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Anthracological data from Middle Palaeolithic contexts in Iberia: What do we know?

Datos antracológicos de contextos del Paleolítico medio en la Península Ibérica: ¿Qué sabemos?

KEY WORDS: Charcoal analysis, Neanderthals, Paleoenvironment, Marine Isotopic Stage, Iberian Peninsula.
PALABRAS CLAVES: Antracología, Neandertales, Paleoambiente, Estadio Isotópico Marino, península Ibérica.
GAKO-HITZAK: Antrakologia, Neanderthalak, paleogiroa, itsasoko egoera isotopikoa, Iberiar penintsula.

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ABSTRACT

In this paper, a state of the art regarding the available anthracological data from Middle Palaeolithic contexts in Iberia is presented. The information retrieved is still very scarce and fragmented, as many Iberian areas present palaeobotanical gaps leading to the lack of information regarding local landscape dynamics. The use of different sampling methods to recover wood charcoal remains is a decisive factor which hampers the comparative study, although the dominance of *Pinus nigra-sylvestris* (black-scots pine) is recorded since, at least, Marine Isotopic Stage 6. This would indicate the widespread presence of cryophilous pine woodlands during the Upper Pleistocene in Iberia pointing to the prevalence of supramediterranean conditions (MAT = 8 - 13 ºC). This state of the art aims to contribute to our understanding of Upper Pleistocene Iberian landscapes based on Neanderthal firewood gathering activities.

RESUMEN

En este trabajo se presenta un estado de la cuestión relativo a los datos antracológicos disponibles para el Paleolítico medio en la península Ibérica. La información obtenida es todavía muy escasa y fragmentada, existiendo muchas áreas peninsulares con lagunas de datos relativos a las dinámicas de la vegetación local. La utilización de métodos de muestreo diferentes en la recuperación de los restos antracológicos constituye un factor decisivo que dificulta el estudio comparativo, aunque el dominio de *Pinus nigra-sylvestris* (pino salgareño-albar) está documentado desde, al menos, el Estadio Isotópico Marino 6. Ello indicaría la presencia de extensiones de bosques de pinos criófilos durante el Pleistoceno superior en la península Ibérica con el predominio de condiciones supramediterráneas (TMA = 8 - 13 ºC). Este estado de la cuestión pretende contribuir a una mayor comprensión de los paisajes ibéricos durante el Pleistoceno superior a partir de la recolección de leña por parte de los grupos neandertales.

LABURPENA

Lan honetan, Iberiar penintsulako Paleolitiko ertainerako eskuragarri dauden datu antrakologikoei buruzko gaur egungo egoera azaltzen da. Lortutako informazioa oraindik ere oso urria da eta zatituta dago eta bertako landarediaren dinamikei buruzko datuetan hutsuneak dituzten eremu ugari daude penintsulan. Hondakin antrakologikoak berreskuratzeko garaian laginketa-metodo ezberdinak erabiltzea faktore erabakigarria da eta horrek alderaketa egitea zailtzen du. Dena den, *Pinus nigra-sylvestris* (Larizio-pinua) zuhaitzaren eremua gutxienez itsasoko egoera isotopiko 6tik dokumentatuta dago gutxienez. Horrek agerian uzten du Iberiar penintsulan goi mailako Pleistozenoan pinu kriofiloen basoak zeudela eta baldintza suprameditarraneoak zirela nagusi (TMA = 8 - 13 ºC). Gaur egungo egoera honen helburua Neanderthalen taldeek egindako egur-bilketatik abiatuta goi mailako Pleistozeno garaiko paisaia iberiarrak hobeto ulertzen laguntzea da.

1. INTRODUCTION

Anthracology or charcoal analysis traditionally focuses on the botanical identification of charcoal fragments in order to obtain palaeoenvironmental (Badal, 1992; Badal and Heinz, 1989, 1991; Chabal, 1992, 1997; Figueiral, 1992; Thiébault, 1988) and palaeoeconomical data (Allué et al., 2016; Caruso et

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Abbreviations: MIS: Marine isotopic stage; MAT: Mean annual temperature.

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al., 2014; Chrzazvez et al., 2014; Henry and Boboeuf, 2016; Henry and Théry-Parisot, 2014; Théry-Parisot, 2001, 2002; Théry-Parisot et al., 2010; Vidal-Matutano, 2017; Vidal-Matutano et al., 2017b). Anthracological remains have the potential to offer palaeoecological and palaeoeconomical information according to the scattered or concentrated distribution of the sampled wood charcoal, respectively. Concentrated anthracological assemblages refer to punctual carbonization of wood by natural or anthropogenic causes. In Palaeolithic sites, the most common concentrated contexts are combustion structures, which are the result of the last firewood collecting actions in the supply area. These assemblages provide interesting palaeoeconomical data regarding firewood acquisition strategies by human groups. On the other hand, scattered anthracological assemblages contribute to meaningful palaeoenvironmental data as they are the result of several combustion events during different human occupations. In this sense, we must take into account that wood charcoal fragments recovered at archaeological sites are the result of firewood selection criteria and, as a consequence, a complete picture of the local flora cannot be achieved. However, as an average representation of cumulative processes resulting from an undefined number of occupation events, scattered charcoal fragments are mostly representative of the woody local flora (Badal and Heinz, 1991; Chabal, 1997).

The emergence of the first systematic approach in charcoal analyses with the *École de Montpellier*, during the 80s and 90s, led to the consolidation of the anthracological methodology and the palaeoecological representativeness of charcoal assemblages (Chabal, 1997). This methodological establishment allowed the development of several regional studies in France, Italy, Portugal or Spain (Badal, 1990; Bazile-Robert, 1979; Chabal, 1991, 1982; Figueiral, 1990; Heinz, 1988). Recently, other research approaches have been applied to charcoal analysis from a palaeoeconomical point of view based on experimentation, observation of microanatomical features due to biological or mechanical processes, dendrological studies or spatial analysis of anthracological remains (Carrión, 2007; Caruso et al., 2014; Henry and Théry-Parisot, 2014; Marguerie and Hunot, 2007; Théry-Parisot and Costamagno, 2005; Théry-Parisot and Henry, 2012; Vidal-Matutano, 2017; Vidal-Matutano et al., 2017a; Vidal-Matutano et al., 2017b). Nevertheless, despite the great advances made in anthracology, there are still very few published studies in Middle Palaeolithic contexts from Iberia (Allué et al., 2017; Allué et al., 2018; Badal et al., 2012a; Daura et al., 2015; Gale and Garruthers, 2000; Ros, 1985; Uzquiano, 1992, 2005; Uzquiano et al., 2008; Uzquiano et al., 2012; Vidal-Matutano, 2017; Vidal-Matutano et al., 2015; Vidal-Matutano et al., 2017a; Vidal-Matutano et al., 2017b; Vidal-Matutano et al., 2018; Zilhao et al., 2016) although they constitute valuable data to go further in our understanding of Iberian Middle Palaeolithic landscapes

