



## This must be the place. Spatial analysis of the Upper Magdalenian seed assemblage of Cova de les Cendres (Alicante, Spain)<sup>☆</sup>

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### ABSTRACT

The spatial analysis of lithic and bone remains has been frequently conducted in Palaeolithic sites to detect activity areas and taphonomic processes. However, it has not been usually applied to archaeobotanical assemblages despite its suitability to shed light on their formation processes. A taphonomic approach to wood-charcoal and seed assemblages is essential to obtain ecological, cultural and economic information.

In the Upper Magdalenian level of Cova de les Cendres (Teulada-Moraira, Alicante, Spain), a series of superimposed combustion structures were documented. At this level, carpological remains are abundant and diverse, and the preservation of the hearths allows us to assess their distribution in relation to these anthropic structures which arranged the human activity in this part of the cave. Species such as *Alkanna tinctoria*, *Buglossoides arvensis*, *Pinus* sp., *Juniperus* spp. or different legumes dominate the non-woody archaeobotanical assemblage. The general distribution of the plant remains highlights their link to anthropic activities. Some post-depositional alterations were detected, mainly due to trampling and the repeated human occupation of the area, although some concentrations point to the existence of better-preserved spaces and illustrate specific deposition events, such as deposits from single burning events. Finally, the spatial distribution of the remains allows for gaining insights into the use of plants as sources of food, fuel and raw material.

### 1. Introduction

Understanding the formation processes of the archaeological assemblages is essential to achieve a comprehensive knowledge of human behaviour (Schiffer, 1987). This question is especially relevant regarding the archaeobotanical remains: identifying the routes of entry of the remains, how they were deposited and charred and which post-depositional processes affected them is key to interpret the assemblage in economic and cultural terms correctly (van der Veen, 2007).

Three types of deposition agents of the archaeobotanical assemblage have been discriminated (Bottema, 1984; Hansen, 2001; Minnis, 1981; van der Veen, 2007): physical, animal and human. Several authors (e.g. Bouby and Billaud, 2005; Dietsch, 1996; Miksicek, 1987) have proposed different criteria to correctly identify the routes of entry of the remains, especially seeds and fruits. These remains will be preserved in normal conditions if a preservation agent affects them and prevents the decay by fungi, microorganisms and insects (Gasser and Adams, 1981). The most

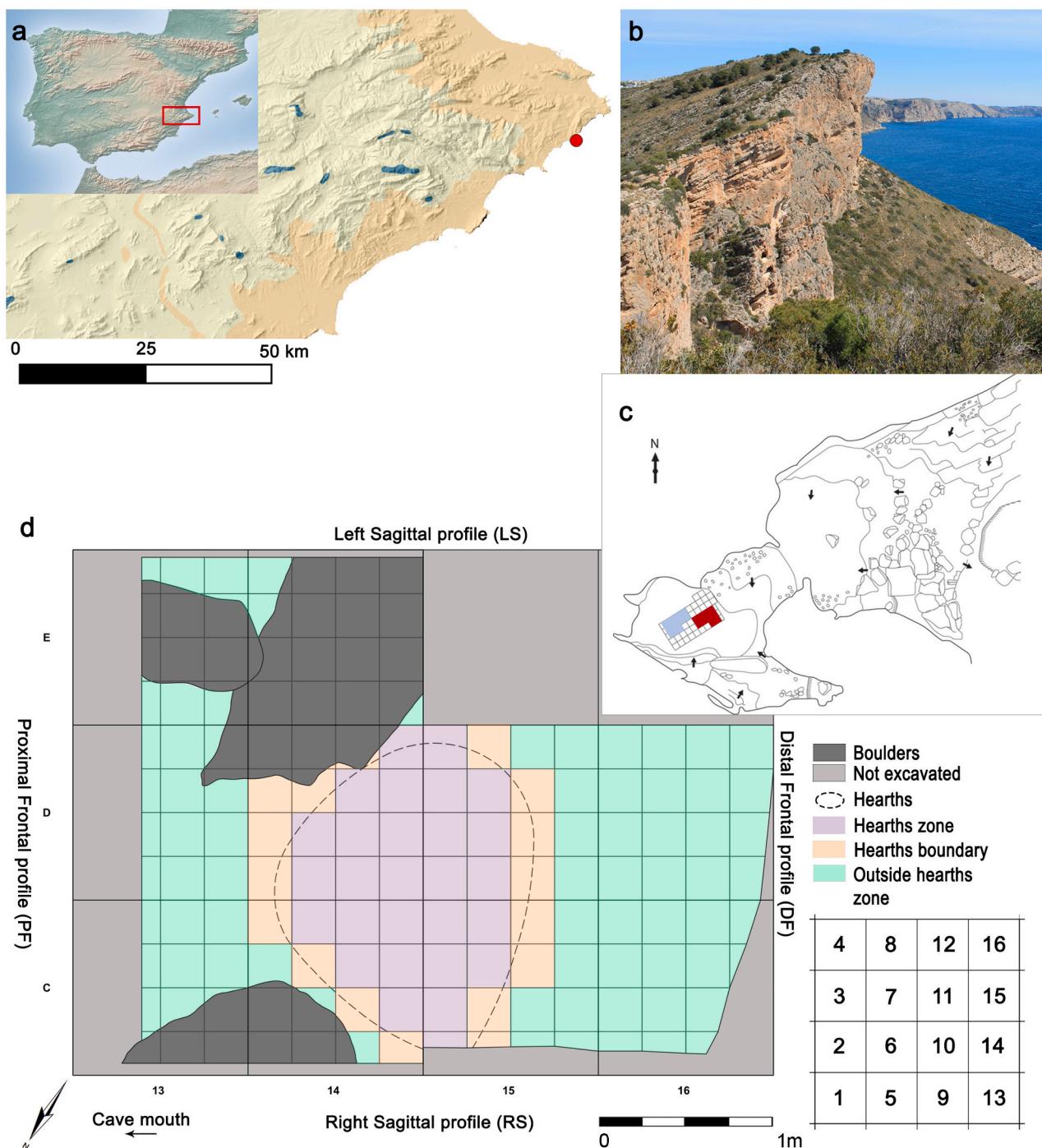
common mode of preservation is carbonisation (Braadbaart and Poole, 2008; Brinkkemper, 2006; Miksicek, 1987; Wright, 2003). When combustion is incomplete, the carbonised plant remains are resistant to further decay and preserve for several millennia in archaeological deposits since the carbon residue is biologically and chemically inert. The chances of a plant remain being charred depend on the route of entry (Dennell, 1976; Fuller et al., 2014; Fuller and Weber, 2005; Sievers and Wadley, 2008; van der Veen, 2007): included in the fuel (firewood or dung), during accidental or intentional fires, accidentally during processing, discarded, etc. Another preservation agent of archaeobotanical remains is the mineralisation, which implies the replacement of the organic cellular structures with mineral solutions (Briggs, 2003; McCobb et al., 2001; Mustoe, 2017; Preiss, 2011).

Once deposited, plant remains are affected by post-depositional processes –biomechanical, geological and anthropic– that can move, mix or even destroy them (Miksicek, 1987; Tryon, 2006; Wood and Johnson, 1987).

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**Fig. 1.** Location of Cova de les Cendres (a), Moraira headland cliffs (b), plan of the cave with Sector A (red) and Sector B (blue) indicated (c) and detailed plan of Sector A (d). The numbering of the sub-squares (on the bottom right corner) and the classification of samples are indicated. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Spatial analysis of the archaeobotanical remains can shed light on some of these taphonomic processes. The distribution of the remains and their link to structures, such as hearths, pits, or postholes, is one of the Dietsch's criteria (1996) to define an anthropic origin of the assemblage. This type of analysis can also detect some uses of plants, such as bedding or construction, as well as areas of plant food processing, as reported for the assemblage of Ohalo II (Weiss et al., 2008). Moreover, combined with the study of other archaeological material (fauna, lithics, etc.), it can recognise post-depositional processes.

Spatial analysis of lithic or bone remains has been a common topic in the Palaeolithic literature during the last decades (e.g. Bailey and

Galanidou, 2009; Brenet et al., 2018; Clark, 2017; Deschamps et al., 2022; Henry et al., 2004; Rosell et al., 2012; Sánchez-Romero et al., 2024; Sossa-Ríos et al., 2024; Vaquero, 2008; Villaverde et al., 2017), frequently applied to shed light on the spatial organisation of the occupations and the activities developed in the site. Nevertheless, the spatial study of archaeobotanical remains is quite rare, and most of the cases focus on charcoals (Mas et al., 2021; Vidal-Matutano, 2017), being the works centred on carpological remains from hunter-gatherer contexts (Alperson-Afil et al., 2009; Roda Gilabert et al., 2013; Weiss et al., 2008) practically inexistent.

This paper presents the complete study of the Upper Magdalenian

**Table 1**  
Main results of the carpological analysis of the Upper Magdalenian level (XI).

	Hearths	Hearths boundary	Outside hearths zone	Total Level XI
No. of samples	58	19	77	154
Vol. of sediment (litres)	174	57	231	462
Vol. Flotation (ml)	2083.5	672	3673	6428.5
Vol. Flotation/ sediment	11.97	11.79	15.90	13.91
Number of remains	1593	586	1621	3800
Number of reproductive remains	1261	423	1136	2820
Number of vegetative remains	322	162	469	953
Number of parenchyma remains	10	1	16	27
Density of remains (remains/l sediment)	9.16	10.28	7.02	8.23
Density of reproductive remains	7.25	7.42	4.92	6.10

**Table 2**  
Number of remains by type of preservation.

	Hearths	Hearths boundary	Outside hearths zone	Total Level XI
Charred reproductive remains	1142	374	728	2244
Mineralised reproductive remains	119	49	407	575
Charred vegetative remains	300	145	417	862
Mineralised vegetative remains	14	13	35	62
Uncharred vegetative remains	8	4	17	29
Charred parenchyme remains	10	1	16	27

carpological assemblage of Cova de les Cendres (Teulada-Moraira, Alicante) and its spatial analysis. The main objectives of this work are 1) to assess the formation processes of the archaeobotanical assemblage based on the spatial analysis, 2) to evaluate the relation of the plant remains with the combustion structures and the potential of these remains to detect activity areas, 3) to reconstruct the use of plant resources during the Upper Magdalenian.

## 2. The site

Cova de les Cendres (Teulada-Moraira, Alicante, Spain) is located at the cliffs of the Moraira headland, just on the current coastline, 60 m.a.s.l. It is a large cavity with two main areas. The external is wide (30x50 m), well lit and characterised by the accumulation of big stone blocks. It leads through a 2 m high entrance to the inner chamber (600 m<sup>2</sup>), where the archaeological works are carried out (Fig. 1) (readers are referred to Supplementary Material [SM] for certain figures and tables).

In Cova de les Cendres, human occupations extended from the Aurignacian to the Bronze Age. Regarding the Pleistocene sequence, nine archaeological levels have been distinguished, ascribed to the Aurignacian (XVIC and XVID) (35,340 – 31,020 cal BP), Gravettian (XV, XVIa and XVIb) (31,000 – 25,340 cal BP), Solutrean (XIII) (23,230 – 20,050 cal BP) and Middle and Upper Magdalenian (XII, XI and IX).

(19,270 – 14,340 cal BP) (Bel and Villaverde, 2024; Martínez-Alfaro et al., 2019; Villaverde et al., 2019, 2012, 2010).

This paper focuses on the Upper Magdalenian occupations (level XI), dated between 16,240 and 15,530 cal BP. This level has been documented in Sector A (Fig. 1d), in 8 square meters, which represents a small part of the inner chamber. The extension and thickness (around 15 cm) of the level are irregular as a consequence of diverse post-depositional alterations that have caused the disappearance of the unit in particular points (see SM 1). Nevertheless, the presence of three big boulders has limited the erosion of the level (Fig. 1d), contributing to its general conservation in most of this area and allowing the preservation of the abundant archaeological record (Villaverde et al., 2012). Regarding its formation, the presence of subangular and fissured detrital material, sometimes in a vertical position, together with a clayey silty sands matrix, points to repeated freeze-thaw processes (Bergadà et al., 2013).

