediment sequences at the site; in this article, we discuss the samples that proved to be rich in dung content. These originate from the following excavated areas: 1) five sediment blocks c. 15 × 8 cm and three monoliths c. 25–30 × 15 cm were extracted from sections at the open area south of Building 1, from finely stratified sequences of ashy lenses that in two cases included clay constructed features; 2) one block from the interior space of a partly excavated building in Trench Z1; 3) two monoliths from the area outside the wall of Building 2 (Trench Θ3, north profile) that contain trampled and disorganised dung remains; 4) three blocks from the open area between Buildings 1 and 2, Trench H3, where distinct sedimentary units and in-situ ash remains were preserved (Figs. 2 and 3).

The samples were extracted from exposed profiles during excavation; the undisturbed blocks were subsequently air dried; impregnated under vacuum with epoxy resin; cut; mounted on glass slides 14 × 7 cm, and ground and polished down to the standard petrographic thickness of 30 μm (see Courty et al., 1989: 57–62).

The thin sections were analysed using a polarising microscope under magnifications ×10 to ×400. Each identified unit was described according to standard guides and atlases of micromorphology (Bullock et al., 1985; Courty et al., 1989; Stoops, 2003; Stoops et al., 2010). In this paper, we focus on part of this dataset, i.e. the identification, typology, relative abundance as recorded by area, related distribution, orientation, clustering and bedding patterns of dung components within the recorded and analysed sedimentary sequences.

3.1.2. Phytoliths

Samples of loose sediment for phytolith analysis were collected alongside the undisturbed blocks from the same sedimentary sequences, to ensure comparability and maximise the potential for interpretational associations. Subsequently, 21 samples from this archive were selected for analysis, based on the micromorphological evidence on dung abundance, in order to examine questions on ecology, and origins and composition of animal diet and fuel.

The lab preparation of phytolith slides included sieving through a mesh of 500 μm, separation of c. 1 g of sediment, treatment with HCl to remove carbonate material, clay removal by suspension in distilled water, removal of organic and carbonised material by heating under 500 °C, and separation of phytoliths by centrifuging in liquid of 2.3 specific gravity (solution of Sodium polytungstate). Subsequently, c. 30 μg of the separated content was mounted on a glass slide using Entellan©, and covered with a glass coverslip (described in detail by Shillito, 2011: 27–28).

The identification and recording of phytoliths was conducted by following Piperno (2006), Rosen (1992), Tsartsidou (2009), and the reference collection at the University of Reading. At least 300 phytoliths of consistent morphology were counted in each slide, as suggested by Albert and Weiner (2001). In the discussion of the results, emphasis is placed on grass morphotypes of taxonomic significance that enable us to examine questions on ecological and environmental strategies of the inhabitants of Koutroulou Magoula (see Piperno, 2006: 28).

3.1.3. Plant macroremains

Samples for water flotation and subsequent archaeobotanical analysis were systematically collected during the excavation from all types of archaeological contexts to enable analysis of a representative assemblage. The information gathered can provide useful insights into the range of plant-related activities at the site and elucidate the multiple roles of plants in the socio-economic life of the Koutroulou Magoula community.

The discussion on plant macroremains here focuses on the macrobotanical content of dung-rich deposits, as indicated by micromorphology. On the current state of research these comprise a group of 26 sediment samples, mainly originating from the open spaces in between and around Buildings 1 and 2 (Trenches Θ1, Θ2, H3 and Θ3ext); one sample was collected from the interior space defined by wall features in Trench Z1.

The volume of each sample followed the dimensions of the excavated unit, aiming to collect at least 40 l of sediment when possible. All samples were processed with a modified version of a York style flotation machine (French, 1971). The light, floatable organic matter was poured into a stack of two brass sieves with 1 mm and 0.3 mm aperture for the retention of the coarse and fine material (flot) respectively. The heavier fraction (residue) sank at the bottom where it was retained into a 1 mm aperture mesh. All the flots and heavy residues were dried under shade to prevent damage of their organic content.

The flots were sorted for plant macro-remains, using a low-power binocular stereo-microscope with magnifications ranging between ×7 and ×45. Heavy residues were sorted for archaeobotanical and other organic remains and small finds with the naked eye. All plant macroremains were separated from the flots and heavy residues and identified according to morphological criteria, based on modern reference material, seed identification manuals and atlases (e.g. Jacomet, 2006;

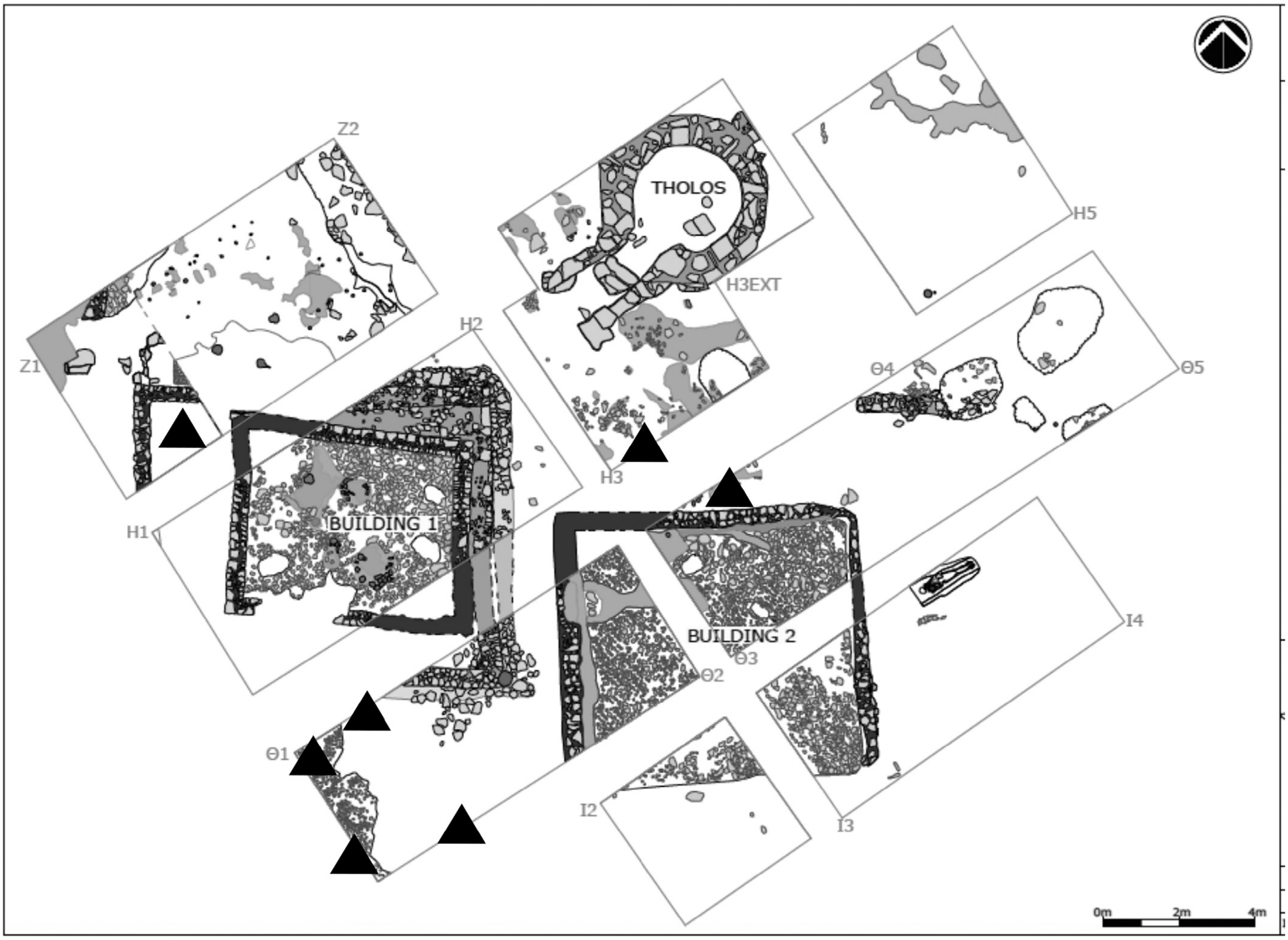

Fig. 2. Plan of the main excavated features at the site (2001–2016). The triangles indicate the locations of the sampling sections discussed in this article.

Cappers et al., 2006, 2009). An attempt was made to identify all plants to species level but in several instances poor preservation allowed their assignment to only a more general Genus or Family category. Nomenclature follows Flora Europaea (Tutin et al., 1964–1980).

Quantification was carried out on the basis of the minimum number of characteristic plant parts. In total, over 50 identifiable and quantifiable items were counted in most samples (coarse and fine flot and residue section), which suggests relative abundance of plant content. The high degree of fragmentation of cereal grains encountered in the examined samples led to the parallel systematic estimation of the number of their fragments according to the following scheme: < 20, 20–100, > 100. Finally, a note for the presence of charcoal and other organic remains in each sample was made. The taxonomic and anatomical identification of plant macroremains in these samples, e.g. the presence of seeds, fruits, and chaff, is used to provide evidence on animal feeding patterns and, by extension, on the integration of animal-related practices with human-plant interactions (Charles, 1998).