1.1. Middle Palaeolithic: diversity of landscapes and climates

Upper Pleistocene is framed between ca. 126 ka and 11.7 ka BP (Rasmussen et al., 2006, 2014). During this long period of time the climate and the landscape did not remain stable, but continuous climatic changes with varying intensity depending on periods and regions had place. Thus, the first of the marine isotopic stages that took place during the Upper Pleistocene was MIS 5 or Last Interglacial (Woillard, 1978), a period characterized by the presence of a minimum ice volume at high latitudes between ca. 126 – 75 ka BP. The climatic fluctuations recorded during MIS 5 have led to their division into cold (5d and 5b) and warm episodes (5c and 5a) together with the warmest interval (5e or Eemian) where similar climatic conditions to the present were developed (Sánchez Goñi et al., 1999; Shackleton, 1969). MIS 4 glacial period (ca. 75 – 60 ka BP) was characterized by a minimum of summer insolation on the northern latitudes producing a greater extension of polar ice caps and a descent of the sea level (Rasmussen et al., 2006; Sánchez Goñi and d'Errico, 2005). Finally, MIS 3 period (ca. 60 – 25 ka BP) was not less variable from a climatic point of view, since it was an interstate period identified by the alternation of temperate cycles or Dansgaard-Oeschger events (Dansgaard et al., 1993) and cold phases or Heinrich events (Heinrich, 1988). Therefore, Middle Palaeolithic human groups lived in several environments occupying different European altitudes and latitudes. Biogeographic characteristics of each area would have led to the recognition of a plurality of landscapes and biotopes where Neanderthal groups may have met their daily needs. The aim of this paper is to collect the available anthracological data during the Middle Palaeolithic in Iberia. This state of the art regarding Middle Palaeolithic charcoal analyses will allow us obtaining significant palaoenvironmental data based on firewood gathering by Neanderthal groups in their surroundings. In addition, data review from these contexts will enable to assess the availability of macrobotanical data and the existing gaps in Iberia.

2. MATERIAL & METHODS

Regarding the available Middle Palaeolithic anthracological data in Iberia, the first consideration that should be highlighted is that it still constitutes very limited and fragmented information. Whether due to the poor organic preservation at many sites or a lack of interest, the fact remains that the available data concerning firewood use for Middle Palaeolithic contexts is still scarce (Théry-Parisot et al., 2010). Additionally, some Iberian regions gather most of the published studies while other areas present a total gap. Although this fragmented data could be related to the existence of regions with a deeper tradition in charcoal analyses, the methodological prejudices and the lack of interest in obtaining palaeobotanical data have contributed to

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this situation. Another point concerning the sampling methods used should be highlighted. The diversity of the applied sampling methods hampers a quantitative and qualitative anthracological data comparison between sites. Although systematical recovering methods based on the flotation of sediments have been increased in the last decades since the *École de Montpellier* studies (Badal and Heinz, 1991; Chabal, 1992, 1997), many wood charcoal assemblages are recovered still today by hand-picking sampling leading to biased results. In addition, another difficulty found in some published charcoal analyses has been the non-mention of the recovery method applied, which may hinder interpretation of data.

Table 1 includes the Middle Palaeolitic sites considered in this work. These archaeological sites, belonging to MIS 6 – 3, provide available palaeoenvironmental data for these chronologies and the most representative level (in terms of number of wood charcoal fragments identified) of each site has been selected. Those sites in which the anthracological results have been published quantitatively are reflected in the Table. In this sense, those sites with quantitative data presenting, at least, 100 wood charcoal fragments identified in a stratigraphic unit have been graphically represented. Additionally, those sites without quantitative data published appear at Table 1 following a presence / absence system. Finally, other factors such as longitude, latitude and altitude (m a.s.l.) have been recorded for each site, as they are influential variables in the composition of local flora (Rivas Martínez, 1987). In addition, the sampling method applied at each site has also been recorded.

Although the discussion of this work is not focused on pollen data obtained for these chronologies, a comparative study of how many Iberian Middle Palaeolithic contexts presenting palynological, anhracological or both proxies analyses has been considered. Regarding this, palynological data tend to be more abundant than charcoal analyses (Fig. 1). MIS 3 period, the moment when there is greater available palaeobotanical data compared to previous periods, clearly reflects this dynamic with a total of 10 sites presenting data from both proxies. This indicates that the application of different archaeobotanical proxies to obtain complementary data concerning landscape dynamics is not a widespread practice yet.

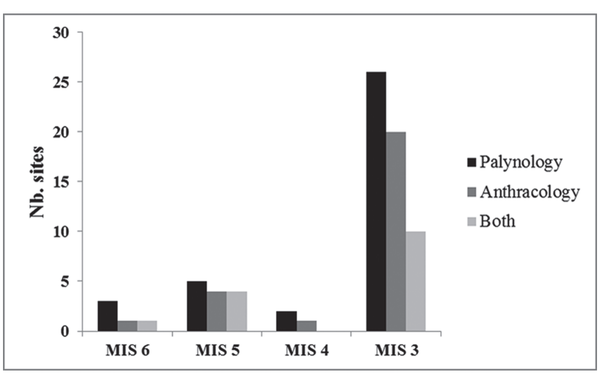

Fig. 1. Number of Iberian Middle Palaeolithic sites presenting palynological, anthracological and both archaeobotanical proxies. / Número de yacimientos del Paleolítico medio de la Península Ibérica con datos palinológicos, antracológicos y de ambos proxies.

The identified flora at the published Middle Palaeolithic sites has been classified into five main groups:

- Cryophilous pines, mostly identified as *Pinus nigra-sylvestris*. Nowadays, *Pinus sylvestris* and *Pinus nigra* can be found above 1000 – 1200 m asl occupying the supramediterranean and/or oromediterranean mountains of Iberia, although *Pinus sylvestris* requires cooler conditions than *Pinus nigra* and mostly grows in the oromediterranean bioclimatic belt (Rivas Martínez, 1987).
- Warm pines, identified as *Pinus pinea, Pinus halepensis or Pinus pinea-pinaster*. These are pine species with warmer bioclimatic requirements than the previous ones, documented generally at archaeological sites located south of the 40ºN parallel (Badal et al., 2012b).
- Juniper forest and heliophilous taxa. Although the distinction between the different species of the *Juniperus* genus (*J. oxycedrus, J. phoenicea, J. communis, J. thurifera*) cannot be reached based on the anatomical observation, they are all species showing a great resistance to conditions of extreme aridity. For this reason, other taxa with heliophilous nature such as woody legumes, *Ephedra o Artemisia* have also been included in this group.
- Mixed forest, composed by sclerophyllous and deciduous taxa like Rosaceae species, Pistacia, Labiatae, *Rhamnus* or Cistaceae. In northern Iberian sites this group includes Eurosiberian taxa like *Corylus avellana* or *Castanea sativa*, which are only present in these latitudes.
- Ripisylve, composed by taxa present in the bottom of the valleys or in humid areas (*Fraxinus, Salix-Populus, Ulmus*).

Along with these categories, other taxa have been considered separately such as *Betula* (Birch), *Quercus* evergreen (evergreen oaks), *Quercus* deciduous (deciduous oaks), *Olea europea* (Olive tree), *Acer* (Maple) and *Buxus sempervirens* (Bow). Although these taxa could be included in the previous groups, their abundance in some regions and / or their significance as bioindicators has determined their individual consideration.