The lithic industry is characterised by a diversified microlaminar component (backed bladelets and marginal backed bladelets, bladelets with fine direct or inverse retouches, pointed bladelets, retouched microbladelets, etc.) and a balanced presence of burins and scrapers (Bel and Villaverde, 2024; Roman, 2004; Villaverde et al., 2012). The bone industry is especially abundant, among which harpoons stand out (Roman and Villaverde, 2012). Regarding subsistence, hunting was specialised on red deer (*Cervus elaphus*), complemented by ibex (*Capra pyrenaica*) and roe deer (*Capreolus capreolus*), among others, although rabbit (*Oryctolagus cuniculus*) dominates the archaeozoological record (Real, 2021). The archaeobotanical assemblage of level XI is rich and diverse. The anthracological analysis documents a landscape dominated by *Pinus nigra/sylvestris*, which expanded at this level, whereas *Juniperus* sp. and Fabaceae reduced. The development of pine forests could be linked to a humidity increase (Badal and Carrión, 2001; Badal and Martínez-Varea, 2018). The results of the carpological analysis have been partially published (Martínez-Varea, 2019; Martínez-Varea and Badal, 2018), pointing to the exploitation of Boraginaceae, Fabaceae, Pinaceae and Chenopodiaceae, among others. As part of this study investigating the spatial distribution of archaeobotanical remains, additional samples have been analysed from the site.

The level XI we report on for the spatial analysis of archaeobotanical remains, includes a 1.5–2 m diameter zone with superimposed combustion structures (SM Fig. 2). The spatial analysis of different materials (only plotted remains) showed that these hearths, and the big boulders, conditioned the spatial organisation of activities in this area of the cavity (Bel et al., 2015). The archaeostratigraphical analysis evinced that the level presents a cumulative palimpsest structure –formed by an undetermined number of occupations during a time-lapse of certain duration– which hinders the delimitation of different phases.

## 3. Materials and methods

The archaeological works were carried out in a grid of 1 m<sup>2</sup> squares subdivided in 16 sub-squares (S<sub>s</sub>) of 25x25 cm. The sediments were collected in 5 cm thick spits, adapted to the natural level. All the sediment was processed with a flotation machine fitted with a 1 mm cloth mesh for the heavy residue and a 0.25 mm cloth mesh for the light fraction. The samples were split with a sieve stack with 4-, 2-, 1-, 0.5- and 0.25-mm sieve sizes to facilitate sorting of archaeobotanical remains in the laboratory.

For the carpological analysis, eight square meters from Sector A were analysed (CD 13, 14, 15 and 16), with samples from spits 10 to 20. Three areas were differentiated: hearths zone, hearths boundary and outside hearths zone (Fig. 1d). 154 flotation samples were included in this study, equivalent to approximately 462 L of sediment. A volume of 6.4 L of plant remains was sorted under a low-power microscope Leica M165C to recover non-woody plant remains: diaspores (hereafter referred to as seeds), stems, bark, leaves and rhizomes. Botanical identification was carried out using the modern plant reference collection of the

Table 3

Reproductive remains from the Upper Magdalenian level (XI). MNI (minimum number of individuals), ubiquity (number of samples in which the taxon is present), frequency (% of samples in which the taxon is present), fragmentation index (MNI/NR) and degree of fragmentation (% of remains fragmented).

			Hearths	Hearths boundary	Outside hearths zone	Total Level XI	MNI	Ubiquity	Frequency (%)	Fragmentation index	Degree of fragmentation (%)
APIACEAE	Apiaceae	Charred seed	1			2	2	2	1.3	1.0	50
		Mineralised seed frag.	1								
ASTERACEAE	<i>Cirsium/Carduus</i> sp.	Charred achene			1	5	2	2	1.3	0.4	80
		Charred achene frag.	4								
BORAGINACEAE	<i>Asteraceae</i> tp. <i>Anthemis</i> sp.	Charred seed			1	1	1	1	0.6	1.0	
	<i>Alkanna tinctoria</i>	Charred nutlet	3	5	68	376	77	66	42.6	1.0	5
		Charred nutlet frag.	2		2						
		Mineralised nutlet	62	19	174					0.9	12.9
		Mineralised nutlet frag.	13	4	21						
		Mineralised seed			1						
		cf. Uncharred nutlet	1	1			2			1.0	
	<i>Buglossoides arvensis</i>	Charred nutlet	47	12	67	313	135	79	51.0	0.8	21
		Charred nutlet frag.	11	2	21						
		Charred seed	1		1						
		Mineralised nutlet	19	13	47		96			0.6	45
		Mineralised nutlet frag.	12	3	53						
		Mineralised seed		1	3						
	<i>Echium vulgare</i>	Charred nutlet			2	9	3	8	5.2	1.0	33.3
		Charred nutlet frag.			1						
		Mineralised nutlet	3		2		6			1.0	16.7
		Mineralised nutlet frag.			1						
	<i>Heliotropium europaeum</i>	Charred seed		1		1	1	1	0.6	1.0	
	cf. <i>Lithospermum</i> sp.	Mineralised nutlet	1			2	2	2	1.3	1.0	50
		frag.									
	<i>Neatostema apulum</i>	Charred seed			1						
		Charred nutlet	1	1	5	17	8	13	8.4	0.8	30
		Charred nutlet frag.	1	1	1						
		Mineralised nutlet		3	2		6			0.8	28.6
		Mineralised nutlet frag.	1		1						
	Boraginaceae	Mineralised nutlet frag.	1		4	6	5	5	3.2	1.0	83.3
		Charred seed			1		1			1.0	
CAPRIFOLIACEAE	<i>Sambucus nigra</i>	Charred seed	1			1	1	1	0.6	1.0	
	<i>Sambucus</i> sp.	Charred seed frag.	1		2	3	1	2	1.3	0.3	100
	cf. <i>Sambucus</i> sp.	Charred seed frag.	2		1	3	1	3	1.9	0.3	100
CHENOPODIACEAE	<i>Corispermum gallicum</i>	Charred seed	3	3	7	18	16	12	7.7	0.9	27.8
	cf. <i>Corispermum gallicum</i>	Charred seed frag.	2		3						
	Chenopodiaceae tp. <i>Atriplex</i> sp.	Charred seed frag.	1			1	1	1	0.6	1.0	100
	Chenopodiaceae	Charred seed		1		1	1	1	0.6	1.0	
		Charred seed	1		1	3	2	3	1.9	1.0	
		Mineralised seed	1				1			1.0	
CISTACEAE	<i>Helianthemum</i> sp.	Charred seed frag.			1	1	1	1	0.6	1.0	100
	Cistaceae	Charred seed			1	1	1	1	0.6	1.0	
CUPRESSACEAE	<i>Juniperus oxycedrus</i>	Charred endocarp	5	1		7	7	5	3.2	0.9	14.3
		Charred endocarp frag.			1						

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Table 3 (continued)

		Hearths	Hearths boundary	Outside hearths zone	Total Level XI	MNI	Ubiquity	Frequency (%)	Fragmentation index	Degree of fragmentation (%)
	<i>Juniperus oxycedrus/ communis</i>	Charred endocarp frag.	1	3	4	2	3	1.9	0.5	
	<i>Juniperus phoenicea</i>	Charred endocarp	1		2	2	2	1.3	1.0	50
		Charred endocarp frag.		1						
	<i>Juniperus sabina</i>	Charred endocarp	7	2		23	16	11	7.1	0.7
		Charred endocarp frag.	14							60.9
	<i>Juniperus cf. sabina</i>	Charred endocarp frag.	1		1	1	1	0.6	1.0	100
	<i>Juniperus thurifera</i>	Charred endocarp	1	1	2	2	2	1.3	1.0	
	<i>Juniperus cf. thurifera</i>	Charred endocarp	1		1	1	1	0.6	1.0	
	<i>Juniperus sp.</i>	Charred endocarp	2		17	10	9	5.8	0.6	88.2
		Charred endocarp frag.	5	3	7					
	<i>cf. Juniperus sp.</i>	Charred endocarp frag.	12		3	15	8	6	3.9	0.5
CYPERACEAE	<i>Eleocharis sp.</i>	Mineralised achene		1	2	2	2	1.3	1.0	50
		Mineralised achene frag.		1						
ERICACEAE	<i>Schoenus nigricans</i>	Mineralised achene	2	1	3	3	3	1.9	1.0	
	Cyperaceae	Charred achene	1		3	3	3	1.9	1.0	66.7
EUPHORBIACEAE	<i>cf. Cyperaceae</i>	Charred achene frag.		1						
	<i>Corema album</i>	Mineralised seed		1	1	1	1	0.6	1.0	
FABACEAE	<i>Euphorbiaceae tp.</i>	Charred endocarp	3	1	2	6	6	3.9	1.0	
	<i>Mercurialis sp.</i>	Charred seed		1	1	1	1	0.6	1.0	
FABACEAE	<i>Lens sp.</i>	Charred seed	2	5	2	14	12	11	7.1	0.8
		Charred seed frag.		1						28.6
FABACEAE		Charred cotyledon	1							
		Charred cotyledon	2		1					
FABACEAE		frag.								
	<i>Medicago/Melilotus sp.</i>	Charred seed	3	2		8	6	8	5.2	0.8
FABACEAE		Charred seed frag.	1	1						37.5
		Charred cotyledon		1						
FABACEAE		frag.								
	<i>Vicia sp.</i>	Charred seed	22	4	18	77	64	41	26.5	0.8
FABACEAE		Charred seed frag.	2	3	5					22.1
		Charred cotyledon	4	2	10					
FABACEAE		Charred cotyledon	2	3	2					
		frag.								
FABACEAE	<i>Vicia/Lathyrus sp.</i>	Charred seed	2	1		7	6	6	3.9	0.9
		Charred seed frag.	1		1					42.9
FABACEAE		Charred cotyledon	1							
		Charred cotyledon			1					
FABACEAE		frag.								
	<i>Vicia/Lens sp.</i>	Charred seed	1		1	2	2	1.3	1.0	
FABACEAE		Charred seed	1		1	14	10	11	7.1	0.7
		Charred seed frag.			7					85.7
FABACEAE		Charred cotyledon								
		Charred cotyledon		2	2					
FABACEAE		frag.								

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Table 3 (continued)

		Hearths	Hearths boundary	Outside hearths zone	Total Level XI	MNI	Ubiquity	Frequency (%)	Fragmentation index	Degree of fragmentation (%)
	cf. Fabaceae	Charred seed Charred cotyledon frag.	1	1	2	2	2	1.3	1.0	50
LAMIACEAE	<i>Ajuga chamaepitys</i>	Charred seed Charred seed frag.	1	2	6	3	6	3.9	0.6	66.7
	cf. <i>Ajuga chamaepitys</i>	Charred seed frag.	1	1	1	1	1	0.6	1.0	100
	cf. <i>Ajuga sp.</i>	Charred seed frag.	1		1	1	1	0.6	1.0	100
	<i>Ajuga/Teucrium</i> sp.	Charred seed frag.		1	1	1	1	0.6	1.0	100
	<i>Nepeta</i> cf. <i>latifolia</i>	Charred seed	3	1	4	4	4	2.6	1.0	
	<i>Teucrium aureum/</i> <i>montanum</i>	Charred seed	1		1	1	1	0.6	1.0	
	<i>Teucrium</i> sp.	Charred seed	1		1	1	1	0.6	1.0	
MORACEAE	Lamiaceae	Charred seed frag.	2		2	2	2	1.3	1.0	100
PINACEAE	cf. <i>Ficus carica</i>	Charred seed		1	1	1	1	0.6	1.0	
	<i>Pinus cf. sylvestris</i>	Mineralised seed		1	1	1	1	0.6	1.0	
	<i>Pinus</i> sp.	Charred cone scale frag.	241	13	275	46	39	25.2	0.2	100
	cf. <i>Pinus</i> sp.	cf. Charred cone scale frag.		6	6	1	3	1.9	0.2	100
POACEAE	<i>Festuca/Lolium</i> sp.	Charred caryopsis frag.	1	1	2	2	2	1.3	1.0	50
	Poaceae tp. <i>Phleum</i> sp.	Charred caryopsis	1		1	1	1	0.6	1.0	
	cf. Poaceae	Charred caryopsis frag.	1		1	1	1	0.6	1.0	100
	Cereal (intrusive)	Charred caryopsis frag.		1	1	1	1	0.6	1.0	100
PLANTAGINACEAE	<i>Plantago</i> sp.	Mineralised seed	1		1	1	1	0.6	1.0	
RANUNCULACEAE	Polygonaceae	Charred seed	1		1	1	1	0.6	1.0	
	cf. <i>Caltha palustris</i>	Charred seed	6	2	14	12	9	5.8	0.8	35.7
	Ranunculaceae tp. cf.	Charred seed frag.	1		4					
	<i>Caltha palustris</i>	Charred seed		1	8	5	6	3.9	0.6	87.5
	cf. <i>Reseda</i> sp.	Charred seed frag.	2	4	1					
	<i>Galium</i> sp.	Charred seed	1		1	1	1	0.6	1.0	
	<i>Viola</i> sp.	Charred seed		1	1	1	1	0.6	1.0	
PTERIDOPHYTE	<i>Isoetes</i> type 1	Macrospore	53	53	53	53	6	3.9	1.0	
	<i>Isoetes</i> type 2	Macrospore	9	9	9	9	1	0.6	1.0	
	<i>Isoetes</i> type 3	Macrospore	21	21	21	21	3	1.9	1.0	
	Fern type 4	Macrospore	1	1	1	1	1	0.6	1.0	
	<i>Isoetes</i> sp.	Macrospore	1	1	1	1	1	0.6	1.0	
	Pteridophyte	Macrospore	5	5	5	5	2	1.3	1.0	
	<i>Chara</i> sp.	Oospore	1		1	1	1	0.6	1.0	
	Dicotyledon	Charred seed		1	1	1	1	0.6	1.0	
	Angiosperm	Charred cotyledon Charred fruit frag./ parenchyma	2		2	2	2	1.3	1.0	100
	Indeterminate 1		1		1	1	1	0.6	1.0	
	Indeterminate 2	Charred seed frag.	47	84	166	20	20	12.9		100
	Indeterminate	Charred seed		2	2	2	2	1.3	1.0	
	Charred fruit	Charred fruit	1		1	1	1	0.6	1.0	
	Endocarp 1	Charred endocarp frag.	25	6	131	22	39	25.2	0.2	100