3.1.4. *Zooarchaeology*

Zooarchaeological analysis of the animal bone material is at the primary assessment stage; a total of 22,375 animal bone fragments from excavation years 2001–2011 have been preliminarily recorded. The animal bones were recorded by context, within which a count was made of fragments unidentifiable to species, fragments identifiable to species, and quantities of sheep/goat, cattle, pig and dog. Other less frequently occurring species were also noted as present and quantified. Of this material, 32% are identifiable to species; this percentage, however, may increase during the detailed recording process. Identification manuals (e.g. Schmidt, 1972) and comparative osteological reference material from the University of Southampton were used as aids to identification, where necessary. The quantification method used was based on NISP (Number of Identified Specimens) counts.

4. Results and interpretation

4.1. *The animals*

The study of the faunal remains from Koutroulou Magoula, although still at a very preliminary stage, suggests an assemblage heavily dominated by domesticated species, mainly ovicaprids (72.7%), with cattle (14.1%) and pig (11.9%) represented at lower proportions. The presence of dog (1%) in the assemblage is also notable. Wild species comprise an extremely low percentage of the assemblage; these include red deer (0.2%), roe deer (0.2%), hare, and tortoise (noted as present). Evidently, domesticated animals were the primary producers of the dung remains accumulated at the site. The predominance of herbivore domesticates in the assemblage of Koutroulou Magoula, although unsurprising, is important in understanding the patterning of animal dung deposition and its implications for human-animal cohabitation and interactions on site.

Observations on the taphonomy of animal bones indicate various depositional pathways of animal remains across the site and can provide additional evidence on animal-related activities. Fragmentation patterns vary within the assemblage, suggesting differences in exposure

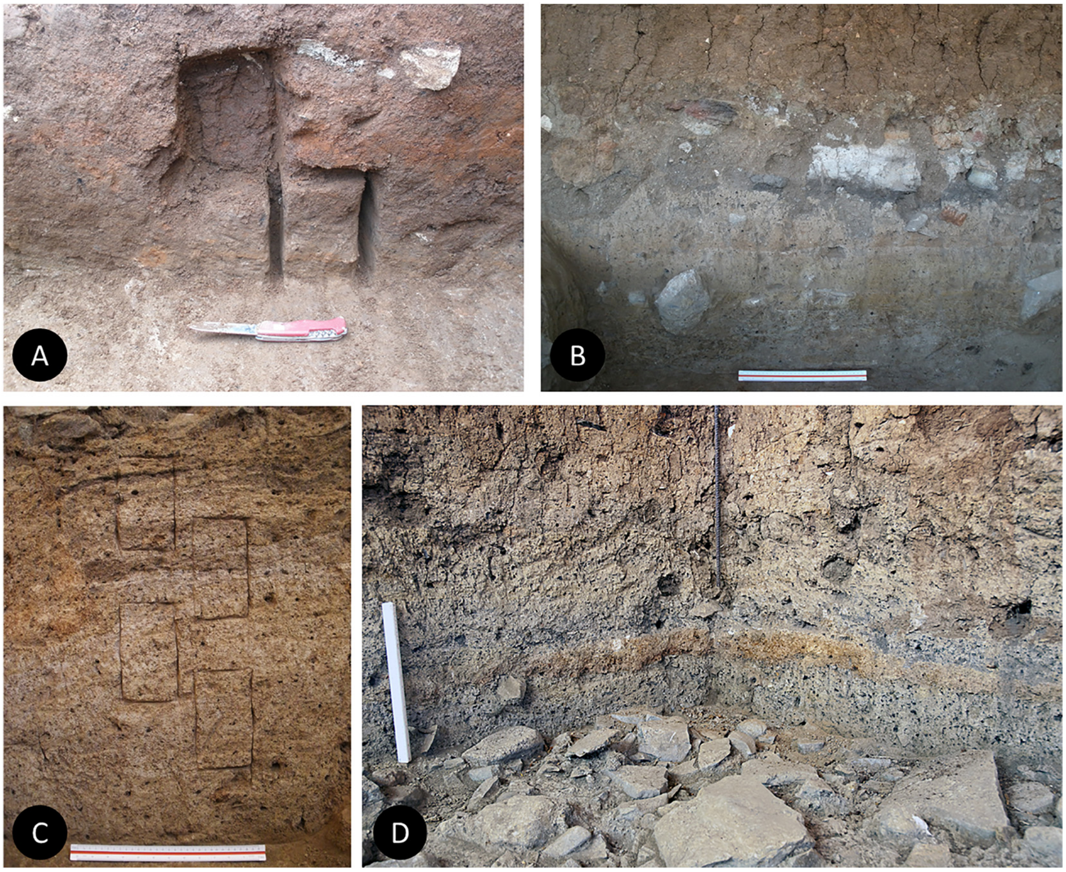

Fig. 3. Photos of stratigraphic profiles sampled for micromorphology: A – Interior space in Trench Z1; B – Open space in Trench H3, note the thick ash layer at the top of the sequence; C – Midden-like sequence in Trench Θ1, south profile; D – Ashy sequence with preserved clay feature in Trench Θ1, north-east corner.

to mechanical forces; for example, the open area west of Building 2 yielded bone material only in fragments or splinters, possibly due to heavy trampling, which could be linked to evidence for penning activity in this area (discussed below). Another interesting result is that only one neonatal bone was found within the assemblage examined (material from 2001 to 2011 seasons). This lack should not be overstated, as preservation and recovery biases may be involved; it is, however, an indication of possible differential treatment of neonates, perhaps away from the main settled area.

In addition, there is evidence for butchery of the animal remains in the form of cut and chop marks, as well as evidence for the partial burning and breaking of bones, particularly cattle metapodia, in order to access the bone marrow contained within. There is also evidence for bones having been burnt to a higher temperature resulting in a uniform black colouration. These bones do not appear to have been burnt in situ in the context from which they were recovered, but rather may represent the redeposition of material from burning contexts elsewhere.

4.2. Micromorphological identification of dung: preserved components and attributes

The presence of animal dung at Koutroulou was documented by the identification of the following components and attributes, which have been established as indicators of faecal material by experimental and ethnoarchaeological studies (e.g. Canti, 1997, 1998, 1999; Courty et al., 1991; Macphail et al., 1997; Shahack-Gross, 2011).

Firstly, the presence and abundance of calcareous faecal **spherulites** was considered the most reliable indicator of dung, as these microscopic components are formed during the digestion process (Canti, 1997, 1998, 1999). Faecal spherulites were recorded as dispersed components within the sedimentary matrix, and clustered up to 40% in abundance by area (Figs. 4–6). The highest abundance, c. 20% overall, was observed in thin, laminated, phytolith-rich deposits, interpreted as in-situ animal penning based on comparison with published references (e.g. Courty et al., 1991; Macphail et al., 1997; Shahack-Gross, 2011). Spherulites, both in clusters and dispersed, were also recorded up to 5–10% in more diverse, midden-like units, and in minimally disturbed ash accumulations, indicating use of dung fuel. Dispersed spherulites were recorded in lower concentrations of ≤5% in massive, homogeneous deposits as dispersed redeposited material. The presence of spherulites in these sediments documents recurring dung accumulation at Koutroulou Magoula.

However, absence of spherulites does not equate with absence of dung content. Due to their calcareous composition, they are susceptible to dissolution/alteration in wet acidic conditions; in addition, there is natural variation in spherulite production between and within species (Canti, 1997, 1999; Matthews, 2005). Two possible cases of partially dissolved spherulites were observed (Units K11-4 and K04-2) (Fig. 5-D). Other alterations of spherulites include darkened appearance due to reduced burning (Canti and Nicosia, 2018); such alterations were apparent in fuel contexts (Fig. 5-B).

The second major component identified as dung-derived comprises abundant **phytolith** material, mostly disarticulated but also multicelled, in association with organic staining and partially decomposed plant tissue, originating from ingested plants (see Courty et al., 1991; Shahack-Gross, 2011). Phytoliths were frequently observed together with faecal spherulites, intermixed in aggregates and lenses, an association that strengthens their interpretation as dung components (Figs. 4, 5, 7, 8). These clusters, lenses, and continuous bands comprised c. 20–30% concentrated phytoliths, and c. 20–30% spherulites, colourless to pale yellow in PPL and isotropic in XPL. Such dung aggregates were predominant in deposits interpreted as penning and in

