Journal of Archaeological Science: Reports 47 (2023) 103803

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

An interdisciplinary approach to the combustion structures of the Western Mediterranean Iron Age. The first results

Belarte Maria Carme[a,b,*], Portillo Marta[c], Marta Mateu[b], Saorin Carme[d], María Pastor Quiles[b,f], Vila Sílvia[e], Valentina Pescini[b]

[a] ICREA - Catalan Institution for Research and Advanced Studies, Spain
[b] ICAC - Catalan Institute of Classical Archaeology, Spain
[c] Department of Archaeology and Anthropology, Archaeology of Social Dynamics (2017SGR 995), Institució Milà i Fontanals (IMF), Spanish National Research Council (CSIC), Barcelona, Spain
[d] Department of History and Archaeology, Universitat de Barcelona, GRAP (Grup de Recerca en Arqueologia Protohistòrica). PGC2018-099579-B-I00, IAUB (Institut d'Arqueologia de la Universitat de Barcelona), Spain
[e] Universitat de Lleida, Spain
[f] University of Alicante, Spain

ARTICLE INFO

Keywords:
Fire installations
Protohistory
Western Mediterranean
Iberian Peninsula
Microarchaeology
Interdisciplinarity

ABSTRACT

Iron Age combustion structures on the eastern Iberian Peninsula have traditionally been analysed through the study of their morphological aspects and their association with archaeological finds. Approaches including microarchaeology and a combination of different disciplines are still rare for this area and period, despite the fact that they will be able to provide more information on the construction techniques, fuels and uses of fire facilities. The authors are currently undertaking the project entitled "Transdisciplinary and Experimental Study of Combustion Structures in the Western Mediterranean during Protohistory (first millennium BC)" (TRANSCOMB) aimed at implementing an interdisciplinary methodology for the study of protohistoric hearths and ovens. This paper presents the results of the analyses (anthracological studies, phytoliths and calcitic microfossils, micromorphology and FTIR) conducted on a selection of combustion structures. Micromorphological and FTIR analyses give us detailed information on the construction technique and materials used. Macrobotanical and microfossil records indicate fuel sources. The different analyses also provide information on the temperatures obtained in the studied combustion structures. The coordination between specialists and the comparison of results obtained from the different techniques have provided a complementary view of the aspects studied. These need to be extended by further research, including experimental work, within the framework of our project.

1. Introduction

This article aims to present and discuss the first results of an interdisciplinary project investigating fire structures in the north-western Mediterranean: the TRANSCOMB Transdisciplinary and Experimental Study of Combustion Structures in the Western Mediterranean during Protohistory (first millennium BC)) Project. The project study area includes the northeastern Iberian Peninsula, the south of France and the Balearic Islands. The chronological span is the first millennium BC, focusing particularly on the Iron Age (from the 8th century BC to the turn of the era). The results presented here derive from information retrieved at archaeological sites on the Mediterranean fringe of the Iberian Peninsula.

The Iron Age archaeological sites in this area share some general characteristics, such as a predominantly elevated locations and good visual control of the surroundings. Most settlements are of the agglomerated type with regular urban layouts, houses sharing party walls and sometimes grouped in blocks separated by streets or organised around a central area of collective use. Construction techniques and materials are mainly stone, earth, wood and other plant materials (Belarte, 2008; Belarte et al., 2009). Domestic architecture can vary according to different factors, such as the chronology, the geographical area or the natural environment. House walls are mainly built with mud bricks on stone plinths, although massive earth walls are also documented.

* Corresponding author at: ICREA - Catalan Institution for Research and Advanced Studies, Spain.
E-mail addresses: cbelarte@icac.cat (M.C. Belarte), mportillo@imf.csic.es (M. Portillo), mmateu@icac.cat (M. Mateu), csaorin@ub.edu (C. Saorin), mpastor@icac.cat (M. Pastor Quiles), vpescini@icac.cat (V. Pescini).

https://doi.org/10.1016/j.jasrep.2022.103803
Received 28 June 2022; Received in revised form 19 December 2022; Accepted 21 December 2022
Available online 11 January 2023
2352-409X/

Finally, a few walls are built entirely of stone, which in some cases are preserved up to significant heights (2–3 m).

In terms of domestic equipment, the most frequent features are combustion facilities, mainly hearths and, less frequently, ovens. These are usually interpreted as being related to food processing or preparation. Most of the structures, especially hearths, are located indoors, and are considered to have been for private use. On the other hand, ovens which are usually outdoors, were probably collective facilities (Belarte et al., 2016).

These combustion structures present different morphologies, locations and building techniques, particularly the hearths (with or without a preparation layer, in a shallow pit or at floor level, etc.). However, they also have common elements, especially the existence of an earthen surface for the fire (Belarte, 2021). These traits are also common in other areas of the Mediterranean during the Iron Age, as well as in earlier periods. It is therefore to be expected that the same study methodology can be applied to a wide geographical area and over long periods.

Research into Iron Age combustion structures presents specific difficulties. For example, they were regularly cleaned and their combustion surfaces do not always display traces of fuels. Moreover, objects related to their use (e.g. pottery or other cooking utensils) may be scarce due to a slow abandonment of the site or post-depositional processes. In addition, in some rooms, there are traces of several fires across the floor and in some of them it is not clear whether they were specially built hearths or only occasional fires. Generally speaking, research into Iron Age archaeological sites usually includes the study of objects and macro-remains, as well as a systematic sampling of sediments for other bio-archaeological studies, whilst geochemical or micromorphological analyses are less frequent.

Using a multidisciplinary approach within the framework of the TRANSCOMB Project we aim to characterise the combustion features of the area and period, in order to gather information about aspects such as construction materials and techniques, fuel management and the activities related to these structures (culinary or others). We focus on the relationship between different morphologies and locations and diverse uses of combustion installations, in terms of their functionality (domestic vs artisanal uses), duration (sporadic fires vs long-term structures) and formation processes. All this will contribute to a more in-depth knowledge of the exploitation of natural resources, the organisation of daily activities, the use of space and the household organisation of Iron Age societies.

The methodology integrates thin section micromorphology, geochemical analyses, archaeobotany (anthracology, phytoliths and calcitic microfossils), and organic residue analysis. To date, we have sampled a total of 35 combustion structures from 16 archaeological sites in the south of France, Catalonia, the northern Valencian region and the Balearic Islands. Most of them are still under study.

Together with these analyses, an experimental archaeology programme has been set up. This consists of building replicas of combustion installations, lighting them with different fuels while recording times and temperatures, and collecting samples from the combustion surfaces that are also being analysed for comparative purposes (Belarte et al., 2022).

This methodology, either in whole or in part, has been applied to other contexts and periods and by different researchers (e.g. Gur-Arieh et al., 2012; March et al., 2012; Gur-Arieh et al., 2014; Aldeias et al., 2016; Mallol et al., 2017; Shahack-Gross, 2018, among others). However, such interdisciplinary analyses for the Western Mediterranean Iron Age are still scarce.

As for the specific objectives of this paper, we aim to present the first results obtained from the interdisciplinary analyses applied to a selection of combustion installations. More precisely, these results come from a combined interpretation of anthracological studies, phytoliths, calcitic microfossils, micromorphology and FTIR analyses.

2. Materials and methods

2.1. Description of the structures

We have chosen to present the results from four combustion structures located at two different sites (two at each) (Fig. 1 and Table 1). Several such installations have been excavated at each of the settlements; they functioned in pairs in the same space and had different or complementary uses. Although this is not the general rule, it can also be found at other protohistoric sites.

Although these sites are still being excavated and studied; the persons in charge of fieldwork kindly allowed us to analyse the combustion structures. However, the results of some of the contextual research are not yet available.

Two of the combustion structures (EC04 and LL25) are from Tossal de la Vila (TV) (La Serra d'en Galceran, Castelló) in the Valencian region (Fig. 1). The site is on a hilltop 954 m above sea level. The fire structures described here correspond to the first occupation period of the site, during the Late Bronze Age-Early Iron Age (8th-7th centuries BC), after which the settlement was destroyed by fire (Aguilella et al., 2016). We have selected one of the excavation areas, where four contiguous spaces separated by party walls have been unearthed, each of them containing two combustion structures (most likely a hearth and an oven). We are presenting the results obtained from LL25 (hearth) and EC04 (oven) (see Table 1, Figs. 2 and 3a) in Sector 47, the southernmost room of this excavation area. Other fire installations on the site have been previously studied by one of us (Saorin, 2018).

The other two fire structures (LL7080 and LL7078) (Fig. 3b-c) are from Masies de Sant Miquel (MSM) (Banyeres del Penedès) on the central coastline of Catalonia, 40 km north of Tarragona, on a gentle elevation 143 m above sea level and 25 m above the surrounding plains. This is a major urban site with a surface area estimated at 3.5–4 ha and a continuous occupation from the 6th to the 3rd centuries BC. The site was discovered in the 1980s but was not subjected to a systematic excavation programme until the 2020s (Noguera et al., 2020, 40; Sala et al., 2020,

Fig. 1. Map of the study area with the location of the two archaeological sites mentioned in the text, as well as the main present-day towns.

Table 1
Summary of the main characteristics of the analysed combustion structures.

Site and code acronym	Combustion structure	Type of structure	Length and width (cm)	Shape	Building material and technique	Stratigraphic unit	Location
Tossal de la Vila (8th-7th century BCE) (TV)	EC04	Oven	100 × 30–60	Elongated, irregular	Mud and slabs	47105 (earth with gravel)	Attached to a wall
	LL25	Hearth	72 × 68	Oval	Mud, with border	41709 (earth with gravel)	Next to EC04
Masies de Sant Miquel (late 3rd century BCE) (MSM)	LL7080	Hearth	60 × 40	Irregular	Mud. Built inside a shallow pit	7080 (earth with charcoal and ashes), 7083 (earth, reddened)	Central
	LL7078	Hearth	70 × 40	Quadrangular-irregular	Mud. Built inside a shallow pit	7078 (compact earth with ashes)	Next to a wall

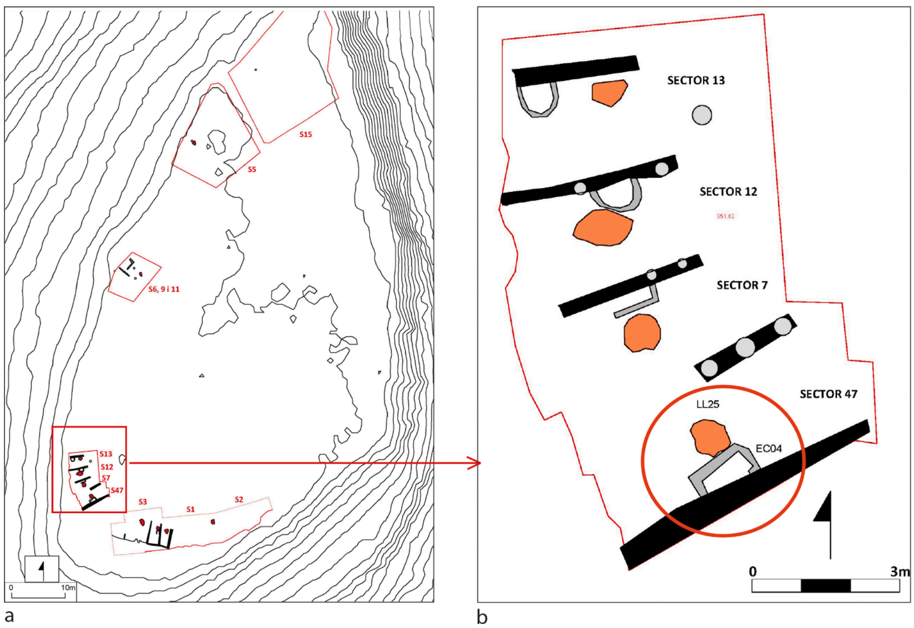

Fig. 2. a) General plan of Tossal de la Vila (TV) archaeological site; b) Plan of the excavated area with the location of Sector 47 and the fire structures (in orange) (after Falomir et al. 2021, modified).

