Quaternary Science Reviews 111 (2015) 81–93

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

Neanderthal firewood management: evidence from Stratigraphic Unit IV of Abric del Pastor (Eastern Iberia)

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ARTICLE INFO

Article history:
Received 17 September 2014
Received in revised form
14 January 2015
Accepted 14 January 2015
Available online

Keywords:
Neanderthals
Abric del Pastor
Charcoal analysis
Palaeoenvironment
Firewood gathering
Taphonomy

ABSTRACT

This paper presents anthracological data from Abric del Pastor (Alcoi, Spain), a Middle Paleolithic rock shelter site. Analysis of 1077 wood charcoal remains from Stratigraphic Unit IV (S.U. IV), collected within archaeological combustion structures and from loose sediment outside of structures, allowed us to characterise the local landscape, as well as to approach the interaction between Neanderthal groups and their local environment. Taxonomic identification suggests that firewood was gathered from nearby sources, with predominance of juniper (*Juniperus* sp.) followed by thermophilous shrubby taxa. Additional analysis focussing on post-depositional processes affecting charcoal have shown features indicative of biodegradation and mechanical action. The results of this study contribute significant anthracological data towards our understanding of Late Pleistocene Mediterranean landscapes and Neanderthal forest management in this region.

1. Introduction

The Late Pleistocene started with Marine Isotope Stage 5 (MIS 5) (ca 128-74 ka BP), specifically with a warm phase called Eemian or MIS 5e (ca 128-110 ka BP), the last time when the earth's climate was very similar to the present (Shakleton et al., 2003). The Eemian in Iberia is followed by cold periods with the development of steppe landscapes comprising Ericaceae, Graminae and Compositae (MIS 5d-5b), alternating with warm periods featuring open forests dominated by oaks and hornbeams in the north and evergreen oaks in southern Iberia (MIS 5c-5a) (Sánchez-Goñi and d'Errico, 2005). Very few Middle Paleolithic sites in Europe, and in the Iberian Peninsula in particular, have yielded plant macroremains attesting to Neanderthal environmental interactions during MIS 5-4, whereas palaeoenvironmental data from MIS 3-2 are more abundant (Uzquiano, 2008; Carrión, 2012; Badal et al., 2012; Burjachs et al., 2012; Allué et al., 2013). In fact, our knowledge on early Neanderthal environments is poorly documented (López-García et al., 2012; Blain et al., 2013) and mostly based on pollen analyses at a global scale (Sánchez-Goñi et al., 1999; Kukla et al., 2002; González-Sampériz et al., 2010; Carrión, 2012).

This paper presents first wood charcoal results from Abric del Pastor, an early Middle Paleolithic site in eastern Iberia chronologically framed within MIS 5-4 (Fig. 1). As this period remains insufficiently known, the site of Abric del Pastor constitutes an interesting place for the study of ecological conditions during an interglacial period, an interval with warmer conditions associated with the spread of mixed forests (sclerophyllous and deciduous taxa). Our main aim by wood charcoal analysis is to provide a local image of the flora in a mountainous environment and firewood management data in combustion structures by Neanderthal communities. Finally, we address taphonomic processes affecting the charcoal assemblage, as these provide clues to the integrity of the assemblages, guiding us towards an unbiased interpretation of paleolandscapes and their use by past human societies.

2. Regional setting

2.1. Geographical and archaeological context

Abric del Pastor is a small rock shelter (60 m^2) facing north-east. It is located in the Mariola Mountains of Alcoy, Alicante, on the right

