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The utility of livestock dung for reconstructing recent ethnological and environmental histories

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Animal dung is evaluated here as a tool to reconstruct recent societal and environmental changes. Studies completed on the macro- and micro-contents from dung deposited in a mountain cave in Catalonia during the 1970–1980s, preceding the socio-economic changes in the area, was supplemented by the testimony of the last shepherd alive in the area. This information was also compared with evidence from aerial photographs of the area surrounding the cave taken in 1956 and 2009. Although taphonomic distortion of the dung shape precluded its assignment to its producers based on morphology, information from the organic remains reflects the agro-pastoral activities in the mountainous area of the Catalan coast. A lack of calcium phosphate and abundant phytolith and epidermal remains from wild species indicates that the dung was excreted by ovicaprines, who sheltered in the cave during spells of adverse weather. These indicators also signify that the animals fed only on natural vegetation. Insect remains in the dung include fragments of chafers, dung and ground beetles, bees and ants, and whilst the latter may have foraged in the cave, the others may have been accidentally ingested by herbivores. The nannofossils and diatoms found in the dung derive from tertiary crops 4 km away from the cave but within the range of the ovicaprine herd. The lack of cereal and vegetable remains in the dung is consistent with the ethnographic record that shepherds and farmers could not afford to supplement the herds' diet with fodder crops or grain, a consequence of the low productivity of the local subsistence agriculture. This study further discusses the socio-economic impacts of the introduction of intensive farming, industrialisation and tourism in Catalonia during the latter part of the last century and how they are represented in the dung.

Keywords: Animal dung, Phytoliths, Diatoms, Insects, Karst, Catalonia

Introduction

Where sufficiently well preserved, coprolites (fossilised animal dung) have been used successfully for archaeological and vegetational reconstructions (e.g., Cabanes et al. 2009; Carrión et al. 2001, 2005; Charles 1998; González-Sampétriz et al. 2003; Scott 1987). This is because animal and plant micro- and macro-remains, having passed through an animal's gut, may survive as a consequence of natural desiccation, partial mineralisation, or both. The resultant coprolites may be representative of the prey species, local and regional vegetation and agriculture (Linseele et al. 2010, 2013; Wallace and Charles 2013). For example, a recent study, using seeds and pollen from dung excreted by modern cattle and sheep, provided a faithful representation of the local vegetation (Schepers and Van Haaster 2015). The subsistence economy in the Negev Highlands during the Iron Age, Byzantine and Early Islamic period has been elucidated from the macro- and micro-plant remains preserved from the dung of free-grazing livestock (Shahack-Gross et al. 2014). Pollen has also been extracted from carnivore dung (Scott et al. 2003) and the composition of the late

Pleistocene–Holocene vegetation of the Central Zagros mountains has been reconstructed using pollen from hyaena dung from Wezmeh cave in western Iran (Djamali et al. 2011).
Despite this, the utility of animal dung as a tool to reconstruct ethnological histories and environmental changes requires further evaluation. Such studies have the potential to document the environmental and social impacts, and vanishing ethnoarchaeological information from agro-pastoral regions, often as a consequence of urbanisation since the middle of the last century. Knowing the previous composition of the forest vegetation and the land-use of agro-pastoral societies would also help in the implementation of current managing and reforestation practices, aimed at preventing the devastating summer fires that regularly occur in Mediterranean areas (Moreno and Oechel 2011; Trabaud and Lepart 1980; Whelan 1995). In addition, comparing recent ethnographic records with coprolite remains can provide a blind test for reconstruction of earlier periods.
The recent discovery of animal dung in a cave in the El Montmell area in the highlands of the Catalan coast provides an opportunity to study recent environment and social changes in the area (Fig. 1). The dung had been deposited by livestock sheltering in the cave. The contents are well preserved and the former agro-pastoral practices and changes in vegetation are known, based on the testimony of the last shepherd alive in the area, supplemented by aerial photographs taken between 1956 and 2009 (Figs. 2 and 3). This is an exceptional discovery because well-preserved animal dung is rarely found in temperate/semi-arid regions, whilst dung may be the only source of palaeoecological information in arid environments (Carrión et al. 2001; Djamali et al. 2011; Scott 1987).

Background

Dung rapidly decomposes under the warm and moist conditions of most temperate/arid environments but may be recovered from cave and rock shelter sites, where stable, cooler conditions retard decomposition and facilitate the preservation of macro- and microfossil remains in the dung (Delhon et al. 2008; Mercuri et al. 2010; Shahack-Gross 2011). In Iberia, only a few unburnt dung remains have been unearthed in cave deposits (Cabanes et al. 2009; Carrión et al. 2001; González-Sampétriz et al., 2003). The French term fumier, referring to mixtures of dung and animal litter, is also applied to sedimentary layers of burnt or otherwise preserved dung in caves (e.g., Allué et al. 2009; Badal 1999; Bergadà 1998). These layers have provided substantial information about past societies, palaeoenvironment, palaeoclimate and the diet of animals during the Quaternary. For example, dung, surface soil and sediments deposited in a cave in southeast Iberia have been used to reconstruct local and regional vegetation and the study showed that the animal dung yielded the highest concentration and diversity of pollen taxa (Carrión 1999a, 1999b; Carrión 2002; Carrión et al. 2005).
Carrión et al. (2007) provide reconstructions of the Pleistocene landscapes of Central Iberia from pollen identified in hyaena dung, which indicated a combination of steppe-grassland areas with Asteraceae and Chenopodiaceae, and wooded areas composed of Pinus and Juniperus species. The authors also detected mixed oak forests, which were interpreted as refugia of temperate and Mediterranean vegetation. In a similar study, hyaena coprolites have been used as part of a multi-proxy approach to reconstruct the glacial and late glacial landscapes of northeast Iberia (González-Sampétriz et al. 2003). These identified steppe, Mediterranean shrubs, coniferous forest and refuges of meso-thermophilous taxa, which characterised the varied climatic phases. However, it was concluded that a multi-proxy approach, including pollen analyses sourced from different traps, would provide more accurate reconstructions of past vegetation.
Similarly, Carrión et al. (2006) have explored the potential of bat droppings (guano) as a tool for palaeo-landscape reconstruction. They compared the pollen spectra of surfaces with modern dung samples from nine caves in southeastern Iberia and concluded that guano could be a concise tool for environmental reconstructions, because it may effectively preserve pollen, with levels of taxon diversity and preservation superior to surface samples from caves.
In the Balearic archipelago, diet and the causes of the extinction of the cave goat, Myotragus balearicus Bate, have been inferred from the contents of their dung found in caves. DNA, pollen and macrofossils depict the animal as a mixed feeder, greatly dependent on box shrub (Buxus balearica) (Alcover et al. 19 Bartolomé et al. 2011; Welker et al. 2014). Several causes seem to account for its extinction. These include increasing aridity changed the vegetation to open maquis from the original mesophyllous cover in a short period of time, which induced the dramatic decline of several species and in particular of box. The goat's limited agility and lack of awareness to a new predator may also have made them easy prey for the first humans that reached the archipelago.
Being such a specialised feeder, it is believed that they could not adapt to such a rapid change in vegetation (Alcover et al. 1999; Bartolomé et al. 2011; Welker et al. 2014). The climatic trend during the late Holocene in the Balearic archipelago has been inferred using stomatal density and indices of epidermal remains of Buxus identified in the dung of the cave goat (González-Sampériz et al. 2003; Rivera et al. 2014). Stomata density can be directly associated with CO_2 levels (Woodward 1987) which show that by the Late Holocene CO_2 levels were rising in the Balearic archipelago (Rivera et al. 2014).
The Bronze Age environment and agricultural practices have been reconstructed from pollen, phytolith and faecal spherulites from a fumier uncovered in a cave in the karst landscape of Atapuerca in central Iberia (Cabanes et al. 2009). Phytolith and faecal spherulites remains depict a range of land uses, including forest, grazing pastures and cultivated fields, and the use of the cave for crop-processing and other agricultural activities. A pollen analytical study of more recent badger (Meles meles) dung by Carrión et al. (2005) did not reveal any changes in the anthropogenically modified landscape of Central Iberia over the last 300 years. The residue from a carnivore diet contained within the dung did not bias their results.

This paper attempts to test the utility of animal dung as a tool to reconstruct recent environmental changes and human activities in the El Montmell region. This is achieved by comparing the information on agro-pastoral and vegetation composition provided by the dung remains, against contextual evidence, the shepherd's testimony and aerial photographs.

Methods

The samples examined were recovered from a cave in La Moixeta in the El Montmell mountains, part of the Catalan Pre-coastal range, at an altitude of 450 m a.s.l. (41°21′ 28.55′′ N, 1°31′ 18.19′′ E). The substrate of the Montmell range is a mixture of limestones and other calcareous rocks ranging in age from the Jurassic to the Miocene (Fig. 4). It has a gradually undulating relief with small cliffs, canyons and numerous caves (Figs. 2 and 3) (Casas-Sainz and De Vicente 2009; Enciclopèdia Catalana 2013; Masana 1994; Riba et al. 1976). The vegetation biome surrounding the cave is Mediterranean, with some Euro-Siberian elements present on north-facing slopes and bordering watercourses (Tables 1 and 2, Fig. 5). The dominant vegetation is composed of evergreen oak (Quercus ilex) woodland with laurustinus (Viburnum tinus) forming a dense, richly bushy sclerophyllous understorey and restricted growth of deciduous shrubby vegetation on the stream's banks, including olive willow (Salix elaeagnos subsp. angustifolia) and thickets of Mediterranean coriaria (Coriaria myrtifolia) and bramble (Rubus ulmifolius) (Tables 1 and 2, Fig. 5) (Quadrada 2007; Rovira i Gómez 1982). In the recent past, much of this would have been reduced by grazing, creating an evergreen oak-dominated wood pasture.

The cave occurs alongside a gorge cut by a tributary stream, the Marmellar. It is situated 15–20 m above the bank of the stream, where the bridge connects the road towards La Moixeta. The cave has an outer chamber with a narrow, deep internal chamber and it is largely infilled with sandy sediment. Extensive deposits largely of animal dung were found partly buried in the surface sediments of both chambers and similar material occurred in small cavities in the roof of the cave, where several abandoned bird nests were present.

The ethnographic and historical context

A few Pyrenean farming houses controlled agro-pastoral activities in Catalonia and the resident owners employed low-paid sharecroppers and shepherds. Pastoralism was a large-scale enterprise that exerted a firm control over the economy and pastoralists were the sole providers of meat for the main cities.

In fact, butchers from the main cities in the south had to travel to the north to buy livestock, which would be delivered during winter time as part of a transhumance cycle. The area sustained twice the current population until the beginning of the 21st century, when transhumance in Catalonia finally collapsed (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). The agro-pastoral economy of the mountainous area of the Catalan coast was substantially different from the Pyrenean economy. According to the nonagenarian shepherd Alfons Guasch i Martí, the harsh climatic conditions of the El Montmell mountains, only allowed the development of what is essentially subsistence-based agriculture, with small crops of barley and wheat, supplemented with a few vegetables, such as potatoes. Small farms only stocked a few pigs, chickens, a small ovicaprine flock and occasionally a mule, donkey or a horse, but never cattle.