184). Combustion structures were located inside House CA01 from the last occupation phase. The building has an elongated, rectangular floor plan with an earthen floor and two functioning fire structures (Morer et al., in press) (Table 1 and Fig. 4).

2.2. Methodology and techniques

In order to study the combustion structures, we have developed systematic sampling methods to conduct integrated micro-contextual studies at high-resolution. Each of these four structures has been sampled for phytolith analysis and FTIR (Figs. 3 and 5). Sediment samples were also extracted for anthracological study, and individual blocks for micromorphology of thin sections (Fig. 6). The analytical methodology is explained in Sections 2.2.1 to 2.2.4.

2.2.1. Anthracology

The study of charred wood remains makes it possible to identify the plant species used in the ovens and hearths (Chabal, 1992). A variable amount of litres of sediment was collected from each hearth (2 l for MSM LL7080, 5 l for MSM LL7078; 6 l for TV EC04 and 8 l for TV LL25). The sediment was floated using 4, 2, 1 and 0.25 mm sieves (Kabukcu and Chabal, 2021; Chabal, 1997). The anthracological analysis was performed at the Bioarchaeology and Palaeoenvironment Laboratory at the Catalan Institute of Classical Archaeology (ICAC) in Tarragona. The collected remains were observed under reflected light microscopy, both bright- and dark-field (Olympus BX51), using magnifications of x50, x100 and x200. Charcoal identification was based on anatomical features described in wood anatomy atlases (Schweingruber, 1990) and websites (e.g. Wood Anatomy, InsideWood Database and Xylem Database).

2.2.2. Phytoliths and calcitic microremains

The integrated study of phytoliths and calcitic microfossils may allow the distinction between wood and dung fuel remains, or mixtures of both (see Table 1 in Portillo and García-Suárez, 2021). A total of twenty-eight sediment samples was selected from Tossal de la Vila (EC04 and LL25, coded as TV samples) and Masies de Sant Miquel (LL7078 and LL7080, MSM) (Table 3). Six control sediment samples from their vicinities were analysed for comparative purposes. Phytolith analyses followed the methods of Katz et al. (2010). A weighed aliquot of *ca.* 40 mg of dried sediment was treated with 50 μl of a volume solution of 6 N HCl and 450 μl 2.4 g/ml sodium polytungstate solution [$Na6(H2W12O40)$]. Microscope slides were mounted with 50 μl of sample. Morphological identification was based on modern plant reference collections and standard literature (Twiss et al., 1969; Twiss, 1992; Brown, 1984; Rosen, 1992; Mulholland and Rapp, 1992; Piperno, 2006; Portillo et al., 2014; Albert et al., 2016). Wherever possible, the terms used to describe phytolith morphologies follow the standards of the International Code for Phytolith Nomenclature 2.0 (Neumann et al., 2019).

Fig. 3. View of the four analysed combustion structures, with the location of the samples taken for phytolith and FTIR analyses: a) Hearth LL25 and Oven EC04 at the TV archaeological site; b) Hearth LL7078 at MSM; c) Hearth LL7080 at MSM.

The methods used for calcitic microfossil analyses (dung spherulites and wood ash pseudomorphs) were similar to those proposed by Canti (1999). Approximately 1 mg of dried sediment was mounted on a microscope slide with Entellan New (Merck). Both phytoliths and calcitic microfossils were examined at × 200 and × 400 magnifications using a Leica DMEP optical microscope at the Institució Milà i Fontanals of the Spanish National Research Council (IMF-CSIC) in Barcelona. Samples were also compared with modern reference ethnoarchaeological records from Mediterranean areas that have followed a similar methodology (Tsartsidou et al., 2008; Portillo and Matthews, 2020; Portillo et al., 2012, 2014, 2017, 2020a, 2021; Portillo and García-Suárez, 2021).

2.2.3. Micromorphology

The study of soil and sediment thin sections (on a micro-scale) provides information on their in-situ composition, formation processes and possible use (Mateu et al., 2019). In this research, we took one undisturbed and oriented sample from each combustion structure (Fig. 6). The thin sections were prepared in the University of Barcelona Institute of Geology laboratory following standard protocols. The samples were consolidated with polyester resin by total impregnation through capillarity, then sliced into 30 μm-thick sections and placed on slides (Loaiza and Poch, 2015: 19-20; Verrecchia and Trombino, 2021). The thin sections were studied at the Catalan Institute of Classical Archaeology Archaeometric Studies Unit (UEA - ICAC) under a petrographic optical microscope (×20 to × 200 magnifications), in Plane Polarised Light (PPL), between Crossed Polarisers (XPL) or Oblique Incident Light (OIL). The descriptions and interpretations are based on criteria from Bullock et al. (1985), Courty et al. (1989) and Stoops (2003), and the features used to infer the technological characteristics proposed by Friesem et al. (2017), Cammas (2018) and Mateu and Daneels (2020).

2.2.4. FTIR (Fourier Transform Infrared Spectroscopy)

As a spectroscopic technique, it obtains information on the molecular structures of crystalline and amorphous materials, as well as organic materials. It is based on the absorption of energy caused by the interaction between electromagnetic radiation and the material to be analysed; in this case, the interaction of the infrared with the analysed sediment. Eleven sediment samples from Tossal de la Vila (EC04 and LL25, coded as TV samples) were collected, ten of them from the combustion surfaces of both structures and one from the edge of Hearth LL25. At Masies de Sant Miquel (LL7078 and LL7080, MSM), 18 samples were collected, seven of them from the hearth combustion surfaces, four from the layer above them, four from the floor and, finally, three more from the section of the block extracted for micromorphology analysis. For each sample, a few milligrams of sediment were homogenised and powdered with an agate mortar, mixed with a few milligrams of KBr and pressed into a 7 mm pellet using a manual hydraulic press (Specac). Infrared spectra were obtained at a resolution of 4 cm 1 by 32 scan with an iS5 from Thermo Fisher Scientific. Spectra were collected at 32 scans at a resolution of 4 cm^{-1}. The software used for the interpretation of the spectra was OMNIC and the mineral database used is available at the Kimmel Centre for Archaeological Science (Weizmann Institute of

Fig. 4. a) General plan of Masies de Sant Miquel (MSM) archaeological site; b) Plan of the excavated area with the location of House CA01 and the combustion structures (in orange) (after Morer et al., in press modified).

Fig. 5. a) Collecting samples for phytolith and FTIR analyses; b) Collecting a block of sediment for micromorphology.

Science, Israel). The origin of the calcite was determined according to Chu et al. (2008) and Regev et al. (2010) and the thermal alteration of the clays was identified following Berna et al. (2007). When clay is exposed to elevated temperatures, it is altered and becomes more disordered. The infrared spectra of clays exposed to high temperatures change depending on the type of clay, the temperature, and the length of exposure. Identification of clays by FTIR is only possible if the clay sample being analysed contains a single clay mineral. Unfortunately, several different clay minerals are often mixed together; when this is the case, it is very difficult to identify the type of clay in the sample (Weiner, 2010).

3. Results and discussion

3.1. Anthracology

Altogether in MSM and TV, the sediment samples from the combustion surfaces and preparation layers of hearths and ovens provided a total of 136 wood charcoal remains. Most of them cannot be determined taxonomically due to their poor state of conservation. Indeed, the charcoal remains consist of small, often vitrified fragments. Vitrification is a common phenomenon affecting charcoal remains and consists of the fusion and homogenisation of cell walls, although the causes of such processes are still unclear and a matter of debate in anthracology (Courty et al., 2020; Marguerie and Hunot, 2007; McParland et al., 2010; Théry-Parisot and Henry, 2012). At MSM indeterminate remains amounted to 43.7%, while at TV they were 83%. Despite this, some fragments were sufficiently well preserved to allow taxonomic identification. At MSM a total of 6 taxa were identified (Table 2 and Figs. 6 and 7). The most abundant species is represented by *Pinus sylvestris/nigra* (n = 10) followed by *Quercus* evergreen (n = 5), *Ficus carica* (n = 4), *Phillyrea/Rhamnus* (n = 2), *Juniperus* sp. (n = 2) and *Arbutus unedo* (n = 1). At TV the variety of plant species present is slightly lower, as only 4 taxa have been discovered (Table 2 and Figs. 6 and 7). Fragments belonging to the *Quercus* family are the most frequent (n = 9) followed by Rosaceae Prunoideae and R. Maloideae (n = 1 each). Finally, *Acer* sp. was also identified (n = 1).

The charcoal fragments identified at both MSM and TV come from a “concentrated” archaeological context (Chabal 1992; Di Pasquale, 2011) and it is therefore difficult to discuss their paleoenvironmental significance in depth. It is also difficult to deduce whether there was a “selection” of specific species, given the scarcity of charcoal assemblages and the lack of wider environmental archaeology studies (on-site and extra-site analyses). However, it can be noted that pine and oak were the most commonly used species, which fits in with other research conducted in both the Valencian and Catalan regions for the same chronological periods (Belarte et al., 2021: 238; Vila Moreiras, 2018; Vila Moreiras and Piqué, 2012; Piqué et al., 2011; Buxó and Piqué, 2008). Those trees are characteristic of Mediterranean vegetation with some specific variations typical of the respective altitudinal zones. They may therefore have been more easily available. In addition, both pine and oak are considered to be superior quality wood and were commonly used both as a building material and as a fuel (i.e. high calorific value). The presence of the other identified species is not surprising as they could be characteristic of the undergrowth of pine and oak woods and therefore easily available in enormous quantities.

Table 2
Anthracological results. Relative frequencies of charcoal remains identified at Tossal de la Vila (TV) and Masies de Sant Miquel (MSM). Results are shown per archaeological structure and stratigraphic unit.

	Anthracological Results					
Site	**MASIES DE SANT MIQUEL**			**TOSSAL DE LA VILA**		
Structure Stratigraphic Unit	LL7080 7078	LL7078 7083	Total remains	EC04 47105	LL25 47109	Total remains
Taxa	N. abs.	N. abs.	N. abs.	N. abs.	N. abs.	N. abs.
Acer sp.	0	0	0	0	1	1
Angiosperm	0	1	1	1	1	2
Arbutus unedo	0	1	1	0	0	0
Gymnosperm	0	1	1	0	0	0
Ficus carica	1	3	4	0	0	0
Juniperus sp.	1	1	2	0	0	0
Pinus sp.	0	2	2	0	0	0
Pinus type *sylvestris/nigra*	3	7	10	0	0	0
Quercus sp.	0	0	0	3	2	5
Quercus sp. evergreen	4	1	5	0	4	4
cf. *Quercus*	0	0	0	0	1	1
Phillyrea/ Rhamnus	1	1	2	0	0	0
cf. Rosaceae/ Prunoideae	0	0	0	0	1	1
cf. Rosaceae/ Maloideae	0	0	0	0	1	1
Indeterminable	13	8	21	15	58	73
Total analysed remains	23	25	48	19	69	88
Total identified remains	10	18	28	4	11	15

3.2. Phytoliths and calcitic microfossils

Phytoliths were noted in all samples in different amounts (Fig. 8).