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Table 3 (continued)

	Hearths	Hearths boundary	Outside hearths zone	Total Level XI	MNI	Ubiquity	Frequency (%)	Fragmentation index	Degree of fragmentation (%)
Endocarp 2	Charred endocarp frag.	456	52	120	628	105	53	34.2	0.2
Endocarp 3	Charred endocarp frag.	23	8	12	43	7	33	21.3	0.2
Endocarp 4	Charred endocarp frag.			2	2	0	2	1.3	0.2
Endocarp 6	Charred endocarp frag.	13		1	14	2	4	2.6	0.2
Endocarp 7	Charred endocarp frag.	3	4	8	15	3	10	6.5	0.2
Endocarp 8	Charred endocarp frag. Charred seed Charred seed frag. Charred endocarp frag. Mineralised seed Mineralised seed frag. Charred fruit frag. Mineralised floral structure	3	1	127	113	5	413	0.6	0.2
Unidentifiable		93	8	25	24	1	1		100

Laboratory of Archaeology of Universitat de València, as well as by relying on published identification atlases and guides (Bojnánský and Fargašová, 2007; Cappers et al., 2006; Sabato and Peña-Chocarro, 2021).

The spatial analysis was carried out with QGIS (version 3.16.4). We created random coordinates (Rios-Garaizar, 2012; Sánchez-Romero et al., 2022) for each carpological remain –all of them non-plotted with total station during the fieldwork– based on the minimum spatial units used in the fieldwork (Ss): the remains were randomly distributed inside the polygons of 25 cm side length each. Nevertheless, some of these spatial units are smaller, with size and morphology conditioned by the presence of the boulders or the progressive loss of the verticality of certain profiles that caused the reduction of the excavated area. The spatial analysis must take into account two factors that may influence the distributions: firstly, the uneven documentation of level XI across the studied area, and secondly, the lack of samples from certain points (see SM 1 and SM Fig. 1) (most were discarded because they include materials from two levels). Even so, most of the excavated area is well represented in our analysis. We applied kernel density estimation (KDE) to assess the higher or lower concentration of remains in particular spaces (Eixa et al., 2011\_2012; Sánchez-Romero et al., 2022; Sañudo et al., 2012). Considering the characteristics of the area and in order to obtain sufficient detail of the potential concentrations, we have used a 0.35 m search radius for KDE. Besides, average nearest neighbour (ANN) analysis was performed to assess whether the distributions of material are clustered, random or dispersed.

## 4. Results

### 4.1. Seed remains analysis

For this study, in level XI, 3800 plant remains were analysed. Of them, 2820 are reproductive (seeds and fruits), 953 are vegetative (leaves, bark fragments, fibres and uncharred and mineralised wood fragments) and 27 are fragments of parenchyma (it was not possible to distinguish if they are fruit fragments or underground storage organs). The density of remains is high, with 8.23 remains per litre of sediment, similar in the hearths zone and their boundary but lower outside the hearths zone (Table 1). Among the recovered remains, only a fragment of cereal caryopsis was excluded of the analysis, due to its clear intrusive character, probably coming from a Neolithic pit documented in the area.

Regarding taxonomy, 1400 reproductive remains and 881 vegetative specimens (60 % of the assemblage) were classified into family, genus or species levels. A total of 83 different taxa were identified, with a minimum number of species (MNE) of 52.

Regarding the preservation of the assemblage, 82.5 % was affected by carbonisation, while 16.8 % of the remains were preserved due to mineralisation (Table 2). Mineralisation processes affected both seeds and wood fragments, and the conditions required for this type of preservation were assessed by Martínez-Varea et al. (2020). Some wood fragments were classified just as uncharred since they do not clearly show the small crystallised granules and filled cell lumina and pits characteristic of the mineralised fragments. The fragmentation is high, especially in the hearths zone (probably accentuated by the concentration of some remains, such as *Pinus* cone scales), with just 29.1 % of the reproductive remains preserved complete. Some taxa have a high degree of fragmentation, such as *Cirsium/Carduus* sp., *Juniperus* spp., *Buglossoides arvensis*, *Sambucus* sp. and the different Fabaceae. This high fragmentation has hindered the taxonomic identification: 408 reproductive specimens were classified as unidentifiable and 1004 as indeterminate (including the different groups of endocarp fragments).

If we focus on the determinable reproductive assemblage (seeds and fruits), they belong to 73 taxa and at least 46 different species (Table 3, Figs. 2, 3). Nearly half of the identified remains belongs to two species of Boraginaceae: *Alkanna tinctoria* (26.8 %) and *Buglossoides arvensis* (22.3 %). These taxa could be over-represented due to their preservation even

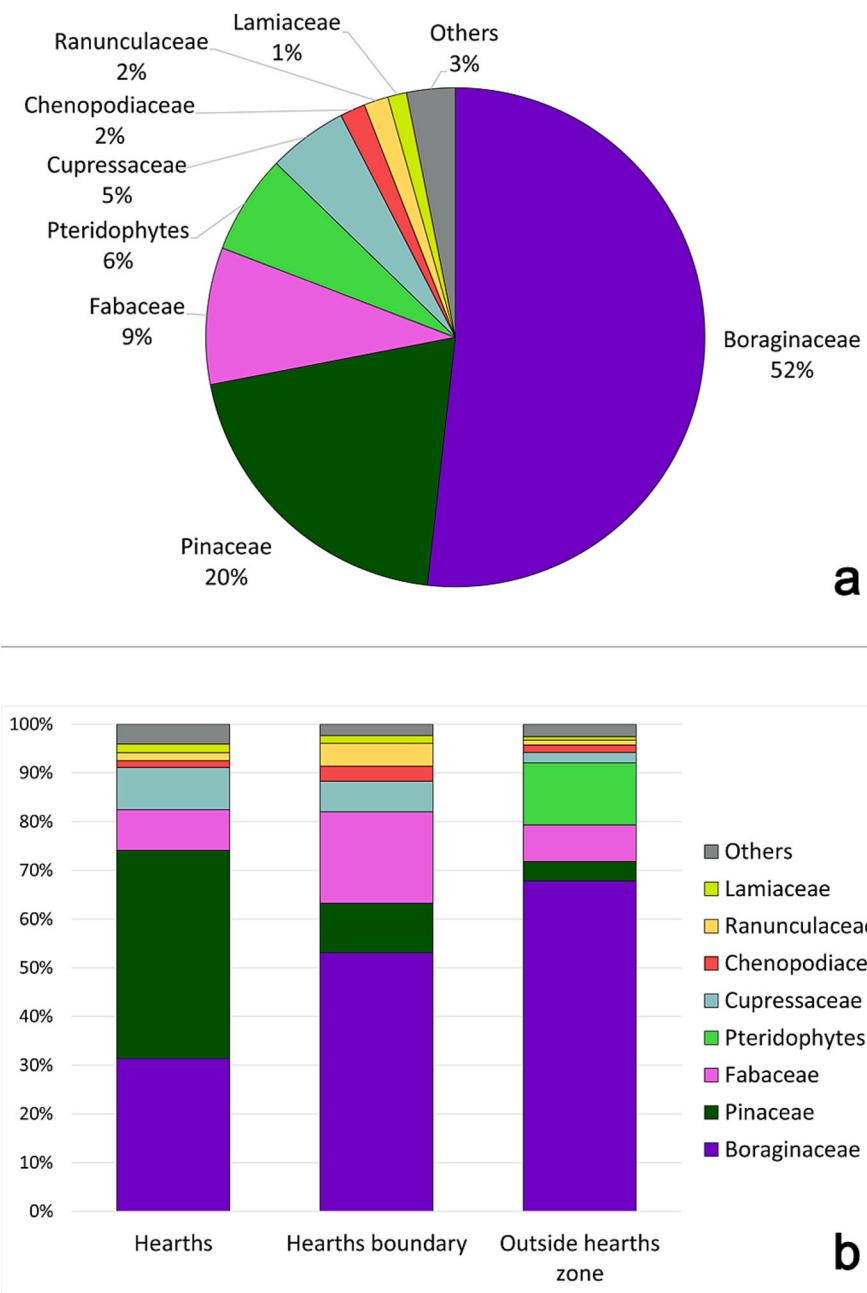


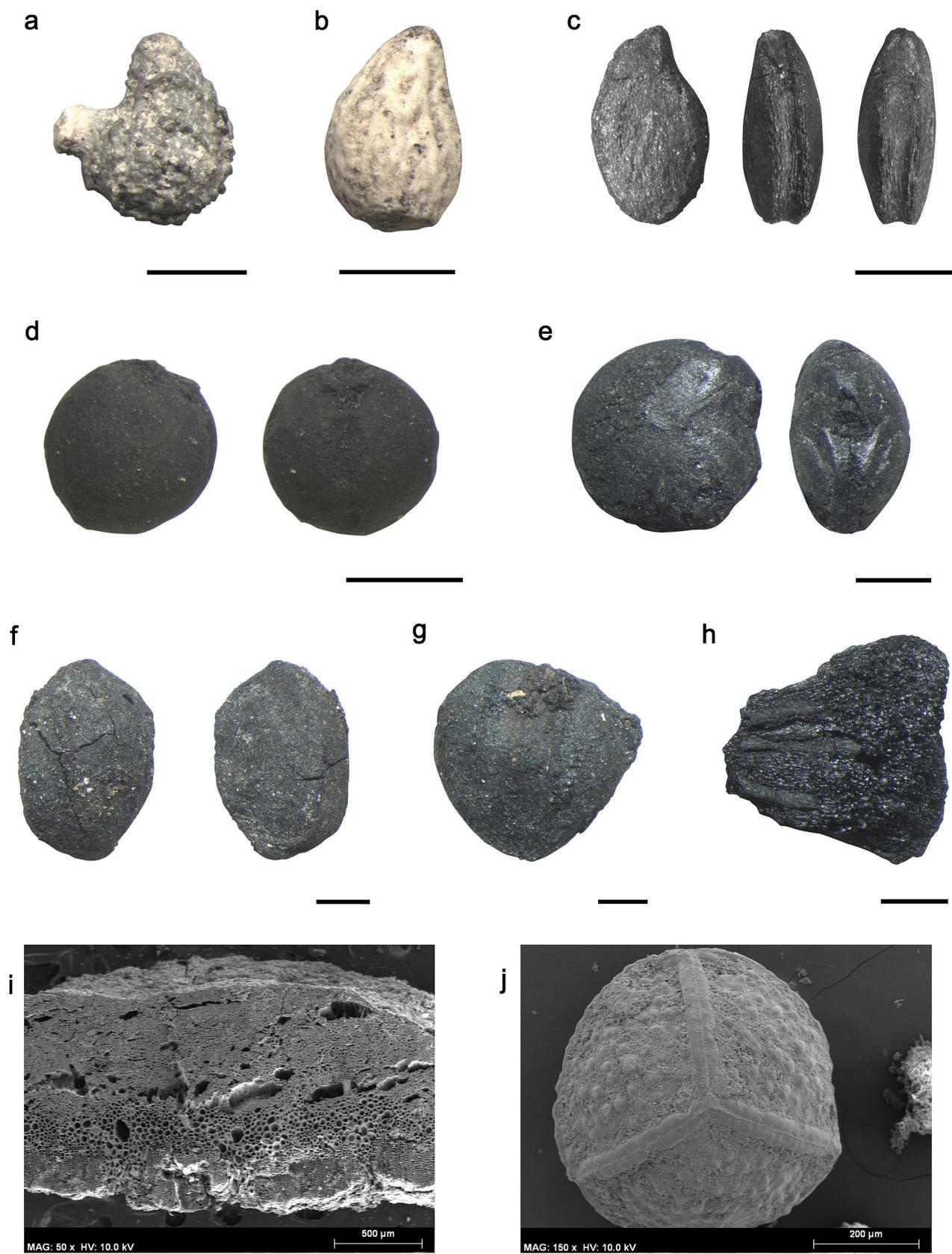
Fig. 2. Percentage of identified reproductive remains in the assemblage (a) and in the defined areas (b).

uncharred (Messager et al., 2010; Pustovoytov et al., 2004). In fact, if we consider only the charred remains, *Alkanna tinctoria* would lose its relevance since just 80 remains were charred; *Buglossoides arvensis* would keep its prominence since most of its remains are heat-affected (162). They are followed by pine cone scale fragments (19.6 %). Fabaceae make up 8.8 % of the identified assemblage, with at least four different species, *Vicia* sp. being the most abundant (77 remains). Macrospores of at least four species of Isoetaceae have a significant presence (6.4 %), followed by Cupressaceae (5.1 %), among which *Juniperus sabina* stands out (23 remains). Some families, such as Chenopodiaceae, Ranunculaceae and Lamiaceae, have a similar presence, around 1 %. The rest of the families represent less than 1 % of the assemblage: Cyperaceae, Asteraceae, Ericaceae, Poaceae, etc. Most of these species and families have been documented in other levels of the site (Martínez-Varea, 2019; Martínez-Varea et al., 2019a; Martínez-Varea, 2022). This scale of abundance of the reproductive assemblage is

not excessively modified if we account for the MNI since the main taxa do not have a high fragmentation degree.