Against this background, all resources were heavily utilised. Dung from different livestock might be employed selectively (cf. Charles 1998; Linseele et al. 2013; Shahack-Gross 2011; Wallace and Charles 2013). Whilst dung from ovicaprines might be burnt as fuel or utilised for other purposes, Alfons confirmed that in El Montmell area, ovicaprine, human, pig and avian dung was only used to fertilise horticultural and cereal crops and occasionally pastures. He pointed out that burning dung was unnecessary owing to the great abundance of wood in the area. However, he highlighted that smoke from fires made from horse and mule dung had a specialist use: for the collection of honey. Smoke makes the bees docile to ensure that the honey was collected safely. Industrialisation, changes in agriculture practices and the boom in tourism caused the demise of transhumance in Catalonia between 1920 and 1960 (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). The introduction of intensive farming and the augmentation of irrigation systems generated extra costs that the smaller farms could not absorb. It drastically reduced the grazing ground and consequently it raised the price of winter forage and reduced herd numbers. More intensive agriculture meant that the herds were no longer needed to fertilise the fields (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). Industrialisation had a more detrimental impact on the farms. The massive growth of cities from 1920 onwards and the tourist boom of the 1960s created a high demand for employment, which offered much better economic benefits when compared to the farming houses. The final development leading to the demise of transhumance was the construction of hydroelectric stations in the Pyrenean region, stemming from the increasing energy demands of the incipient industrialisation and the expansion of urban areas. This attracted the remaining manpower available in the farming areas and resulted in a drastic depopulation of the Pyrenees from which the region never recovered (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). Furthermore, the wool industry also collapsed, owing to cheaper imports and more efficient production methods that were achieved using modern technology.

The disappearance of a pastoral herd-based economy and the sharp depopulation of the central mountainous area of the Catalan coast differed to the changes evident in the Pyrenean region (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). El Montmell was a typical highlands settlement in the central area of the Catalan coast. According to the former shepherd Alfons Guasch i Martí, before small-scale urbanisation, the settlement

comprised a nucleus with scattered farmhouses in the surrounding mountains. Larger farms had usually a resident owner who rented out smaller farms to sharecroppers and the caves to shepherds.
Owners and tenants also employed temporary workers at the busiest times of the year. It was one of the main local centres of transhumance, taking large flocks of sheep from the lowlands to summer pasture in the uplands, and its economy was mainly based on these herding activities, supplemented by subsistence agriculture and forestry.
Unlike in the Pyrenees, Alfons noted that on the Catalan coast, subsistence and sedentary agro-pastoral activities and exploitation of the forest only allowed the subsistence of relatively small populations.
However, socio-economic activities of the village were impermeable to changes occurring elsewhere in Catalonia until the 1940s. People in El Montmell had a comfortable socio-economic standard and there was less competition for local resources. Locals would cooperate and that jobs were fairly organised and local resources were shared amongst the local populations. Consequently, local populations were not attracted by the opportunities offered by early industrialisation. In fact, the population of El Montmell remained at 529 inhabitants until the end of the 1950s (Institut d'Estadística de Catalunya 2013). Alfons believes that the decline in subsistence agro-pastoral and forest activities in the area of El Montmell was a consequence of increasingly adverse weather conditions. Without these, local emigration would not have been so dramatic. Extreme snowstorms, frost and freezing temperatures between 1930 and 1955 devastated local agriculture. Alfons remembers the frost of 1955 when most olive trees perished and the harvest was so severely damaged that olives were unsuitable either for picking or for oil extraction.
Later local wood production ceased because woodcutters could not compete with the much cheaper imports during the mid-1980s. In addition, the introduction of cheaper materials, such as plastic and silicone, progressively replaced cork to make bottle stoppers (Espadalé i Reballí 2005; 2010; Rocas i Gutiérrez and Espadalé i Reballí 1987). Local producers in El Montmell abandoned the industry. Groves of cork oak (Quercus suber) and other wood pasture were progressively replaced by pine plantations (Pinus halepensis) and the ground flora became dominated by Mediterranean heather (Erica multiflora), box (Buxus sempervirens) and elements of the garrigue, mainly composed of kermes oak (Q. coccifera) (Espadalé I Reballí 2005, 2010; Rocas i Gutiérrez and Espadalé I Reballí 1987). According to Alfons, the farms surrounding the cave of La Moixeta and the nearby hamlet of Marmellar were totally abandoned in the 1960s and a proportion of the agricultural land was sold to developers. The population in El Montmell dwindled to 162 by 1981 (Institut d'Estadística de Catalunya 2013). Currently, the farm at Cal Turró is in ruins, surrounded by vineyards, whereas Cal La Moixeta has been converted into a 'rustic' restaurant and hotel, and most of the agricultural land is urbanised one (Figs. 2 and 3). This situation forced people to migrate to Barcelona and other cities, to find job opportunities offered by tourism and industrialisation from the 1950 to the 1960s onwards. The area has recovered since 1990 rising from 256 to 1175 inhabitants in 2006. Alfons believes that this is largely as a result of improvements in the road network, restoration and gentrification of traditional Catalan farm houses, small-scale urbanisation projects and the expansion of rural tourism (Enciclopèdia Catalana 2013).
The depopulation and the disappearance of subsistence pastoral activities in the area led to changes in the vegetation, such as the disappearance of grazing and natural reforestation. Natural expansion of scrub communities and conifers also occurred, particularly in the central mountainous areas of the Catalan coast. Before the industrialisation and tourist boom, human intervention led to fragmentation of former oak wood pasture with vineyards and afforestation with extensive P. halepensis plantations. With the abandonment of grazing, the scrub community, including Brachypodium and Stipa sp., and shrubs, such as S. elaeagnos, R. ulmifolius, C. myrtifolia, Bupleurum fruticosum, Rosa canina, Crataegus monogyna, Prunus spinosa and Pinus sp. (Figs. 2 and 5) (Gordi et al. 1996; Otero et al 2013; Vila i Subirós and Gordi 2001), re-colonised or invaded abandoned agricultural land, hillsides formerly used for grazing and any deserted settlements. These changes can be seen by comparing the aerial photographs taken in 1956 and 2009 (Figs. 2 and 3). The photo from 1956 depicts the two rural houses and a landscape structured with arable land and pasture. In contrast, by 2009, it has been replaced by some urban development
and natural re-forestation of Aleppo pinewoods with an understorey of heather or scrub. The golden age of transhumance in Catalonia occurred between the 16th and 19th centuries (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí, 1973). Transhumance centres were located along the Pyrenees and were organised in three regions, which exhibited distinct traditions and vocabulary, the cabanesa (western area), carrerada (eastern area) and lligalo (southern area). Shepherds from the cabanesa spent their summers in the central area of the Catalan coast moving between the La Noguera, Segrià, Urgell and Les Garrigues districts, whereas shepherds from the lligalo regions would take their herds to the Maestrat district in València and the mountains in Teruel province (Aragón). The shepherds from the carrerada region migrated to L'Empordà, Vallès counties and El Penedès, where Alfons was located (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973).
The weather conditions in the Pyrenees are extreme in winter and there is insufficient forage to feed ovicaprine flocks. Pyrenean shepherds would consequently migrate southwards to access forage crops, which would grow in the milder conditions of the coastal mountains (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). Northern transhumant shepherds would leave part of their herds with southern sedentary shepherds and take the rest to the available pastures. In summertime, when the harsh hot and dry conditions of the southern mountains would deplete the fodder in the pastures, the southern shepherds would give part of their herds to the Pyrenean ones, to be fed in the northern pasture, thereby completing the transhumance cycle (Llobet and Vilà Valentí 1951; Miralles and Tutusaus 2005; Vilá Valentí 1973). Our informant, Alfons, always dealt with the same shepherd: Joan Muntanyès de Cal Miquel. He would travel 132 km through mountain passages for 20 days, from La Pedra I La Coma (Sant Llorenç de Morunys,

Solsonès County) in the carrerada transhumance region, to Alfons' farm (Fig. 6). They would mark their own individual animals before amalgamating their herds and Alfons would only keep those that would not survive the trip to the north, such as old and new born animals. Shepherds would pay for the service by donating several of their animals.
In the coastal mountains of Catalonia, sedentary shepherds such as Alfons would feed their herds on natural vegetation only and seek refuge in caves from bad weather and during the heat of the day in summer. Occasionally, they would sleep in caves overnight. The caves were exclusively used by the shepherds who paid a yearly rent to the owner. Nomadic shepherds never used the caves and rested under trees or in designated stonemason refuges during transhumance periods. Alfons explained that the shepherds from El Montmell never roamed for more than a few kilometres from the local farm and used three caves in the area: 'la Cova de la Plana Joana' and 'la Cova dels Costers', both located near the La Juncosa del Montmell, and 'Cova de La Moixeta'. Shepherds from the farms near the cave of La Moixeta, Cal Turró and Cal La Moixeta (Figs. 2 and 3) had used the cave for at least four generations. Alfons purchased the herds from the shepherd in La Moixeta area when the latter retired.
Alfons stated that sheep defaecated and trampled on their dung in the caves during long spells of bad weather. Dogs very seldom defaecated inside the caves and wild animals avoided them. However, after the abandonment of agro-pastoral activities in the area, the caves were used intermittently by wild animals, in particular by badgers and foxes. Alfons explained that he and other locals would regularly find fresh dung on the cave floor when badgers used the cave as overnight shelters, setts and latrines. He noted that badgers dug a hole at the cave entrance to defaecate in. Foxes would shelter in the caves when they were not occupied by badgers.

Methods

Morphological analysis

Twelve dung samples were collected from the La Moixeta cave and housed at the Museu Arqueològic del Vendrell (Catalonia). They were organised into two groups MADV/561 (Figs. 7A–B and 8A–F) and MADV/562 (Fig. 9A–M). Four dung specimens from MADV/561 were used in this study (Fig. 7A–D). The surface of the dung was examined using a Nikon SMZ-10 binocular light microscope (10× to 60×). Dung size and morphology were measured following Chame (2003).

Radiocarbon dating

In the absence of any other dating evidence, the two samples of animal dung from the group MADV/561 (Figs. 7A and B) were dated at the Oxford Radiocarbon Accelerator (ORAU), and a further sample from a dung specimen (Fig. 7A) of the group MADV/561 (Fig. 7A) was AMS (Accelerator Mass Spectrometry) dated at the Radiocarbon Dating Laboratory at the University of Waikato (Hamilton, New Zealand). AMS is used on samples smaller than that needed for standard radiocarbon dating. It counts C14 atoms, rather than atoms which are decaying (Budzikiewicz and Grigsby 2006). The first used the standard methodology by McNichol et al. (2001), whereas the second applied the Conventional Age or Percent Modern Carbon (pMC) method following Stuiver and Polach (1977).

Geochemical analysis

Chemical composition of two specimens of animal dung from the group MADV/561 (Fig. 7A and B) were analysed using a Bruker D8 XRD with CuKα1 radiation at the School of Earth and Environment at the University of Leeds. The scans were processed using the Bruker Eva with ICDD (International Center of Diffraction Data) Powder diffraction Files and quantified using Bruker Topas software.