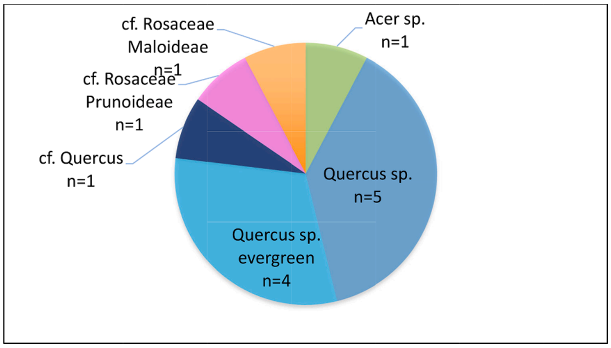

Fig. 6. Graphic representation of the main species present at TV. Total analysed remains: n = 88. Total identified remains: n = 15.

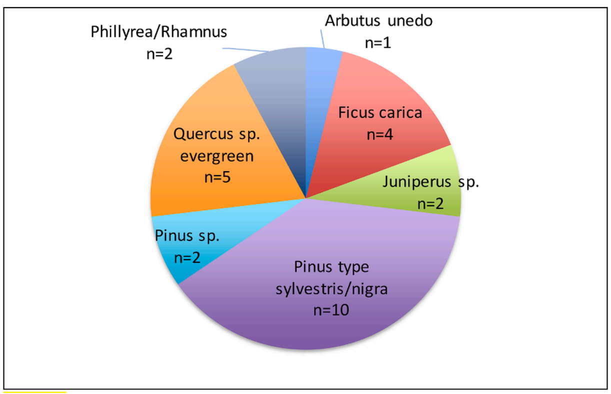

Fig. 7. Graphic representation of the main species present at MSM. Total analysed remains: n = 48. Total identified remains: n = 28.

Phytolith numbers in the TV samples ranged from 22.000 to 260.000 per 1 g of sediment (Table 3), whereas most of the MSM samples yielded higher concentrations (up to 520.000 phytoliths/g sediment, LL7078, Sample No. 6).

The phytoliths weathering index (*ca.* 4–22% TV samples, *ca.* 0.7–33% MSM samples, (Table 3), widely used as an indicator of the state of preservation of phytolith assemblages, refers to unidentifiable phytoliths presenting pitted surfaces and irregular shapes that may derive from depositional and post-depositional weathering and alteration by dissolution for example (Portillo et al., 2020a), and particularly in this case to bioturbation, as indicated by thin section micromorphology (see Section 3.3). In addition to weathering, certain phytoliths from these assemblages were partially affected by melting due to increased heating temperatures, although these were recognisable and morphologically identified. Phytoliths were identified in low concentrations in these samples and thus results should be taken with precaution.

The morphological results show that monocotyledonous phytoliths, mainly grasses, dominated in most of the assemblages, with an average of around 60–84% in TV and MSM samples, respectively (Table 3). Grass phytoliths mainly belonged to the Pooideae subfamily, which is common in well-watered environments and is particularly resistant to both dissolution and increased temperatures (Cabanes et al., 2011; Portillo et al., 2020a) (Fig. 8a). Phytoliths from the leaves and culms of grasses, including flabellate bulliforms, acute bulbosus (prickles or trichomes) and elongate polylobates, were also common in the assemblages (Fig. 8b). Inflorescences were characterised mainly by elongate dendritic and dentate phytoliths, in addition to epidermal cells such as *papillate*, although the latter only in lower amounts in MSM assemblages, as they are particularly vulnerable to taphonomic processes (Cabanes et al., 2011; Portillo et al., 2020a). Multicellular or interconnected phytoliths, from both the floral parts of grasses and the leaves and stems of those plants, were also noted in most of the TV samples in different proportions, but were almost completely absent in MSM assemblages (Table 3, Fig. 8c). Of particular note is the presence of diagnostic spheroid echinate phytoliths produced by the leaves of the Arecaceae family (palms), such as dwarf palm (*Chamaerops humilis*) (Fig. 8d). Arecaceae leaf phytoliths were only observed in MSM samples (Table 3). Lastly, phytoliths from woody/herbaceous dicotyledonous plants included diagnostic morphotypes from their leaves, such as hairs and their epidermal bases. To a lesser extent platelets and spheroids were

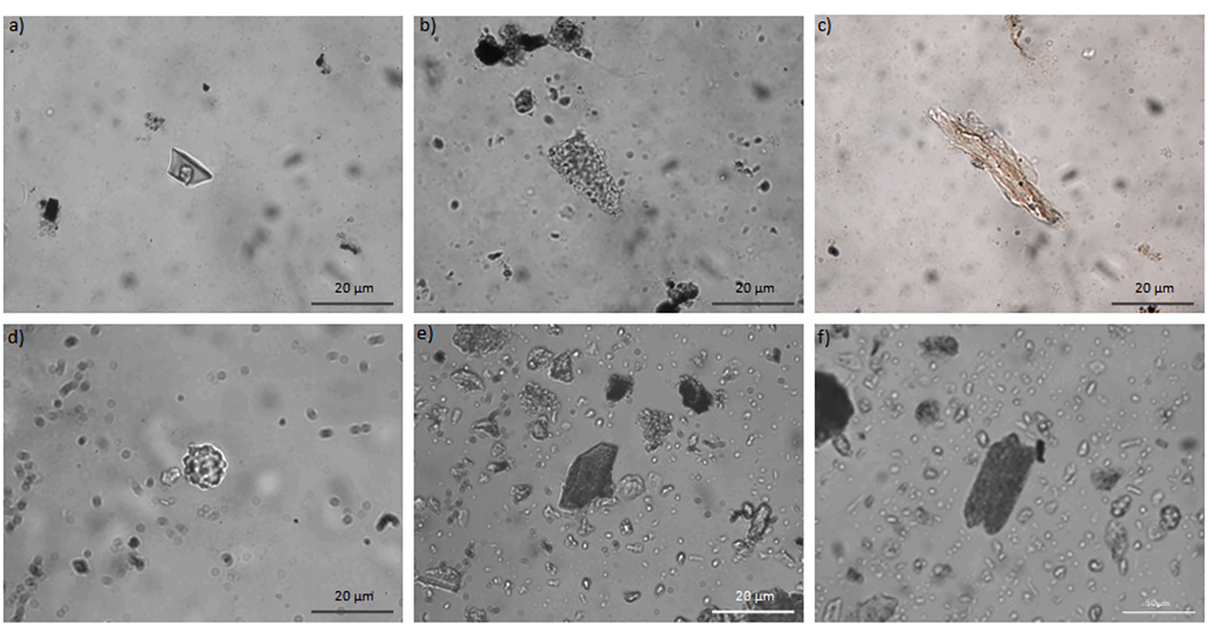

Fig. 8. Photomicrographs of phytoliths and calcitic microfossils from Tossal de la Vila (TV) and Masies de Sant Miquel (MSM) (×200 or × 400). a) Short cell rondel from Pooideae grasses (Sample TV-LL25-8); b) Epidermal appendage acute bulbosous (sample TV-EC4-5); c) multicellular elongate phytoliths (Sample TV-LL25-8); d) spheroid echinate (MSM-LL7078-2); e) calcitic wood ash pseudomorph resembling *Quercus sp.* (MSM-LL7080-4); f) calcitic wood ash pseudomorphs comparing favourably to *Pinus sp.* (MSM-LL7080-2).

Table 3
Description of samples and main phytolith and ash pseudomorph results obtained from Tossal de la Vila (TV) and Masies de Sant Miquel (MSM) samples.

Site/ structure	SU	Sample num.	N. phytoliths g /sediment (m)	N. phytoliths counted	Multi-celled phytoliths (%)	Phytoliths weathering (%)	Grasses (%)	Palms (%)	Dicotyledonous leaves (%)	Dicotyledonous wood/ bark (%)	N. ash pseudomorphs g/ sediment (m)
TV EC04	47105	1	0.26	75	10.7	4	72.5	0	8.7	14.7	0.07
	47105	2	0.15	40	5	7.5	76	0	3.9	12.6	0.02
	47105	3	0.005	15	13.3	20	68	0	3.2	8.8	0.01
	47105	4	0.16	41	2.4	17.1	58	0	8.1	16.8	0.01
	47105	5	0.15	40	0	12.5	68	0	8.2	11.3	0.03
	47107	6	0.15	43	0	7	78.1	0	7.1	7.8	0
TV LL25	47109	7	0.07	21	4.8	4.8	44.8	0	11.2	39.2	0.1
	47109	8	0.09	27	7.4	11.1	59.3	0	2.2	27.4	0.05
	47109	9	0.002	6	33.3	16.7	50	0	0	33.3	0.02
	47109	10	0.003	9	22.2	22.2	31.3	0	1.3	45.3	0.06
	47109	11	0.004	14	14.3	7.1	70	0	5.1	17.7	0.03
	47109	12	0.006	20	10	10	44	0	8.6	37.4	0.03
	47107	13	0.19	49	12.2	12.2	75.1	0	5.9	6.7	0.02
MSM LL7078	7078	1	0.24	66	0	4.5	91.8	0	2.2	1.4	0.14
	7078	2	0.15	44	0	2.3	90	4.5	1.9	1.3	0.25
	7078	3	0.003	8	0	12.5	82.5	0	3	2	1.25
	7078	4	0.004	12	0	8.3	78.3	8.3	3	2	0.71
	7078	5	0.07	20	0	15	82	0	1.8	1.2	0.21
	7048	6	0.52	145	0.7	0.7	95	0	2.6	1.7	0.04
	7048	7	0.28	82	0	2.4	91.7	1.2	2.8	1.8	0.07
MSM LL7080	7080	1	0.49	145	0	3.5	91.3	0	2.3	2.9	0.05
	7080	2	0.21	64	0	1.6	90.3	0	6.1	2	0.04
	7080	3	0.46	140	0	2.9	93.3	0	2.3	1.5	0.06
	7080	4	0.43	140	0	0.8	91.6	0	4	3.7	0.05
	7083	5	0.01	131	0	50	40	0	6	4	0.05
	7083	6	0.001	2	0	33	53.3	0	8	5.3	0
	7048	7	0.35	102	0	5.9	88.6	0.9	2.7	1.8	0.03
	7048	8	0.61	85	0	3.2	90.8	2.7	1.6	1.6	0.04

also common in most of the samples, with an average of around 27% in the TV samples (n = 10, Table 3). This is also noteworthy, given that dicotyledons are minor phytolith producers.

Furthermore, the calcitic microfossil records are dominated by wood ash pseudomorphs, particularly in the MSM assemblages (up to 250.0000 ash pseudomorphs/g sediment, LL7078, Sample No. 2, Table 3). In contrast, calcitic spherulites derived from dung were completely absent in all the samples. Calcitic ash pseudomorph concentrations in the TV assemblages ranged from 22.000 to 260.000 per gram of sediment (Table 3), whereas most of the MSM samples yielded higher concentrations (up to 520.0000 phytoliths/g sediment, LL7078, Sample No. 6). Most of these calcitic microfossils display characteristic regular-shaped rhomboid morphologies directly comparable to *Quercus sp*. and *Pinus sp*. (see Fig. 8a in Portillo et al., 2017; and Fig. 5 in Portillo et al., 2020c), although the latter only in MSM samples (Fig. 8e-f). This is consistent in turn with the wood charcoal macro-botanical assemblages dominated by both oak and pine in the MSM records (see Sub-section 3.1).