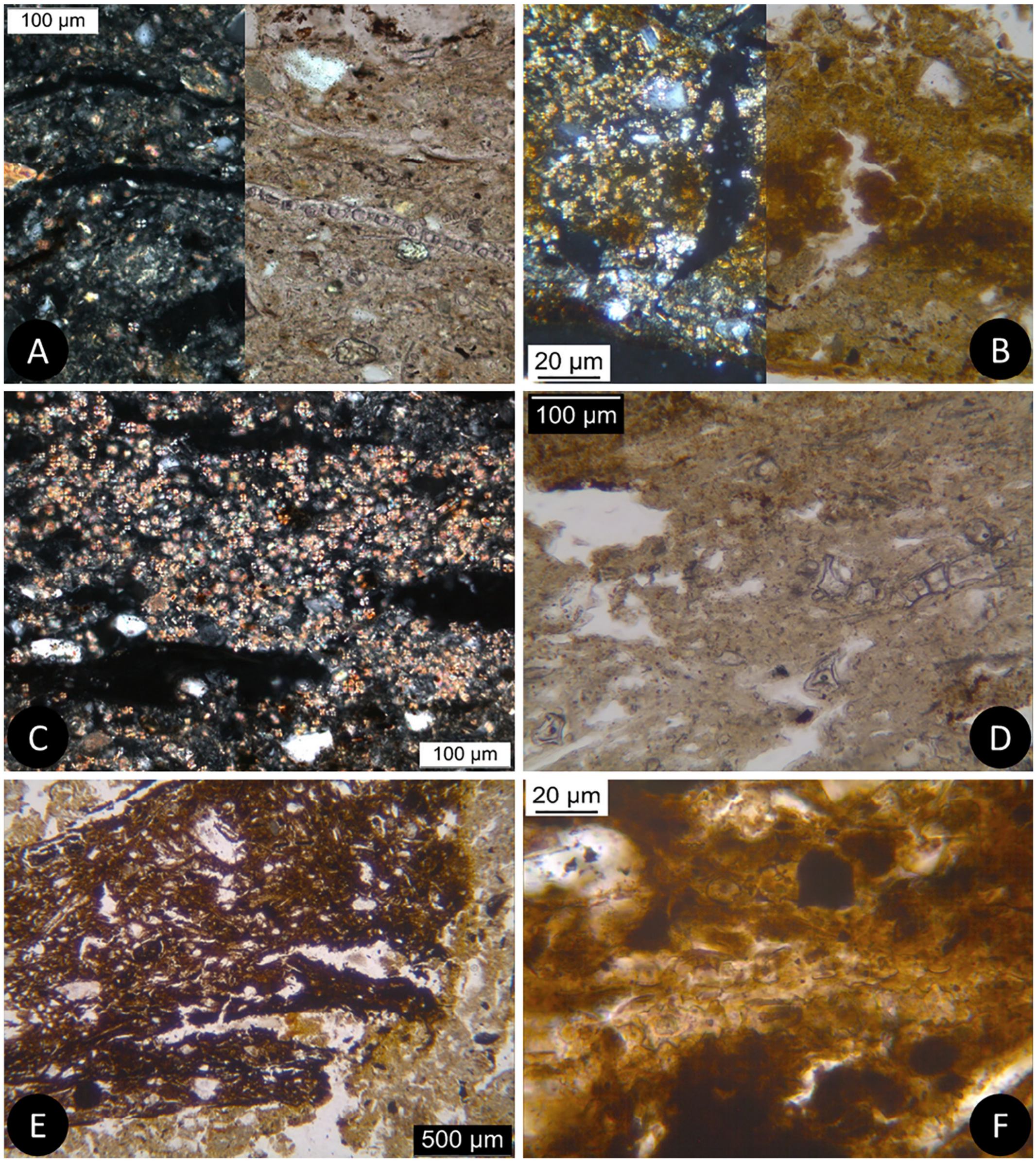

Fig. 4. Photomicrographs of dung components: A – Phytolith-rich matrix with recurring dispersed faecal spherulites (XPL left, PPL right), note the orientation of two articulated phytolith cases; B – Clustered faecal spherulites associated with staining of organic origin (XPL left, PPL right); C – Dense cluster of faecal spherulites (XPL); D – Phosphatic matrix with preserved bulliform phytoliths (PPL); E – Partially charred phytolith-rich aggregate, likely of dung origin (PPL); F – Detail of E, showing articulated saddle phytoliths masked by staining.

accumulated fuel, but were observed with less frequency in most other examined units as minor components (usually < 5%), incorporated as dispersed and mixed material. In addition, partially charred phytolith-rich aggregates were identified recurring in Trench Θ1; very dark brown in PPL, almost isotropic in XPL, with c. 20% concentration of charred plant, phytoliths, and plant pseudomorph voids, these aggregates are tentatively interpreted as partially charred dung due to the high plant content and association with faecal spherulites in very few examples.

An additional feature associated with dung deposits is the presence of **phosphatic** material: some aggregates and deposits in Koutroulou Magoula exhibit the groundmass characteristics of calcium phosphate, i.e. light yellow in PPL and almost isotropic in XPL, a result of high levels of organic content in dung (see Karkanas and Goldberg, 2010). Such aggregates preserved occasionally the impressions of phytolith material (Figs. 4, 6), and in one example a bone inclusion suggests omnivore origin. In general, dung spherulites and phytoliths were frequently observed in association with amorphous staining, green to dark brown, possibly amorphous humic or iron phosphates (Figs. 4, 5, 8).

Finally, in some cases, dung deposits preserved **microlaminated fabrics**, which are known to characterise penning deposits as a result of trampling-induced compaction and reorganisation (Courty et al., 1991; Macphail et al., 1997; Shahack-Gross, 2011). This type of fabric was recorded as strong orientation and laminated bedding of constituents, and contributed to the interpretation of certain units as likely penning deposits preserved in situ, thereby enabling us to identify locations where animals were kept within the settlement (Figs. 5, 8).

4.3. Pathways and histories of dung accumulation

4.3.1. Types of dung-rich deposits: depositional associations of dung

The dung components identified through soil micromorphological analysis were observed as major constituents of four principal types of

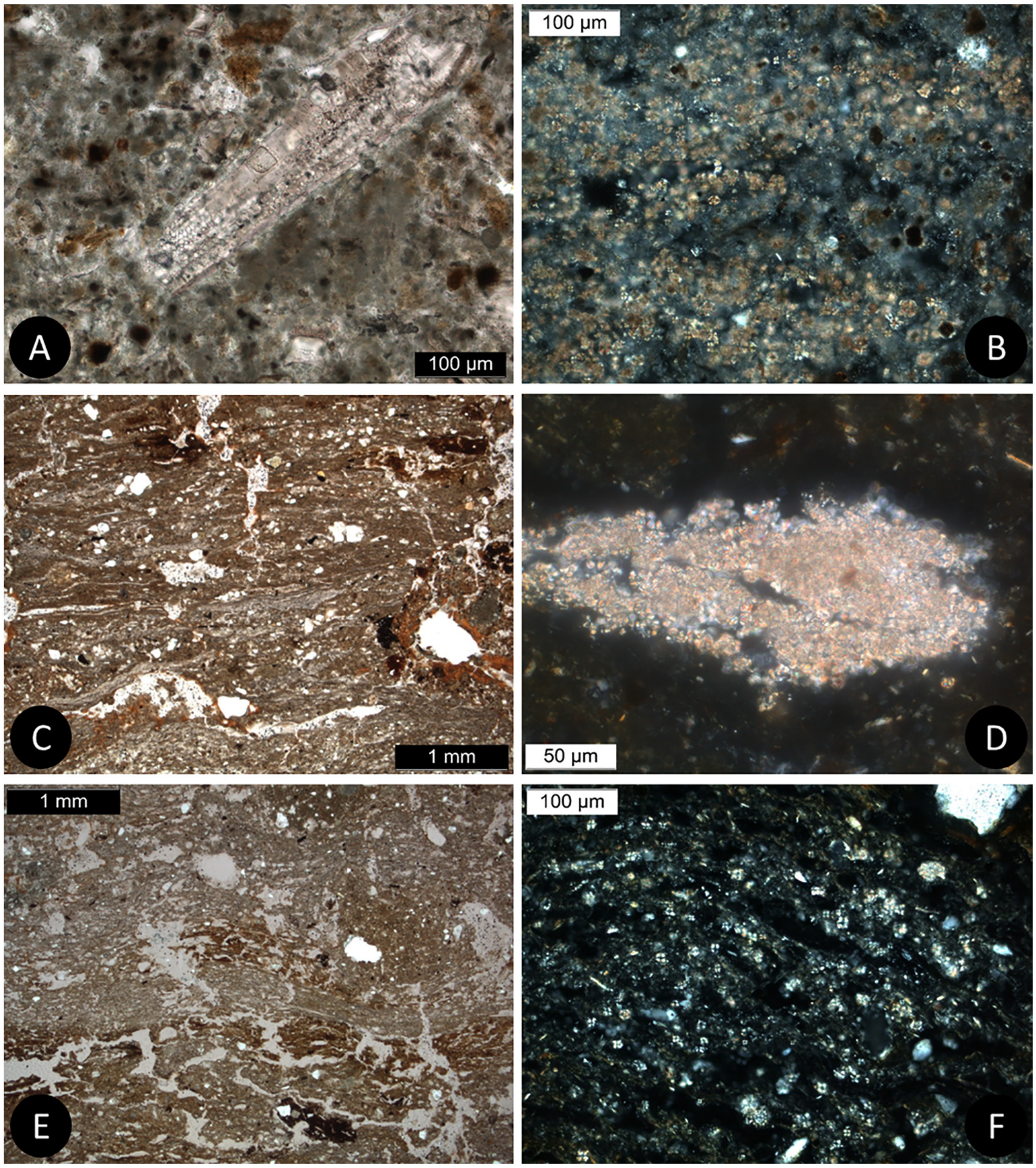

Fig. 5. Photomicrographs of dung-rich deposits. A – Articulated leaf/stem grass phytolith in calcitic ash matrix (PPL); B – Clustered spherulites in calcitic ash. Note the darkened cases at the right due to reduced burning (XPL); C – Microlaminated phytolith-rich deposit (PPL); D – High magnification detail, showing a calcareous cluster that could represent altered (dissolved?) spherulites (XPL); E – Undulating phytolith-rich bands (PPL); F – Detail of E, showing abundant spherulite content.

deposits, which indicate different component micro-histories and variable degrees of disaggregation and mixing.