Epidermal and phytolith analyses

In order to examine plant content, the samples were washed to remove extraneous material and lightly ground in a mortar to separate the epidermal fragments. Two subsamples weighing 10 g each were prepared. These were placed in a 5-ml test tube of concentrated HNO_3 in a boiling water bath for 1 minute. The samples were then diluted with 200 ml of water and sieved through 0.5 mm and 0.125 mm filters. The 0.125–0.5 mm fraction was spread on glass microscope slides in a 50% aqueous solution of glycerine. Cover slips (24×60 mm) were fixed onto the slides with DPX microhistological varnish. The slides were examined under a microscope at 100× to 400× magnification to view traverses 2 mm wide and 60 mm long with 3 mm between traverses. Vegetation percentages were registered by standard microhistological analyses of dung and compared to diet of current herbivores (Table 5) (cf. Bartolomé et al. 2011; Crocket 1959; García-González 1984; Stewart 1967).
Phytolith analysis of the faeces of ca. 1 g of faecal material was carried out. This was processed using standard methods, including chemical treatments to remove carbonates and organic matter centrifugation and density separation, and mounted for high magnification light microscopy and imaging (at 1000×, using oil immersion) (Strömberg 2004). Over 200 (217) diagnostic phytoliths were counted, resulting in an overall phytolith count of 375 (Table 3).
The phytoliths were classified using a reference collection from modern plants and grouped into ecologically relevant classes (Strömberg 2003, 2004). Those relevant to this study are (1) Forest, diagnostic of woody and herbaceous dicotyledons, conifers and ferns; (2) Closed-habitat grasses (Bambusoideae, Pharoideae, etc.); (3) Open-habitat grasses, divided into (a) Pooideae (C_3), (b) the named PACMAD clade (Duval et al. 2009; GPWG 2001), including Panicoideae (mainly C_4), and Chloridoideae (~C_4) and other PACMAD grasses (C_3 or C_4); (4) Grass short cell phytoliths of unclear affinity; (5) Non- GSSC phytolith typical of grasses (e.g., wavy elongates and trichomes) and (6) Ubiquitous or unknown phytoliths.
The relative abundances of phytoliths from these classes were used to determine the composition of the phytolith producing plants incorporated in the dung (Table 3). C_3, C_4 and CAM photosynthesis are the three biochemical

mechanisms are used by plants in carbon fixation (Sage et al. 2012). C_3 are plants that live in cooler humid conditions, whereas C_4 and CAM plants have devised alternative ways to survive hot conditions (Sage et al. 2012). Modern vegetation types close to the cave contain moderate to low numbers of three grasses, Stipa offneri, Brachypodium retusum and Brachypodium phoenicoides. To investigate whether these grasses contributed to the dung assemblage, phytoliths were extracted from leaf material of Brachypodium distachyum var. monostachyum, Brachypodium pinnatum, Brachypodium sylvaticum, Stipa tenuissima and Stipa neesiana, and analysed for comparison.

Pollen analysis

Pollen samples were subjected to conventional analytical techniques of acetolysis and treatment with hydrofluoricacid for the more siliceous samples (Moore et al. 1991). Pollen counting was conducted at 400×, and 350 grains were counted for each sample. A 2000 slide European and Mediterranean pollen reference collection stored at Newcastle University was used to aid uncertain identifications.

Diatom and nannofossil analyses

Four diatom samples were exposed to acid according to the standard procedure established by Renberg (1990) and permanent slides were prepared with Naphrax®. Diatoms were identified under the lightmicroscope (Olympus BX40). Sample preparation of nannofossils was conducted by spreading a fraction of dry sediment on to a cover glass together with a drop of distilled water. This procedure aimed to avoid laboratory contamination and to retain original composition of the sample (see Monechi and Thierstein 1985). The suspension was smeared on the cover glass with the aid of a wooden toothpick and then dried on a hot plate. The cover glass was fixed on the slide with synthetic UV curing (Norland Optical Adhesive). The slides were examined under a light microscope, both in transmitted and in polarised light, at a magnification of 1250×, scrutinising for calcareous nannofossils (CNs).

Entomological analysis

Two samples were examined for insect remains. A sample was rehydrated and gently disaggregated in distilled water and the second was prepared without rehydration. The few insect fragments recovered were stored in 70% ethanol. Insect remains were identified under a low power binocular microscope.

Results

Morphological analysis

The dung specimens vary greatly in size and shape, and are very irregular, ranging from cylindrical to more flattened specimens (Table 3, Figs. 7–11). Much of the material had clearly been disturbed by the trampling of animals in the cave. The cylindrical specimens display deep striations comparable to those exhibited by current omnivore and herbivore mammal dung, such as that of badger, bear, wolf, dog and humans (Fig. 9C–F, I–K and 10A and B) (Martí Boada pers. comm.). Except for three wellcompacted specimens, the rest were externally rough dark brown and internally reddish and quite crumbly. Four show distinctive insect burrows (Figs. 7–11).

Radiocarbon dating

Samples submitted to the Oxford Radiocarbon Accelerator Unit, contained insufficient carbon for dating, but other material sent to the Radiocarbon Dating Laboratory at the University of Waikato (Hamilton, New Zealand) returned modern dates of 30–50 years old (Table 4).

Geochemical analysis

The specimens are unlithified and composed of a calcareous clay–silt matrix with scattered angular to subangular quartz grains. The presence of bone-derived calcium phosphate is used as a diagnosis for carnivore dung (Chin 2002; Pesquero et al. 2014) and this was not detected. The mineral composition of MADV/ 561 was slightly different from MADV/561(A) (Fig. 12A and B).

Epidermal and phytolith analyses

The phytolith assemblage in the dung is diverse in terms of morphotypes. It mostly (~57%) consists of short cells of grass silica (GSSC), with an additional ~22% non-diagnostic grass phytoliths (Fig. 13A–I). The remainder is almost all non-diagnostic morphotypes (Tables 5–6). This indicates that virtually all phytoliths in the sample derive from grasses. The diet represented by the dung therefore contained relatively abundant grass. The GSSCs are >90% pooid, with predominantly keeled rondels, conical rondels and several large crenates (Fig. 14A–D). PACCMAD forms contribute only 3.8% of the GSSC assemblage, all of which are indicative of C_3 PACCMAD grasses (e.g., Cortaderia selloana) (Kondo et al. 1994). Although C. selloana is originally from South America, its presence in the phytolith assemblage is not surprising. Known as Pampas grass in English, it was introduced to France between 1775 and 1862 (Bossard et al. 2000), and has spread over much of Europe including Iberia. During the last 15 years, it has become an invasive alien and has had a negative impact upon the native flora of northern Spain, especially in Cantabria (Sanz-Elorza et al. 2004). 'Gineri' or 'plomalls', as it is known in Catalan, has been widely used as an ornamental grass in Catalonia for the last century. It was planted in the public gardens when the agricultural land in LaMoixeta was urbanised in the 1960s, and has spread in private gardens (Domènech et al. 2005; Linder et al. 2010). Thus, the concurrent presence of Cortaderia sp. pollen supports the age of the dung provided by radiocarbon dating. It also suggests that some agro-pastoral activities were still being practised while the urbanisation of the area was being developed.

The grass community that the dung producers grazed upon was likely to have been almost 100% C_3. Predominance of grass communities belonging to C_3 are to be expected in arid mountainous areas, because they are better adapted to

cooler elevation that are exposed less often to very hot conditions (Sage et al. 2012). The high abundance of keeled rondels is consistent with, but by no means exclusive to, Brachypodium sp. (Fig. 14A–D). In addition, a subset of the crenate forms is reminiscent of those produced by this genus. However, the sample does not contain the bilobates and polylobates that are abundant and typical of the Brachypodium leaf phytolith assemblages studied elsewhere (Strömberg, unpubl. data). Certain crenates are also similar to those found in Stipa and related grasses but the diagnostic stipoid bilobates are missing from the assemblage (Fig. 14A–D). The grasses consumed by the herbivore therefore were mostly unknown pooid grasses and a very small proportion of Brachypodium and Stipa. The presence of the unknown pooid grasses reflects the sharp decline in pasture grasses and agricultural land except for a few vineyards and orchards over the last 50 years (Figures 2 and 3).

Pollen analysis

The specimens contained large quantities of pollen, dominated by 70% of Genista type. This suggests a typical vegetation cover of Mediterranean garrigue but with some wet-loving taxa, as evidenced by the presence of Salix (Table 6). There were also trace amounts of Pinus, Quercus, Ulmus, Mercurialis, Trifolium, Poaceae, Phillyrea, Galium, Rumex, Artemisia, Potentilla, Plantago, Geranium, Filipendula and spores of Filicales. This assemblage corresponds to the extant flora in the immediate vicinity, except for Filipendula. Although F. vulgaris has been recorded in nearby localities, it is locally a very rare species (Table 6).

Diatoms and nannofossil analyses

Examination of the dung revealed Nitzschia sp. and afurther species of diatoms (Fig. 15A-PO). Unfortunately, the identified genus includes both freshwater and marine species. Albeit relatively abundant, they were insufficient to run statistical analysis(Fig. 15A-O). Three species of CNs, all coccoliths, were obtained from the two samples analysed, presumably having been ingested with mineral matter. The preservation of the specimens is very poor, with extensive overgrowth and/or dissolution, even though these taxa are resistant to diagenetic processes, in particular dissolution (Fig. 16A–E) (Thierstein 1980). The three species from the dung are stratigraphically distributed as follows: Watznaueria barnesiae from the Bajocian to the Maastrichtian (Middle Jurassic to Late Cretaceous); Cyclagelosphaera margerelii, from the Bajocian to the Palaeocene and C. deflandrei, from the Tithonian to the Maastrichtian (Late Cretaceous) (Bown 1998); few specimens belonging to the genus Reticulofenestra sp., ranging from the Palaeocene to the Pleistocene, with a peak between the Eocene and the late Miocene, were also found (Fig. 16A–E) (Wei and Wise 1990; Young 1998).

Whilst there are no studies of the substrate microfossils of the cave or those of the upper layers, the temporal distribution of C. margerelii and W. barnesiae includes the Jurassic-Lower Cretaceous limestones into which the cave is eroded, as well as the Cretaceous strata which outcrop in the area surrounding the cave (see Figs. 4 and 16A–E).

In contrast, the Cenozoic distribution of Reticulofenestra sp. does not correspond to the age of the rock present near the cave, and the original source of these nannofossils is likely to be in other strata in the catchment which also includes Palaeocene and Eocene rocks further north, ca. 4.5 km from the La Moixeta cave (see Fig. 4). Either the nannofossils were transported to the cave via the drainage system, or they were incorporated in dung as a result of incidental ingestion during grazing some distance from the cave (see Fig. 4).

Entomological analysis

Insect remains from animal dung include not only those exploiting it as a primary habitat and their predators (cf. Skidmore 1991), but also those accidentally ingested by the herbivore. The samples included insect remains of diverse sizes belonging to species currently inhabiting the area (Fig. 17A–F). It is unfortunate that the fragments of pronotum and elytron of Geotrupes cannot be identified beyond the species pair, G. spiniger (Marsh.)/stercorarius (L.) (Fig. 17A–F). Both, however, occur in the dung of a wide range of large herbivores (Koch 1989), although the fragmented nature suggests the accidental consumption of a specimen by a grazer. The European mole cricket, Gryllotalpa gryllotalpa (L.), is largely subterranean, occurring in loose damp soils (Harant and Jarry 1982) and in wetlands (Marshall and Haes 1988), although in the Mediterranean region it is also recorded from dry, stony and sandy soils (Harris 1982). Introduced to North America early last century, Weiss and Dickerson's (1918) comment that adults may hibernate in horse manure and other warm places may be relevant to its appearance in dung in a cave. Meadow spittlebugs (Philaenus cf. spumarius) are numerous in grassland, depositing the familiar 'cuckoo spit' to protect their larvae on stems, and like the indeterminate weevils (Curculionidae), were probably accidentally ingested whilst grazing. Ants (Formicidae indet.) and the bumblebee, Bombus cf. terrestris, are probable accidental visitors to the cave and nothing can be added with regard to the indeterminate Hymenoptera (Fig. 17A–F).