Regarding the ubiquity (number of samples where a taxon is present) (Table 3), the most frequent taxa are *Buglossoides arvensis*, which appears in 51 % of the samples, and *Alkanna tinctoria*, recovered in 42.6 %. They are followed by *Vicia* sp. (26.5 %), *Pinus* sp. (25.2 %) and the Indeterminate 2 (12.9 %). The rest of the taxa appeared in less than 10 % of the samples. Therefore, overall, the most frequent taxa are the most abundant, except Isoetaceae macrospores, which are concentrated in 1 to 6 samples. Among the unidentified remains, we can highlight the frequency and abundance of the three first types of endocarps (21–34 % of the samples).

Regarding the vegetative remains (Table 4, Fig. 4), bark fragments of *Pinus* sp. (394 fragments) and *Viscum* sp. (361) make up most part of the assemblage (85.3 %). Some bark fragments could not be firmly identified to these taxa, and 31 fragments do not have enough characteristics



**Fig. 3.** Reproductive remains: *Alkanna tinctoria* (a), *Buglossoides arvensis* (b), *Corispermum gallicum* (c), *Vicia* sp. (d), *Lens* sp. (e), *Juniperus oxycedrus* (f), *Juniperus sabina* (g), *Pinus* cone scale (h and i), *Isoetes* type 3 (j). Scale 1 mm unless otherwise indicated.

**Table 4**

Vegetative remains from the Upper Magdalenian level (XI).

			Hearths	Hearths boundary	Outside hearths zone	Total Level XI
GYMNOSPERMS	<i>Pinus nigra/sylvestris</i>	Uncharred wood frag.	3	2	3	8
		Mineralised wood frag.		1	5	6
	<i>Pinus</i> sp.	Charred bark frag.	64	42	288	394
		Charred needle frag.	19	1	7	27
		Mineralised needle frag.		1		1
		Mineralised wood frag.		1		1
	<i>cf. Pinus</i> sp.	Charred bark frag.	3	1	3	7
		Mineralised needle frag.			3	3
	<i>Juniperus</i> sp.	Mineralised wood frag.		5	5	10
		Uncharred wood frag.			2	2
	<i>Conifer</i>	Uncharred wood frag.	3		4	7
		Mineralised wood frag.			5	5
	<i>Gymnosperm</i>	Uncharred wood frag.	1			1
ANGIOSPERMS	<i>Stipa tenacissima</i>	Charred rhizome frag.	1		2	3
	<i>Poaceae</i>	Mineralised stem		1		1
	<i>cf. Poaceae</i>	Mineralised leaf frag.	1			1
	<i>Monocotyledon</i>	Charred stem frag.	15	2	4	21
		Mineralised stem frag.		1	1	2
		Mineralised leaf frag.	2	2	1	5
		Mineralised fibers	3			3
		Root frag./Parenchyma	2			2
	<i>Quercus</i> sp.	Mineralised wood frag.			2	2
	<i>cf. Thymus</i> sp.	Mineralised leaf frag.	2			2
	<i>cf. Lamiaceae</i>	Mineralised wood frag.	1			1
	<i>Viscum</i> sp.	Charred bark frag.	176	96	89	361
		Charred stem frag.	1			1
		Roasted wood frag.		1		1
	<i>cf. Viscum</i> sp.	Charred bark frag.			3	3
	<i>Angiosperm</i>	Uncharred wood frag.			3	3
		Mineralised wood frag.	1		4	5
		Charred stem frag.			2	2
		<i>cf. Charred peduncle</i>	1		1	2
		Charred root frag.	1			1
	<i>Indeterminate</i>	Mineralised stem/peduncle frag.			2	2
		Mineralised leaf frag.	1			1
		Uncharred peduncle/wood frag.		1		1
	<i>Unidentifiable</i>	Charred bark frag.	16	1	6	23
		Charred epidermis frag.		1	7	8
		Uncharred wood frag.	1		3	4
		Mineralised wood frag.			7	7
		Fibers	3	1		4
		Underground organ			2	2
		Indeterminate plant structure	1		2	3
		Uncharred indeterminate plant tissue		1	2	3
		Ashes			1	1
		<b>TOTAL Vegetative remains</b>	322	162	469	953
	<i>Parenchyma</i>	Charred parenchyma frag.	10	1	16	27

to be identifiable. A relevant ensemble of uncharred and mineralised wood fragments was also recovered and their taxonomic composition is similar to those of the anthracological record (Badal and Martínez-Varea, 2018), with a predominance of Gymnosperms over Angiosperms. In the first group, *Pinus nigra/sylvestris* (14 remains) and *Juniperus* sp. (12) have a similar presence. The identification of Angiosperms wood was hindered by the presence of mineral deposits inside the cells. We have identified some fragments of *Quercus* sp., cf. Lamiaceae and *Viscum* sp. Fragile non-woody elements, such as leaves and stems, were preserved both charred and mineralised. Most of this assemblage is formed by pine needles (31), mainly charred, and *Monocotyledon* charred stem fragments (21). Six mineralised fragments of *Poaceae* and *Monocotyledon* leaves were also documented. We have also recovered two fragments of a leaf of cf. *Thymus* sp. Finally, among the rhizome or roots, we have identified a fragment of *Stipa tenacissima*, two of a *Monocotyledon* and one fragment classified as *Angiosperm*.

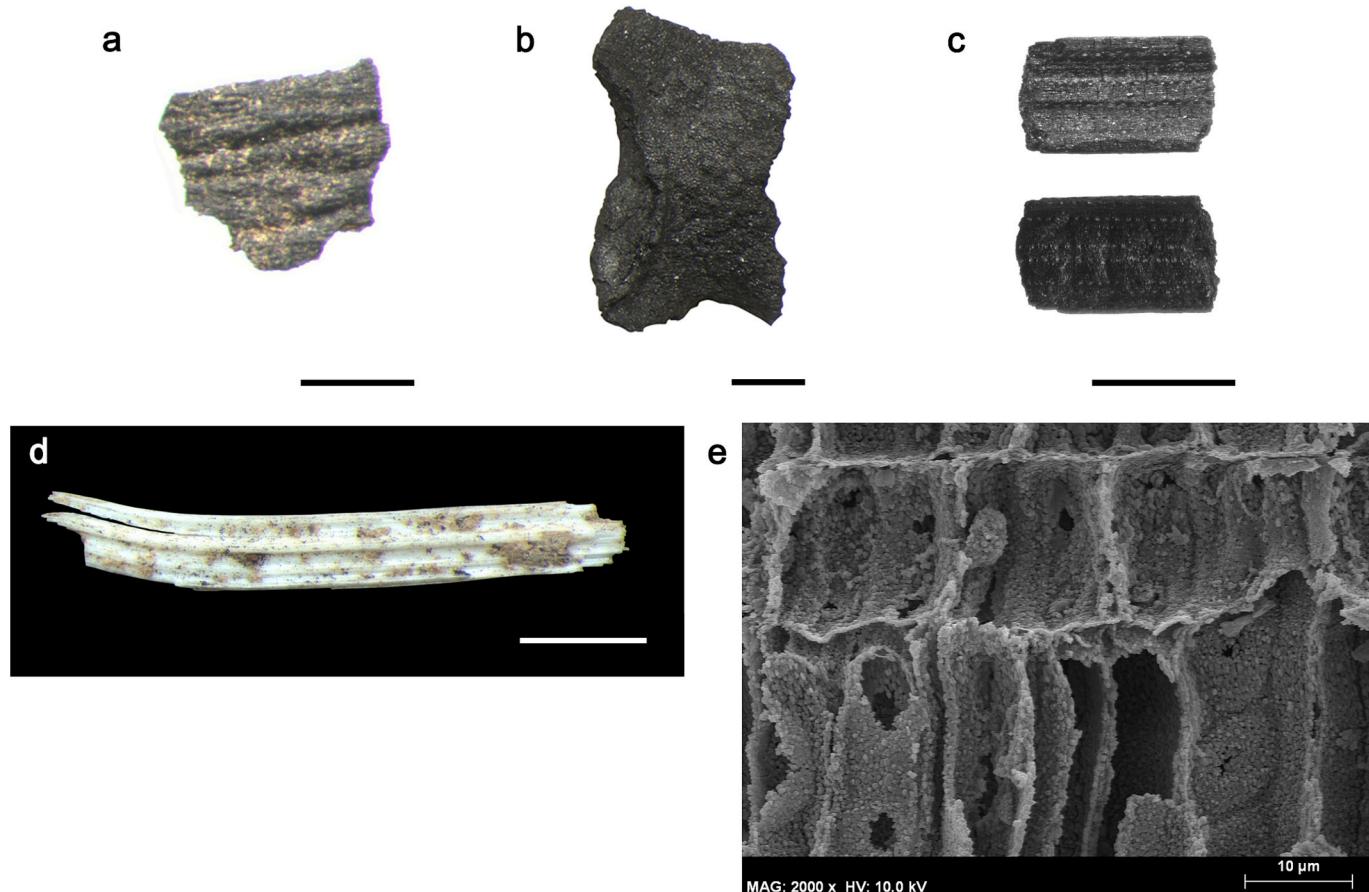
#### 4.2. Spatial analysis

Concerning the spatial distribution of the carpological remains, most of the excavated area is well represented in our analysis, but the irregular representation of level XI across the studied area and the exclusion

of samples with materials from two levels in certain zones must be considered (see SM 1 and SM Fig. 1).

The projection of the density of the light fraction –which is mainly formed by wood charcoal and carpological remains– by litre of sediment (Fig. 5) shows a more significant presence in squares CD/15–16, with a slight difference between the hearths zone and the rest of the surface: in the hearths boundary and, mainly, outside the hearths zone, there is a greater proportion of sub-squares with high density of light fraction (Table 1). The archaeobotanical remains analysed in this work show a similar distribution: they are clearly more represented in squares CD/15–16 and show some high-density concentrations (SM Fig. 3 and SM Table 1). However, there is a negative relationship in some sub-squares between the density of the light fraction and the distribution of the carpological remains, such as in C14-Ss10, 11, 14, 15 and C15-Ss3, where the density of wood charcoal is low (4.83 ml/l on average) but a significant amount of non-woody remains was recovered. On the contrary, D15-Ss1 provided a great amount of wood charcoal (45.33 ml/l) but a small set of seeds. Overall, the distribution of archaeobotanical remains (wood charcoal and carpological remains) agrees with the distribution of other archaeological items, such as lithics or faunal remains (Bel et al., 2015).

Considering the type of preservation, both types –charred and



**Fig. 4.** Vegetative remains: *Viscum* sp. bark (a), *Pinus* sp. bark (b) and needle (c), Monocotyledon leaf (d) and *Juniperus* sp. wood (radial section) (e). Scale 1 mm unless otherwise indicated.

mineralised – were documented together in part of the samples (Figs. 6, 7). However, some differences in their distribution are detected. The charred remains are very abundant, and their distribution matches that of the whole assemblage. The mineralised remains show three main concentrations: inside the hearths zone (square C15), C16, and D16. The greater discrepancy is observed in the last square due to the abundance of the mineralised pteridophyte macrospores. We have analysed the distribution of *Alkanna tinctoria* and *Buglossoides arvensis* due to their abundance and types of preservation (Fig. 8). The charred remains of *Alkanna tinctoria* mainly appear outside the hearths zone, primarily concentrated in C16. The mineralised remains of this species show two concentrations: in C16 and C15-Ss4. Regarding *Buglossoides arvensis*, the carbonised remains are accumulated in C15-Ss3 and C16, coinciding with *Alkanna*. The mineralised remains are also concentrated in C15-Ss3 and next to the profile in D15–16.