3.3. Thin section micromorphology

In the thin sections from the sample blocks it was possible to identify the different layers of combustion structures. Common characteristics to all of them include the fact that combustion surfaces can be clearly identified and that they are clean (with no anthropic debris or ashes). In three of them the combustion surface is differentiated from the layer just below, but in MSM LL7078 the difference is not so clear; it looks like the same material but has been hardened and reddened by fire. The most important aspects that can be used for discussion are presented below (for a more detailed description of each structure, see Table 4).

In the TV structures we observe two distinct layers: the combustion surface and the layer underneath it (Fig. 9). In both cases, combustion surfaces have a massive microstructure with low porosity. Nearly the entire groundmass is sorted; it is composed of fine and medium dolomite and calcite sands (Fig. 9 A2 and B3). Due to use and post-depositional processes, these layers (FS) were fractured and we can observe aggregates with plate shapes, as have also been observed macroscopically (Fig. 9 B2). The fine fraction has reddening zones and heterogeneous colours. On the top of the LL25 combustion surface, we observe black particles that are dolomite crystals in a dedolomitisation process (Dorronsoro, 2015; Mateu, 2016) and cemented b-fabric (Fig. 9 A2), both as a result of the direct impact of fire or temperature (Mallol et al., 2017). Both layers under the combustion surfaces are highly bioturbated with fresh organic matter (roots) and earthworm biospheroids. They present a silty-sandy dark groundmass of granular microstructure (Fig. 9 A3). There are small fragments of charcoal, some of pottery, and some small fragments of thermo-altered bone (Villagran et al., 2017) (Fig. 9B4). In these layers we find some microfossils and some dolomite sand, although the sediment is unsorted and heterogeneous; clearly different from that of the combustion surfaces (sorted and massive). This demonstrates intentionality in the mixing and application of the earth layer composing the combustion surfaces and the dumping of the material into the layer below it (Mateu et al., 2022; Daneels et al., 2022). The fuel used is not detected in these structures.

In MSM structures we identify two layers in LL7080 (Fig. 10 A1) and three layers in LL7078 (Fig. 10 B1). The two bottom layers display similar characteristics: heterogeneous and bioturbated groundmass (Fig. 8 A3), with some small charcoal and bone fragments. These layers probably correspond to the earthen floor of the house. In LL7080 there is a sharp boundary between the two layers. On the top, the combustion surface is a massive layer, rubified, with a reddish colour (Röpke and Dietl, 2017). It has a sorted and homogeneous groundmass (medium and fine sands) and a massive microstructure (Fig. 10 A2). It only has a few voids: moldic voids from the vegetal temper used in the mix (Matthews, 2010), small vesicular voids (formed by small air bubbles trapped in the matrix) and plane parallel and perpendicular voids in the upper part (due to the use of the structure) (Cammas, 2018; Mateu et al., 2022). In contrast, in LL7078 we distinguish a massive layer with a gradual boundary with the bottom layer. The massive layer is interpreted as the combustion surface (Fig. 10 B3); it is also rubefied and massive, but has similar components to the bottom layer. The last is heterogeneous (Fig. 10 B4), with some small bone and pottery fragments, and some moldic voids with phytoliths (Fig. 10 B6). We have also observed a third, upper layer. It is sandy (medium calcite and quartz sands) and has aggregates of ash and small charcoal fragments (Fig. 10 B2) (Matthews, 2010; Mentzer, 2014). Most of these aggregates are in bands near the combustion surface (Fig. 10 B5). This would correspond to the remains of fuel used.

3.4. FTIR

The samples analysed from the two TV site structures (Fig. 11) consist mainly of calcite, clay and dolomite in smaller quantities (Table 5 and SM)[1]. In EC04 (oven) all samples, except Sample No. 5, show a high degree of thermal alteration and the presence of ash has been determined. In all the samples of this structure, calcite predominates over clays and dolomite, which appear in lower concentrations. The composition of LL25 (hearth) consists of calcite, clay and dolomite in smaller quantities. In all samples, except in Sample No. 6 (edge), calcite is abundant and exceeds clays. Samples 2, 5 and 6 show very little thermal alteration, while Sample 4 presents major thermal alteration, and stands out for the small amount of clays.

All the samples have calcite of geogenic origin (Chu et al., 2008; Regev et al., 2010), which means that the pyrotechnic process did not reach very high temperatures and therefore the calcite was not transformed.

These results are consistent with other combustion installations studied from the same site (Saorin, 2018) where the composition of the structures is calcite and clay and also a notable presence of dolomite. In this previous study, a reference sample was collected from the access road to the site, and we were able to verify that it had the same composition as the samples from the combustion structures, although the spectral peaks show no thermal disturbance in the minerals.

As for MSM (Fig. 3b-c), the composition of the analysed samples of the two structures (LL7078 and LL7080) is mainly calcite, clay, quartz and, in some cases, a small content of dolomite (Table 3). The presence of peak 472 or 474 in all samples and peak 1052 in Sample 6 of hearth LL7078 also suggests the presence of iron oxides (Balu et al., 2018). In hearth LL7078, Samples 1, 3 and 5 have a higher presence of clay than in the other samples, in which calcite is abundant, followed by clays, quartz, dolomite and iron oxides. Samples 6 and 7 both correspond to the floor next to the fire structure; however, there is a difference in Sample 6 compared to the samples of the combustion surface. Sample 7, in contrast, has the same composition and thermal alteration as the samples collected within the hearth. This is not surprising, since it is very close to the combustion structure and could have been altered as a result of the daily tasks involving fire. In hearth LL7080, Samples 1, 2 and 3 contain more calcite, although clays predominate, followed by quartz, dolomite and iron oxides. In Sample 5, clays are more abundant than calcite. In Sample 6, however, calcite is much more abundant than other materials. Sample 2 is the most altered by fire, although all samples from this hearth are thermally altered. In Sample 7, corresponding to the floor, peaks are almost identical to Sample 2, with a high presence of clay. Finally, the second sample corresponding to the floor (No. 8) shows characteristics similar to Sample 3, with an even greater degree of thermal alteration.

In the case of MSM, all the samples are also of geogenic origin, except

[1] The following Supplementary Materials are available online at CORA. Repositori de Dades de Recerca: https://doi.org/10.34810/data507: Graphs SM1 to 29 (FITR Spectra).

Table 4
Micromorphological description of all samples.

Site and Sample code			Microstructure and porosity	Coarse and fine fraction	Other Components	Pedofeatures
TV	**LL 25**	**Combustion surface US47109B**	Microstructure: massive Porosity: 15%, planes and chambers/vughs	All fine fraction: medium and fine sands (calcite, dolomite, *quartz*) (more than 50%), with microfossils. Silty-clay brown, red and brownish grey (heterogeneous) and dotted micromass (PPL), low interference colours (XPL), crystallitic b-fabric (on the top cemented) c/f distribution porphyric	No	Clayey silt intercalations, residual aggregates (dolomites and microfossils), $CaCO_3$ coatings of voids (NFC), black Ox (hydr) Fe/Mn nodules, bioturbation: roots and vegetal matter, postdepositional infillings in pores
		Layer under combustion surface	Microstructure: granular Porosity: 30%, planes, chambers, vughs	30% coarse fraction: coarse sands and gravels. Fine fraction: medium and fine sands, silty, dark brown and dotted micromass (PPL), low interference colours (XPL), undifferentiated b-fabric	Charcoal, bone fragments Pottery fragments Pollen grains	$CaCO_3$ coatings of voids (NFC), black Ox (hydr) Fe/Mn nodules, bioturbation: roots and vegetal matter, postdepositional infillings in pores, earthworm biospheroids
	EC04	**Combustion surface US47105**	Microstructure: massive Porosity: 15%, planes, vughs	All fine fraction: medium and fine sands (calcite, dolomite, *quartz*) (more than 40%), with microfossils. Silty-clay brownish grey and red (heterogeneous), dotted micromass (PPL), low interference colours (XPL), crystallitic b-fabric c/f distribution porphyric	No	Clayey silt intercalations, residual aggregates (dolomites and microfossils), $CaCO_3$ coatings of voids (NFC), black Ox (hydr) Fe/Mn nodules, bioturbation: roots and vegetal matter, postdepositional infillings in pores
		Layer under combustion surface	Microstructure: granular Porosity: 30%, planes, chambers and vughs	30% coarse fraction: coarse sands and gravels. Fine fraction: medium and fine sands, silty, dark brown and dotted micromass (PPL), low interference colours (XPL), undifferentiated b-fabric	Charcoal, bone fragments Pottery fragments Pollen grains	$CaCO_3$ coatings of voids (NFC), black Ox (hydr) Fe/Mn nodules, bioturbation: roots and vegetal matter, postdepositional infillings in pores, earthworm biospheroids
MSM	**LL7078**	**Upper layer**	Microstructure: complex (massive and granular) Porosity: 20%, chambers and planes	40% coarse fraction: coarse and medium sands (subangular) (quartz, plagioclase and ferromagnesian minerals). Brown and greyish, dotted micromass (PPL), low interference colours (XPL), crystallitic b-fabric c/f distribution porphyric	Ash and some little bone fragments (bottom)	Aggregates, black Ox (hydr) Fe/Mn nodules, bioturbation (roots, seeds, etc.)
		Combustion surface US7078	Microstructure: massive Porosity: 15%, planes and some chambers (bioturbation)	30% coarse fraction: some gravel, coarse, medium and fine sands. Silty reddish brown and dotted micromass (PPL), low interference colours (XPL), undifferentiated b-fabric c/f distribution porphyric	Ash, bone fragments, charcoal fragments (in voids). Some charred plant fragments. Some pottery fragments	Black Ox (hydr) Fe/Mn nodules, bioturbation
		Floor US7048	Microstructure: spongy-granular to massive Porosity: 25% (irregular), planes, chambers (bioturbation)	25% coarse fraction: coarse-medium sands, heterogeneous. Silty brownish grey and dotted micromass (PPL), low interference colours (XPL), undifferentiated b-fabric c/f distribution porphyric	Charcoal fragments, small bone fragments, phytoliths	Bioturbation, black Ox (hydr) Fe/Mn nodules, earthworm biospheroids
	LL7080	**Combustion surface US7083**	Microstructure: massive Porosity: 10%, planes, some chamber (bioturbation), some moldic voids, some vesicles	30% coarse fraction: some gravel, coarse, medium and fine sands. Silty red and cloudy micromass (PPL), low interference colours (XPL), undifferentiated b-fabric c/f distribution porphyric	Phytoliths, charred plant fragments. Some flint fragments (silex), some pottery fragments	$CaCO_3$ coatings of voids, black Ox (hydr) Fe/Mn nodules, bioturbation (slight): postdepositional infillings in pores
		Floor US7048	Microstructure: spongy-granular to massive Porosity: 20% (more irregular), planes, chambers (bioturbation)	25% coarse fraction: coarse-medium sands and gravels (heterogeneous). Silty brownish grey and dotted micromass (PPL), low interference colours (XPL), undifferentiated b-fabric c/f distribution porphyric	Some charcoal, some small bone fragments. Pottery	Black Ox (hydr) Fe/Mn nodules, CaCO3 void coatings, bioturbation: roots, earthworm biospheroids