3. RESULTS & DISCUSSION

3.1. Available anthracological data

Regarding the first chronological period considered (MIS 6), there are still few known archaeological

ID	Site	Location	Latitude	Longitude	m asl	MIS	Level	P	Ch	Method
1	Abric del Pastor	Alcoi, Alicante	38,7131	-0,4909	820	4	IV		x	F
2	Abric Romaní	Capellades, Barcelona	41,3143	1,4128	300	3	Ja	x	x	H
3	Abrigo de la Quebrada	Chelva, Valencia	39,4825	-1,0049	708	3	IV	x	X	F
4	Abrigo de Navalmaillo	Pinilla del Valle, Madrid	40,9237	-3,8081	1114	4	F	x		
5	Cueva del Castillo	Puente Viesgo, Cantabria	43,1730	-3,5803	195	3	20		X	F
6	Cova 120	La Garrotxa, Girona	42,1706	2,5774	460	3	IV	x	X	H
7	Cova Beneito	Muro, Alicante	38,802	-4,4752	650	3	X	x		
8	Cova Bolomor	Tavernes de la Valldigna, Valencia	39,0581	-0,2524	100	6	XI	x	X	DS
9	Cova de l'Arbreda	Serinyà, Girona	42,0936	2,4449	200	3	H	x	X	F
10	Cova del Rinoceront	Castelldefels, Barcelona	41,1624	1,5739	25	5	I	x	X	H
11	Cova del Coll Verdaguer	Cervelló, Barcelona	41,3888	1,9554	450	3	I		X	H
12	Cova del Toll	Moià, Barcelona	41,8112	2,0959	745	3	IV	x		
13	Cova Foradà	Oliva, Alicante	38,8930	-0,1028	100	3	C5		X	H
14	Cova Gran	Santa Linya, Lleida	41,9015	0,8120	385	3	S1C	x	X	H
15	Covalejos	Piélagos, Cantabria	43,2348	-3,5558	105	3	H-J	x	X	F
16	Cueva Bajondillo	Torremolinos, Málaga	36,6236	-4,4916	10	6	XIX	x		
16	Cueva Bajondillo	Torremolinos, Málaga	36,6236	-4,4916	10	5	XVIII	x		
16	Cueva Bajondillo	Torremolinos, Málaga	36,6236	-4,4916	10	4	XVII	x		
16	Cueva Bajondillo	Torremolinos, Málaga	36,6236	-4,4916	10	3	XVI	x		
17	Cueva Antón	Mula, Murcia	38,0547	-1,2947	355	5	AS5	x	x	F
18	Cueva de Abauntz	Arraitz, Navarra	43,0061	-1,6599	650	3	H	X		
19	Cueva de Amalda	Cestona, Gipuzkoa	43,2385	-2,2535	110	3	VII	X		
20	Cueva de Arrillor	Araba, País Vasco	42,9529	-2,7593	710	3	AMK	X		
21	Cueva de la Buena Pinta	Pinilla del Valle, Madrid	40,9437	-3,4081	1114	3	III	X		
22	Cueva de la Carihuela	Piñar, Granada	38,0915	-3,3546	1020	3	VI	X		
23	Cueva de los Moros de Gabasa	Peralta de Calasanz, Huesca	42,0181	0,3752	780	3	G	X		
24	Cueva del Boquete de Zafarraya	Málaga	36,5704	-4,0738	1022	3	II	X	X	H
25	Cueva del Camino	Pinilla del Valle, Madrid	40,9281	-3,8202	1114	5	5	X	X	F
26	Cueva del Conde	Tuñón, Santo Adriano	43,1723	-5,5854	180	3	20A		X	F
27	Cueva del Otero	Voto, Cantabria	43,3229	-3,512	60	3	IX	X		
28	Cueva Morín	Villaescusa, Cantabria	43,3499	-3,8704	57	3	XII	X		
29	Cueva Perneras	Lorca (Murcia)	37,7012	-1,7121	105	3	IX	X		
30	El Esquilleu	Cillorigo de Liébana, Cantabria	43,1250	-4,3526	350	3	XIII	X	X	F
31	El Salt	Alcoi, Alicante	38,6876	-0,5082	680	3	XB	X	X	F
32	Gorham's Cave	Gibraltar	36,0713	-5,2031	10	3	IV	X	X	F
33	Gruta da Oliveira	Torres Novas, Portugal	39,3019	-8,3655	115	3	14-15		X	H
34	Higueral de la Valleja	Arcos de la frontera, Cádiz	36,4120	-5,4622	190	3	VI		X	H
35	Labeko Koba	Mondragón, Gipuzkoa	43,0627	-2,4923	246	3	IX	X		
36	Las Fuentes de San Cristóbal	Veracruz, Huesca	42,2003	0,3425	820	3	G		X	H
37	Lezetxiki	Arrasate, Gipuzkoa	43,0395	-2,4184	345	6	R	X		
38	Roca dels Bous	La Noguera, Lleida	41,8408	0,8294	275	3	R3		X	H
39	Sima de las Palomas	Torre Pacheco, Murcia	37,7969	-0,892	80	3	II	X		
40	Teixoneres	Moià, Barcelona	41,8100	2,0971	900	5	II	X	X	H
41	Tossal de la Font	Vilafamés, Castellón	40,0920	-0,0722	357	3	IIA	X	X	H
42	Vanguard cave	Gibraltar	36,0713	-5,2031	10	3	IV	X	X	–

Table 1: Middle Palaeolithic sites considered and the available anthracological data. CrP = Cryophilous pines; WP = Warm pines; Jun = *Juniperus* and heliophilous taxa; Be = *Betula*; Q = *Quercus* sp.; Qe = *Quercus* evergreen; Qd = *Quercus* deciduous; Mf = Mixed forest; O = *Olea europaea*; Ac = Acer sp.; Bx = *Buxus sempervirens* and R = Ripisylve / Yacimientos del Paleolítico medio considerados y datos antracológicos disponibles. CrP = Pinos criófilos; WP = Pinos cálidos; Jun = *Juniperus* y taxones heliófilos; Be = *Betula*; Q = *Quercus* sp.; Qe = *Quercus perennifolio*; Qd = *Quercus caducifolio*; Mf = Bosque mixto; O = *Olea europaea*; Ac = *Acer* sp.; Bx = *Buxus sempervirens* y R = Rivera."

References	Nb. Charcoal	Min. Taxa	CrP	WP	Jun	Be	Q	Qe	Qd	Mf	O	Ac	Bx	R
Vidal-Matutano et al. 2015	957	16	105		500		89	87	5	126				45
Allué 2002; Burjachs 2012	652	2	651											1
Badal et al 2012a	182	2	181					1						
Ruiz Zapata et al 2008														
Uzquiano 1992	865	11	39			784				40				2
Agustí et al. 1991	59	8	26		11			1	7	14				
Carrión 1992														
Vidal-Matutano et al. 2017a	14	2	12		2									
Ros 1985	393	5	212							74		102		5
Daura et al 2015	7	2								7				
Allué et al. 2017	402	3	350						4	48				
Rosell et al 2014														
Badal 1984	33	8	12		3			5		11		2		
Martinez-Moreno et al 2010; Allué et al. 2018	102	2	101						1					
Uzquiano 2005	–	6	X			x				X				
Cortés-Sánchez et al 2008														
Cortés-Sánchez et al 2008														
Cortés-Sánchez et al 2008														
Cortés-Sánchez et al 2008														
Zilhao et al. 2016	621	13	13	336	138		78	15	22					19
Utrilla et al 2014														
Dupré 1988														
Sáenz de Buruaga 2014														
Ruiz Zapata et al 2008														
Carrión and Dupré 1994														
González-Sampériz 2004														
Lebreton et al 2006	–	5	X		X			X		X	x			
Arsuaga et al 2012	249	6	226			17			1	3				2
Uzquiano et al 2008	373	16	232		17	11				95				18
Leroi-Gourhan 1966														
Sánchez-Goñi 1994														
Carrión and Dupré 1994														
Uzquiano et al 2012	–	6	X			X				X				X
Vidal-Matutano et al. 2018	2999	12	2516		25		54	4	2	21		335	36	6
Carrión et al 2008; Gale and Garruthers 2000	184	7	X	x	X					X	x			
Badal et al 2012a	41	2	37		4									
Jennings et al 2009	–	2		x							x			
Sánchez-Goñi, 1991; Iriarte 2000														
Allué 2002	18	5	7		2				1	2			6	
Arrizabalaga 2014														
Terradas et al 1993	36	2	25		11									
Carrion et al 2003														
López-García et al 2012	4	3	2	1					1					
Olària et al 2004-2005	–	1		cf										
Carrión et al 2008; Gale and Garruthers 2000	49	8	X	x						X	x			X

sites with archaeobotanical data (Fig. 2). Only Bolomor Cave (level XI) provides wood charcoal data for this period, although it constitutes a reduced anthracological assemblage. At Bolomor Cave, undetermined wood charcoal fragments are abundant based on the small size of the fragments (< 1 mm) and the poor preservation, which is not the optimal to guarantee botanical determination at a higher resolution (Vidal-Matutano et al., 2017a). Hence, the anthracological record from Bolomor Cave is not abundant enough to assess the presence of mixed plant formations that should have been more abundant taking into account the current biogeographical location of the site (100 m a.s.l.). Despite this, charcoal analysis from this site shed light on the characterisation of the landscape, with the presence of *Pinus nigra-sylvestris* (cryophilous pines) pointing to the prevalence of meso-supramediterranean conditions (mean annual temperature [MAT] of 8-17 ºC) in Eastern Iberia during MIS 6 (Vidal-Matutano et al., 2017a).