Some differences arise when comparing complete and fragmented seeds (SM Figs. 4, 5). Complete remains present two main concentrations, outside the hearths zone in C16 and inside in C15, but also a remarkable presence in D16. On the contrary, fragmented seeds are mainly concentrated in CD/15, in the hearths zone and its boundary. Density maps show the more significant presence of complete seeds outside the hearths zone and the greater presence of those fragmented inside. However, the concentrations of complete remains outside hearths are mainly composed of two taxa: pteridophyte macrospores in D16 and *Alkanna* in C16, the latter probably forming a very localised concentration between two sub-squares. The most striking difference is in C16, with the remarkable presence of complete remains and the scarcity of those fragmented.

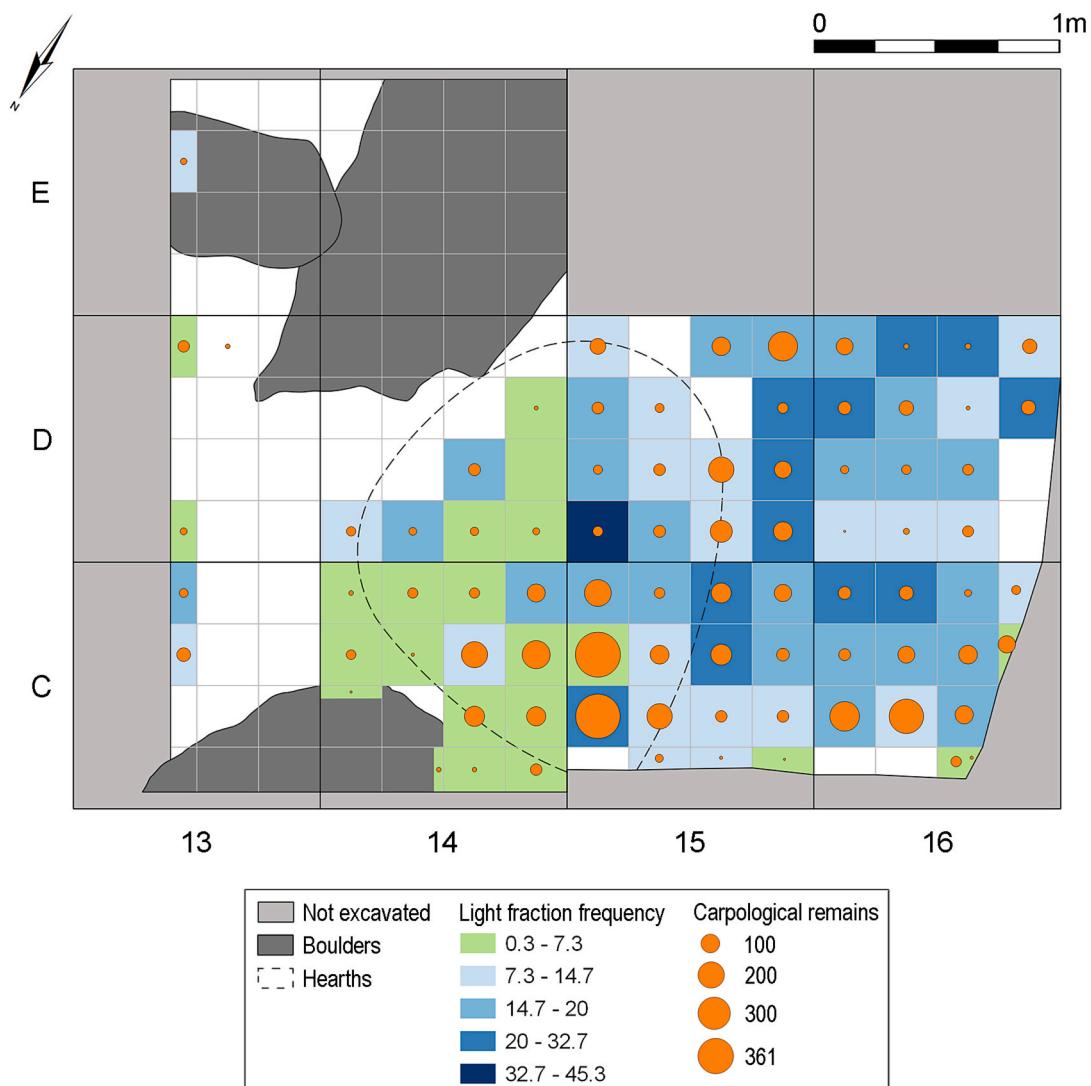
Some of the carpological remains present intense alterations due to the charring process, such as swelling, crushing, popping, protrusions,

cracks, shiny surface and spongy texture (Antolín, 2012; Braadbaart, 2008) (see SM 2.1 and SM Table 2). They are mainly present in the hearths zone or in their boundary and have a considerable representation in the distal part of D16 (Fig. 6).

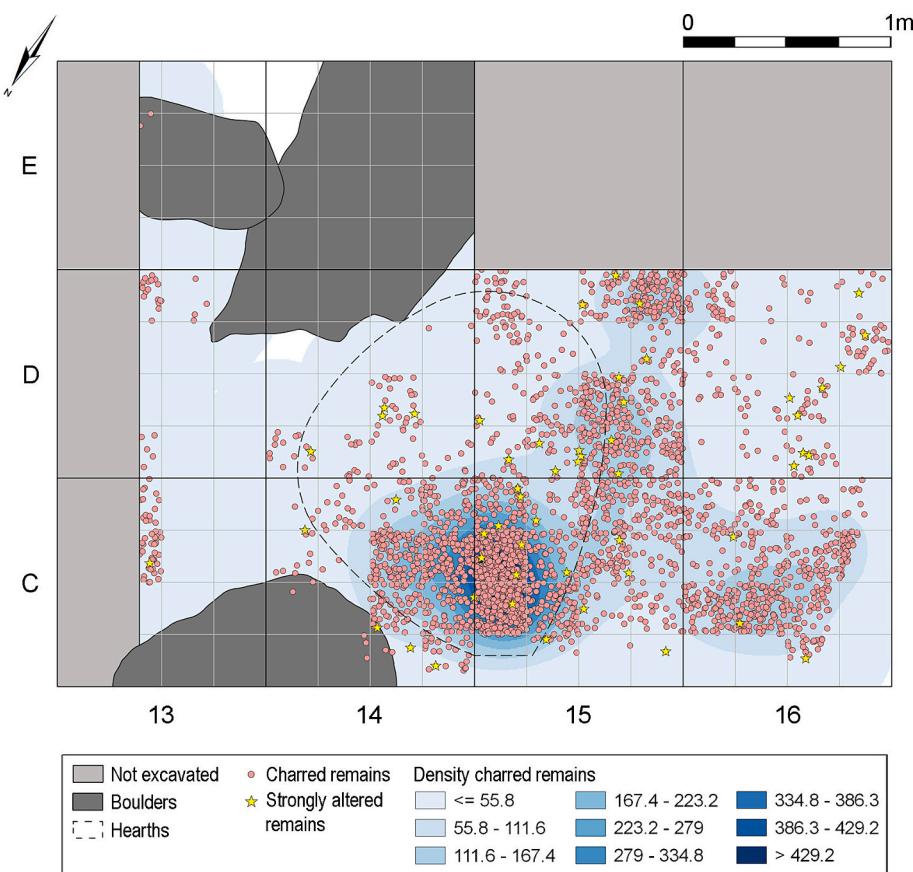
We have performed a specific analysis of the distribution of some of the documented taxa because of their abundance or their link to human activities. It is the case of *Alkanna tinctoria*, which is basically present in squares C15 and C16, forming a high-density concentration in the latter. *Buglossoides arvensis* is more scattered in the analysed area. However, most of its remains were recovered in CD/15–16, with some noticeable concentrations in C15-Ss3, C16 and D15-Ss12-16/D16-Ss4 (Fig. 8). Regarding the Fabaceae remains, they are mainly documented in CD/15–16, with a remarkable concentration in the hearths (C15). In fact, some taxa, such as *Medicago/Melilotus* sp. or *Lens* sp., are more restricted to the combustion zone, whereas *Vicia* sp., which is the most abundant species of this family, is also scattered outside the hearths in CD/16 (Fig. 9).

Most of the *Juniperus* spp. carpological remains were recovered in the hearths zone and its boundary (Fig. 10). The pine scale fragments show a similar distribution, mainly concentrated in C14-Ss11-15 (Fig. 11). The cf. *Caltha palustris* remains are also linked to the combustion zone and their limits (Fig. 12). As briefly mentioned above, the pteridophyte macrospores show a clustered distribution, concentrated in two points of square D16 (Fig. 12).

Other taxa are not abundant, but their economic or ecological interest moves us to assess their spatial distribution (SM Figs. 6, 7). The *Cirsium/Carduus* sp. seed fragments –except one remain– were recovered in a sample from the hearths zone. *Sambucus* sp. is mainly restricted to square D15. On the contrary, *Corispermum gallicum* and Cyperaceae remains are dispersed throughout the analysed area. *Corema album* is



**Fig. 5.** Frequency map of density of flotation and carpological remains (hereinafter, to improve the readability of the maps, the unexcavated areas adjacent to the sagittal profiles and distal frontal profile are not depicted).



**Fig. 6.** Distribution and density map of charred remains.

restricted to DE/13 and CD/14, whereas *Ajuga chamaepitys* is restricted to CD/15–16, although they do not show any concentration. Regarding the Poaceae caryopsis, they mainly come from the hearths zone. The intrusive cultivated cereal was recovered in D16-Ss9, next to a Neolithic pit.

Part of the assemblage could not be identified, but their spatial distribution could be interesting (SM Fig. 8). It is the case of the Indeterminate 2, which is restricted to squares CD/15–16, with a noticeable concentration in the boundary of the hearths zone in C15. Endocarp 1 has a strong concentration in D15-Ss12 and 16, although it also appears more scattered in C/15–16. Endocarp 2 has two apparent concentrations: C15-Ss2 and 3 and D15-Ss16. Finally, endocarp 3 is distributed throughout the area, although most remains are in the hearths zone.

Some vegetative remains show striking spatial distribution patterns. It is the case of *Viscum* sp. and *Pinus* sp. bark fragments. *Viscum* bark is mainly concentrated in the hearths zone, in C/14–15, but also outside the combustion space, in C16. It has a notable concentration in C14-Ss10 and 14. On the other hand, pine bark is distributed throughout CD/15–16, with the highest representation in C16 (Fig. 13). We can underline that *Viscum* bark fragments are present throughout the level, whereas pine bark has a higher presence in the middle and upper part of the stratum (SM Table 3).

Monocotyledon leaves and stems are concentrated in two points linked to the combustion structures (C14-Ss12 and 16, and D15-Ss9, 10, 14). Inside the hearths, they are mainly carbonised, whereas they present a larger proportion of mineralised remains at the boundary. Pine needles are concentrated in the hearths zone of square C14, and some remains are scattered in D15 and CD/16 (Fig. 14).

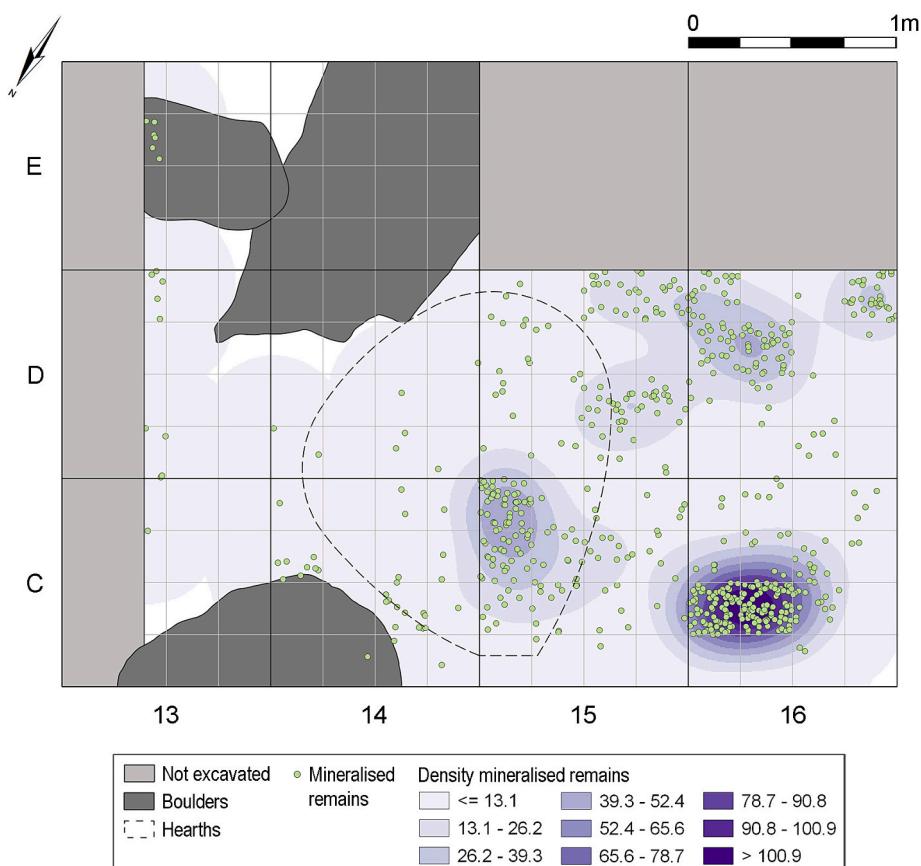
The fragments of mineralised wood are mainly present outside the hearths zone, especially in square C16 (coinciding with the high concentration of mineralised *Alkanna tinctoria* nutlets), although some fragments –uncharred and mineralised– are inside the combustion

structures and in their boundary (Fig. 14).