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http://dx.doi.org/10.1016/j.quascirev.2015.01.010
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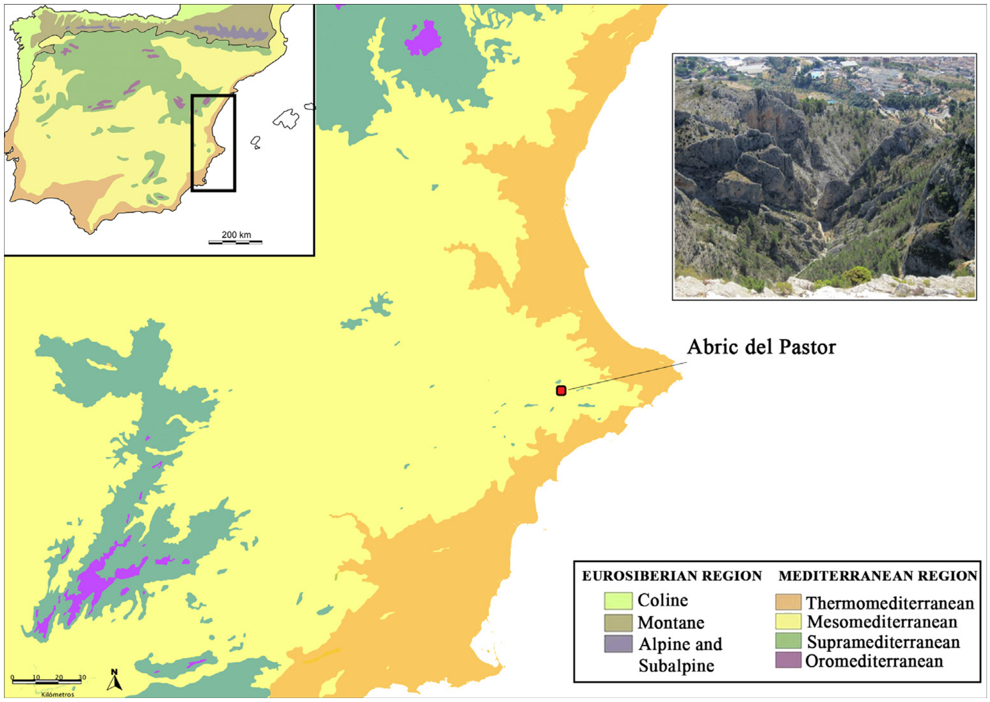

Fig. 1. Location of Abric del Pastor site and Barranco del Cint in the current bioclimatic map of Iberia.

bank of a gorge named Barranc del Cinc, at 820 m above sea level. This highland region is characterized by numerous valleys and natural corridors.

The site is an eroded karstic paleotube belonging to a larger karstic network linked to the phreatic activity of the Serpis River. It is framed within a Miocene Tortonian formation composed of bioclastic calcirudites. The rock shelter itself is made up of a limestone cobble conglomerate.

In 1953, M. Brotons carried out the first archaeological excavations in the central part of the rock shelter, which only affected the upper part of the deposit (about 50 cm) and yielded rich lithic and faunal assemblages. The archaeological record retrieved in those years is devoid of a reliable stratigraphic context (Galván et al., 2008; Molina et al., 2010).

Current excavations, ongoing since 2005, have yielded new contextualized data (Machado et al., 2013; Hernández et al., 2014). These cover an area of 42 m^2 (70% of the total surface area). The sedimentary sequence known to date is 1.5 m-thick and has been divided into six stratigraphic units, according to macroscopic and micromorphological sedimentological criteria.

The main source of the sediment is the conglomerate bed that forms the roof, composed of fossiliferous limestone cobbles. The matrix consists of relatively fresh micritic calcite. Overall, there is very little clay, only present as fine coatings and infillings. The stratigraphic sequence is as follows (from base to top):

S.U. VI (unknown thickness): it has only been identified in a test pit near the back wall. It is composed of dark brown silty-sandy sediment with 40% of clasts and gravel. Archaeologically, it is characterized by the presence of combustion features associated with anthropogenic faunal remains, lithic artifacts and charcoal fragments.

S.U. V (25 cm thick): So far, this unit has also been identified only in the test pit. It is composed of dark brown silty-sandy sediment with a similar proportion of gravel to S.U. VI. Very few archaeological remains have been recovered so far.

S.U. IV (70 cm thick): This unit was identified over the entire excavated area and comprises an alternation of cobble beds (IVa, IVc, IVe and IVg) and finer-grained, pale brown sandy-gravelly layers (IVb, IVd and IVf).

S.U. III (3–12 cm thick): This is a thin, discontinuous, locally cemented pale brown layer of calcareous sand and gravel. Archaeological remains are scarce relative to the other units.

S.U. II (8–13 cm thick): It is a small lens of dark brown sediment truncated by S.U. I, and found only in the NW corner of the excavated area. It has been possible to identify a combustion feature with bone fragments around it.

S.U. I (30–65 cm thickness): It represents several episodes of Holocene sedimentation. This unit has yielded hand-made pottery fragments mixed with Middle Palaeolithic remains in secondary position derived from the dismantling of the top of the Pleistocene deposit.