During MIS 5 period, the number of sites is still scarce (Fig. 3). Available data is very fragmented and come from Cueva del Camino, level 5 (Arsuaga et al., 2012), Teixoneres, level II (López-García et al., 2012), Cova del Rinoceront, level I (Daura et al., 2015) and Cueva Antón, level AS5 (Zilhão et al., 2016). At Cueva del Camino and Teixoneres, both located at an altitude higher than or equal to 900 m a.s.l., the dominance of cryophilous pines is recorded together with the presence of other taxa like birch or mixed plant formations of Maloideae (Rosaceae family) and *Quercus* sp. deciduous. However, data from Teixoneres should be interpreted with caution since the analysed assemblage is too scarce due to wood charcoal recovering by hand-picking methods (n = 4). The same observation can be argued with respect to Cova del Rinoceront, as only a limited wood charcoal assemblage has been recovered (n = 7). Anthracological data from Cueva Antón, level AS5, is significantly different from the previous sites. At this site, although cryophilous pines are present at the record, the charcoal assemblage indicates open Aleppo pine forests (*Pinus halepensis*) with juniper and some oak growing under climatic conditions similar to present. The differences observed in flora composition between Cueva del Camino and Cueva Antón may be due to differences in latitude and altitude, but also because the archaeological levels could be framed in warmer or colder sub-phases of MIS 5.

During MIS 4 period, a vacuum regarding anthracological data is documented with the exception of Abric del Pastor, level IV (Vidal-Matutano et al., 2015) (Fig. 4). This site shows more than half of the anthracological record dominated by junipers and heliophilous taxa together with cryophilous pines. Besides this, a heterogeneous mixed forest, evergreen / deciduous oaks and

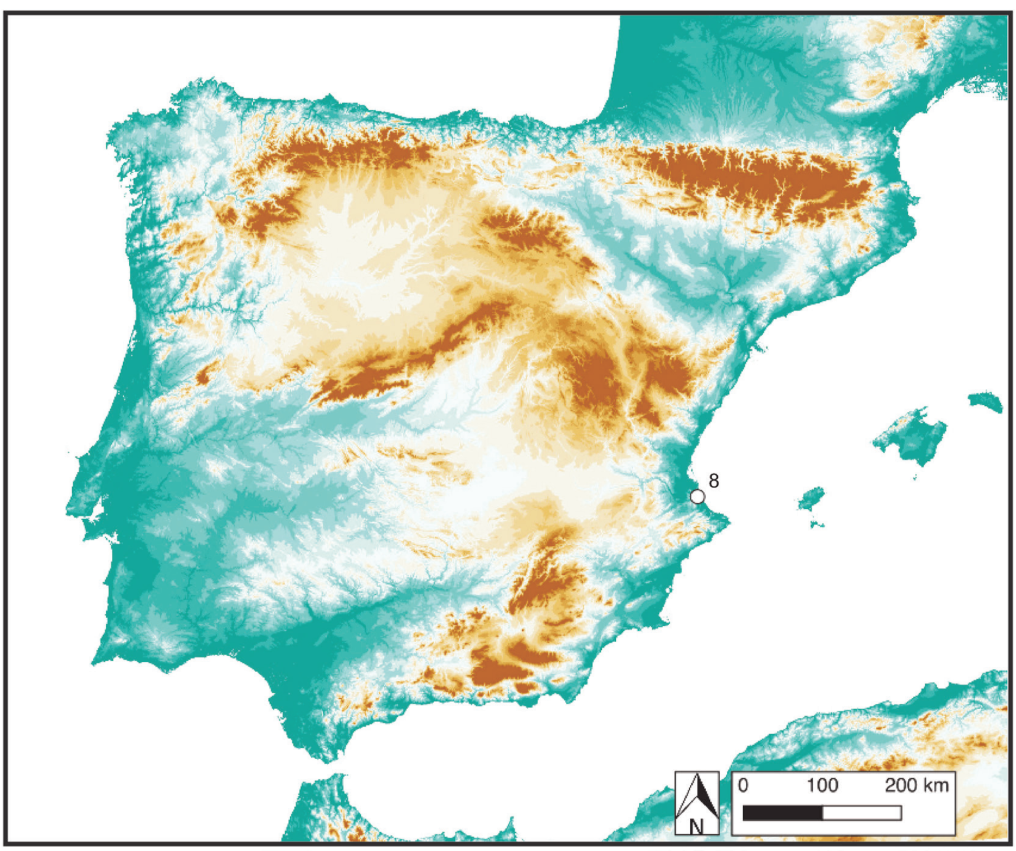

Fig. 2. Available anthracological data during MIS 6 period in Iberia. The number of the site refers to Table 1. / Datos antracológicos disponibles para el MIS 6 en la península Ibérica. El número se corresponde con el sitio indicado en la Tabla 1

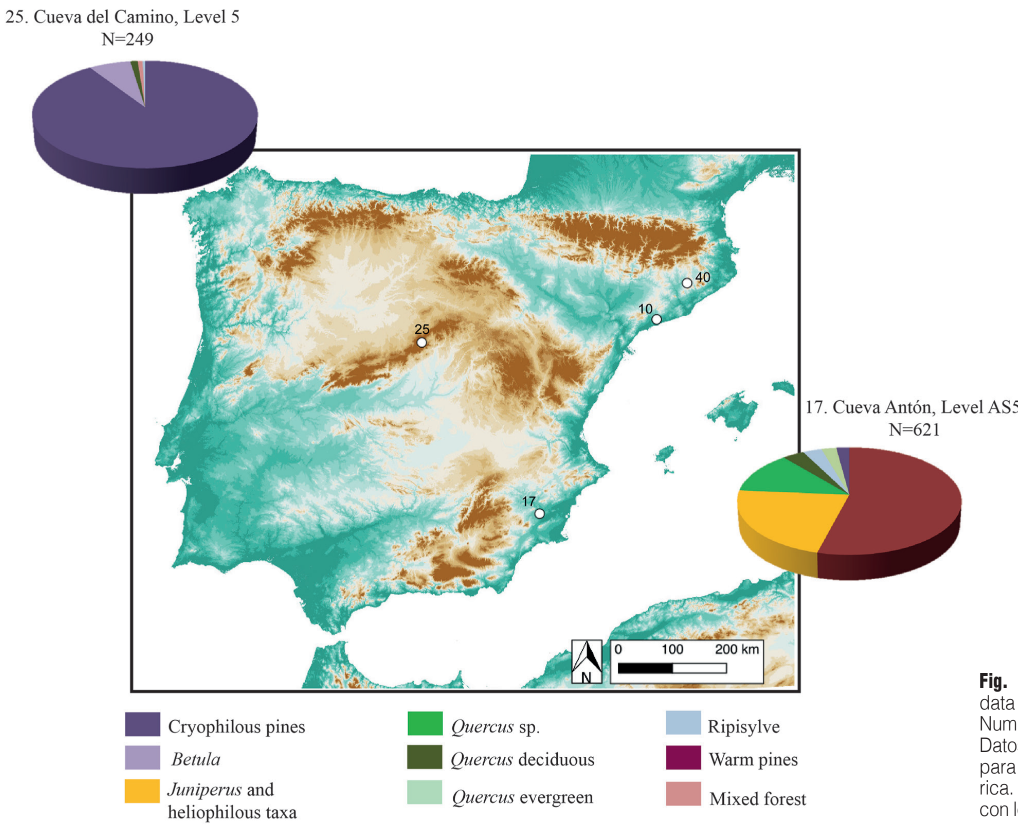

Fig. 3. Available anthracological data during MIS 5 period in Iberia. Numbers of sites refer to Table 1. / Datos antracológicos disponibles para el MIS 5 en la península Ibérica. Los números se corresponden con los sitios indicados en la Tabla 1