## 5. Discussion

### 5.1. Formation of the carpological assemblage

Hearths are central elements of hunter-gatherers' campsites, around which economic, social and cultural activities develop (Binford, 1983; Brooks and Yellen, 1987; Galanidou, 2000; O'Connell, 1987; Yellen, 1977). Hearth-related accumulations have been frequently described in Palaeolithic sites (Bailey and Galanidou, 2009; Deschamps et al., 2022; Henry et al., 2004; Vaquero and Pastó, 2001; Vidal-Matutano, 2017; Villaverde et al., 2017). In Cova de les Cendres, the preservation of overlapping combustion structures allows us to assess the distribution of the archaeobotanical remains in relation to these anthropic structures, around which activities took place along the Upper Magdalenian. However, we must take into account that the analysis is restricted to a reduced area of the potentially occupied space, where, moreover, the level has been eroded at some points (SM Fig. 1). The presence of the three big boulders conditioned the use of the space and allowed its subsequent preservation. Although the combustion structures are well preserved, some post-depositional alterations could befall as a result of the human reoccupation of this space. In fact, the presence of archaeobotanical charred remains throughout the area points to their scattering from the hearths due to trampling, cleaning activities or natural processes, although runoff was not detected in the micromorphological analysis (Bergadà et al., 2013). Thus, most of the assemblage can be classified as Hubbard and Clapham's type C (1992) and Fuller and Weber's grade 3 (2005), that is, representing recurrent activities or carbonisation events which cannot be discriminated because of the palimpsest structure of the deposit. However, some remains can be classified as primary refuse or residual primary refuse (Miksicek, 1987;



**Fig. 7.** Distribution and density map of mineralised remains.

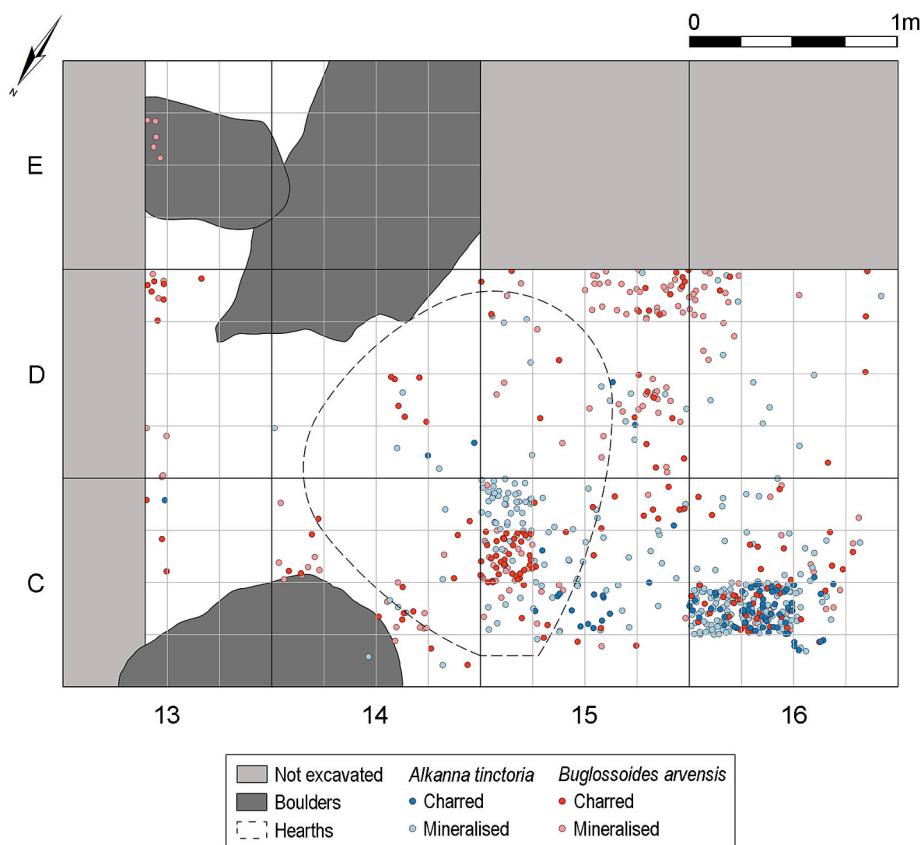


Fig. 8. Distribution of charred and mineralised remains of *Alkanna tinctoria* and *Buglossoides arvensis*.

(Schiffer, 1987, 1972) or in Hubbard and Clapham's type B (1992) since they are still in the hearths zone. We cannot dismiss that this zone was not used to light a fire during some occupational episodes or particular phases of the different occupations. Furthermore, we must consider the possible existence of combustion structures outside the analysed area that could alter some remains. Despite these shortcomings, considering the significance of this combustion zone, some relevant ideas derive from the spatial analysis to characterise human activities and post-depositional processes.

Based on the distribution of lithics and faunal remains, and mainly on the distribution of lithic chips, the likely concentration of human activities was in squares CD/15–16 (Bel et al., 2015). Plant remains are also more frequently documented in squares CD/15–16, which points to a link between the archaeobotanical effectiveness and human activities. This positive spatial relation between carpological and other archaeological remains may reject that the formation of the carpological assemblage would be the result, in general terms, of natural processes, such as runoff or bioturbations. The intensity of the occupation could explain the high fragmentation of the reproductive remains: 70.9 % of the assemblage is fragmented.

Considering the higher frequency of remains in squares CD/15–16, some abundant taxa have a very focused distribution in this part of the area: *Alkanna tinctoria*, *Fabaceae* and pine bark. Their distributions fit particularly well with the preferred human occupation of this space. Furthermore, the remarkable presence of charred remains of *Alkanna* and pine bark outside the hearths zone could be linked with the post-depositional alterations related to human reoccupation of this space, such as trampling or cleaning tasks.

Some taxa are concentrated in the hearths zone. It is the case of *Juniperus* endocarps, pine scale fragments or *Viscum* sp. bark. On the one hand, this reinforces the interpretation of their presence in the cave because of the gathering of firewood: juniper, pine and mistletoe were

identified among the anthracological assemblage (Badal and Martínez-Varea, 2018). Juniper fruits, pine cones and mistletoe twigs could still be attached to the gathered branches. On the other hand, their high concentration evinces an isolated event in a space that could be less post-depositionally altered. The distribution of the remains highly altered by fire, mainly restricted to the hearths zone, can be interpreted similarly. Their scarce frequency makes a post-depositional displacement less probable, contrasting with other abundant remains, such as pine bark and charred Boraginaceae, which frequently appear outside the hearths zone. Although we have not analysed the vertical distribution of the remains in detail, we can use the stratigraphical field information to assess the distribution of some taxa. In this sense, mistletoe bark fragments and the juniper endocarps are concentrated in the hearths in the lower part of the level, whereas pine bark fragments are mainly documented through the area in the upper part of the level, where mistletoe is also distributed outside the hearths (SM Table 3). This distribution could point to better preservation of the original positions in the first moments of the formation of the level and to more frequent alterations in its upper part. These differences detected in the vertical sense are coherent with some duration of the formation of the level. The widening of the vertical analysis in the future, including more taxa and comparing them with the distribution of other remains, can shed light on this question.

The documentation of some edible seeds in the hearths zone or in their surroundings could be explained by an accidental loss during cooking. It could be the case of legumes, which must be processed before their intake by soaking or boiling (Stahl, 1989; Valamoti et al., 2011). The edible seeds of *Cirsium arvense* and *Carduus Marianus* are pounded and boiled before consumption (Berdonces i Serra, 1998; Bouby and Billaud, 2005, p. 276). Moreover, they are represented mainly in a localised concentration, hence they could be linked to a one-off event. Humans could also gather Poaceae caryopsis and processed them by

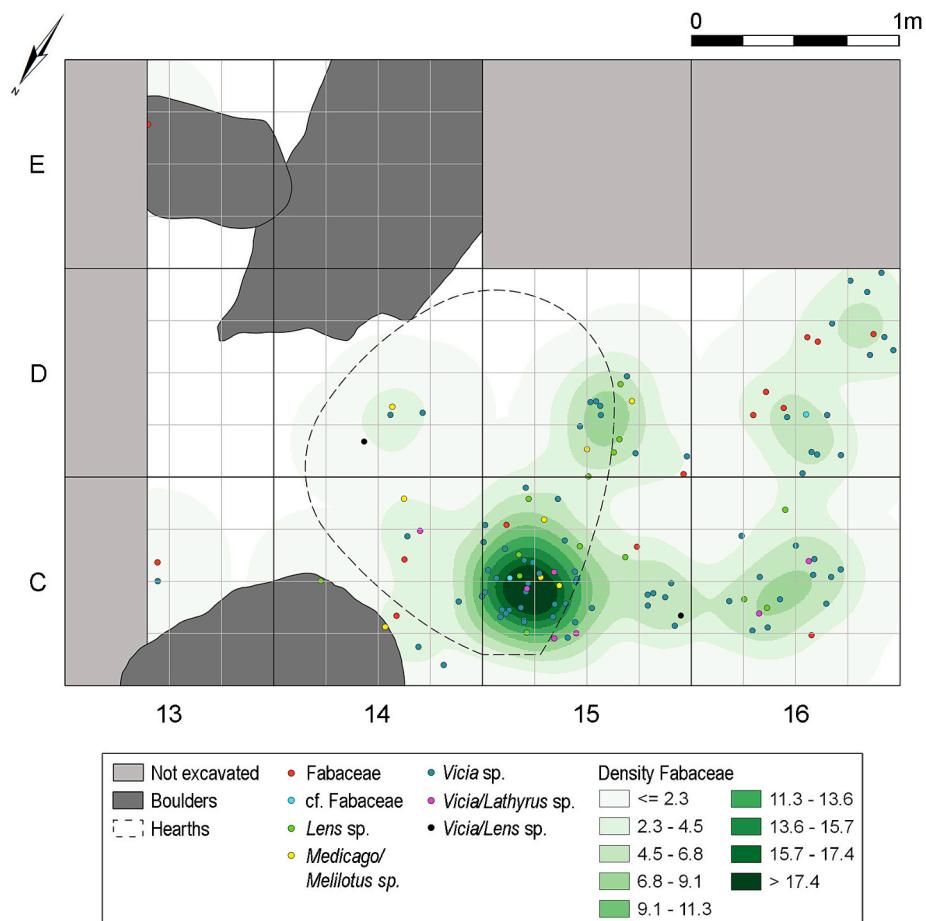


Fig. 9. Distribution and density map of Fabaceae seeds.