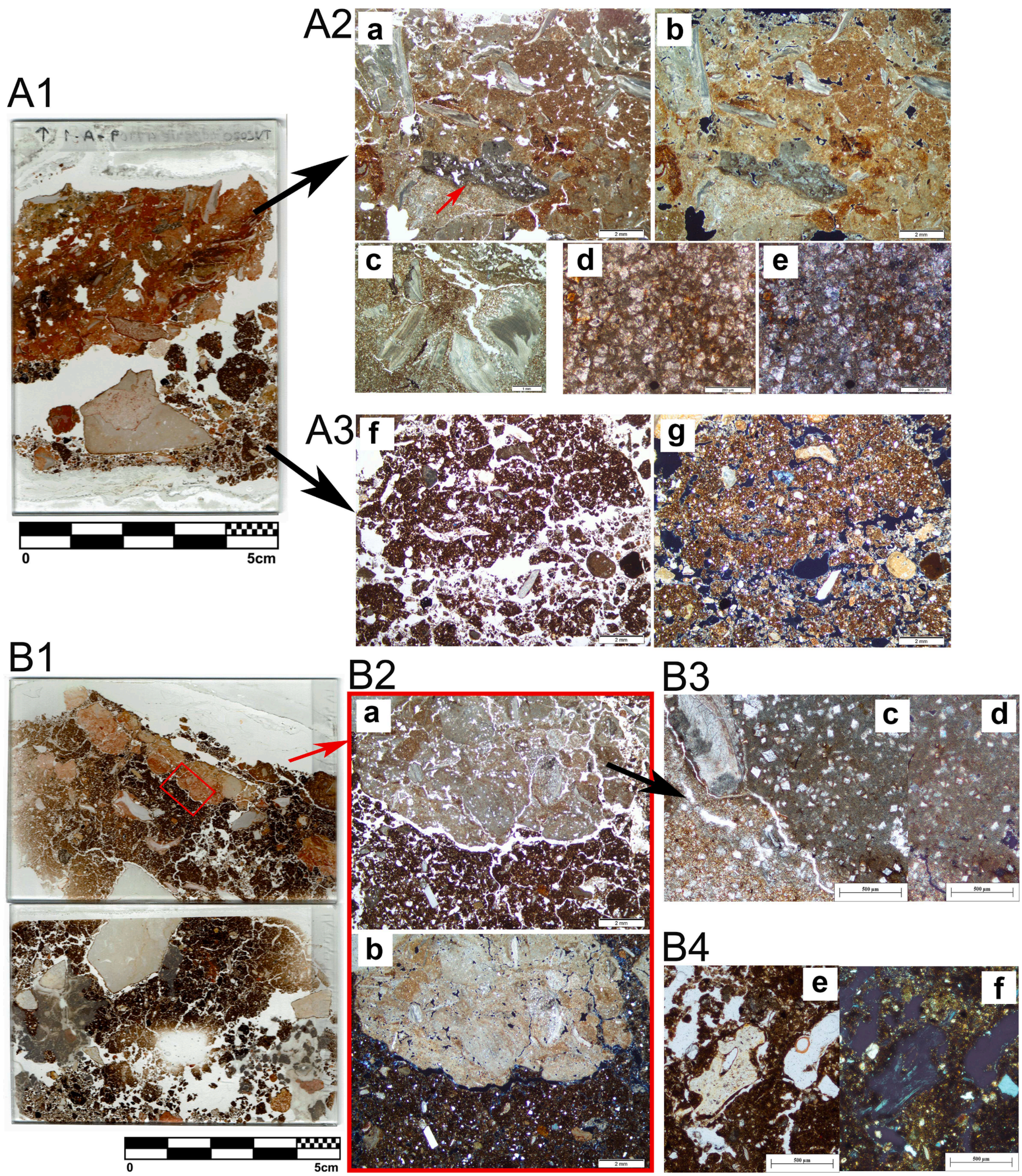

Fig. 9. Photomicrographs of TV combustion structures. A) LL25. A1, thin section; A2, combustion surface: massive microstructure with cemented b-fabric (red arrow) (a: PPL - Plain Polarized Light; b: XPL- Crossed Polarized Light), c: detail of microfossils (PPL), detail of dolomite sands (d: PPL and e: XPL); A3, layer underneath combustion surface: granular microstructure (f: PPL and g: XPL). B) EC04. B1, thin sections; B2, boundary between the combustion surface (plate aggregates) and the layer underneath it (a: PPL and b: XPL); B3: detail of combustion surface (massive microstructure and dolomite sands) (c: PPL and d: XPL); B4: thermally altered bone fragment in layer underneath combustion surface (e: PPL and f: XPL).

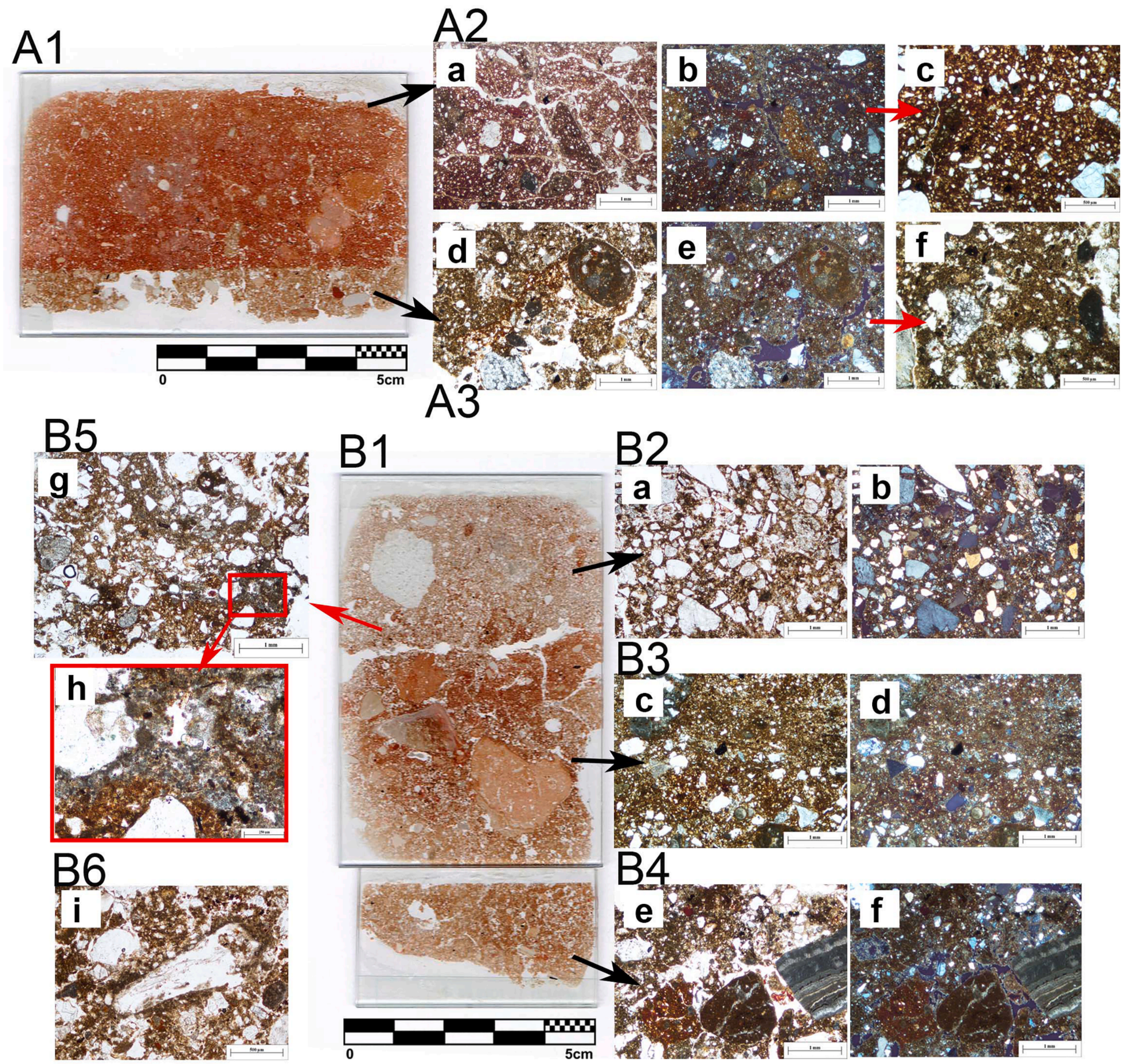

Fig. 10. Photomicrographs of MSM combustion structures. A) LL7080. A1, thin section; A2, combustion surface: plane voids on the top (a: PPL and b: XPL), c: detail, massive microstructure with sorted groundmass (PPL); A3, layer below combustion surface (possible floor): spongy-granular to massive microstructure and heterogeneous (a: PPL and b: XPL), f: detail, unsorted groundmass (PPL). B) LL7078. B1, thin sections; B2, bottom layer: sandy groundmass (a: PPL and b: XPL); B3, combustion surface: massive microstructure but unsorted (c: PPL and d: XPL); B4, layer underneath combustion surface (possible floor): same composition, but more porous than the previous (e: PPL and f: XPL); B5, g: sandy bottom layer with ash bands (PPL) and h: red square detail of calcitic ash (PPL); B6, i: moldic void with phytolith on layer below combustion surface (floor) (PPL).

for Sample 10, an ash layer of anthropogenic origin (Chu et al., 2008; Regev et al., 2010). Calcite of vegetal origin is found exclusively in the sample corresponding to an ash layer. Calcite pseudomorphs are the main component of ash derived from the combustion of woody plants when subjected to temperatures of between 400 °C and 500 °C (Alonso-Eguíluz and Albert, 2021).

4. Discussion

The following discussion points arise from the results obtained.

4.1. Taphonomy, preservation and formation processes

A range of anthropogenic and natural depositional and post-depositional processes, such as heating and weathering, along with plant and animal bioturbation and atmospheric agents such as rain, can make identification and interpretation of fire remains and particularly ashes in the study area even more challenging. Nevertheless, their micro-contextual examination in micromorphological thin section may allow the identification of the formation processes and contextual associations of individual components including phytoliths and calcitic microremains at high-resolution (e.g. Gur-Arieh et al., 2014; Portillo et al., 2019, 2020c). Several processes may have affected the preservation and integrity of both microfossil records in this study, including for example: i) depositional and post-depositional dissolution resulting in partial or complete weathering of certain phytolith morphologies (e.g. epidermal appendage *papillates*), ii) heating resulting in the partial melting of phytoliths and a decrease in the concentrations of calcitic microfossils; and iii) mixing processes including bioturbation and therefore also anthropogenic mixing activities, that may result in weathering and alteration and a decrease or even the loss of both microremains (e.g. Cabanes et al., 2011; Gur-Arieh et al., 2014; Portillo et al., 2020b).