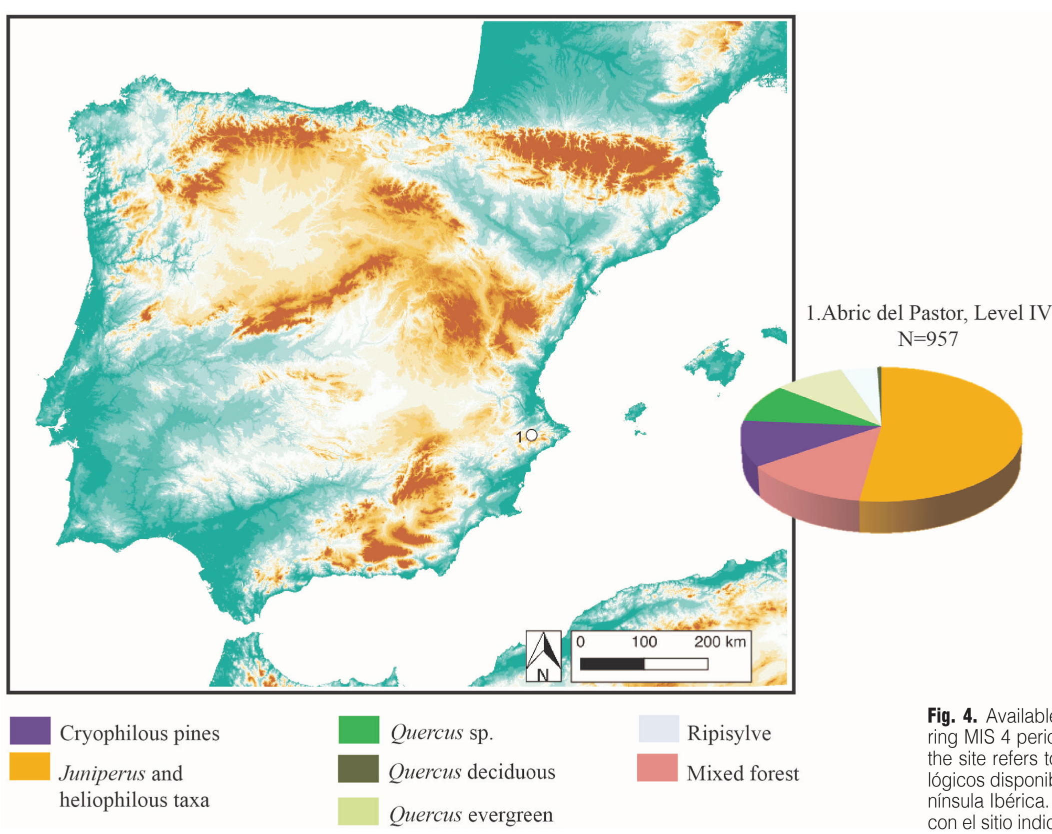

Fig. 4. Available anthracological data during MIS 4 period in Iberia. The number of the site refers to Table 1. / Datos antracológicos disponibles para el MIS 4 en la península Ibérica. El número se corresponde con el sitio indicado en la Tabla 1.

riverine taxa are also present, reflecting the typical plant formations present in a ravine like the one where Abric del Pastor is located. The predominance of juniper forest in this record is revealing prevailing arid, dry and cold conditions in, at least, eastern Iberia.

The number of known sites and the available anthracological data is noticeably increased since MIS 3 period (Fig. 5). In the north of Iberia (Fig. 5a), the available data from Cueva del Conde, level 20A (Uzquiano et al., 2008) and Cueva del Castillo, level 20 (Uzquiano, 1992) point out to the predominance of two taxa with different moisture requirements: the birch at Cueva del Castillo and cryophilous pines at Cueva del Conde. Uzquiano (1992) explains the differences in the dominant taxa based on the ecological characteristics of each area, i.e. the western area would be characterized by lower humidity conditions that would enable the development of cryophilous pine woodlands, while birch plant formations with higher moisture requirements would be present in the eastern area. It is significant to mention that the "mixed forest" category include the presence of *Corylus avellana* (hazel) and *Castanea sativa* (chestnut) at both sites, being Eurosiberian taxa with high humidity requirements that only grow at these latitudes (Costa et al., 2005). Complementary anthracological data, although not quantitatively available, come from Covalejos levels H-J (Uzquiano, 2005) and El Esquilleu level XIII (Uzquiano et al., 2012) which indicate the presence of