Our study focuses on lithostratigraphic subunits IVb, IVc and IVd (Fig. 2). These subunits are the result of the palimpsest dissection analysis toward single human occupation identification with the intervention of the geoarchaeological study of sedimentary facies, the spatial analysis and the lithics and faunal refits. Excavation of S.U. IV has revealed certain aspects of Middle Palaeolithic settlement patterns. The spatial distribution of the assemblages corresponding to different occupation episodes is significantly similar, featuring a central hearth or group of hearths, residues of anthropogenic activity around them and an empty space at the back of the rock shelter. However, there are differences in the kinds of activity performed as indicated by the composition of the lithic and faunal assemblages. While animal processing prevailed in S.U. IVa and IVc, specifically consumption of *Testudo hermanni* (Sanchis et al., in press), S.U. IVb is characterized by a predominance of knapping activity (Machado et al., 2013). S.U. IVd, currently under excavation, reflects a similar pattern to S.U. IVb, although with a larger number of combustion features.

So far, the absence of burnt flint objects of significant thickness has hampered TL dating. At present, the chronological framework

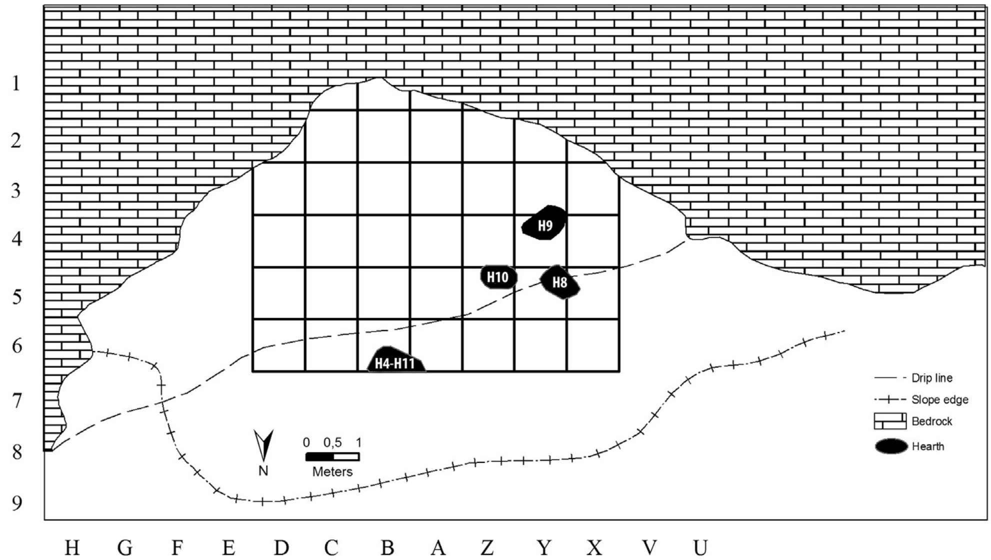

Fig. 2. Plan view of the site with the location of S.U. IV combustion structures analysed for this study.

of S.U. IV, V and VI is based on TL dates obtained from burnt flint belonging to the M. Brotons lithic collection, and those are older than 75 ± 10 ka (N. Mercier, pers. comm.).

2.2. Present day vegetation

The current bioclimatic conditions are subhumid Meso-mediterranean (mean annual precipitation between 600 and 1000 mm and mean annual temperature between 13 and 17 °C) (Rivas-Martínez, 1987). *Pinus halepensis* (Aleppo pine) is dominant over most of the area, along with *Quercus coccifera* (kermes oak), *Quercus faginea* (Portuguese oak), *Juniperus oxycedrus* (Cade), *Rhamnus alaternus* (Mediterranean buckthorn), *Cistus albidus* (white rockrose) and *Pistacia lentiscus* (mastic tree). Some xerophytic scrubs such as *Artemisia* sp. (wormwood), *Rosmarinus officinalis* (rosemary) and *Ulex parviflorus* (furze) grow in the gorge. The riverine vegetation at the bottom of the canyon is composed of *Nerium oleander* (oleander), *Populus nigra* (black poplar), *Fraxinus ornus* (ash) and *Tamarix* (tamarisk).