In-situ **trampled/penning**: These were identified as very thin layers from 0.2 cm up to 1 cm, composed by microlayers and lenses of dung with abundant single-celled phytoliths, interlaced with long articulated phytolith material that may originate from animal bedding; these principal components exhibit banded distribution and strong sub-horizontal orientation (Figs. 5-E, 7-C, 8). Planar vegetal impressions are the predominant void type. Other inclusions were observed in lower concentrations: up to 10% charred flecks and traces of rounded sediment aggregates and rock fragments. All units of this type were associated with brown and green (organic) staining. The abundance of faecal spherulites varies, from predominant (concentrations > 30%) to rare traces; this is attributed, at least partly, to processes of dissolution (Canti, 1999).

These deposits represent distinct episodes of dung accumulation, with preserved patterns of orientation and bedding that can be attributed to trampling (Banerjea et al., 2015; Shahack-Gross et al., 2003). In particular, the preservation of lenses and micro-laminae of dung and/or phytoliths indicates minimal reworking and supports the interpretation of these deposits as in-situ accumulations, likely remains of animal penning (Courty et al., 1991; Shahack-Gross, 2011). These episodes of activity may represent different timeframes, from short-lived, to intermittent, and more continuous, according to variation in thickness and their depositional succession. The limited thickness of these units is in accordance with experiments that have shown substantial volume loss of dung post-depositionally (Shahack-Gross, 2011).

In-situ **fuel**: Dung remains were also identified as major constituents of fuel in preserved in-situ burning deposits (Figs. 3-B, 5, 7). In-situ burning was determined based on evidence of progressive change in combustion conditions, observed as diffuse contacts between oxidised ash on top and charred underlying units (Courty et al., 1989: 107–110; Mallol et al., 2007, 2013a, 2013b; Matthews, 2010). Some ash deposits were associated with thin, spatially constrained clay constructions in area Θ1 and close to the walls of Building 1 (described below in Section 4.3.1.1: Micromorphology of thin, spatially-constrained clay constructions). These presumably indicate domestic hearths in an open or semi-open area (Fig. 3-D).

Fuel deposits include dark brown to black organic-rich units comprising randomly distributed, coarse charred plant and dung, as indicated by faecal spherulites dispersed in groundmass (5%) and in concentrations up to 40%. Such units occur at the basal part of accumulated fuel, and were affected by low-temperature charring in reduced conditions (Boardman and Jones, 1990; Courty et al., 1989: 110; Matthews, 2010). They are considered most likely part of the fuel material and not pre-existing surfaces (as shown elsewhere: Mallol et al., 2007, 2013a, 2013b), due to the predominantly organic content and its coarse and uncompacted organisation. The fuel origins include both wood and dung.

Fuel deposits also include undisturbed ash where calcitic pseudomorph crystals are the main component of the fine fraction (> 40%), intermixed with phytoliths and clustered faecal spherulites (20–30%) (Fig. 5-B). Calcitic ash originates from high temperature (> 500 °C) burning of wood (Courty et al., 1989: 106), whilst the abundance of phytoliths and spherulites attests dung input, thereby suggesting again mixed fuel composition. Maximum fire temperatures would not have reached 800 °C, as no molten silica was recorded; in addition, calcite, phosphorus and potassium often found in ashes act as fluxes and reduce substantially the temperature (see Canti, 2003; Courty et al., 1989: 107–110).

Also, examples of phytolith-rich ash were identified as light yellow (PPL) and almost isotropic deposits with weak to local orientation and random basic component distribution where phytoliths are the predominant component of the matrix (c. 40%), with recurring (5%)calcareous spherulites dispersed and in clusters, 5–10% charred plant remains, as well as 20–30% rounded sediment aggregates (Fig. 7). Brown organic staining features were quantified as 10–20% by area. This description agrees with what Courty et al. (1989: 106) describe as grass ash after low temperature burning. However, the presence and abundance of calcareous spherulites indicate dung as, at least partial, fuel source.

Episodic secondary deposits: Dung was also one of the sources of material deposited in midden-like accumulations at the site (Fig. 3-C, Fig. 6). These depositional units were identified as bands up to 6 cm in preserved thickness, with intergrain aggregate related distribution of locally oriented components of multiple origins, in variable proportions: 5–20% charred plant remains, 5–30% phytoliths frequently associated with plant impressions, 5–10% dung aggregates and 5–10% dispersed calcareous spherulites, 10–20% diverse rounded/subrounded sediment aggregates, and recurring bone and rock fragments usually in lower frequencies (< 5%). The episodic character and low degree of reworking of these deposits is attested by their clear and prominent boundaries, the low compaction of relatively coarse constituents, and the frequent preservation of component associations in patterns such as clustering and orientation within the diverse matrix.

The contribution of dung in the overall composition of midden-like deposits is difficult to assess, due to the multiple possible origins of phytolith material. The presence, however, of randomly distributed calcareous spherulites suggests that, at least in part, the loose phytoliths in these units are also dung-derived, in addition to the plant material preserved in distinct aggregates. Different types of dung aggregates coexist in these deposits: lenses of high concentrations of phytoliths and spherulites; phosphatic aggregates with sometimes still discernible phytolith outlines; and partially charred phytolith-rich organic aggregates (Figs. 4, 6). This diversity suggests that the accumulated faecal material came from different sources and followed varied paths of transportation and mixing to final deposition.

Homogenised deposits: These are much thicker stratigraphic units of sandy silt loam with massive bedding and embedded related distribution; they comprise unsorted, randomly oriented and distributed, diverse coarse components within a fine matrix. In some of these units, dung indicators were observed as recurring calcareous spherulites dispersed within the groundmass in concentrations at least 5% in all examined fields of view; this indicates that dung was a major contributor in the formation of the sediments, introduced after complex processes of disaggregation, mixing, and transportation. Dung aggregates, however, are occasionally present even in these units, in abundance up to 10%, which suggests incomplete homogenisation of this material.

In summary, three distinct taphonomic pathways of dung accumulation were documented in Koutroulou Magoula. First, residues of penning activity at the site remained in situ, and were trampled/compacted, and affected by post-depositional processes such as water action and dissolution, organic decomposition, and mineralisation. These deposits retained their initial depositional, contextual, and spatial associations. The second pathway was initiated by the identification of dung as material resource; dung was subsequently collected, processed (e.g. mixing, drying), stored, and used as fuel to enable burning-related activities. Finally, the most widespread mode of formation of dung deposits involves complex and prolonged histories of disaggregation, transportation, and mixing, that resulted in redistribution of dung components across the site and incorporation within sediments of multiple origins. Based on their degree of disaggregation and homogenisation, such re-deposited components seem to have been affected by different degrees of exposure and post-depositional reworking.

4.3.1.1. Micromorphology of thin, spatially-constrained clay constructions. In direct association with dung-rich deposits, clay features up to 6 cm in thickness were identified within dung-rich sequences in area Θ1 and close to the walls of Building 1. Most cases were recognised as horizontally aligned, isolated, worn-out fragments, but one feature was found relatively intact. This is ca. 1.5 m long, has tapering edges, a sharp upper contact, and a diffuse lower one (Fig. 3-D). At the microscopic scale, the material of this construction consists of sandy silty clay matrix with highly heterogeneous inclusions: clay-rich, mostly rounded soil lumps, rounded pottery, flint, fine bone and burnt and unburnt clay construction material fragments with visible straw imprints (overall up to 30%). The heterogeneity and relatively high porosity of this material suggest rather expedient, informal preparation.

The surface of this construction is microscopically ragged and appears heavily worn out. Direct evidence of burning such as surface reddening was not observed. However, on the surface of this construction, partially recrystallised, reworked, and bioturbated ashes were identified, particularly around pores, and mixed with sediment fragments derived from the underlying clay construction. These ashy sediments are ubiquitously stained with brownish decayed organic material and are particularly rich in phytoliths, charcoal and partially charred material (up to 20%). Although spherulites were not identified, their overall appearance suggests a mixture of wood, grass, and dung ashes. Moreover, ash recrystallisation and mild cementation suggests formation in an open environment influenced by weather conditions. These ash remains, albeit reworked, originate from burning activity that may have occurred in relation to the underlying constructed surface.