Discussion

Taken overall, geochemical and biological materialsagree with the contextual evidence that the dung originated from ovicaprine, rather than human, canine or other carnivore sources. The lack of calcium phosphate removes carnivores as the possible dung producers, and the included plant remains, pollen, epidermal and phytolith remains, and the calcareous clay–silt matrix with some quartz grains, suggest that the dung also contained sediment from the cave and other extraneous material via taphonomic processes, probably largely trampling by the animals, which may have destroyed any pelletal structure. The fact that pollen, epidermal and phytolith remains are entirely from natural vegetation concurs with the shepherd's comment that herds were fed entirely on natural vegetation and pasture. The herds may have obtained the pre-Quaternary diatoms and nannofossils from water in the catchment. If this was the case, it would certainly concord with the contextual evidence that the herds did not roam far from the cave.

Alternatively, some could be contaminants from the Cretaceous outcrops into which the cave is eroded; or could have been ingested incidentally during grazing from dust on vegetation. Dietary mineral deficiencies may also lead to herbivores licking and chewing calcareous rocks (e.g., Chládeka and Zapletal 2007; McDowell 1996). It is significant that the shape of the dung specimens was not diagnostic of the producers. These had been distorted and some samples resembled carnivore (Figs. 9C–F, I–K and 10A and B), cattle (Fig. 7A–D) and human (Fig. 10A–C and B–D), rather than ovicaprine dung.

The dung also reflects the changes in vegetation as described by the contextual evidence, and the presence of unknown pooid grasses is the only difference from current vegetation. This reflects the sharp decline in pasture over the last 50 years, the abandonment of agro-pastoral practices in the area, and the partial urbanisation of some of the agricultural land, except for a few vineyards and orchards. It also registers the consequent natural re-colonisation of the scrub community and conifers, in the mountainous area of the Catalan coast.

Conclusion

Interpreted in the light of the ethnographic evidence, the multidisciplinary study of the animal dung provides a reasonable picture of land use around the cave of El Montmell, as well as identifying the source as ovicaprines.

The mineral content and pollen, phytolith, and dermal contents of the dung allow the inference that the only producers of the dung were the local herds of sheep and/or goats that used the cave in the recent past as shelter. The lack of cereals and vegetables remains also confirms that the herds were entirely fed on natural vegetation, at least during episodes when the animals utilised the cave. The shepherd was able to confirm that because agricultural productivity was so the flock's diet was not supplemented with cereals and vegetables. Nannofossils and diatoms, sourced from outcrops 4 km away from the cave, may indicate that herds roamed locally. The contents of the dung registered the existence of grazing pastures, which, as the aerial photographs confirm, have been lost over the past 50 years to the rapid expansion of forest and scrub, although the paucity of current grazing means that this in itself is a new habitat. As a caveat, it should be noted that the shape of the dung was not diagnostic of the producers and some specimens resemble the coprolites of carnivores.

Taphonomic processes, including animal trampling and digging, have distorted the original shape, and mixed the dung with the cave's sediment. More animal dung is expected to be unearthed in the older layers of the cave sediment, since evidence for agriculture and cattle farming has been recorded in the surrounding caves from at least the secondcentury AD (Burés et al. 1992). Thus, the cave of El Montmell and perhaps other caves in the area have the potential to provide a palaeoenvironmental record for the central mountainous area of the Catalan coast. This preliminary study also serves to underline the potential of a multidisciplinary study of recent coprolites, backed by ethnographic research, in providing the background to the interpretation of past environments and societal changes.

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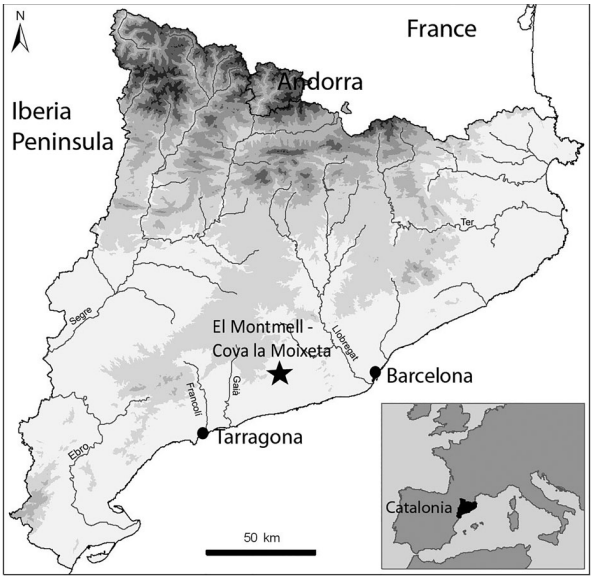

Figure 1 Physical map of Catalonia placing the cave where the dung was uncovered.

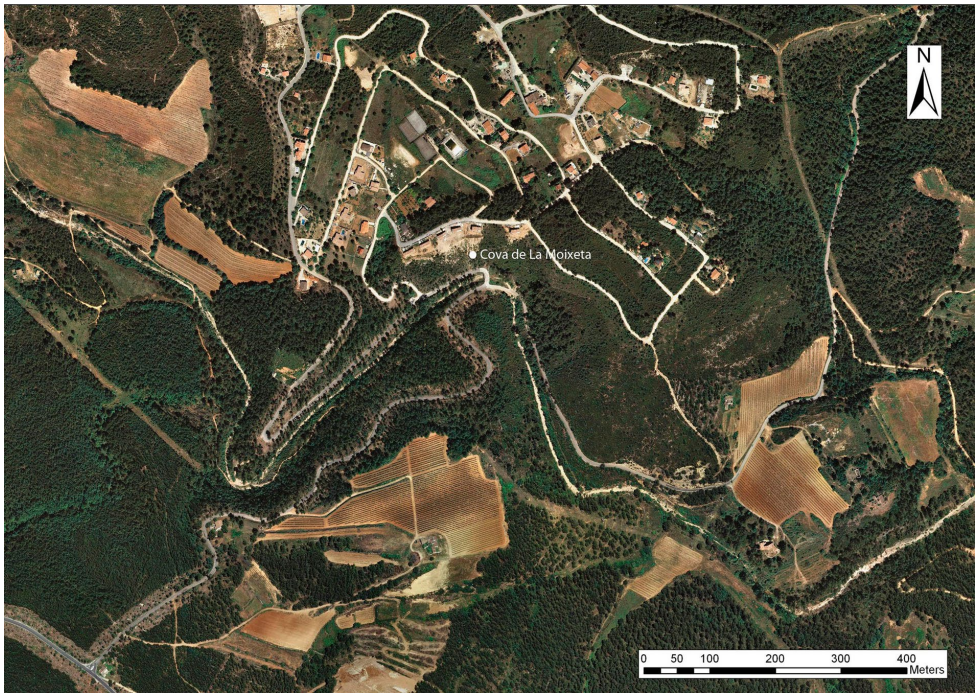

Figure 2 Aerial photo of the Urbanisation La Moixeta cave taken in 2009.

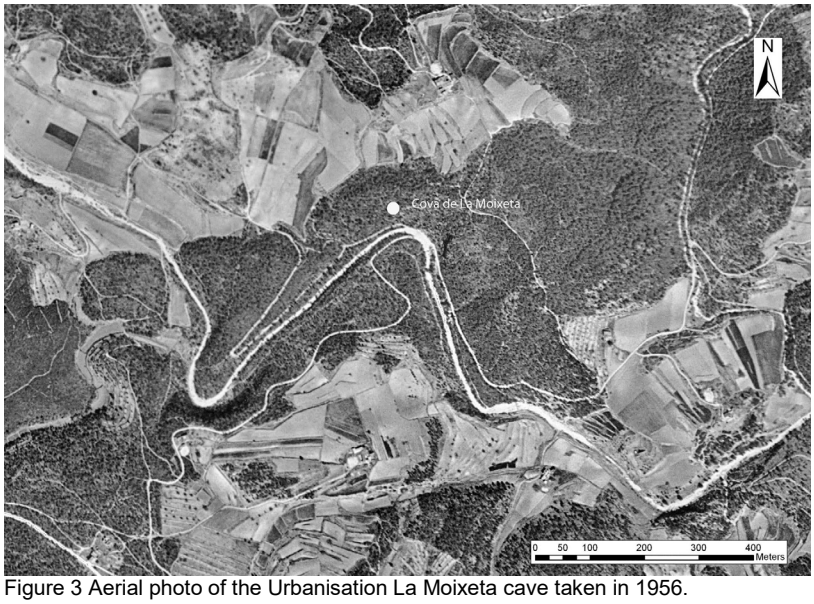

Figure 3 Aerial photo of the Urbanisation La Moixeta cave taken in 1956.