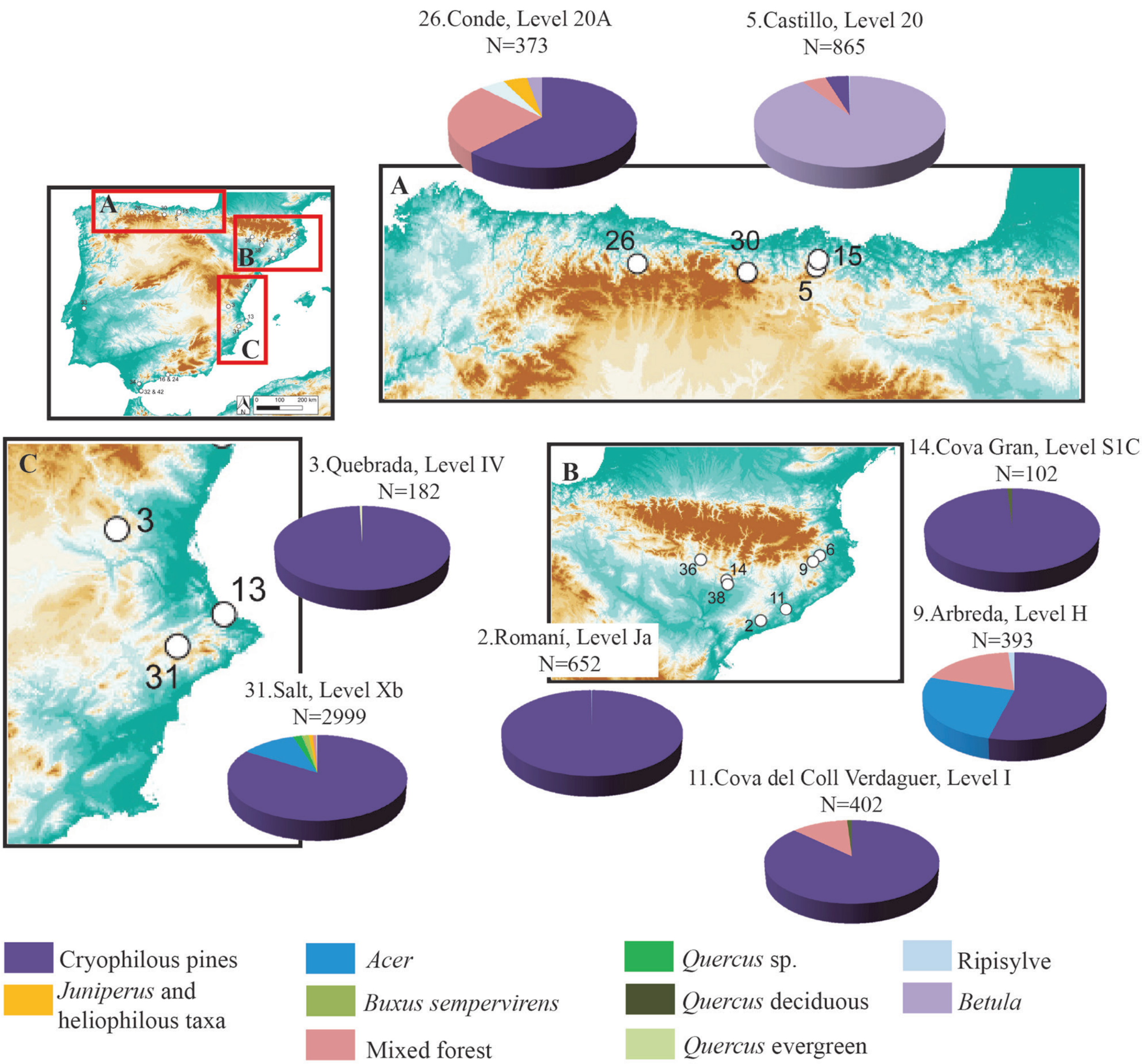

Fig. 5. Available anthracological data during MIS 3 period in Iberia. Numbers of sites refer to Table 1. / Datos antracológicos disponibles para el MIS 3 en la península Ibérica. Los números se corresponden con los sitios indicados en la Tabla 1

the plant formations mentioned. In northeast Iberia (Fig. 5b), anthracological data from Cova de l'Arbreda, level H (Ros, 1985), Abric Romaní, level Ja (Allué, 2002), Fuentes de San Cristóbal, level G (Allué, 2002), Roca dels Bous, level R3 (Terradas et al., 1993), Cova 120, level IV (Agustí et al., 1991), Cova Gran, level S1C (Allué et al., 2018) and Cova del Coll Verdaguer, level I (Allué et al., 2017) come mainly from hand-picking sampling, excepting Cova de l'Arbreda. They all reflect the dominance of *Pinus nigra-sylvestris*, together with the presence of junipers, evergreen / deciduous oaks, the mixed forest and riverine taxa. The almost absolute dominance of cryophilous pines at Abric Romaní and Cova Gran should be interpreted with caution since wood charcoal fragments from these sites were recovered by hand-picking methods. Indeed, flotation methods at Cova de l'Arbreda –an archaeological site with similar altitude than Abric Romaní or Roca dels Bous– allowed obtaining a more heterogeneous anthracological assemblage with a high presence of Maple. In eastern and southeastern Iberia (Fig. 5c), significant available data come from Quebrada, level IV (Badal et al., 2012a) and El Salt, level Xb (Vidal-Matutano et al., 2018), showing a general trend consisting in the dominance of cryophilous pines together with the presence of Maple, Oak forest and the mixed forest. In this sense, qualitative differences between both sites may come from the different number of wood charcoal fragments identified and published until now, as there are no differences in the sampling methods applied or the biogeographical conditions. Data from Cova Foradà, level C5 (Badal, 1984) and Tossal de la Font, level IIa (Olària et al., 2004-2005) represent values too low to have palaeoecological representativeness. In western Iberia the only available anthracological data come from Gruta da Oliveira, levels 14-15 (Badal et al., 2012a), even though they are too scarce to be representative of the area. Despite this, the few available data seem to be consistent with other Iberian areas, i.e. *Pinus nigra-sylvestris* dominance with junipers and heliophilous taxa. Finally, even though anthracological data from Gorham's Cave, level IV, and Vanguard Cave, level IV (Gale and Garruthers, 2000) are not published in absolute values, the presence of warm pines identified as *Pinus pinea-pinaster* (stone-pinaster pine) together with the presence of *Olea europaea* and Mediterranean shrubland taxa place the south of Iberia as one of the warmer areas in Europe during MIS 3 (Finlayson and Carrión, 2007). This assumption is confirmed by the presence of *Olea europaea* macroremains at other sites like Cueva del Boquete de Zafarraya, level II (Lebreton et al., 2006) and Higueral de la Valleja, level VI, where an olive nutshell recovered was dated at 42630-41390 cal. BP (Jennings et al., 2009).

3.2. Hand-picking vs. flotation: Are both methods equally representative of the local landscape?

As Table 1 shows, in most of the Middle Palaeolithic sites where anthracological data has been obtained hand-picking or flotation methods have been applied, although the recovering of wood charcoal fragments by hand still constitutes the most used sampling method (Fig. 6).

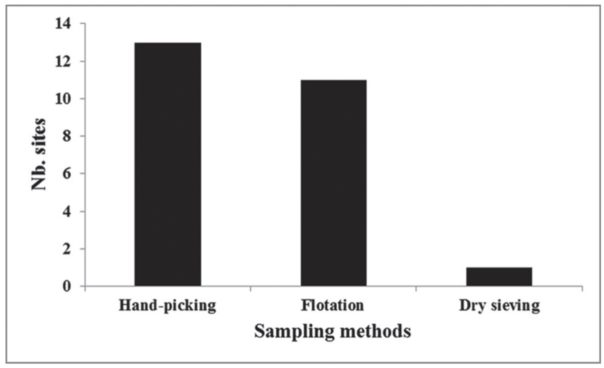

Fig. 6. Sampling methods used in Middle Palaeolithic sites from Iberia (data from Table 1). / Métodos de muestreo utilizados en yacimientos del Paleolítico medio de la península Ibérica (datos extraídos de la Tabla 1).

In order to reveal the danger involved from extracting palaeoecological inferences from those wood charcoal assemblages recovered by hand-picking, a comparative study between these two sampling methods is presented concerning units IX and Xa from El Salt, a MIS 3 Palaeolithic site located at Eastern Iberia (Vidal-Matutano, 2017; Vidal-Matutano et al., 2017b; Vidal-Matutano et al., 2018) (Table 2). The aim of this comparative study has been to assess if the palaeoecological data obtained from each sampling method is representative of the assemblage and if there is a statistical relationship. Thus, the Jaccard Index comparing the sampling methods in each unit allowed observing a trend towards dissimilarity (Table 3). Accordingly, the application of one or other method would not mean obtaining the same results. The spatial distribution of the hand-picked wood charcoal fragments from unit IX together with the frequency map of the anthracological remains recovered by flotation methods clearly reflects the squares where a double sampling method was applied and those where the material was only recovered by hand (Fig. 7). Hence, hand-picking of wood charcoal has provided the almost absolute predominance of the most frequent taxon (*Pinus nigra-sylvestris*) and the botanical identification of different taxa recovered as a single one (Labiatae + *Pinus nigra-sylvestris* or Cistaceae + *Pinus* sp.). The frequency map with wood charcoal fragments retrieved by flotation methods indicates a higher density of anthracological remains in A5, B5 and A6 squares, where some of the combustion structures from unit IX are located. The R value for hand-picking results points out to a clustered distribution pattern ($R = 0.39$), whereas R value for flotation results indicates a random distribution pattern ($R = 0.66$). Both values have a statistical significance of 99% ($C \geq 2.58$).