4.3.2. Contextual and spatio-temporal patterns in dung accumulation

The different types of dung deposits in Koutroulou were accumulated following individual depositional histories of continuity and change over time, within specific contexts. Below we examine in detail three such contexts:

In Trench Θ1 (Fig. 6), at the lowest examined levels, dung is preserved as discontinuous micro-aggregates within homogeneous sediments, as well as in disaggregated form, indicated by the consistent recurring presence of calcareous spherulites in the sedimentary matrix. Overlying these sediments, widespread accumulation of successive, fine, midden-like deposits was documented; most of these fine bands were rich in dung or comprised continuous dung lenses that could be indicative of intermittent penning in this area, as partially reworked

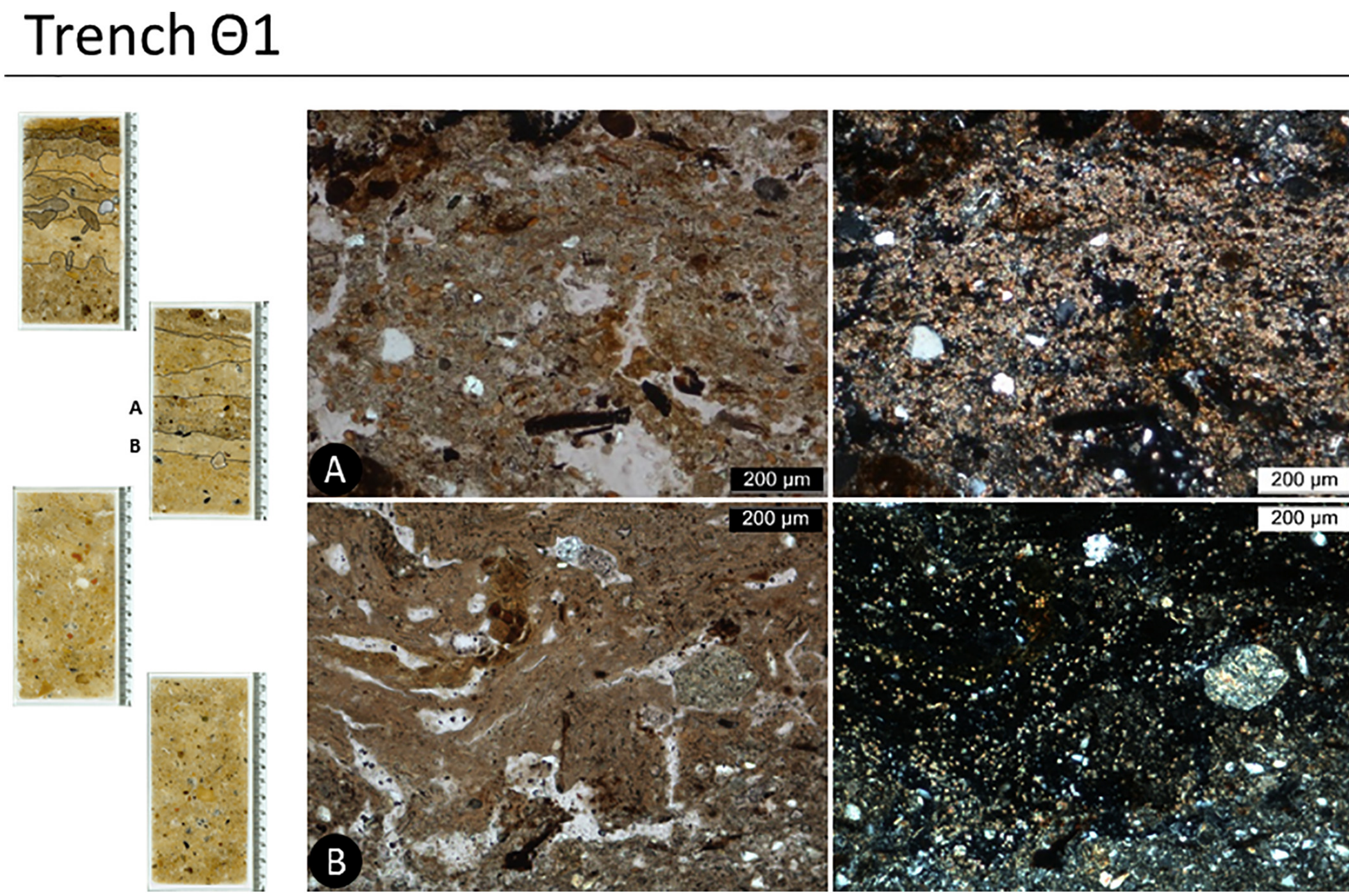

Fig. 6. Thin sections from the midden-like sequence in Trench Θ1 (left) and photomicrographs (right) showing dung aggregates with abundant spherulite content (PPL left, XPL right).

residues in an unroofed penning area (see Matthews, 2005: 391; Shillito and Ryan, 2013). In addition, within these sequences there are preserved remains of other activity, such as a small-scale and low-temperature burning episodes in the form of in-situ charred fuel remains, and truncated constructed clay features, in direct association with the dung deposits. These constructed clay features show evidence of non-standardised preparation, attesting to their ephemeral use and maintenance in an open environment. This area, south of Building 1, is known archaeologically to have been mostly open, used for a variety of domestic and other activities. At certain periods, this area may also have been partially roofed, as indicated by the existence of a series of postholes; the repeated preparation of stone paved surfaces in this area also indicates varied use of space. The micromoprphological evidence highlights that practices related to animal management and/or its by-products contributed significantly to the accumulated sediments in this open area of the site, alongside other activities related to the use of constructed clay features, burning, and discard practices of mixed domestic refuse.

The observed distinct change from more reworked/transported accumulated sediments to better preserved depositional episodes is likely due to intensification of activity, resulting in more rapid accumulation rates and burial of deposits that protected them from surface erosion and weathering (see Mallol et al., 2007; also Shillito and Matthews, 2013). Although this offers better resolution of separate episodes of activity and accumulation, the deposit constituents are similar, which suggests a degree of continuity and cyclicity throughout the sequence.

In Trench H3 (Fig. 7), preserved likely penning deposits were identified in the lower part of the examined sequence, followed by a more homogenised unit with indication of horizontally oriented dung lenses, which could originate from similar, more sporadic, activity. A compacted, likely trampled, surface interrupts these deposits, and coincides with a level of horizontally oriented macroscopic remains in linear distribution; this episode indicates a period of stability in the sequence of accumulation. It is followed by another unit of oriented phytolith material, with at least 16 distinct microlayers; this unit is interpreted as in-situ remains, possibly again of penning activity (but more tentatively due to near absence of spherulites). The sequence is topped by a thick (c. 12 cm) unit of minimally disturbed fuel, calcitic, and phytolith- and spherulite-rich ash of combined wood and dung origin, formed by distinct sub-units that could represent episodes of fuel addition to an existing fire or successive firing episodes (see also Mallol et al., 2013a). In either case, it is worth noting that dung was used as part of the selected fuel in all stages of this substantial burning activity. In summary, there is evidence that this open area was used for animal penning and received (human and animal) traffic; subsequently, its character changed and became a place of intensive burning activity. Interestingly and highly relevant to this study, this sequence highlights how dung transformed from deposit to resource.

The final example examined here comes from the interior space in Trench Z1 (Fig. 8). The lowest examined deposit was formed by dense accumulation of dung material, mainly phytoliths and infrequent spherulite clusters, topped by laminated dung bands interlaced with articulated phytoliths that could be remains of non-ingested bedding/fodder material. These residues indicate long-term penning activity in this context. Subsequently, an episode of deposition of daub-like fragments interrupted the deposition; these fragments could originate from an episode of collapse / temporary abandonment, which could be linked to a phase of reconstruction identified in the wall foundations of this structure. The sequence resumes with more penning-like deposits being formed, suggesting continuity in the use of the structure. These