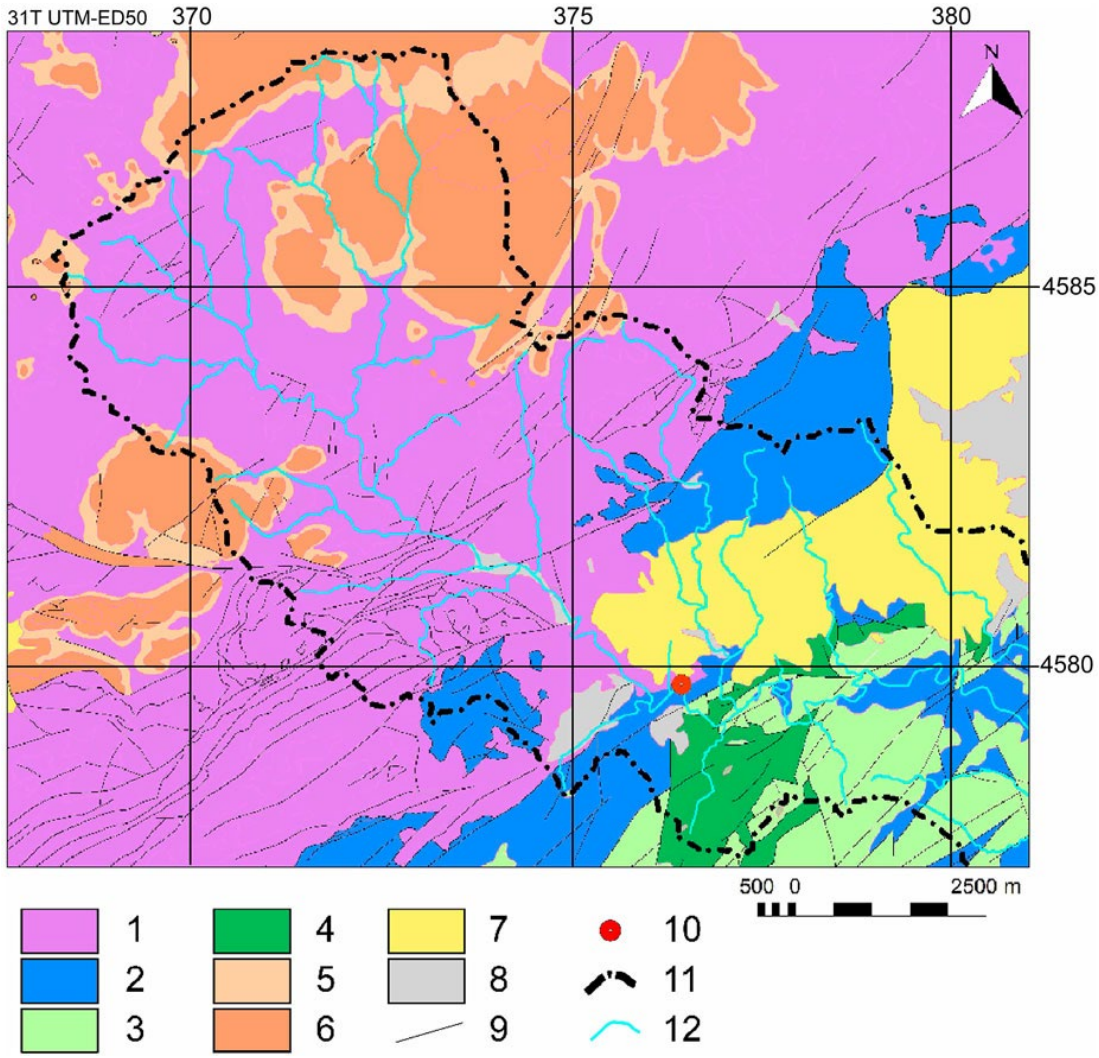

Figure 4 Geological map of the surroundings of the cave. Geologic map scale1:50・000, sheet number 419 (Instituto Geológico y Minero de España, 2006). Legend: 1 – Triassic: marls–limestone: 2 – Jurassic–Early Cretaceous: sandstones and clays, and clays and limestones; 3 – Lower Cretaceous: limestones and dolomite intercalations; 4 – Lower–Upper Cretaceous: calcarenites, marls, clays; and sandstones; 5 – Palaeogene–Palaeocene: clays; 6 – Palaeogene–Eocene: limestone and marls; 7 – Neogene–Miocene: conglomerates; 8 – Quaternary: coarse sediments, gravel; 9 – Faults and mechanical contacts; 10 – Moixeta Cave; 11 – Boundary of the river basin of Marmellar tributary; 12 – Drainage basin of the Marmellar tributary, as it is seen from the bridge.

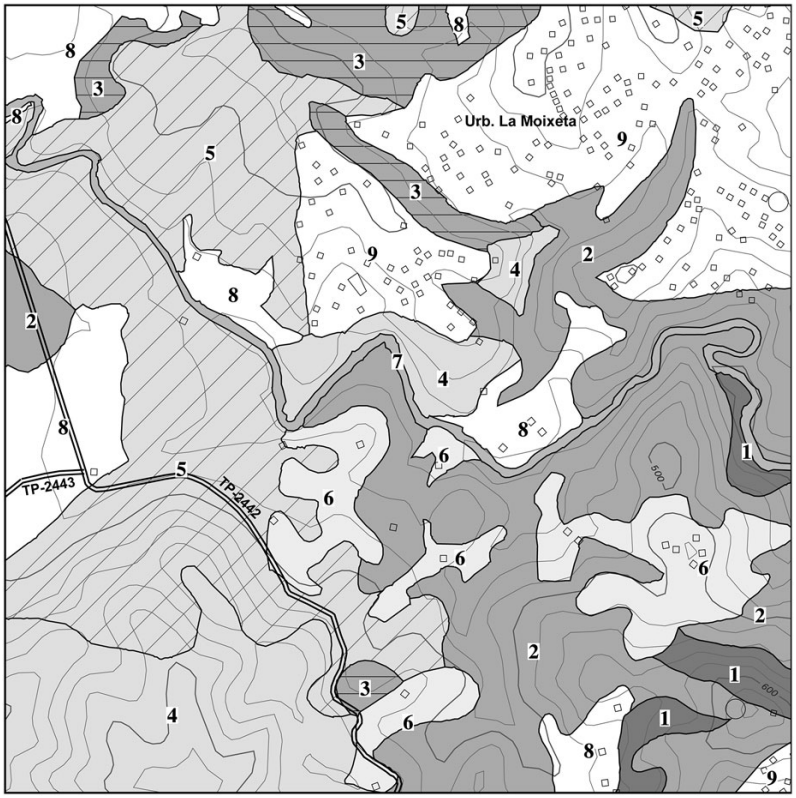

Figure 5 Habitats map of La Moixeta at 1:25・000 scale (Abril and Vallejo 1991; Cambra et al. 2006; Quadrada 2007). La Moixeta Habitat map. Legend: 1 – Lowland holm-oak forests; 2 – Aleppo pine (P. halepensis) forests with a thermo- Mediterranean woody understory; 3 – Aleppo pine (P. halepensis) forests with a calcicolous scrub layer; 4 – Kermes oak (Q. coccifera) garrigues, locally with Aleppo pine regeneration; 5 – Rosemary (Rosmarinus officinalis) scrubs, locally with Aleppo pine regeneration; 6 – Dry grasslands usually dominated by Brachypodium phoenicoides; 7 – River bank vegetation complex: willow shrubby formations + Rubus ulmifolius thicket + hygrophilous rush and tall grass formations; 8 – Vineyards; 9 – Urbanised areas with patches of natural vegetation.

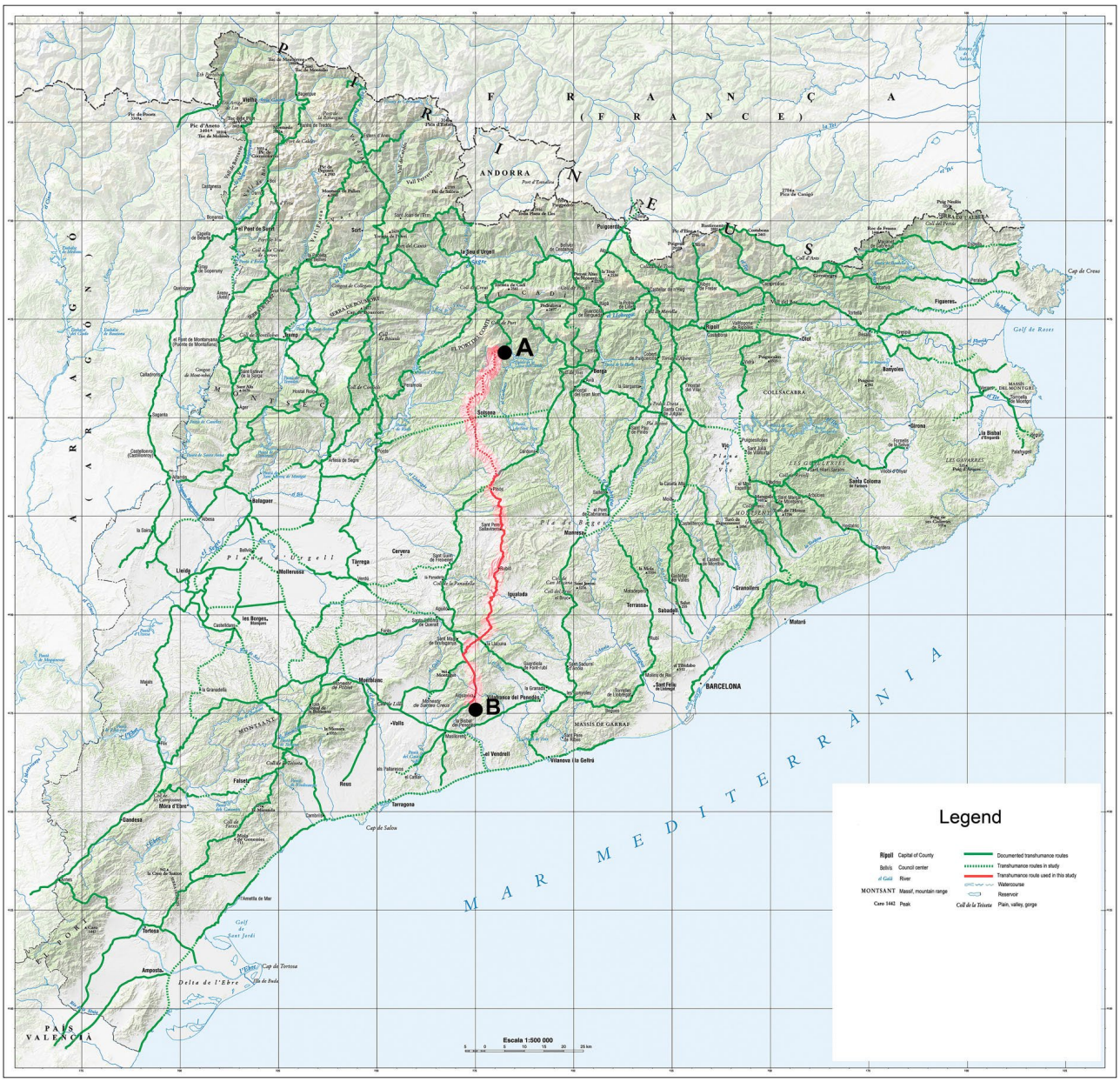

Figure 6 Map showing the main transhumance routes in Catalonia. The route used by the Pyrenean shepherd is highlighted in red (modified from Fundació del Món Rural and Institut Cartogràfic i Geològic de Catalunya 2010). A Sant Llorenç de Morunys and B La Juncosa del Montmell.

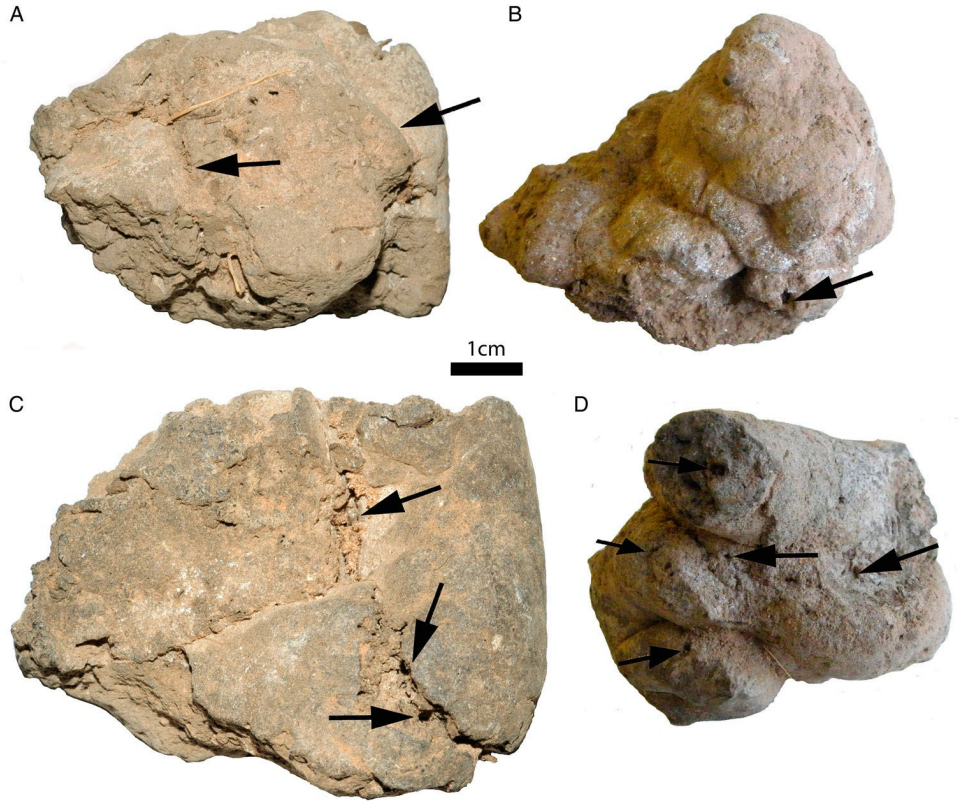

Figure 7 Specimens A–D used in this study, belonging to the group of dung from different producers reference MAVD-561 stored at the Museu Arqueològic del Vendrell. A–C and B–D are photos of both sides of the same specimens. Notice striations in dung A–C (arrows), and A–C and B–D (arrows) displaying dung beetle burrows.