With regard to the formation process of the structures themselves,

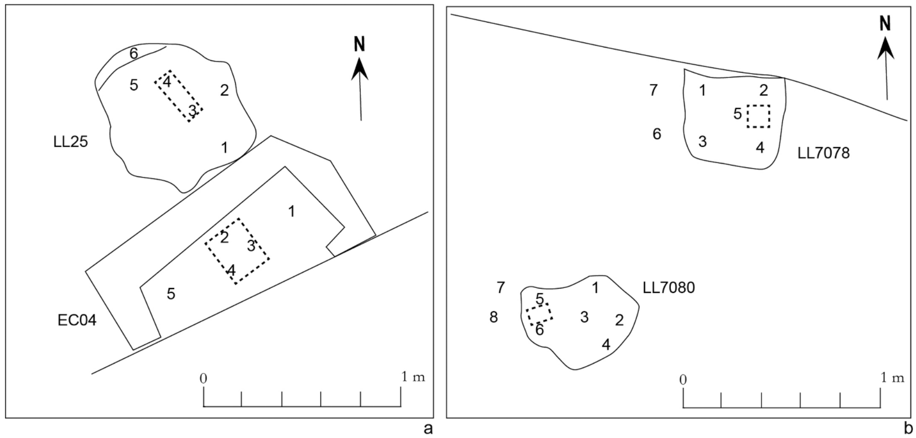

Fig. 11. Schematic plans of combustion structures from TV (a) and MSM (b) with the location of the samples (numbered) and the blocks for micromorphology (marked with dashed lines). Samples 9 and 10 in MSM LL7080 have been subsampled from the section of the block extracted for micromorphology analysis.

micromorphology allows for a more refined identification of the components and constructive typologies (see Table 1), as well as for a distinction to be made between occasional fires and built hearths. In the case of TV, where the structures are bordered by earth or stone edges, the combustion surfaces are clearly differentiated from the filling layer (which is highly bioturbated) at a micromorphological level. At MSM, the two hearths have been built inside a shallow pit; they are made with earth, with no border. However, differences in the construction technique of the two analysed structures can be detected at a micromorphological level: for LL7080, a built-up combustion surface can be clearly differentiated from the layer below (with characteristic fissures); the combustion surface is homogeneous, with some moldic voids (vegetal temper) (Mateu et al., 2022), which seem to be confirmed by the study of phytoliths, in which more grasses are documented. In contrast, in LL7078 there is no clear difference between the combustion surface and the layer below, as was also observed at a macroscopic level. Thermal alteration is observed but compositionally both layers are very similar, and there are no moldic voids in the combustion surface.

4.2. Reconstruction of temperatures

From the FTIR analysis, it can be observed that all the TV samples contain dolomite, although in small quantities, and that it is fused in the calcite peaks. This means the combustion temperature of most of the samples could have been around 500 °C. Sample 4 from LL25 presents a high degree of thermal alteration, although this has mainly affected the clays, caused their peaks to disappear and this making it impossible to determine the type of clay. As already stated (Section 2.2.4), most of the clays are very difficult to determine by FTIR (Weiner, 2010). In the case of Sample 4 from LL25 discussed here, without determining the type of clay we cannot deduce the temperature that could have been reached in the hearth. The presence of Peak 1029 in Sample 2 from TV EC04 (oven) could indicate the type of montmorillonite clay burned at less than 400 °C (Weiner, 2010).

In the anthracological study, alterations in the charcoal (vitrification) have been observed (see Section 3.1.), which could be related to high temperatures.

Furthermore, through the micromorphology analysis, and observing the degree of thermal alteration of the materials, we can estimate the temperature reached by the structures. As already stated, all the combustion installations present a reddening of the sediment (Mentzer, 2014), but we do not find any high temperature features (either vitrification or melting) (Röpke and Dietl, 2017). As already described in Section 3.3, in the case of TV we observe the same composition in both combustion surfaces, but in LL25 there is a "dissolution" of dolomites and a cementation in the upper part that are not found in EC04. This could indicate that LL25 reached a higher temperature. However, this does not appear to be confirmed by FTIR. One possible explanation is the specific location of the EC04 sample taken for the micromorphology study: this is next to FTIR Sample 5 that, unlike the rest, shows little thermal alteration, with no ash detected.

4.3. Fuel identification

The development of systematic sampling strategies integrating both macro-botanical and microfossil records including phytoliths and calcitic microremains, and their micro-contextual examinations at high-resolution, has led to the identification of a substantial dataset of plant remains, each influenced by different taphonomic processes as outlined above. Although the available macro-botanical wood charcoal records are still limited at both sites, the current study highlights the higher frequency of pine and oak for fuel purposes, as recorded at many contemporary sites in the study region and across the Western Mediterranean (Guérin, 2003; Buxó and Piqué, 2008, among others). This is further supported in the current study by new calcitic microfossil evidence from wood ash pseudomorphs, according to modern reference records from Mediterranean areas (Portillo et al., 2017, 2020c). Furthermore, the phytolith assemblages also indicate the presence of monocotyledonous plants, dominated mainly by the leaves and stems of grasses. Interestingly, phytoliths from palm leaves have been identified in MSM assemblages, suggesting that this plant could also have been used as fuel or thrown deliberately or accidentally onto the fire, although the phytolith dataset is still limited at the site. Both the seeds and leaves of palms are potential plant foods, although ethnographic research in the Mediterranean region illustrates the extensive use of these plants for basketry, matting and building materials (Peña-Chocarro et al., 2015, and references therein). Arecaceae leaf phytoliths and macro-botanical remains from seeds of the dwarf palm (*Chamaerops humilis*) have been recorded at several sites across the Western Mediterranean from the Early/Middle Holocene onwards, and even earlier (Morales et al., 2013, 2016; Zapata et al., 2013; Carrión et al., 2018; Potì et al., 2019).

5. Conclusions

The results presented have made it possible to establish sampling protocols and a methodology for the study of Iron Age combustion structures in the research area, which we hope will be generalised and extended to other contemporary sites and nearby areas. So far, the results obtained correspond to a limited number of structures, but they are promising and allow preliminary conclusions to be drawn. In any case, the coordination between specialists and the comparison of results

Table 5
FTIR results. Minerals are arranged according to their peak height from highest to lowest. Abbreviations: Ca = Calcite; Cl = Clay; Qz = Quartz; Do = Dolomite; Fe = Iron Oxide; (b) = thermally altered clay; (nb) = non-thermally altered clay.

TV Combustion Structure	SU	Sample	FTIR	Calcite Origin
EC04	47105	1	Ca, Cl (b), Do	Geogenic
	47105	2	Ca, Cl (b), Do	Geogenic
	47105	3	Ca, Cl (b), Do	Geogenic
	47105	4	Ca, Cl (b), Do	Geogenic
	47105	5	Ca, Cl (nb), Do	Geogenic
LL25	47109	1	Ca, Cl (b), Do	Geogenic
	47109	2	Ca, Cl (b), Do	Geogenic
	47109	3	Ca, Cl (b), Do	Geogenic
	47109	4	Ca, Do, Cl (b)	Geogenic
	47109	5	Ca, Cl (b), Do	Geogenic
	47109	6	Cl, Ca, Do	Geogenic
MSM Combustion Structure	**SU**	**Sample**	**FTIR**	**Calcite Origin**
LL7078	7078	1	Cl (b), Ca, Qz, Do, Fe	Geogenic
	7078	2	Ca, Cl, Qz, Do, Fe	Geogenic
	7078	3	Cl (b), Ca, Qz, Do, Fe	Geogenic
	7078	4	Ca, Cl (b), Qz, Do, Fe	Geogenic
	7078	5	Cl, Ca, Qz, Do Fe	Geogenic
	7048	6	Ca, Cl (b), Fe, Qz, Do	Geogenic
	7048	7	Ca, Cl (b), Qz, Do, Fe	Geogenic
	Preparation layer	8	Ca, Cl (b), Qz, Fe	Geogenic
	Layer, hearth	9	Ca, Cl (b), Qz, Do, Fe	Geogenic
	Layer, Ash	10	Ca and Cl (b), Qz, Fe	Anthropogenic (Ash)
LL7080	7080	1	Ca, Cl (b), Qz, Do, Fe	Geogenic
	7080	2	Ca, Cl (b), Qz, Do, Fe	Geogenic
	7080	3	Ca, Cl, Qz, vDo, Fe	Geogenic
	7080	4	Ca, Cl (b), Qz, Do, Fe	Geogenic
	7083	5	Cl (+b), Ca, Qz+, Fe	Geogenic
	7083	6	Cl (+b), Ca, Qz+, Do, Fe	Geogenic
	7048	7	Ca, Cl (b)	Geogenic
	7048	8	Ca, Cl (b), Qz, Do	Geogenic

obtained from the different techniques have provided a complementary view of the aspects studied (construction processes, fuels, temperatures).

The comparison between the macroscopic observations made during the excavation of the structures and the micromorphological analysis results allows us to obtain detailed information on the construction technique and materials used. They also bring us closer to being able to distinguish between occasional fires lit on the floor and purpose-built structures with a combustion surface clearly different from the floor level. In turn, FTIR analysis complements the information on the minerals selected in these construction processes. FTIR analysis, together with micromorphology and phytoliths, provides us with complete information on the composition of the materials used to build the combustion structures, the natural deposition of sediment, thermal alteration and the presence of ash (Rodríguez and Cabanes, 2015). This allows us to raise hypotheses on the length of use of the combustion installations and the spaces in which they were located.

Archaeological excavations in the study area and period usually include anthracological analyses, although the microfossil analyses undertaken so far have not been systematic. As we have seen, these allow us to determine the use of plants that cannot be identified by anthracology.

As outlined above, taphonomic pathways must be considered when identifying and interpreting fuel compositions. The macro-botanical and microfossil records point to fuel sources, including pine and oak, and mixed grasses and other monocotyledons, including mainly Pooideae grasses, in addition to palm leaves, possibly derived from matting, basketry and/or building materials, although these may also have been introduced attached to woody fuel materials.

The different analyses also provide information on the operating temperatures obtained in the combustion installations studied. The FTIR analyses suggest temperatures that could be close to 500 °C. This temperature could also be corroborated by micromorphology: reddening, ash and charcoal, and the absence of other features that indicate a higher temperature. Future research should focus on the differentiation between the micromorphological features of a sustained fire and a high intensity fire. This is one of the aspects on which we have focused in our project, with the aim of verifying whether there is an association between factors such as morphology (open structure -hearth- / closed -oven-), construction technique (presence or absence of preparation under the hearth), or location (interior / exterior) of the combustion structure and the temperature reached during combustion, as well as the relationship between this variable and the fuels used. Some of these aspects are also being verified by the experimental part of our project (Belarte, et al. 2022).

In parallel to the analyses discussed above, the data obtained from the experimentation studies, the results of which are still being analysed, seem to confirm some of the aspects pointed out, for example, concerning the temperatures obtained, the alteration of the sediments or that of the fuels themselves (Belarte et al., 2022).

The continuation of this research, both from an analytical and experimental point of view, will allow us to confirm or extend the interpretations we have deduced so far from the results obtained.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This research has been funded by the Spanish Ministry of Science and Innovation (PID2019-104661GB-I00/AEI/10.13039/501100011033) and supported by the MIRMED-GIAC (ICAC-URV-UAB) Research Group (2017 SGR 970).

VP is funded by a Juan de la Cierva (Formación) contract (FJC2019-040406I/AEI/10.13039/501100011033 – Transeant Project).

MPQ holds a Margarita Salas (MARSALAS21-19) postdoctoral contract (Next Generation-EU, Spanish Ministerio de Universidades, Universidad de Alicante).

MM holds a Beatriu de Pinós (2021BP00103) postdoctoral contract (Universities and Research secretariat of the Ministry of Research and Universities-Generalitat de Catalunya).

We acknowledge the collaboration of the following research teams and projects:

GRACPE-UB (Pròmac subgroup) research group, for having provided archaeological data from Masies de Sant Miquel archaeological site, within the projects *Caracterización social y funcional de los asentamientos urbanos de la Iberia septentrional* (PID2019-106224GB-I00) and *El canvi* *sociocultural a la Cessetània oriental durant la Protohistòria i l'època romana republicana* (CLT009/18/00043).