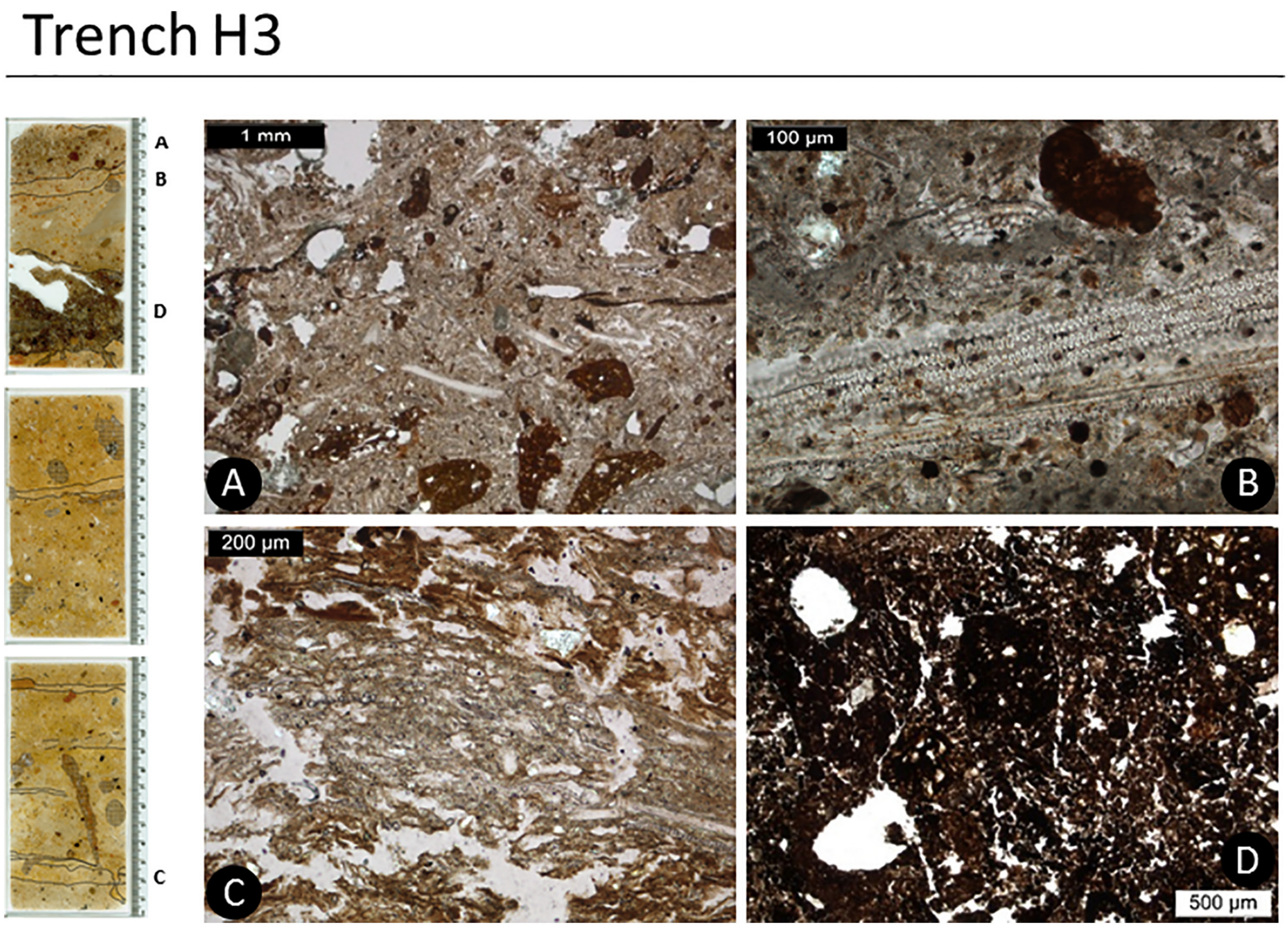

Fig. 7. Thin sections from the sequence in Trench H3 (left) and photomicrographs (right) of dung-rich units: A - phytolith-rich ash of likely grass and dung origin; B - articulated cereal phytolith in dung and wood ash context; C - laminated dung deposit with abundant phytoliths; D - charred organic-rich unit at the lower part of in-situ burning sequence.

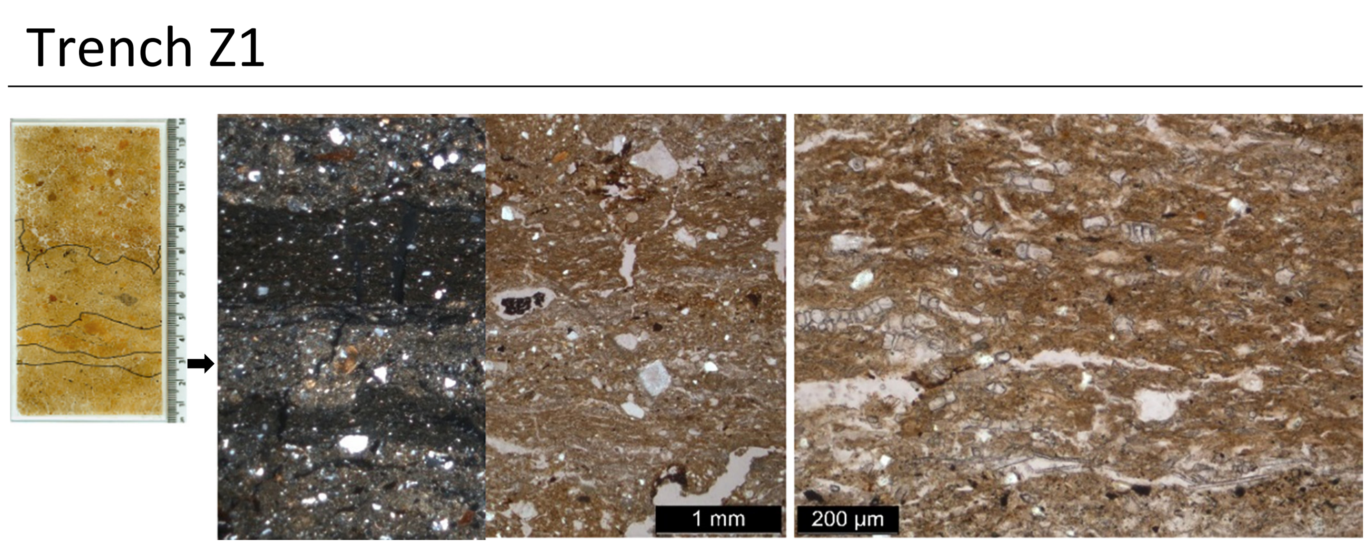

Fig. 8. Thin section from the interior sequence in Trench Z1 showing the units described in the text (left) and photomicrographs (right) of well-preserved dung deposits: left - phytolith-rich successive dung bands (XPL left, PPL right); right - detail showing phytolith abundance, including clearly discernible stacked bulliform morphotypes.

deposits are clearly truncated on top, as indicated by sharp and irregular contact with the overlying deposit, which comprises a chaotic accumulation of diverse residues from multiple origins and is interpreted as post-abandonment fill, and signifies the end of the structure's primary use.

Through the reconstruction of depositional histories in these stratigraphic sequences a dynamic picture emerges, one of context-specific and ever-changing patterns of activity and deposition, highlighting the temporality of the micro-scale and short-term episodes as the primary norm of the lived experience of Koutroulou Magoula.

Furthermore, units of microlaminated dung, indicative of trampling and interpreted as penning remains, were formed in the interior space defined by two intersecting walls in Trench Z1, as well as in external areas, in Trench H3 and Θ1. This evidence suggests that animals were kept both in open areas and in more limited enclosed spaces within built structures; in other words, penning was performed in variable ways, possibly linked to seasonal variations or longer-term changes in practices; differences in treatment among animal species or among individual households or social groups cannot be excluded.

Dung-rich fuel deposits were identified in Trench H3 and in Trench Θ1, both in open area contexts. They represent, however, examples of very different burning activity: the burning activity documented in Trench H3 formed a thick layer of ash, with distinct successive episodes of build-up, which highlights the continuous use of this burning spot. In contrast, in Trench Θ1, low-temperature charring occurred as an isolated event on top of a midden sequence, and mixed fuel deposits with evidence of moderately high temperature of burning were identified in association with thin clay constructions in the same outdoor area close to the wall of Building 1. These differences in fire temperature, duration, and spatial extent indicate a range of fire-related activities that took place at the site, in association with a variety of structures, beyond the clearly identified ones as hearths.

The fuel composition in the examined cases ranges from a combination of wood and dung to predominantly dung/grass. Dung appears, therefore, to have been a fuel resource utilised for different burning activities. Selection of dung as fuel could be related to high availability of dung at the site, or to the burning properties of dung, as it has been shown to produce heat of long duration and high temperature (Braadbaart et al., 2012; Gur-Arieh et al., 2014).

Finally, redistributed dung was ubiquitous in the examined samples: dung residues were observed in finely stratified midden-like accumulations in Trench Θ1; homogenised deposits with dung input were identified in Trench Θ1 and H3, as well as in other areas with lower abundance of dung components. This widespread occurrence of dung remains in varied states of disaggregation and reworking highlights the multitude of depositional pathways of dung accumulation.

4.4. Plant-derived components in dung

Samples from dung-rich deposits were selected for a pilot study of pant remains, as the analysis of the plant content of dung can provide direct data on animal diet, and, further information on available ecological resources and options to the inhabitants of Koutroulou Magoula.

4.4.1. Phytoliths

Given that different phytolith morphotypes bear different significance for interpretation (see Piperno, 2006), in the following section we explore possible taxonomic and anatomical distinctions based on the produced dataset.

At the broadest level, the comparison between grass and non-grass morphotypes shows that all phytolith samples were grass dominated (Fig. 9). Grasses, however, are known to be prolific producers of phytoliths, whereas dicots produce far lower amounts and variable morphologies (Tsartsidou et al., 2007). It is not, therefore, possible to estimate accurately the proportional representation of these two plant categories. The overwhelming predominance of grass types is, nonetheless, consistent with herbivore diet being the main source of the assemblage. Small ratio fluctuations between samples do not exhibit any identifiable trends or associations.

Among grass taxa, the phytolith assemblage indicates co-existence of different sub-families with different habitat preferences. As summarised in Table 1, the presence of rondels is indicative of pooid grasses, which grow in cool and moist conditions and include the Near Eastern cereal species, whilst the abundance of saddle types is characteristic of chloridoid grasses, tolerant to drought and inclusive of many weed species (Piperno, 2006); the combined presence of (tall) saddles, bilobes, and keystone bulliform types, as well as multi-celled examples with concentrated stomata or stacked bulliform cells, have been associated with arundidoids, i.e. reed species, which thrive in wet/marshy environments (see Jenkins and Rosen, 2007; Ollendorf et al., 1988). This variety of grass taxa in dung-rich deposits suggests that humans and animals were interacting with a range of plant resources that provided a variety of dietary options; these may have originated from tall and short grassland, including cultivated and fallow fields, and wet/marshy niches; it is, however, also possible that these different plant categories co-existed in much closer symbiotic relationships in plots around the settlement. Potential fluctuations in availability of and access to these ecological resources could have been dependent on seasonal factors and intersecting agricultural and husbandry cycles.

The relative abundance of phytolith paleoenvironment indicators in samples of different contexts and deposit types was juxtaposed to examine whether different pathways of incorporation of plant material in these samples affected assemblage composition. As shown in Fig. 10, however, all samples exhibit a signature of mixed plant assemblages with very subtle differentiations. Looking at the correlations between the frequencies of individual morphotypes with taxonomic significance, statistically significant co-variance was identified between saddles, bilobes, and bulliforms, which suggests similar pathways of incorporation into the assemblage (Fig. 11). In contrast, the concentrations of rondels

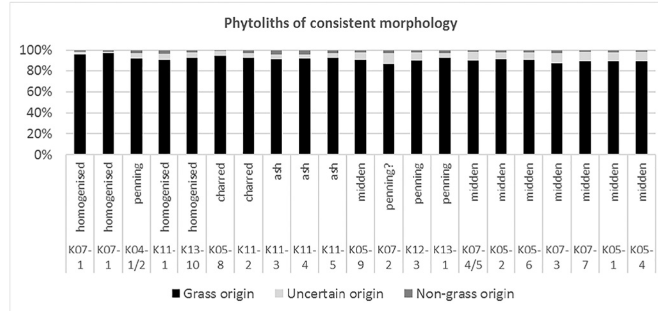

Fig. 9. Relative abundance of grass and non-grass phytoliths of consistent morphology in each sample.