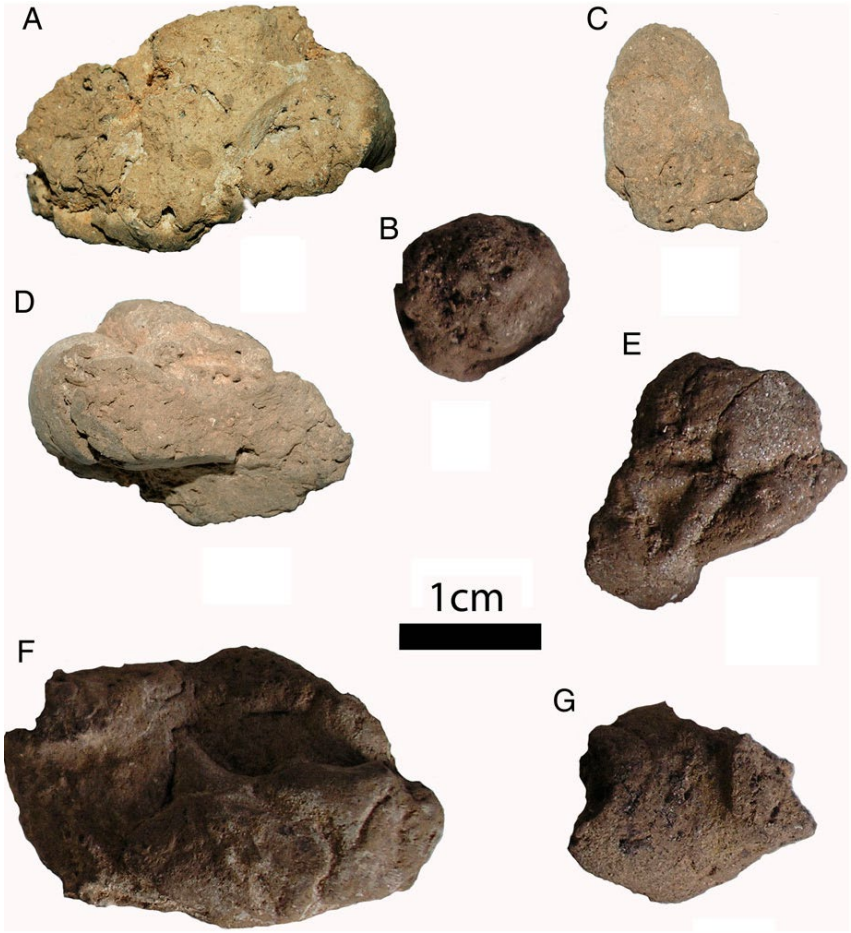

Figure 8 Group of dung from different producers reference MAVD-561 stored at the Museu Arqueològic del Vendrell. A–D are photos of both sides of the same specimen.

Figure 9 Group of dung reference MAVD-562 stored at the El Museu del Vendrell. A–D; B–E; C–F; G–L; H–J; and I–K are photos of both sides of the same specimens, and M is a single shot of a specimen.

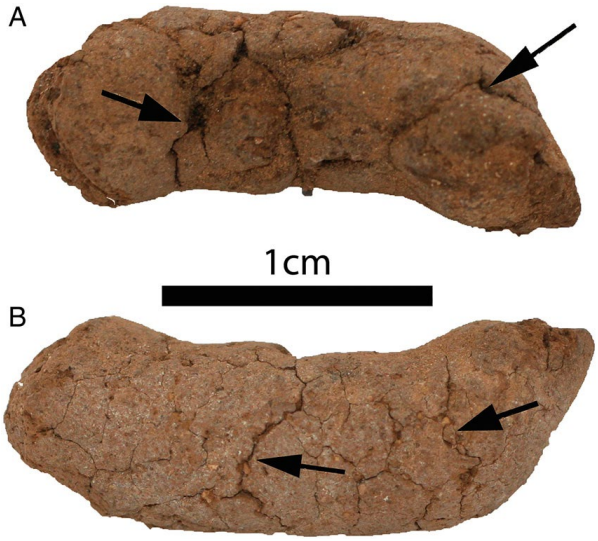

Figure 10 Cylindrical dung displaying deep transverse and concentric striations (arrows). A and B are photos of both sides of the same specimen.

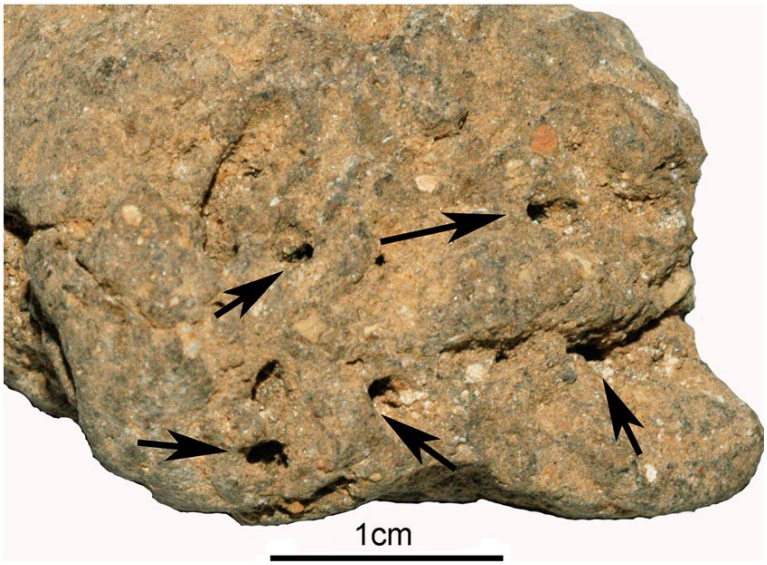

Figure 11 Dung displaying beetle burrows.

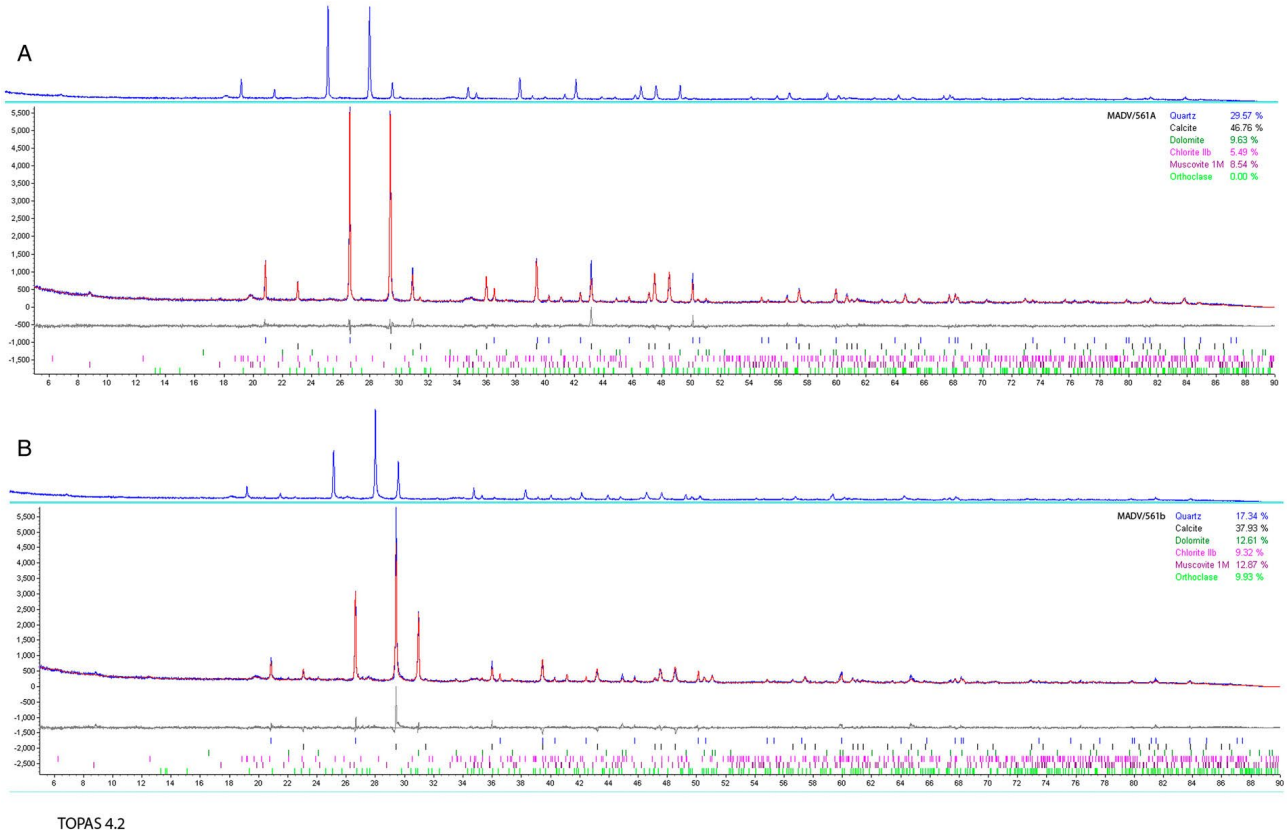

Figure 12 Graph showing the mineral composition of the two specimens of dung analysed, MADV/561 (Figs. 11A and B). MADV/ 561(A) Aquartz 29.57%, calcite 46.76%, dolomite 9.63%, chlorite IIb 5.49%, muscovite 1M 8.54%, and orthoclase feldspar 0.00%, MADV/561(B) quartz 17.34%, calcite 37.93%, dolomite 12.61%, chlorite IIb 9.32%, muscovite 1M 12.87%, and orthoclase feldspar 0.93%.