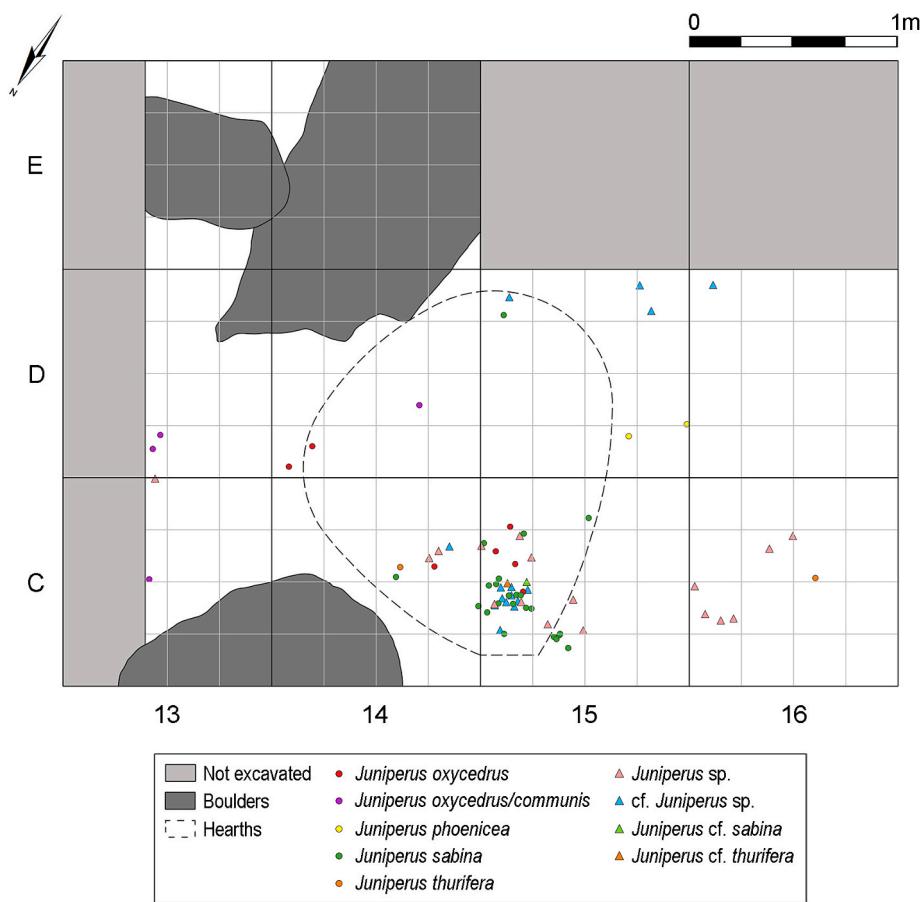


Fig. 10. Distribution of *Juniperus* spp. remains.

roasting, when they could fall into the hearth, where they are close to each other.

Other edible plant remains are scattered throughout the analysed area. This is the case of *Corema album*. Up to now, it has not been identified in the Middle and Upper Magdalenian levels of the site (Martínez-Varea et al., 2019b). Their dispersed distribution allows us to reject a possible intrusion from underneath levels due to localised bioturbations. The broad sampling carried out in level XI confirms the rarefaction of this species, of which just six remains were recovered. We hope that the widening of the study of level XII in the future will shed light on the evolution of this plant.

A feature widely documented is the presence of concentrations very spatially localised, both among abundant and scarce taxa or categories of remains: *Alkanna tinctoria*, *Buglossoides arvensis*, *Juniperus* endocarps, pine scale fragments, *Viscum* sp. bark fragments, *Cirsium/Carduus*, Monocotyledon leaves and stems, pteridophyte macrospores, indeterminate 2, endocarp 2, and uncharred and mineralised wood fragments. They are concentrated both horizontally and vertically (SM Table 4). These concentrations, or at least most of their remains, are probably the result of individual deposition events, as has been suggested for the scarce taxa at El Salt (Vidal-Matutano, 2017). In this sense, their restricted spatial distribution may preserve a configuration similar to the original one, suggesting less altered parts of the deposit, which could be linked to quick sedimentation processes. This is an exceptional feature in a cave context, where post-depositional alterations are frequent, as it was documented in other units and areas of the site (Bel, 2022), devoid of the singular preservation conditions of the analysed one.

In future analyses, it could be interesting to compare the situation of some of these concentrations with the spatial patterns of lithics, bones or lithic refits. The possibility that some result from natural post-depositional processes, such as bioturbations not detected during the

fieldwork, is generally rejected by the carbonisation of most of the remains and the spatial patterns exhibited. The natural growth of *Isoetes* inside the cave can be rejected since they grow in rivers and ponds on sandy soils (Jermý, 1964; Prada, 1983). We have pointed out elsewhere that they could be introduced to the cave with the plant for an unknown possible use or floating on fresh water transported to the cave (Martínez-Varea et al., 2019a). Besides, the spatial analysis proves its utility minimising the importance of some abundant species in the daily life of these human groups because most of the remains of a taxon could be deposited in a particular event. For instance, pine scales are very abundant in two adjacent sub-squares of C14, so they could result from the deposition of a few pine cones, considering the abundance of pine scales contained in one fruit.

Moving on to comment on particular concentrations, the high-density accumulation in square C16 is mainly formed by *Alkanna tinctoria* and *Buglossoides arvensis* nucules, besides mistletoe bark fragments. Considering their position outside the hearths zone, their restricted extension and the presence of charred and mineralised nucules of the same Boraginaceae taxa, they could represent a secondary refuse accumulation (Schiffer, 1972), formed in a particular episode and linked to cleaning processes of the hearths. Initially, they could be deposited in the hearths zone, where they were partially affected by fire; the presence of mineralised nucules –not charred– may be explained by their more protected location during the combustion event, maybe mixed with ashes, which avoided its carbonisation. These uncharred nucules could subsequently survive thanks to their natural high mineral content. This spatial coincidence of two states of preservation of the same taxa has also been interpreted as secondary deposition in Franchthi Cave (Hansen, 2001).

Concerning the Monocotyledon leaves and stems, the micromorphological analysis of the combustion structures of level XI documented

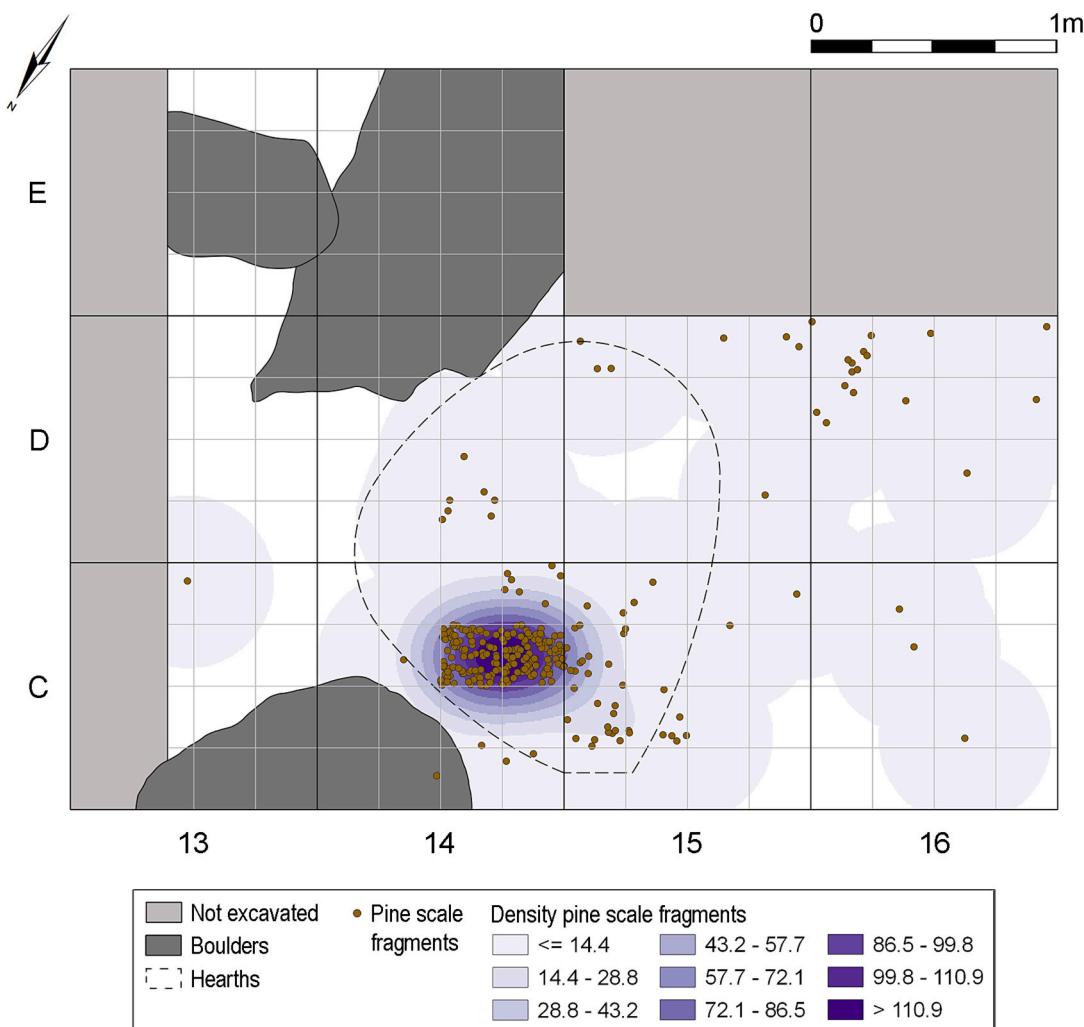


Fig. 11. Distribution and density map of *Pinus* sp. cone scale fragments.

the presence of articulated silica phytoliths (Bergadà et al., 2013). The location of the micromorphological sample was next to the concentration of leaves and stems from C14 so that they could be related. The leaves and stems of these plants could be used to make some vegetal bedding during the occupation of the area, as the micromorphological analysis highlights for the contact between the two microfacies of level XI (Bergadà et al., 2013, p. 73). Considering the fragility of these remains, their two very localised concentrations related to the hearths zone could indicate that these spaces had particularly good conservation conditions.

Regarding the mineralisation processes, they could significantly affect square D16, where most remains are mineralised and a concentration of pteridophyte macrospores was recovered. Their clustered distribution could be linked to a particular depositional event, and then they would be affected by mineralisation agents. A great source of phosphates in level XI could be discarded, based on the absence of guano accumulation (Bergadà et al., 2013). The mineralised remains subjected to energy dispersive X-ray microanalysis had high calcium content (Martínez-Varea et al., 2020). The bones deposited in the level or the cave walls could be the source of calcium carbonate.

## 5.2. Uses of plants

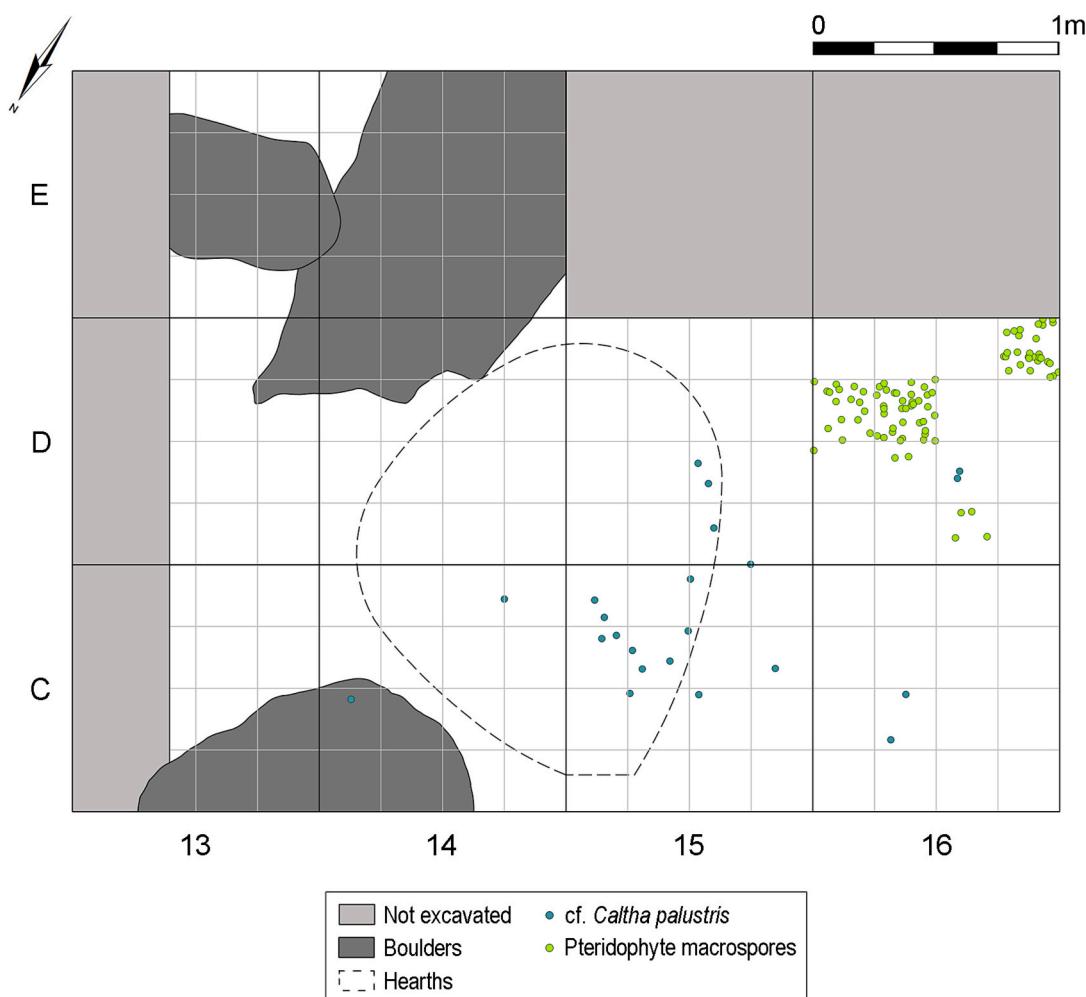
The results of the spatial analysis of the archaeobotanical remains combined with the characteristics of the carpological assemblage, the comparison with the anthracological record and the traditional uses of

the identified plants shed some light on the use of plants by hunter-gatherers during the Upper Magdalenian in Cova de les Cendres.