Table 1
Plant taxa identified at Koutroulou and their habitat preferences, as inferred by the presence of characteristic phytolith types (palaeoenvironmental significance after: Jenkins and Rosen, 2007; Ollendorf et al., 1988; Piperno, 2006; Shillito, 2011; Tsartsidou, 2009).

Grass subfamily	Associated phytolith morphotypes	Palaeoenvironmental significance
Pooidae	Rondels, crenates	Tall grasses of cool and moist environments, including Near Eastern cereals
Chloridoidae	Saddles	Short and drought-adapted grasses, including certain weed species
Arundidoidae	(Tall) saddles, bilobes, keystone and stacked bulliforms, sheets with many stomata	reeds, wet/marshy environments

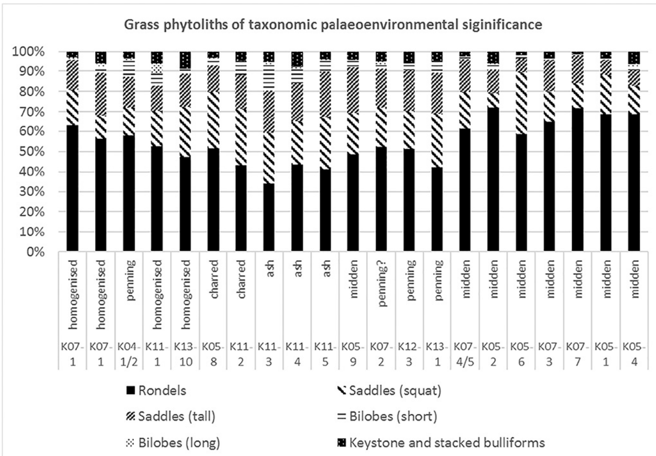

Fig. 10. Relative abundance of phytolith morphotypes with environmental significance in each sample.

		Bulliform types	Total saddles	Total bilobes	Rondel
Bulliform types	Pearson Correlation	1			
	N	21			
Total saddles	Pearson Correlation	**.593**	1		
	Sig. (2-tailed)	.005			
	N	21	21		
Total bilobes	Pearson Correlation	**.717**	**.769**	1	
	Sig. (2-tailed)	.000	.000		
	N	21	21	21	
Rondel	Pearson Correlation	.028	.315	.104	1
	Sig. (2-tailed)	.905	.164	.653	
	N	21	21	21	21

Fig. 11. Correlations between counts of phytolith morphotypes with paleoenvironmental significance. Statistically significant correlations ($P < 0.01$) are highlighted in bold.

do not exhibit correlation with the other types; this independent variance could be interpreted as due to different and more varied origins of input. Rondels are produced by pooid grasses, which include cereals; diverse types of input for cereals would be consistent with a combined origin from foddering and grazing, crop processing, and other craft activity.

Distinctions between wild grasses and domesticated cereals within the pooid sub-family, as well as between wheat-like and barley-like cases, were attempted based on preserved diagnostic multi-celled inflorescence phytoliths, after Rosen (1992). However, the low numbers of identifiable cases and the uncertainty of the method due to the range of possible variability within taxa (Shillito, 2013) do not allow secure conclusions or further meaningful interpretation based on these preliminary observations.

Phytolith analysis provides us also with the opportunity to examine the contribution of different plant anatomical parts to the overall assemblage. In Koutroulou Magoula, combined presence of dendritic

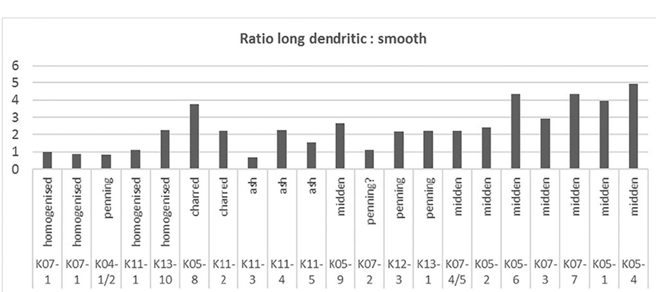

Fig. 12. Ratio of inflorescence:leaf/stem phytoliths in each sample.

types, encountered in the inflorescence of grasses, and smooth cells, from the leaf and stem parts, indicates that whole plants were consumed and deposited. The ratios of husk vs leaf/stem phytoliths (Fig. 12) demonstrate that husk types are generally more abundant; taking into account, however, that grass inflorescences have been shown to produce more phytoliths than other parts (Tsartsidou et al., 2007), this difference is not surprising. Fluctuations in these ratios indicate that husks were consistently more abundant in the samples from Trench Θ1, where the highest numbers of wheat-like husk multi-celled phytoliths were also counted. This association could be suggestive of accumulated residues of crop processing, intermixed with dung remains in a multi-purpose area.

The ratio of husk vs leaf/stem phytoliths deposited could also be related to seasonal plant growth; seasonal cyclicity, however, was not traceable in any of the examined sequences; any potential seasonal signatures may have been occluded by practices of storage of grain and fodder.

4.4.2. Plant macroremains

The plant macroremains in the examined assemblage were mostly preserved through carbonisation; examples of mineralised plant remains were also identified.

The sample composition is generally mixed and exhibits only small variations in relative proportions of plant taxa. The most abundant identified categories comprise grains and chaff of einkorn and emmer followed by grains of barley. Ratios of the cereal finds in the samples examined are 50%, 30% and 20% for einkorn, emmer and barley respectively. Wild/weed seeds belonging to different plant families and genera are also omnipresent in the samples in calculable amounts, with a standard contribution of 15% to 30% in the total counts for each sample. Fruits (namely seeds of fig and cornelian cherry) appear less frequently and in lower numbers. Finally, legume remains of lentil and common pea were only occasionally identified.

The highly fragmented state of glume wheat grains in the Koutroulou Magoula archaeobotanical assemblage retrieved from dung-rich deposits could point toward their potential consumption by animals, most probably in the form of spikelets (grain enclosed in glumes). As shown experimentally, the ruminant digestion of glume wheat grains ends up in their breaking down to forms that are not easily identifiable and quantifiable at the macroscopic level (Valamoti and Charles, 2005). The feeding of grain to animals may be practiced for extra energy provision during the period of lactation or when livestock grazing is hindered by weather conditions, as a way for the deliberate fattening of animals or as a means of indirect storage in case of agricultural surplus that can be later used as food or in exchange of food (Halstead, 1993, 1998a, 1998b). The cereal chaff items (i.e. einkorn and emmer glume bases) on the other hand may have been incorporated in the dung either as digested fodder food (alone or attached to grains) (Nesbitt et al., 1996) or as a component of dung cakes (Anderson and Ertug-Yaras, 1998) or mixed with dung when thrown as a separate fuel constituent onto a fire. Figs are also palatable to animals and survive passage through their digestive system (Valamoti and Charles, 2005). Ethnographic records note their utilisation as animal food especially during winter (Forbes, 1998).

Of particular interest to this study is the group of wild/weed seeds and their habitat preferences, as these can provide further insights into the origins and degree of diversity of herbivore diet. The macrobotanical assemblage includes both annual and perennial taxa, with preferred habitats that include arable and fallow fields, other types of grassland, and wet/aquatic environments, suggesting interaction with such microecosystems in the surrounding area of the site (see also summary Table 2).

4.4.3. Herbivore diet: ecology and animal feeding strategies

To recap, phytoliths identified in dung deposits originate from C3 pooid and arundidoid and C4 chloridoid grasses that grow in different

Table 2
Summary of the major habitat preferences and life cycle of the main wild/weed seeds considered in the study (A = annual, P = perennial, I = indeterminate) (main sources of ecological information: Gennadios, 1914; Polunin, 1969, 1980; Tutin et al. 1964–1980).

Weed (arable/ruderal)	Weed/grassland	Dry places/grassland	Damp places/meadows
Bilderdykia convolvulus (A)	*Bromus* sp. (P)	*Anthemis* sp.(I)	*Ranunculus* sp. (I)
Chenopodium album (A)	*Cynodon dactylon* (P)	Compositae (I)	
Eragrostis minor (A)	Gramineae (I)	*Echium vulgare* (P)	**Wet environments**
Galium/Asperula sp. (A)	Labiatae(I)	*Erodium* sp. (I)	
Lithospermum arvense (A)	*Phalaris* sp. (I)	*Stipa* sp.(P)	*Scirpus* sp.(P)
Lolium temulentum (A)	*Polycnemum majus/arvense* (A)		
Lolium sp. (A)	*Verbena officinalis* (P)		**Small seeded legumes**
Malva sp. (I)			
Portulaca oleracea (A)			*Medicago* sp. (I)
Rubiaceae (A)			Leguminosae small (I)
Rumex sp. (I)			

conditions. Plant macroremains from similar contexts include crop processing products and by-products, such as cereal grains and glume bases, as well as wild seeds, a combination that also highlights diverse sources of diet. The absence of direct correspondence between the taxa identified by the two methods is likely due to different potential for and precision of identification of plant taxonomic and anatomical categories (e.g. seeds do not produce diagnostic phytoliths), and to working with very different sample sizes; we therefore treat the two plant-derived datasets as complementary. Based on this evidence, animal feeding at Koutroulou Magoula emerges as a set of combined practices that likely involved both on-site cereal-based foddering and small-scale movements of herds to graze on nearby open pastures. The range of identified plant taxa indicates engagement with different ecological resources, which would have enabled seasonal diversity in animal diet throughout the year (see also Koromila et al., 2017).