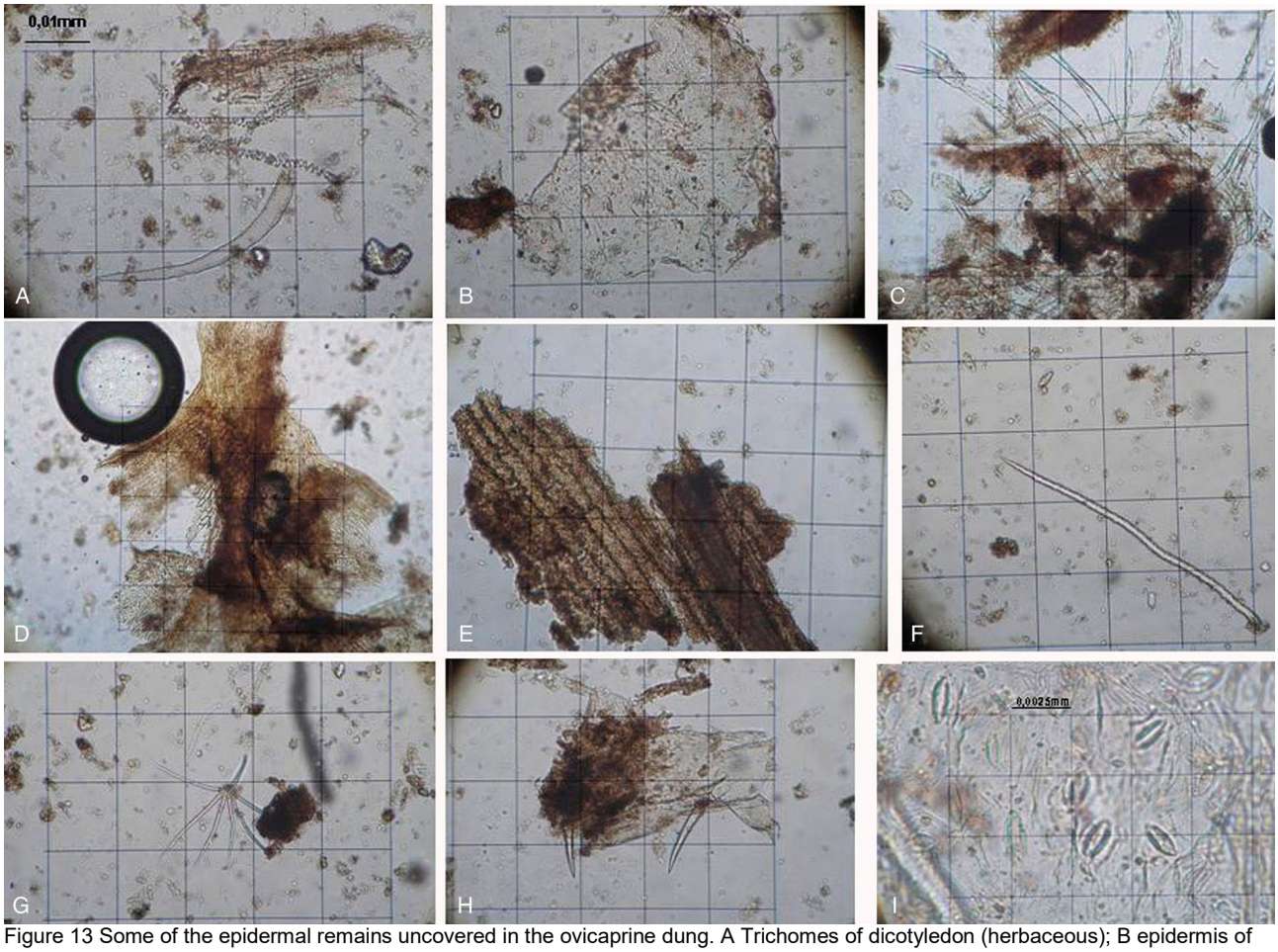

Figure 13 Some of the epidermal remains uncovered in the ovicaprine dung. A Trichomes of dicotyledon (herbaceous); B epidermis of dicotyledon (herbaceous); C trichomes and epidermis of dicotyledon (herbaceous); D epidermis of bryophyte; E epidermis of monocotyledon (graminid); F trichomes of leguminid (Trifolium?); G trichomes of Rosaceae (Rubus?); H trichomes and epidermis of dicotyledon (herbaceous); I epidermis and stoma of dicotyledon (herbaceous).

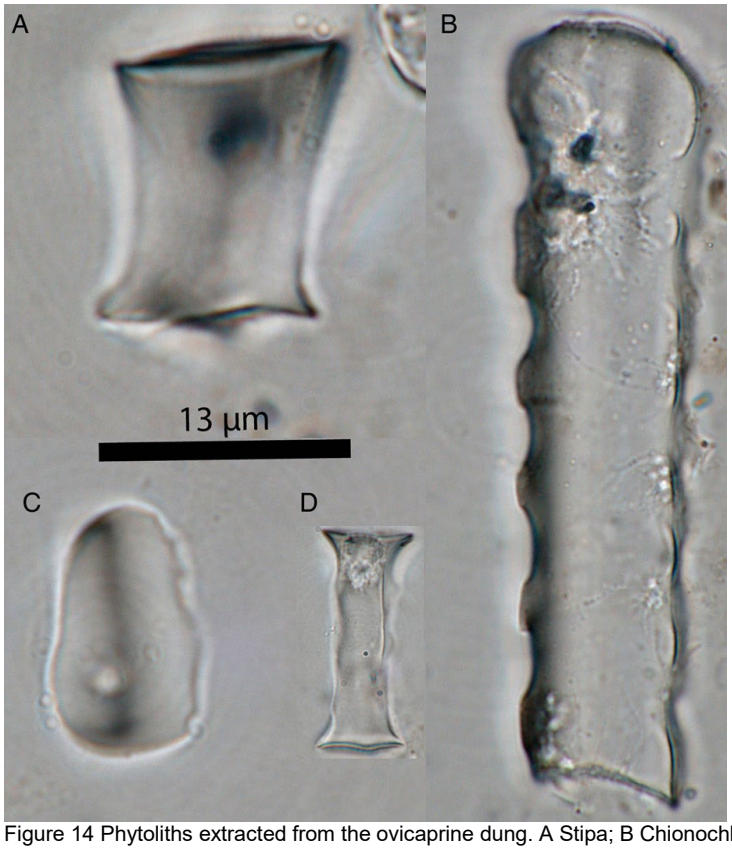

Figure 14 Phytoliths extracted from the ovicaprine dung. A Stipa; B Chionochloid; C Keeled Rondels; D Brachypodium

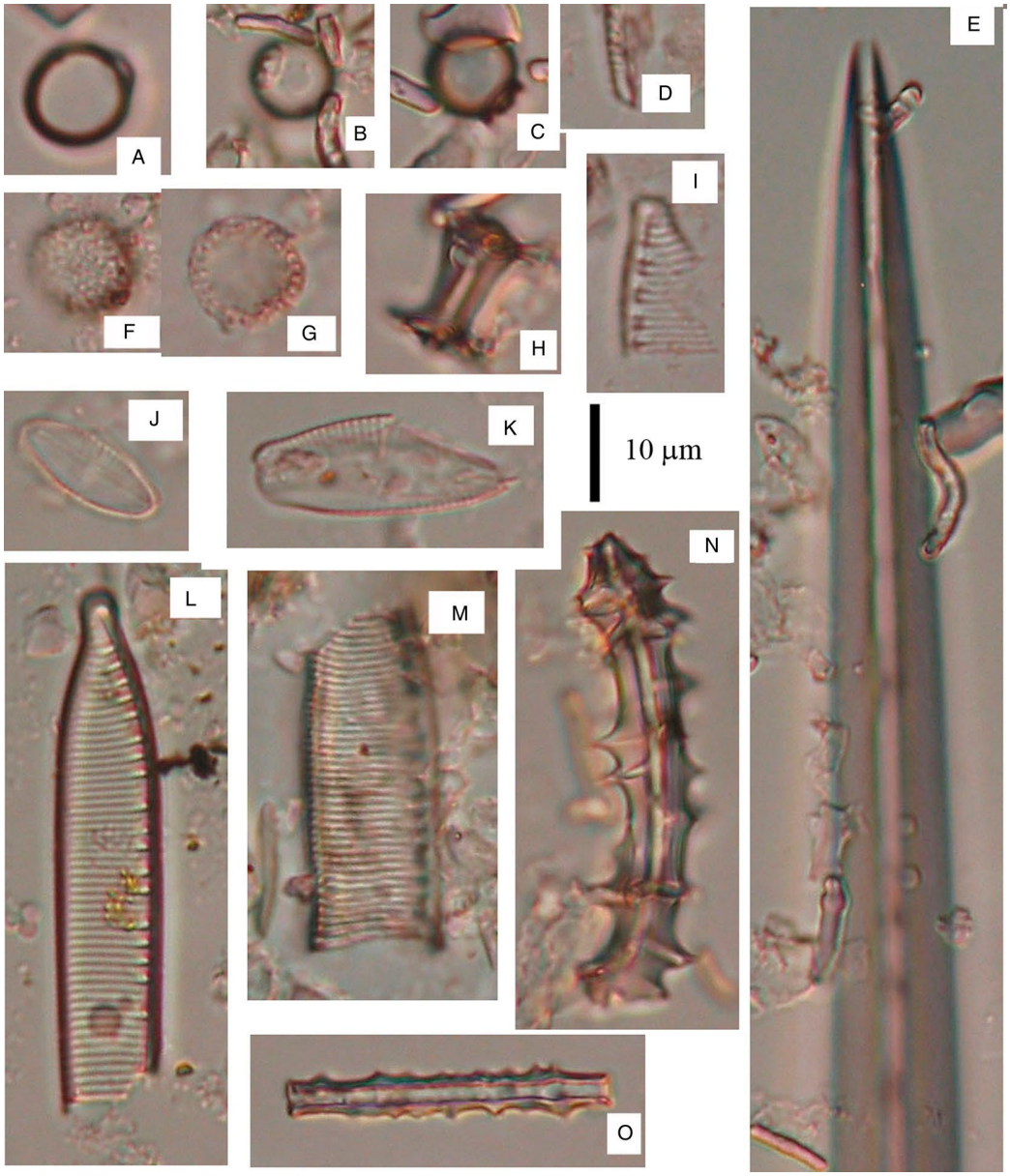

Figure 15 A–C cysts; D unknown diatom; E part of a sponge spicule; F–G Diatom? – Aulocoseira?; H cyst; I Nitzshia sp.; J–K unknown diatoms; L–M Nitzshia sp.; N–O spicules.

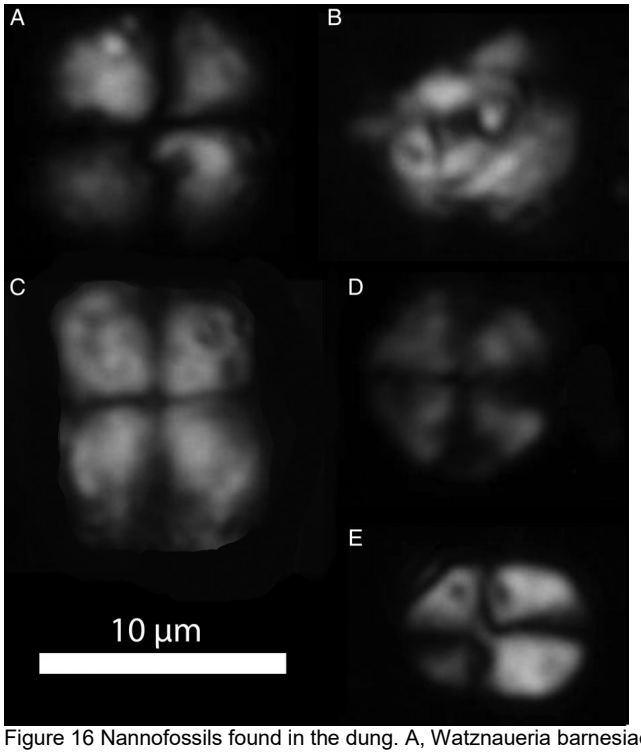

Figure 16 Nannofossils found in the dung. A, Watznaueria barnesiae; B, Reticulofenestra sp.; C and D, Cyclagelosphaera deflandrei; E, Cyclagelosphaera margerelii.