Regarding unit Xa from the same site, botanical identification of the hand-picked wood charcoal frag-

Units	IX				Xa			
Sampling method	**Flotation**		**Hand-picking**		**Flotation**		**Hand-picking**	
Taxa	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Acer sp.	10	6,45	2	2	43	7,30	12	3,88
Angiosperms	4	2,58			9	1,53	1	0,32
Buxus sempervirens	1	0,65	1	1				
Conifers	15	9,68	4	4	67	11,38	9	2,91
Ephedra sp.					2	0,34	1	0,32
Fabaceae	1	0,65						
Juniperus sp.	11	7,10			26	4,41	2	0,65
Monocotyledoneae					1	0,17		
Olea europaea					4	0,68		
cf. *Pinus nigra-sylvestris*					2	0,34		
Pinus nigra-sylvestris	105	67,74	93	93	407	69,10	281	90,94
Pistacia sp.	1	0,65			1	0,17		
cf. *Prunus* sp.					1	0,17		
cf. *Quercus* sp.					2	0,34		
Quercus sp.	3	1,94			13	2,21	3	0,97
Quercus deciduous					4	0,68		
Quercus evergreen					2	0,34		
Salix-Populus	4	2,58			5	0,85		
Total charcoal	**155**	100	**100**	100	**589**	100	**309**	100
Total taxa	**8**		**3**		**11**		**5**	

Table 2: Anthracological data from units IX and Xa of El Salt based on the sampling methods. / Datos antracológicos procedentes de las unidades IX y Xa de El Salt según los métodos de muestreo.

Unit	Jaccard Index
IX	0,4
Xa	0,5

Table 3: Jaccard Index results considering the sampling methods applied in units IX and Xa from El Salt. / Resultados del Índice de Jaccard considerando los métodos de muestreo aplicados en las unidades IX y Xa de El Salt

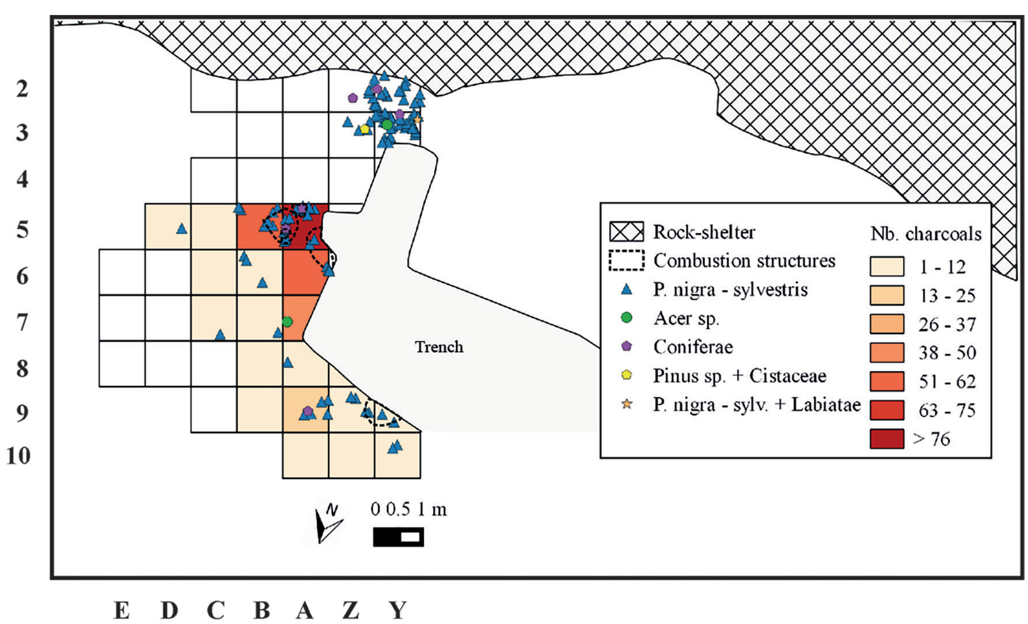

Fig. 7. Spatial distribution of the hand-picked charcoal fragments (symbols) and frequency map of the charcoal fragments from flotation in unit IX. White squares represent the lack of anthracological data. / Distribución espacial de los fragmentos de carbón recogidos a mano (símbolos) y mapa de frecuencias de los carbones recuperados en flotación para la unidad IX. Los cuadros blancos representan la ausencia de datos antracológicos.

ments revealed the collection of 2 - 3 different taxa considered as a single fragment, together with the recovering of small burnt bones or blackish sediment as charcoal during field work (Fig. 8 A). The spatial distribution of anthracological remains from flotation allowed observing a not so clustered pattern and a greater recovering of material (Fig. 8 B). R value for hand-picking results is located in the limit between a clustered and random distribution (R = 0.55), possibly due to the great effort made during the manual recovering of wood charcoal. Besides this, the distribution pattern of wood charcoal from flotation clearly tends to randomness (R = 0.66). Both values have a statistical significance of 99% (C ≥ 2.58).