*Juniperus* endocarps, mistletoe bark, and pine cone scales, bark and needles could be brought to the cave with the firewood, as these species are documented in the anthracological assemblage (Badal and Martínez-Varea, 2018). The uncharred wood fragments could be remains of the firewood that fell among the ashes where their combustion stopped (Chravazzez, 2013) or of the firewood stock.

Hunter-gatherers could use a great variety of species, including seeds and fruits, as food. Legumes are a source of proteins and minerals (FAO, 2016), and *Cirsium arvense* and *Carduus marianus* seeds are rich in fatty acids (Berdones i Serra, 1998, p. 276). *Corispermum gallicum* (Badal and Martínez-Varea, 2022) and Poaceae seeds could be used as food, previously processed near the hearths. *Buglossoides arvensis* seeds have a high content of fatty acids (Jones, 2009), so we cannot discard an intentional gathering with this aim. *Corema album* and *Sambucus* fruits, rich in vitamin C (Génevè and Génevè, 2013, p. 145; Martínez-Varea et al., 2019b), could be gathered as food, and their inedible seeds discarded. Humans could also consume stems, leaves or roots of Lamiaceae, *Reseda* sp., *Galium* sp. or cf. *Caltha palustris*, being their seeds unintentionally deposited in the cave.

Other remains can be related to the use of plants as raw material. It is the case of the *Stipa tenacissima* rhizomes or the Cyperaceae seeds, which would be discarded when the leaves of these species were processed for basketry and ropemaking manufacture. Monocotyledon and Poaceae stems and leaves could be the remains of this raw material or parts of the



**Fig. 12.** Distribution of cf. *Caltha palustris* and pteridophyte macrospores.

bedding (Bergadà et al., 2013). *Alkanna tinctoria* roots provide red dye used to colour leathers and textiles (Pardo de Santayana et al., 2018, pp. 97–98), so their seeds could be unintentionally brought to the cave with the whole plant. Their abundance coincides with evidence of fur extraction and process based on archaeozoological remains (Real, 2021) and the significant presence of endscrapers (Villaverde et al., 2012).

The relevance and diversity of plants in the Magdalenian subsistence were also detected in other sites, such as Santa Maira (Aura et al., 2005), Taforalt (Carrión Marco et al., 2018), Franchthi Cave (Hansen, 1980) or Balma de l'Abeurador (Vaquer and Ruas, 2009). This archaeobotanical record suggests an intensification of the use of plants as food, with an increase in processing (Power and Williams, 2018), and with other aims (Aura et al., 2020).

## 6. Conclusions

The Upper Magdalenian level of Cova de les Cendres has provided a rich archaeobotanical assemblage. Together with wood charcoal fragments, seeds, leaves, stems, bark and uncharred wood were also documented. Their abundance and diversity, ecological requirements and spatial distribution support their introduction by humans into the cave, unintentionally or intentionally, for various purposes: firewood, food and raw material.

Concerning the spatial analysis, the general distribution of the archaeobotanical remains mainly agrees with that of lithics and faunal remains, highlighting their link to anthropic activities and pointing out the preferred location of the humans that occupied this area. On the one

hand, part of the carpological assemblage was post-depositionally altered, mainly due to trampling and the repeated human occupation of the area. Nevertheless, the degree of integrity of the level must also be assessed based on other proxies, such as the spatial analysis of the lithic and bone industry, faunal remains or refits of different materials. On the other hand, some concentrations point to the existence of better preserved areas throughout the formation of the level, which illustrate singular deposition events, such as a firewood input. Besides, some taxa, represented by scarce remains, may also preserve a location similar to the original one. Despite the post-depositional processes, the recovery of fragile remains, such as Monocotyledon leaves and stems, points to good preservation of the assemblage and the stability of the deposit in particular spaces.

The spatial study of the carpological remains allows us to relate the archaeobotanical record with human activities, even detecting some actions. However, the characteristics of the record limit the possibility of reconstructing activity areas: we only have remains preserved thanks to carbonisation or mineralisation, so it is difficult to document the uses developed away from hearths. In a context of a reoccupied area such as this, this type of analysis seems more useful to recognise certain formation processes, not only of the archaeobotanical assemblage but also of the archaeological deposit. Our work has raised new questions in this sense, but the main results obtained will be integrated within the broad spatial analysis of level XI, which will include the whole archaeological assemblage, so our current interpretations can be confirmed or corrected.

Spatial analysis of archaeobotanical remains, particularly of

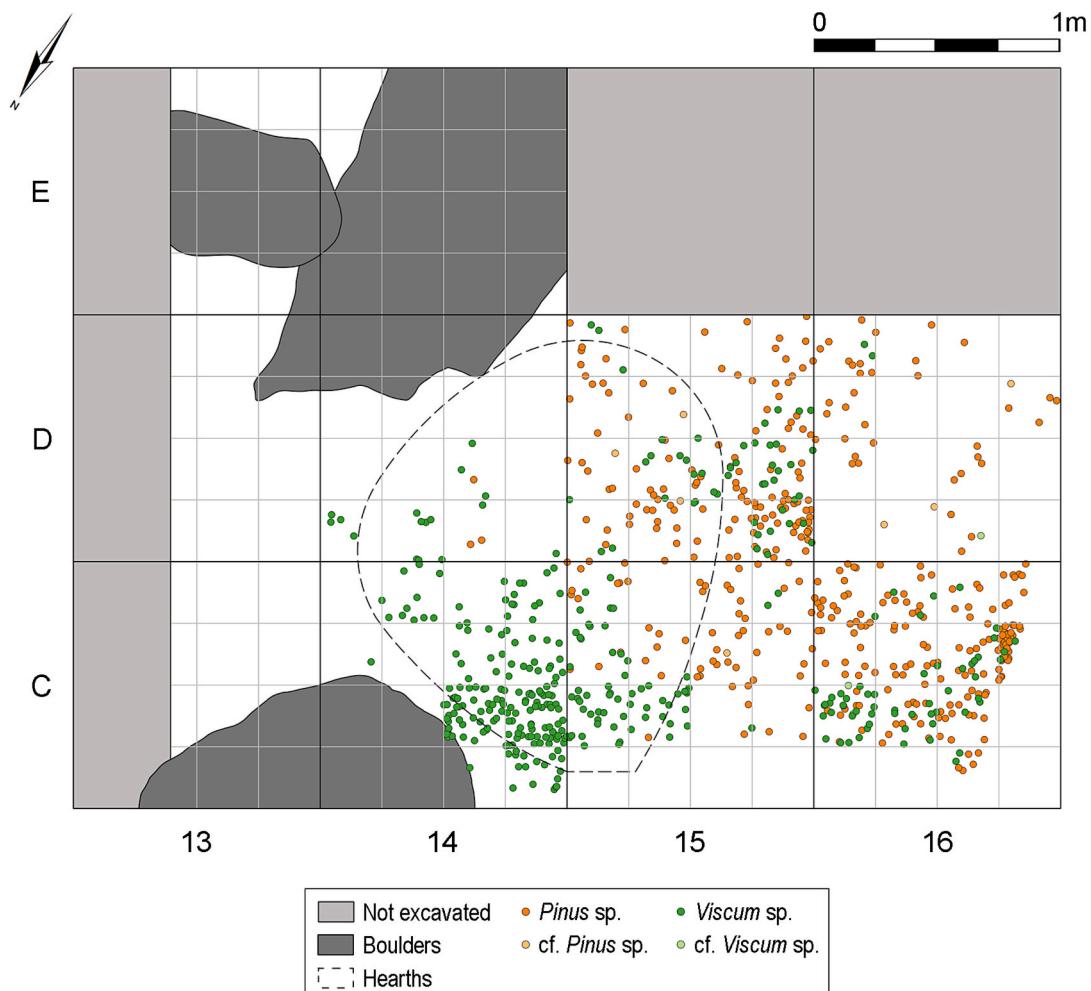
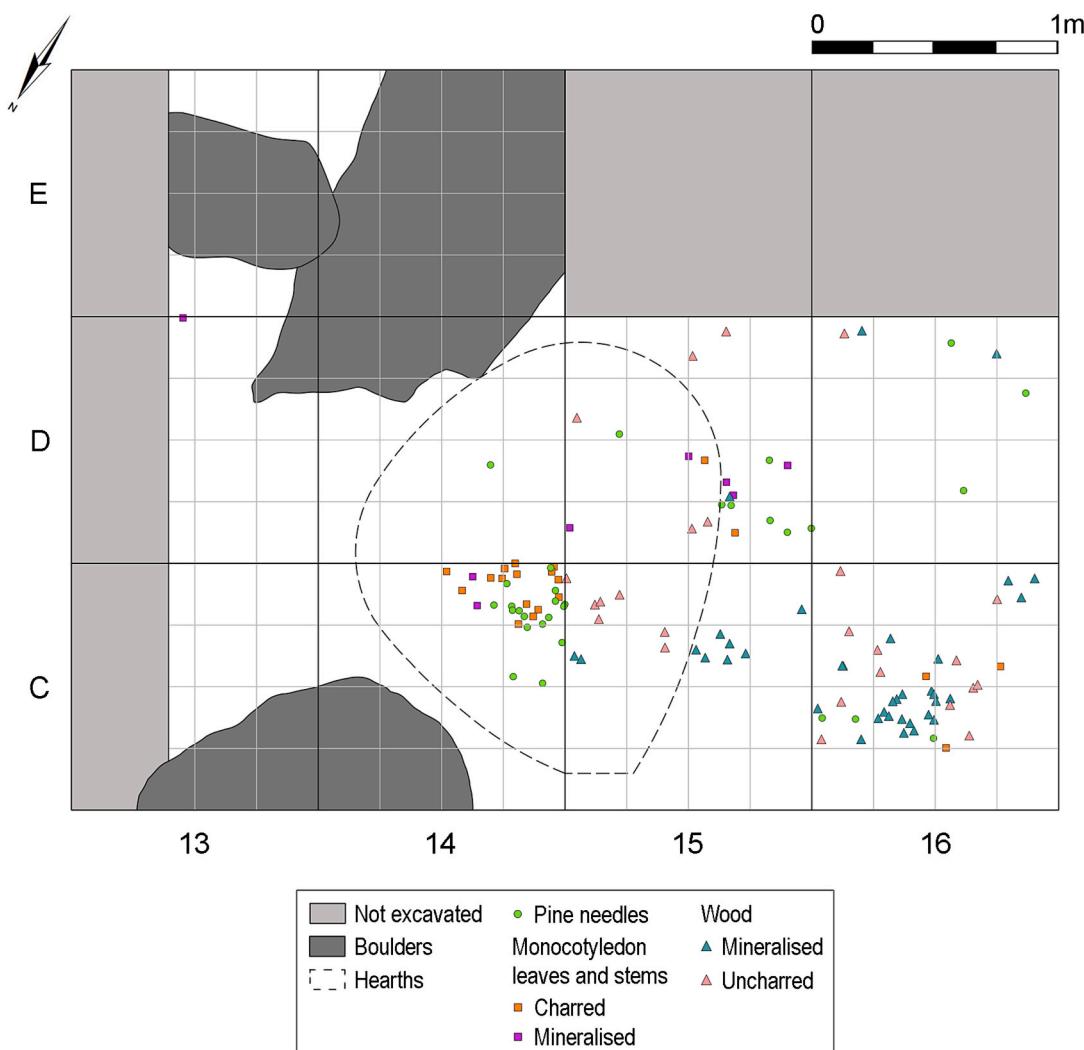


Fig. 13. Distribution of *Pinus* sp. and *Viscum* sp. bark fragments.



**Fig. 14.** Distribution of *Pinus* needles, Monocotyledon leaves and stems and mineralised and uncharred wood.

carpalogical assemblages, in Palaeolithic sites is rare, partially due to the scarcity of carpalogical analysis itself. However, our study underscores the necessity of extending this kind of research to shed light on the use of plants by Palaeolithic hunter-gatherers –a sphere of their daily life frequently undervalued by archaeologists– and to broaden the assessment of the formation processes of the archaeological deposits.

#### CRediT authorship contribution statement

**Miguel Ángel Bel:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Carmen María Martínez-Varea:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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#### 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.

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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2025.105378>.

#### Data availability

Data will be made available on request.

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