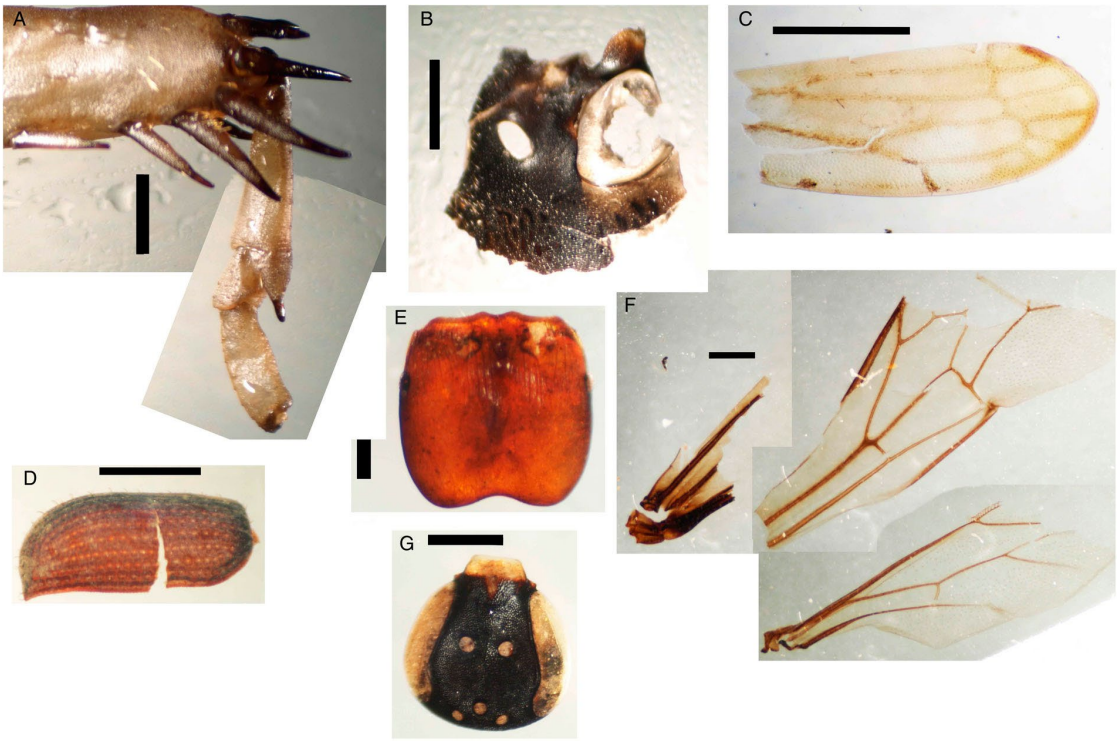

Figure 17 Insects uncovered in the dung. A, Gryllotalpa sp.; B, Gryllotalpa sp. head; C, Philaenus sp.; D, Curculionidae indet.; E, Messor sp.; F, Bombus sp.; G, Hymenoptera indet.

Table 1 Vegetation of La Moixeta relief: 1 *Quercus ilex* – *Q. faginea* maquis (*Viburno tini-Quercetum ilicis*); 2 Aleppo pine forest on Mediterranean scrub; 3 Kermes oak garrigue (*Quercetum cocciferae*)

	[1]	[2]	[3]
Aspect	NW	W	SSE
Inclination (°)	25	5	15
Altitude (m)	440	430	460
Total cover (%)	95	90	95
Tree cover (%)	–	60	5
Tree height (m)	3		–
Shrub cover (%)	–	50	95
Shrub height (m)	2	1	1,5
Herb cover (%)	–	40	60
Area (m^2)	60	150	60
Quercetea ilicis characteristics			
Q. ilex	2.2	1.1	+
Q. coccifera	+	2.2	5.4
Phillyrea latifolia	1.1	+	+
Rubia peregrina	+	+	+
Pistacia lentiscus		+	1.1
Asparagus acutifolius		+	+
Lonicera implexa	+	+	
Rhamnus alaternus		+	1.1
Viburnum tinus	2.2		
Ruscus aculeatus	+		
Smilax aspera	+		
Viola alba	+		
Clematis flammula		+	
Querco-Fagetea characteristics			
Q. faginea	4.3	2.2	
Buxus sempervirens	3.3		
Coronilla emerus	1.1		
Anemone hepatica	+0.3	.	
Euphorbia amygdaloides	+		
Rosmarinetea characteristics			
Rosmarinus officinalis		1.2	+
Erica multiflora		+	+
Bupleurum fruticescens			+
Stipa offneri			+.2
Argyrolobium zanonii			+
Euphorbia nicaeensis		+	
Other species			
P. halepensis	(+)	4.3	1.1
Brachypodium retusum		2.2	2.3
Bupleurum fruticosum	1.3	+	
Carex halleriana		+0.2	+0.2
Juniperus communis	1.2	+	
Juniperus oxycedrus		+	+
Teucrium chamaedrys		+	+
Ulex parviflorus		1.2	+
Brachypodium phoenicoides		2.3	
Genista scorpius			1.1

Other species present only in one relevé

Rel. 1: *Aphyllanthes monspeliensis*, *Campanula* sp., *Carex* gr. *ornithopoda*, *Genista hispanica* subsp. *hispanica*, *Genista patens*, *Hedera helix*, *Helleborus foetidus*.

Rel. 2: *Carex flacca*, *Cistus albidus*, *Cistus salvifolius*, *Clematis vitalba*, *Conopodium majus* subsp. *ramosum*, *Osteragus monogyna*, *Doryonium hirsutum*, *Knautia* sp., *Lavandula latifolia*, *Lonicera etrusca*, *Ranunculus* sp., *Rubus ulmifolius*.

Rel. 3: *Centaurea linifolia*, *Doryonium pentaphyllum*, *Fumana ericifolia*, *Galium lucidum*, *Ononis minutissima*, *Polygala rupestris*, *Rhamnus* cf *saxatilis*, *Sedum sediforme*, *Thymus vulgaris*.

Relief code: Country, county, community (Province), locality, UTM, survey date, authors.

1 [2-010306]: E Montmell (Tarragona), La Moixeta, 31T CF3766793, 01/03/2006, I. Soriano, L. Chamorro, L. José-María

2 [3-010306]: E Montmell (Tarragona), La Moixeta, 31T CF7641796S, 01/03/2006, I. Soriano, L. Chamorro, L. José-María

3 [1-010306]: E Montmell (Tarragona), La Moixeta, 31T CF7643797, 01/03/2006, I. Soriano, L. Chamorro, L. José-María

Table 2 List of vegetation identified along the Riera de Marmellar river bank (willow shrubby formations + *Rubus ulmifolius* thicket + hygrophile rush and tall grass formations). C. 400 m a.s.l.

Trees
Fraxinus angustifolia
Shrubs
*Salix elaeagnos**
*Rubus ulmifolius**
Coriaria myrtifolia
Bupleurum fruticosum
Rosa canina
Crataegus monogyna
Prunus spinosa
Herbs
*Rumex obtusifolius**
Mentha rotundifolia
Polygonum persicaria
Juncus inflexus
Dipsacus fullonum
Cirsium monspeliense
Scirpus holoschoenus
Prunella vulgaris

*means abundant species.

Table 3 Sizes of the ovicaprine dung uncovered in the cave of La Moixeta.

Specimen number	Length × width (cm)
MADV/561A	1.62 × 0.67
MADV/561B	1.16 × 0.70
MADV/561C	2.05 × 0.69
MADV/561D	1.86 × 1.37
MADV/561E	1.16 × 0.88
MADV/561F	1.42 × 0.71
MADV/561G	2.37 × 1.03
MADV/562A	7.49 × 4.42
MADV/562B	7.35 × 5.38
MADV/562C	3.16 × 1.95
MADV/562D	1.95 × 1.83
MADV/562E	1.88× 1.40
MADV/562F	1.22 × 1.15
MADV/562G	4.13 × 3.15
MADV/562H	6.03 × 3.79

Note: Specimens followed numbering from Figs. 10 and 11.

Table 4 Dating of a dung specimen (Fig. 7A–C) of the group MADV/561 (Fig. 7B–D), applying the Conventional Age or Percent Modern Carbon (pMC) method following Stuiver and Polach (1977)

	$\delta^{13}C$	$D^{14C}C$	$F^{14}C\%$	Higher calibrated age (68.2% probability)	Lower calibrated age (95.4% probability)
Total uncertainty years ±error	−28.8± 0.2‰	143.4 ± 4.6‰	141.3 ± 0.5%	1973–1977 calAD	1971–1980 calAD

Note: The isotopic fractionation, $\delta^{13}C$, is expressed as ‰ w.r.t. PDB.

Table 5 Phytolith percentage and number extracted from the dung specimens

Phytolith counts (%) of sample								
Phytolith morphotypes* (%)								
	GSSC							
FI	CH TOT	POOID-D	POOID-ND	PACCMAD general	Other GSSC	Non-diagnostic grass	Other non-diagnostic grass	Total phytolith count
1.07	0.27	10.04	41.1	2.13	2.93	21.9	20.03	375

*GSSC, grass silica short cell; FI, forest indicator; phytoliths; CH TOT, closed habitats GSSC phytoliths; POOID-D, diagnostic pooid GSSCs; POOID-ND, non-diagnostic pooid GSSCs; PACCMAD general, C3/C4 PACCMAD clade (Panicoideae, Arundinoideae, Chloridoideae, Centothecoideae, Micraioideae, Aristidoideae and Danthonioideae) GSSCs; Non-diagnostic grass, trichomes and wavy and spiny epidermal long cells and other morphotypes abundantly produced by grasses; Other non-diagnostic grass, phytoliths forms found in any types of plants.

Table 6 Pollen percentage and number of vegetation fragments found in the dung specimens

Pollen type	%	Epidermal fragments	Total
Genista type	70	*P. halepensis*	146
Mentha type	11	*Juniperus oxycedrus*	12
Ericaceae	4.9	*Ruscus aculeatus*	9
Salix sp.	3.4	*Legumes*	5
Prunus type?	6.1	Other *dicotyledons*	332
Poaceae, *Phillyrea*, *Galium*, *Rumex*, *Quercus*, *Artemisia*, *Potentilla*, *Plantago*, *Geranium*, *Ulmus*, *Filipendula* and Filicales	4.6	*Gramineae*	318
		Briophyta	34
		Leguminosae	40
		Rubus sp.	36
		Floral fragments	22
		Fruit fragments	11
		Stem fragments	347
		Unidentifiable plant fragments	525
		Animal fragments (insects)	38