5. Discussion

5.1. Understanding interspecies co-habitation

This study provides ample evidence of persistent animal presence within the habitational space and serves to underline the significance of the role of animals living alongside humans in the Neolithic community of Koutroulou Magoula. The abundance and widespread spatial distribution of accumulated dung remains and the identification of recurring likely penning deposits in different contexts within the settlement strongly suggest that the presence of domestic animals constituted an integral part of daily experience. In addition, both lines of plant data (macroremains and phytoliths) implied the combination of in-site keeping and foddering of animals, together with small-scale mobility of the herds and grazing of nearby open habitats. It is, therefore, suggested that humans and animals lived in close proximity, shared common spaces, and participated into routine reciprocal relations and interactions (see also Armstrong Oma, 2010, 2013; Overton and Hamilakis, 2013; Hamilakis and Overton, 2013). Furthermore, such close co-habitation and co-existence entails a distinctive sense of sensoriality (cf. Hamilakis, 2013), one based on the tactile, aural and olfactory proximity to animals and their bodily functions.

Such human-animal co-existence and reciprocal engagement can be illustrated by considering the various tasks and roles involved and their meaningful, affective and emotive implications: practices of care, such as feeding/foddering or grooming, have been shown to promote empathy (e.g. Argent, 2013; Armstrong Oma, 2010, 2013); animal herding has been highlighted as amplifying a sense of companionship (Argent, 2010; Ingold and Vergunst, 2008; Lorimer, 2006); the appropriation and consumption of animal products or services has been associated with ideas of trust (Ingold, 1994), property and wealth (Russell, 2012), but also exploitation and domination (Ingold, 1994; and for a different view, Armstrong Oma, 2010). These interweaved and, even contradicting, aspects of human-animal relationships are indicative of the multidimensionality of such interaction, which would have informed the practices and relationships performed by the community of Koutroulou Magoula. Whatever the initial model of animal domestication, it seems that thousands of years after this process was completed, a pattern of co-habitation, commensality (cf. Zeder, 2012), and perhaps mutual and trans-corporeal care involving humans and animals was still the norm in Neolithic communities.

5.2. Animal diet, ecology, and landscape mobilities

The study of dung remains at Koutroulou also provides important insights into animal engagement with ecological resources and landscape features, and choices related to animal feeding practices, placing human-animal interaction within a wider geographical scope.

The plant assemblages examined here that are associated with dung include reeds, possibly from wet/marshy areas, and cereals and weeds likely from cultivated and fallow fields near the settlement. The ways in which these plants made their way into the animal diet may have involved short-distance movements of animals and humans in the form of herding – and, thereby, shared human-animal experiences and interactions with the landscape, developing joint familiarity and knowledge of the world outside the settlement (see also Ingold and Vergunst, 2008; Koromila et al., 2017).

The cereal component of animal diet in particular could also have originated from foddering practices, which would presuppose different tasks, roles, and experiences associated with collecting, sorting, storage, and provision of fodder, which likely included both grain and chaff elements.

The suggested diversity in feeding options in Koutroulou Magoula is in accordance with the wider consensus that farming practices in the Neolithic of SE Europe were intensive and small-scale, exhibited diversity and flexibility, and whereby the animal and the plant component were tightly integrated (Bogaard, 2005, 2012; Halstead, 2011, 2014; Valamoti, 2007). This variability would have been part of daily, seasonal, annual, and longer-term life rhythms of the community, e.g. conditioned by seasonal variation in resource availability. Such temporal patterns of variation proved very difficult to identify in the phytolith dataset, possibly due to storage and year-round use of plants. The only evidence for potential seasonal variation in practices and mobility is the lack of any neonatal bones in the faunal record. Taphonomic matters aside (i.e. fragility of neonatal bones), this lack may suggest that at least some phases in the animal life cycle were taking place away from the human habitational areas. Alternatively, neonatal (or perhaps animal in general) deaths could have been subjected to practices of human care and attention, involving perhaps the careful disposal of dead animal bodies.

5.3. Burning and fire-related activities

An additional, indirect finding of our study concerns burning and fire-related practices at Koutroulou Magoula. The presence of dung in association with wood ash and occasionally with thin, perhaps short-lived, clay structures on site suggests that, in addition to the formal and more substantial hearths, there were other spatial features aimed at facilitating fire-related activities, using dung as fuel. These features would have been either single-use structures or used for tasks that did not require the substantial structural apparatus of a hearth. As a result, their archaeological visibility would have been low. The detection of dung in association with ashy layers and thin layers of clay visible in stratigraphic sections enabled us to identify such low-visibility activities that took place in open areas of the site.

5.4. The consumption and values of dung

The evidence examined here indicates that dung was preferred and widely used by the inhabitants of Koutroulou Magoula as a fuel resource. The samples taken from in-situ burning deposits were all dung rich or dung dominated; thereby, it is suggested that fuel choices and strategies in operation at Koutroulou Magoula identified dung as a valuable, useful and fundamental resource for day-to-day tasks and lives. In addition, the abundance of dung components redistributed in the accumulated sediments at the site, through a wide range of processes and histories of deposition, suggests complex processes of recycling, i.e. dung was a material widely available within the settlement and, intentionally or unintentionally, surrounded and conditioned human (and animal) experience. Other potential applications of dung worth investigating include manuring, and use in construction materials. The former is very difficult to assess with the available evidence, as the cultivated fields remain unidentified; it is, however, more and more documented in isotopic studies of Neolithic sites in Greece (e.g. Bogaard, 2012; Vaiglova et al., 2014). The building materials examined in this study did not contain any dung components; it seems, therefore, that the inhabitants of Koutroulou Magoula chose not to use dung for construction, reserving it for other purposes. A relevant observation here is that the main local clay paste recipe in the making of pottery and figurines at Koutroulou Magoula contained much organic material, indicated by the identification of phytoliths and phosphates, components likely originating from dung (cf. Hamilakis et al., 2017). It is reasonable to assume that some of it came from the sources within the site, given its richness in accumulated dung.

Considering the uses and perceptions of dung adds an insight into human-animal relationships at the settlement; along with other animal products such as dairy, meat, fat, and bone, dung was another connecting link of human and animal lives at Koutroulou Magoula: a valued substance that potentially informed decisions and choices on the conditions of human and animal co-habitation and co-existence, underlying in a physical, as well as metaphorical, sense their shared experience of place and living. Human-animal co-existence provided immediate, direct, and regular access to dung and, thus, to a substance of considerable value.

Finally, and perhaps crucially, as dung remains were accumulated within the limits of the settlement, they comprised a significant portion of the sediment build-up of the tell. It could be argued, therefore, that it constituted a part of the physical manifestation of the community's identity. In other words, the tell itself was a gradually accumulating, multi-species monument, created by human *and* animal activity.

6. Conclusions

In this paper, we have integrated micro-stratigraphic, soil micromorphological, archaeobotanical and zooarchaeological evidence to demonstrate that animal dung, mostly from domestic herbivores such as sheep/goat and cattle, but also omnivores like pig, had a significant presence at the site of Koutroulou Magoula and in a variety of contexts: in outdoor and indoor spaces used for penning, including architecturally elaborate, stone-built structures; as component of fuel and in association to fire-related structures; and in several other secondary deposits throughout the site. We have thus established that the site was a habitation context for humans *and* animals, which shared almost every built and un-built space, and their bio-social and bodily cycles were intertwined. We have also provided further evidence that the plant and animal (including human) lives were tightly integrated, with both humans and animals sharing plant foods and exploring environmental contexts in and around the settlement.

Beyond the reconstruction of the life history and depositional processes of a Neolithic site, we would like to use the evidence examined here as a point of departure and reference for a broader comment on our research perspectives and outputs. In this paper we argued that sites like Neolithic tells are not just human monuments, created by the successive vertical accumulation of debris from habitation layers and destroyed and rebuilt structures; they were also created through the accumulation of deposits linked to animals, i.e. dung and other foddering and penning material. This observation, although not new in itself, was not previously given the attention it deserves. In the context of the recent discussion on and calls for a multispecies archaeology (Hamilakis and Overton, 2013; Overton and Hamilakis, 2013; Pilaar Birch, 2018) we have chosen to emphasise it here in light of our rich, empirical supporting evidence. In doing so, we encourage archaeologists to recognise and evaluate the direct and indirect role of animals in the constitution of such sites, which can perhaps allow us to reconceptualise Neolithic tells as multi-species monuments. Furthermore, by directing attention to co-habitation and care and to trans-corporeal and multi-sensorial human-animal interaction, we moved beyond notions of exploitation and management and provide an example of how archaeological research can challenge anthropocentrism. By this, we hope to inspire and motivate further research that will focus on the significant contribution of animals in the shaping of the world, past and present.

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