Ferran Falomir, Gustau Aguilella (Servei d'Arqueologia de la Diputació de Castelló), Joan Negre (Museu de Gandia) and Marta Pérez-Polo (University of Navarra), for having provided archaeological data from Tossal de la Vila archaeological site, within the *El Tossal de la Vila i la Serra d'en Galceran als períodes del Bronze Final-Ferro Antic i Andalusí – 2018-2021* Project, funded by Diputació de Castelló (Plans Anuals d'Excavacions call).

References

Aguilella, F., Falomir, F., Pérez Jordà, G., Laguna, C., García Sánzhez, D.A., Arquer, N., 2016. Tossal de la Vila (la Serra d'en Galceran, Castellón). Un asentamiento en la transición del Bronce Final al Hierro Antiguo. Primeros resultados de las campañas 2012–2014. Quaderns de Prehistòria i Arqueologia de Castelló 34, 5–41.

Albert, R.M., Ruiz, J.A., Sans, A., 2016. PhytCore ODB: a new tool to improve efficiency in the management and exchange of information on phytoliths. J. Archaeol. Sci. 68, 98–105.

Aldeias, V., Dibble, H.L., Sandgathe, D., Goldberg, P., McPherron, S.J.P., 2016. How heat alters underlying deposits and implications for archaeological fire features: a controlled experiment. J. Archaeol. Sci. 67, 64–79. https://doi.org/10.1016/j.jas.2016.01.016.

Alonso-Eguíluz, M., Albert, R.M., 2021. Procesos postdeposicionales y actividades antrópicas en la cueva de Arenaza I (Galdames, Vizcaya). Una aproximación desde la microarqueología. *KOBIE: Serie Bizkaiko Arkeologi Indusketak. BAI* n° 9, 87–98.

Balu, S., Uma, K., Pan, G.-T., Yang, T.-C.-K., Ramaraj, S.K., 2018. Degradation of methylene blue dye in the presence of visible light using SiO_2@α-Fe_2O_3 nanocomposites deposited on SnS_2 flowers. Materials 11 (6), 1030. https://doi.org/10.3390/ma11061030.

Belarte, M.C., 2008. Domestic architecture and social differences in north-eastern Iberia during the Iron Age (c. 525–200 BC). Oxf. J. Archaeol. 27 (2), 175–199. https://doi.org/10.1111/j.1468-0092.2008.00303.x.

Belarte, M.C., Canela, J., Morer, J., Cuscó, O., Ocaña, M., Euba, I., Valenzuela-Lamas, S., 2021. Rural settlement in Iron Age Cessetania (Northeastern Iberian Peninsula): characteristics and socioeconomic role. J. Mediterr. Archaeol. 34 (2), 225–251. https://doi.org/10.1558/jma.21980.

Belarte, M.C., Bonet, H., Sala, F., 2009. L'espai domèstic i l'organització de la societat ibèrica: els territoris de la franja mediterrània. In: Belarte, M.C. (Ed.), L'espai domèstic i l'organització de la societat a la protohistòria de la Mediterrània occidental (Ier mil·lenni). Actes de la IV Reunió Internacional d'Arqueologia de Calafell. Arqueo Mediterrània, 11, Barcelona: Universitat de Barcelona – Institut Català d'Arqueologia Clàssica, pp. 93–123.

Belarte, M.C., Camañes, P., Monrós, M., Principal, J., 2016. Cooking in the Iberian culture (sixth-second century BC): private or public? J. Mediterr. Archaeol. 29 (2), 173–196. https://doi.org/10.1558/jmea.v29i2.32571.

Belarte, M.C., Pastor Quiles, M., Portillo, M., Saorin, C., Mateu Sagués, M., Pecci, A. Vila, S., Pou, J., Castells, G., Morer, J., Fernández, J., 2022. Experimental Archaeology of Iron Age Combustion Structures from the Western Mediterranean. EXARC Journal, 2022/2. Available from: <https://exarc.net/ark:/88735/10640>.

Belarte, M.C., 2021. Forme, fonction et signification des foyers dans la culture ibérique (600–200 av. J.-C.). In: Lamaze, J., Bastide, M. (Eds.), Around the Hearth. Ritual and Commensal Practices in the Mediterranean Iron Age from the Aegean world to the Iberian Peninsula, Berlin, pp. 255–275.

Berna, F., Behar, A., Shahack-Gross, R., Berg, J., Boaretto, E., Gilboa, A., Sharon, I., Shalev, S., Shilstein, S., Yahalom-Mack, N., Zorn, J.R., Weiner, S., 2007. Sediments exposed to high temperatures: reconstructing pyrotechnological processes in late bronze and iron age strata at Tel Dor (Israel). J. Archaeol. Sci. 34 (3), 358–373.

Brown, D.A., 1984. Prospects and limits of a phytolith key for grasses in the central United States. J. Archaeol. Sci. 11, 345–368.

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G., Tursina, T., 1985. Handbook for soil thin section description. Waine Research Publications, Wolverhampton.

Buxó, R., Piqué, R., 2008. Arqueobotánica. Los usos de las plantas en la península Ibérica. Ariel.

Cabanes, D., Weiner, S., Shahack-Gross., R., 2011. Stability of phytoliths in the archaeological record: a dissolution study of modern and fossil phytoliths. J. Archaeol. Sci. 38, 2480–2490.

Cammas, C., 2018. Micromorphology of earth building materials: Toward the reconstruction of former technological processes (Protohistoric and Historic Periods). Quat. Int. 483, 160–179. https://doi.org/10.1016/j.quaint.2018.01.031.

Canti, M.G., 1999. The production and preservation of faecal spherulites: animals, environment and taphonomy. J. Archaeol. Sci. 26, 251–258.

Carrión, Y., Morales, J., Portillo, M., Pérez-Jordà, G., Peña-Chocarro, L., Zapata, L., 2018. The use of wild plants in the palaeolithic and neolithic of Northwestern Africa: preliminary results from the PALEOPLANT project. In: Mercury, A.M., D'Andrea, A., Forinicari, R., Höln, A. (Eds.), Plants and People in the African Past. Progress in the African Archaeobotany. Springer, Cham, pp. 146–174.

Chabal, L., 1992. La représentativité paléo-écologique des charbons de bois archéologiques issus du bois de feu. Bulletin de la Société Botanique de France 139 2-3-4, 213–236.

Chabal, L., 1997. Forêts et sociétés en Languedoc, (Néolithique final, Antiquité tardive): L'anthracologie, méthode et paléoécologie. MSH, Paris.

Chu, V., Regev, L., Weiner, S., Boaretto, E., 2008. Differentiating between anthropogenic calcite in plaster, ash and natural calcite using infrared spectroscopy: implications in archaeology. J. Archaeol. Sci. i35, 905e911.

Courty, M.A., Allué, E., Henry, A., 2020. Forming mechanisms of vitrified charcoals in archaeological firing assemblages. J. Archaeol. Sci. Rep. 30 https://doi.org/10.1016/j.jasrep.2020.102215.

Courty, M.A., Goldberg, P., Macphail, R.I., 1989. Soils and Micromorphology in Archaeology. Cambridge University Press, Cambridge.

Daneels, A., Mateu, M., Fernández, H., Piña, S., Cabadas-Báez, H., 2022. Soil modification in the manufacturing process of Mesoamerican earthen architecture. Boletín de la Sociedad Geológica Mexicana 74 (3), A080422. doi: 10.18268/BSGM2022v74n3a080422.

Di Pasquale, G., 2011. Che cos'è l'archeobotanica. Carocci Editore, Roma.

Dorronsoro, C., 2015. Interés del estudio mineralógico de las arenas gruesas de los suelos. Available from: <http://edafologia.ugr.es/arenas/alttipo.htm>.

Falomir, F., Aguilella, G., Negre, J., Pérez-Polo, M., 2021. Tossal de la Vila 2019. Memòria Científica (Ref:2019/315-CS). Memòria inèdita presentada en la Direcció General de Patrimoni de la Generalitat Valenciana.

Friesem, D., Wattez, J., Onfray, M., 2017. Earth construction materials. In: Nicosia, C., Stoops, G. (Eds.), Archaeological Soil and Sediment Micromorphology. Hoboken, NJWiley, pp. 99–110.

Guérin, P., 2003. El Castellet de Bernabé y el horizonte ibérico pleno edetano. Diputación Provincial de Valencia València.

Gur-Arieh, S., Boaretto, E., Maeir, A.M., Shahack-Gross, R., 2012. Formation processes in philistine hearths from tell es-Sâfi/Gath (Israel): an experimental approach. J. Field Archaeol. 37, 121–131. https://doi.org/10.1179/0093469012Z.00000000011.

Gur-Arieh, S., Shahack-Gross, R., Maeir, A.M., Lehmann, G., Hitchcock, L.A., Boaretto, E., 2014. The taphonomy and preservation of wood and dung ashes found in archaeological cooking installations: case studies from Iron Age Israel. J. Archaeol. Sci. 46, 50–67. https://doi.org/10.1016/j.jas.2014.03.011.

Kabukcu, C., Chabal, L., 2021. Sampling and quantitative analysis methods in anthracology from archaeological contexts: achievements and prospects. Quat. Int. 593–594, 6–18. https://doi.org/10.1016/j.quaint.2020.11.004.

Katz, O., Cabanes, D., Weiner, S., Maeir, A.M., Boaretto, E., Shahack-Gross, R., 2010. Rapid phytolith extraction for analysis of phytolith concentrations and assemblages during an excavation: an application at Tell es-Safi/Gath. Israel. J. Archaeol. Sci. 37, 1557–1563.

Loaiza, J., Poch, R., 2015. Muestreo de suelos con énfasis en micromorfología. In: Loaiza, J., Stoops, G., Poch, R., Casamitjana, M. (Eds.), Manual de micromorfología de suelos y técnicas complementarias. Fondo editorial Pascual Bravo, Medellín, pp. 13–27.

Mallol, C., Mentzer, S.M., Miller, C.E., 2017. Combustion features. In: Nicosia, C., Stoops, G. (Eds.), Archaeological soil and sediment micromorphology. Wiley, Hoboken. pp. 299–330. https://doi.org/10.1002/9781118941065.ch31.

March, R.J., Lucquin, A., Joly, D., Ferreri, J.C., Muhieddine, M., 2012. Processes of formation and alteration of archaeological fire structures: complexity viewed in the light of experimental approaches. J. Archaeol. Method Theory, june 2012. https://doi.org/10.1007/s10816-012-9134-7.

Marguerie, D., Hunot, J.-Y., 2007. Charcoal analysis and dendrology: data from archaeological sites in north-western France. J. Archaeol. Sci. 34 (9), 1417–1433.

Mateu, M., Daneels, A., 2020. La micromorfología aplicada al estudio del patrimonio construido en tierra. Gremium. Revista de restauración arquitectónica 7 (NE 2), 10–23.

Mateu, M., Bergadà, M.M., Armada, X.L., Rafel, N., 2019. Micromorphology of the Early Iron Age semi-cemented floors: El Calvari del Molar (Tarragona, NE Spain) as case study. J. Archaeol. Sci. Rep. 23, 746–762. https://doi.org/10.1016/j.jasrep.2018.11.028.

Mateu, M., Fernández, H., Daneels, A., Cabadas, H., Piña, S., 2022. Earthen architecture in the Mesoamerican Classic Period: a micromorphological approach to its manufacture process. J. Archaeol. Sci. 137, 105525. https://doi.org/10.1016/j.jas.2021.105525.