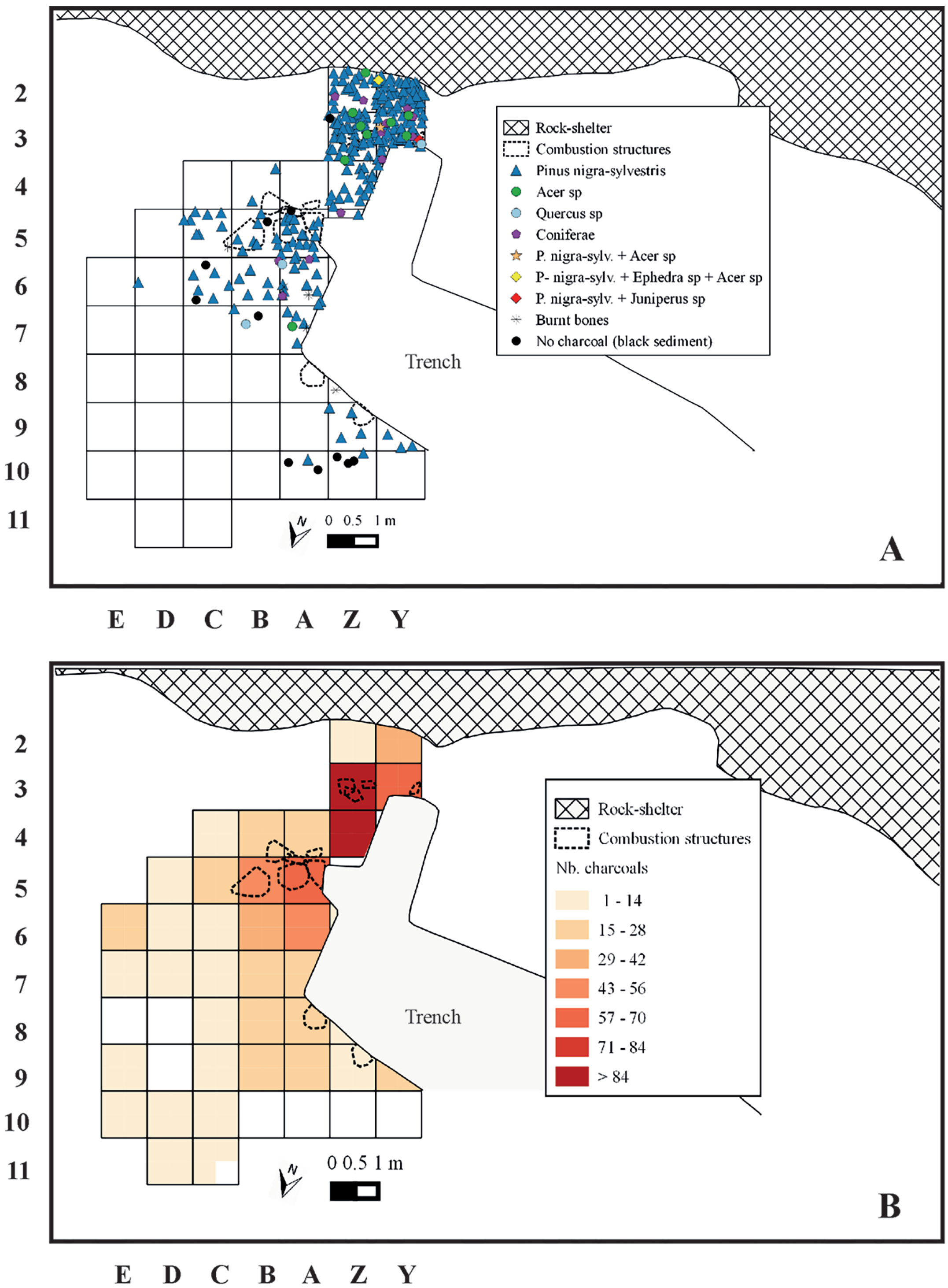

Fig. 8. Spatial distribution of the hand-picked charcoal fragments (A) and frequency map of the charcoal fragments from flotation (B) in unit Xa. White squares in both sampling methods represent the lack of anthracological data. / Distribución espacial de los fragmentos de carbón recogidos a mano (A) y mapa de frecuencias de los carbones recuperados en flotación (B) para la unidad Xa. Los cuadros blancos en ambos métodos de muestreo representan la ausencia de datos antracológicos

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Finally, the analysis of the spatial distribution of anthracological remains based on size groups has shown that 95% of the total hand-picked assemblage corresponds to the largest size groups (> 4 mm y 2 – 4 mm) (fig. 9 A), which correspond to the two more frequent taxa from this unit: *Pinus nigra-sylvestris* and *Acer* sp. (fig. 9 B). This shows that hand-picking sampling leads to the overrepresentation of the most frequent taxa (cryophilous pines) and to the loss of valuable palaeoecological data related to the accompanying plant formations (Badal and Heinz, 1989; Chabal, 1997, 1992). In addition to this, hand-picking requires a much greater effort to achieve the efficiency shown by flotation methods.

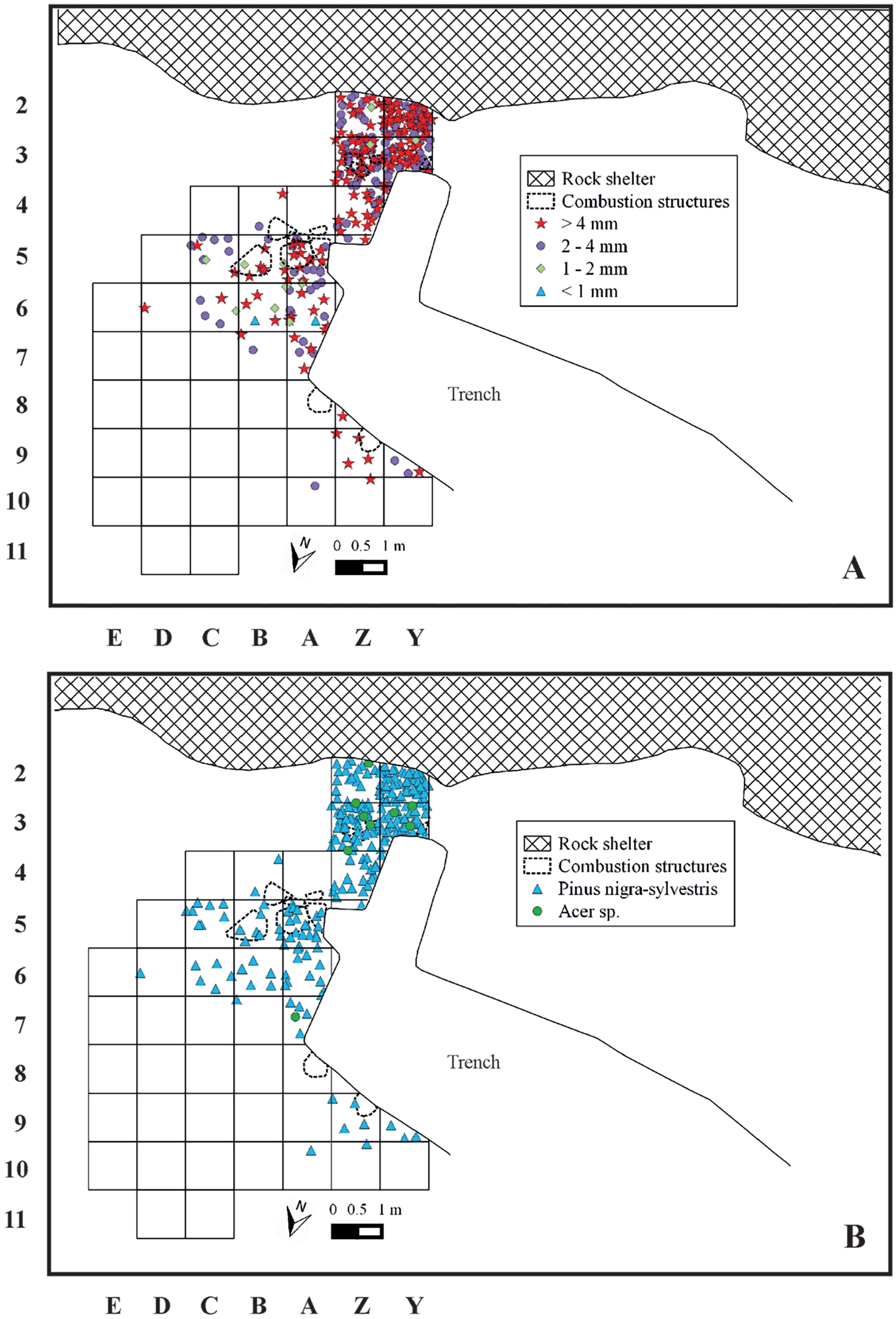

Fig. 9. Spatial distribution of the hand-picked charcoal fragments in unit Xa: (A) size groups and (B) predominant taxa in Distribución espacial de los fragmentos de carbón recogidos a mano en la unidad Xa: (A) grupos de tamaños y (B) taxones dominantes en el conjunto.

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4. CONCLUSIONS

Available anthracological data from Middle Palaeolithic contexts in Iberia are still very scarce. The fragmented information retrieved reflects the existence of areas with greater tradition in wood charcoal analyses (northern, northeastern and eastern Iberia) compared with other less known areas presenting little or absence of data (southern, western and central Iberia). The existing gaps are more common during MIS 6, 5 and 4 periods whereas more recent chronologies (MIS 3) show an increase in the available data. Despite the use of different sampling methods with different resolution degrees during the recovery of wood charcoal fragments, the predominance of *Pinus nigra-sylvestris* since, at least, MIS 6 period is remarkable. This would indicate the widespread presence of cryophilous pine woodlands during the Upper Pleistocene in Iberia pointing to the prevalence of supramediterranean conditions (MAT = 8 - 13 ^{o}C). Although the predominance of cryophilous pines in Iberia is confirmed during most of the Middle Palaeolithic period, data from the little known MIS 4 indicate large open plant formations of junipers and heliophilous taxa in, at least, eastern Iberia. Finally, available data from MIS 3 anthracological contexts allow considering the existence of nuances between the northern Iberia with the presence of more humid components, the northeastern and eastern Iberia with drier bioindicators and southern Iberia with warmer flora. Further research on charcoal analyses from Middle Palaeolithic sites in Iberia preferably sampled with flotation methods will contribute meaningful insights into past landscape dynamics over time allowing the detection of regional and biogeographical nuances.

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