Mateu, M., 2016. Estudi de la terra crua durant la primera edat del ferro al nord-est de la península Ibèrica des de les perspectives micromorfològica i tipològica. Els materials del jaciment de Sant Jaume (Alcanar, Montsià). PhD dissertation, University of Barcelona. Available from: <http://hdl.handle.net/10803/397708>.

Matthews, W., 2010. Geoarchaeology and taphonomy of plant remains and microarchaeological residues in early urban environments in the Ancient Near East. Quat. Int. 214 (1–2), 98–113.

McParland, L.C., Collinson, M.E., Scott, A.C., Campbell, G., Veal, R., 2010. Is vitrification in charcoal a result of high temperature burning of wood? J. Archaeol. Sci. 37 (10), 2679–2687. https://doi.org/10.1016/j.jas.2010.06.006.

Mentzer, S.M., 2014. Microarchaeological approaches to the identification and interpretation of combustion features in prehistoric archaeological sites. J. Archaeol. Method. Theory 21, 616–668.

Morales, J., Pérez-Jordà, G., Peña-Chocarro, L., Zapata, L., Ruíz-Alonso, M., López-Sáez, J.A., Linstädter, J., 2013. The origins of agriculture in North-West Africa: macro-botanical remains from Epipalaeolithic and Early Neolithic levels of Ifri Oudadane (Morocco). J. Archaeol. Sci. 40, 2659–2669.

Morales, J., Pérez Jordà, G., Peña-Chocarro, L., Bokbot, Y., Vera, J.C., Martínez Sánchez, R.M., Linstädter, J., 2016. The introduction of South-Western Asian domesticated plants in North-Western Africa: an archaeobotanical contribution from Neolithic Morocco. Quat. Int. 412, 96–109.

Morer, J., Asensio, D., Gil, B., Jornet, R., Sanmartí, J., Noguera, J., in press. La ciutat ibèrica de les Masies de Sant Miquel. Estat de la qüestió. Tribuna d'Arqueologia 2020-2021.

Mulholland, S.C., Rapp, Jr. G., 1992. A morphological classification of grass silica-bodies. In: Rapp, Jr. G., Mulholland, S.C. (Eds.), Phytolith Systematics: Emerging Issues, Advances in Archaeological and Museum Science. Plenum Press, New York, pp. 65–89.

Neumann, K., Strömberg, A.E.C., Ball, T.B., Albert, R.M., Vrydaghs, L., Scott-Cummings, L. (International Committee for Phytolith Taxonomy ICPT), 2019. International Code for Phytolith Nomenclature (ICPN) 2.0. Ann. Botany 124 (2), 189-199.

Noguera, J., Sanmartí, J., Belarte, M.C., Sala, R., Morer, J., Asensio, D., Ble, E., Jornet, R., Revilla, V., Pou, J., 2020. La ciudad ibérica de Masies de Sant Miquel (Banyeres del Penedès, Tarragona) entre los siglos VII-III a.C. Resultados de una investigación con métodos no invasivos. Arch. Esp. Arqueol. 93, 35–60. https://doi.org/10.3989/aespa.093.020.002.

Peña-Chocarro, L., Pérez Jordà, G., Morales Mateos, J., Zapata, L., 2015. Storage in traditional farming communities of the western Mediterranean: Ethnographic, historical and archaeological data. Environ. Archaeol. 20 (4), 379–389.

Piperno, D.R., 2006. Phytoliths: a comprehensive guide for archaeologists and paleoecologists. AltaMira Press, Lanham.

Piqué, R., Vila Moreiras, S., Alonso, N., 2011. Vegetation and firewood uses in the western Catalan plain from Neolithic to the Middle Age. Saguntum: Papeles del Laboratorio de Arqueología de Valencia N°extra 13, 85–96.

Portillo, M., Matthews, W., 2020. Investigating use of space and human-animal interactions in agricultural built environments: the geo-ethnoarchaeology of livestock dung. In: Otto, A., Herles, M. Kaniuth, K. (Eds.), Proceedings of the 11th International Congress on the Archaeology of the Ancient Near East. Harrassowitz Verlag, Wiesbaden, pp. 497–508.

Portillo, M., García-Suárez, A., 2021. Disentangling human–plant–animal dynamics at the microscale: geo-ethnoarchaeological case studies from North Africa and the Near East. Appl. Sci. 11, 8143.

Portillo, M., Valenzuela, S., Albert, R.M., 2012. Domestic patterns in the Numidian site of Althiburos (northern Tunisia): the results from a combined study of animal bones, dung and plant remains. Quat. Int. 275, 84–96.

Portillo, M., Kadowaki, S., Nishiaki, Y., Albert, R.M., 2014. Early Neolithic household behaviour at Tell Seker al-Aheimar (Upper Khabur, Syria): a comparison to ethnoarchaeological study of phytoliths and dung spherulites. J. Archaeol. Sci. 42, 107–118.

Portillo, M., Belarte, M.C., Ramon, J., Kallala, N., Sanmartí, J., Albert, R.M., 2017. An ethnoarchaeological study of livestock dung fuels from cooking installations in northern Tunisia. Quat. Int. 431, 133–144.

Portillo, M., García-Suárez, A., Klimowicz, A., Barański, M.Z., Matthews, W., 2019. Animal penning and open area activity at Neolithic Çatalhöyük, Turkey. J. Anthropol. Archaeol. 56, 101106.

Portillo, M., Dudgeon, K., Allistone, G., Raeuf, A.K., Matthews, W., 2020a. The taphonomy of plant and livestock dung microfossils: an ethnoarchaeological and experimental approach. Environ. Archaeol. 26, 439–454.

Portillo, M., García-Suárez, A., Matthews, W., 2020b. Livestock faecal indicators for animal management, penning, foddering and dung use in early agricultural built environments in the Konya Plain, Central Anatolia. Archaeol. Anthropol. Sci. 12, 40.

Portillo, M., Morales, J., Carrión, M.J., Aouadi, N., Lucarini, G., Belhouchet, L., Coppa, A., Peña-Chocarro, L., 2020c. Changing plant-based subsistence practices among early and middle Holocene communities in eastern Maghreb. Environ. Archaeol. 26, 455–470.

Portillo, M., Dudgeon, K., Anglada, M., Ramis, D., Llergo, Y., Ferrer, A., 2021. Phytolith and Calcitic Spherulite indicators from modern reference animal dung from Mediterranean Island Ecosystems: Menorca, Balearic Islands. Appl. Sci. 11 (16), 7202.

Potì, A., Kehl, M., Broich, M., Carrión Marco, Y., Hutterer, R., Jentke, T., Linstädter, J., López-Sáez, J.A., Mikdad, A., Morales, J., Pérez-Díaz, S., Portillo, M., Schmid, C., Vidal-Matutano, P., Weniger, G.-C., 2019. Human occupation and environmental change in the western Maghreb during the Last Glacial Maximum (LGM) and the Late Glacial. New evidence from the Iberomaurusian site Ifri El Baroud (northeast Morocco). Quat. Sci. Rev. 220, 87–110.

Regev, L., Poduska, K.M., Addadi, L., Weiner, S., Boaretto, E., 2010. Distinguishing between calcites formed by different mechanisms using infrared spectrometry: archaeological applications. J. Archaeol. Sci. 37 (12), 3022–3029.

Rodríguez, A., Cabanes, D., 2015. Phytolith and FTIR studies applied to combustion structures: the case of the Middle Palaeolithic site of El Salt (Alcoy, Alicante). Quat. Int. 1–11.

Röpke, A., Dietl, C., 2017. Burnt soils and sediments. In: Nicosia, C., Stoops, G. (Eds.), Archaeological Soil and Sediment Micromorphology. Wiley, Hoboken, pp. 173–180.

Rosen, A.M., 1992. Preliminary identification of silica skeletons from Near Eastern archaeological sites: an anatomical approach. In: Rapp, J.G., Mulholland, S.C. (Eds.), Phytolith Systematics: Emerging Issues. Plenum Press, New York, pp. 129–147.

Sala, R., Ortiz, H., Sanmartí, J., Garcia-Garcia, E., Belarte, M.C., Noguera, N., Morer, J., Ble, E., Pou, J., Asensio, D., Jornet, R., 2020. Geophysical survey of the Iberian site (seventh–third centuries BC) of Masies de Sant Miquel (Catalonia, Spain). Interpretative challenges of geophysical data of an Iberian town. Archaeol. Prospect. 27 (2), 181–199. https://doi.org/10.1002/arp.1765.

Saorin, C., 2018. Les estructures de combustió del sector 3 de l'assentament del Tossal de la Vila (la Serra d'en Galceran, la Plana Alta). Quaderns de Prehistòria i Arqueologia de Castelló 36, 73–81.

Schweingruber, F.H., 1990. Anatomy of European Woods. Haupt, Stuttgart.

Shahack-Gross, R., 2018. Fire and society in the eastern mediterranean. A diachronic view. In: Yasur-Landau, A., Cline, E., Rowan, Y. (Eds.), The Social Archaeology of the Levant From Prehistory to the Present. Cambridge University Press, Cambridge, pp. 86–97.

Stoops, G., 2003. Guidelines for analysis and description of soil and regolith thin sections. Soil Science Society of America, Madison.

Théry-Parisot, I., Henry, A., 2012. Seasoned or green? Radial cracks analysis as a method for identifying the use of green wood as fuel in archaeological charcoal. J. Archaeol. Sci. 39 (2), 381–388.

Tsartsidou, G., Lev-Yadun, S., Efstratiou, N., Weiner, S., 2008. Ethnoarchaeological study of phytolith assemblages from an agro-pastoral village in Northern Greece (Sarakini): development and application of a Phytolith Difference Index. J. Archaeol. Sci. 35 (3), 600–613.

Twiss, P.C., 1992. Predicted world distribution of C_3 and C_4 grass phytoliths. In: Rapp, J. G., Mulholland, S.C. (Eds.), Phytolith Systematics: Emerging Issues. Plenum Press, New York, pp. 113–128.

Twiss, P.C., Suess, E., Smith, R.M., 1969. Morphological classification of grass phytoliths. Soil Sci. Soc. Am. Proc. 33, 109–115.

Verrecchia, E.P., Trombino, L., 2021. A visual atlas for soil micromorphologists. Springer, Cham. https://doi.org/10.1007/978-3-030-67806-7.

Vila Moreiras, S., Piqué, R., 2012. Paisatge vegetal i gestió del combustible a la plana occidental catalana entre el neolític i l'edat mitjana: estat de la qüestió des de l'anàlisi antracològica. Revista d'arqueologia de Ponent 22, 9–36.

Vila Moreiras, S., 2018. L'explotació dels recursos vegetals a la plana occidental catalana durant la protohistòria a partir de l'anàlisi antracològica (III-I mil·lenni). PhD dissertation, University of Lleida.

Villagran, X., Mentzer, D.H.S., Miller, C., Jans, M., 2017. Bone and other skeletal tissues. In: Nicosia, C., Stoops, G. (Eds.), Archaeological Soil and Sediment Micromorphology. Wiley Blackwell, Chichester, pp. 9–38. https://doi.org/10.1002/9781118941065.ch1.

Weiner, S., 2010. Microarchaeology. Beyond the Visible Archaeological Record. Cambridge University Press, Cambridge.

Zapata, L., López Sáez, J.A., Ruiz Alonso, M., Pérez Jordà, G., Morales Mateos, J., Kehl, M., Peña-Chocarro, L., 2013. Holocene environmental change and human impact in NE Morocco: Palaeobotanical evidence from Ifri Oudadane. Holocene 23 (9), 1286–1296. https://doi.org/10.1177/0959683613486944.