3. Materials and methods

During the 2013 archaeological field season a systematic soil sampling of a quarter part of each excavated square at S.U. IV was gathered for water flotation, in order to separate organic from inorganic material. Wet sieving of sediment samples was carried out with the use of meshes sizes: a 500 micron mesh for the flot and 1 mm mesh for the heavy residue.

Most of the anthracological material was scattered charcoal from the three lithostratigraphic units that form this study (IVb, IVc and IVd), with the exception of the concentrated charcoal related to several flat combustion features (H4, H8, H9, H10 and H11) (Fig. 2). Following the standardized anthracological methodology (Badal, 1992; Chabal, 1997) the scattered and concentrated samples were collected and processed separately. While scattered charcoal is the result of consecutive combustion events and its spread pattern over human living surfaces, charcoal remains from combustion structures represent isolated events (Chabal, 1997). Due to the nature of its formation, the concentrated wood charcoal record isn't always preserved and is a more accurate time record compared with scattered charcoal assemblage, offering an instantaneous picture of the local flora and the last firewood collecting action in the supply areas (Badal and Heinz, 1991; Chabal, 1997). However, it is important to acknowledge the current limitations of anthracology. Although the presence of particular taxa in the charcoal record is related to their presence in the local environment, their absence may be due to different factors. For instance, some taxa may have not been used for burning, or may have been used only occasionally and not have been preserved in the charcoal record.

For the taxonomic identification of specimens, each fragment of charcoal was manually fractured to provide transversal/cross, tangential and radial sections. Due to the small size of the charcoal remains, we used four meshes in order to separate the material in four fractions (>4 mm, 2–4 mm, 1–2 mm and <1 mm). We employed a Nikon Optihot-100 dark/bright field incident light microscope with 50–500× magnifications. Botanical determination was possible with the aid of specialized plant anatomy bibliography (Jacquiot et al., 1973; Scheweingruber, 1990) and the reference collection of modern charred woods of the Laboratory of the Department of Prehistory and Archaeology, University of Valencia (Spain). Photography and detailed observation of anatomical and bioalteration elements were carried out using a Hitachi S-4100 Field Emission Scanning Microscope and the ESPRIT 1.8 software at the Service for the Support to Experimental Research (SCSIE), University of Valencia. The nomenclature employed was that of *Flora Europaea* (Tutin et al., 1964).

4. Results

4.1. Botanical and taphonomic remarks

A total of 1077 wood charcoal fragments were analysed from the S.U. IV (Table 1). The lithostratigraphic unit IVa was partially preserved due to ancient fieldwork and it was excavated previously to the adoption of wet sieving method of the sediments, so we don't have enough palaeobotanical data available from this unit. Lithostratigraphic unit IVb has provided the smallest quantity of charcoal remains (12), followed by the richest samples from IVc (563) and IVd (502). In spite of the small size of wood charcoal remains, at least 16 plant taxa were identified making up a rich assemblage in which different plant formations are represented, as explained below. However, close to 14% of the data has been identified until

Table 1
Anthracological data for S.U. IV.

Litostratigraphic unit	IVb	IVc				IVd							Total	
Charcoal context	Scattered	H4		Scattered		H8	H9	H10	H11		Scattered			
Taxa	n	n	%	n	%	n	n	n	n	%	n	%	n	%
Angiosperms	2	9	4.50	30	8.26			2	25	16.03	19	7.34	87	8.08
Cistaceae		2	1	1	0.28						1	0.39	4	0.37
Conifers		6	3	16	4.41	4	6		18	11.54	16	6.18	66	6.13
Ephedra sp.	1			5	1.38								6	0.59
Euphorbiaceae				5	1.38								5	0.46
Fabaceae				6	1.65						9	3.47	15	1.39
Fraxinus sp.				1	0.27						5	1.93	6	0.56
Juniperus sp.		100	50.00	146	40.22	32	28	7	76	48.72	124	47.88	513	47.63
cf. *Juniperus* sp.				7	1.93				1	0.64	11	4.25	19	1.76
Labiatae				7	1.93								7	0.65
cf. Labiatae							3						3	0.28
Maloideae	9			16	4.41								25	2.32
Monocotyledoneae tp. Poaceae				1	0.28								1	0.09
Pinus tp. *sylvestris-nigra*				6	1.65				5	3.21	12	4.63	23	2.14
Pistacia sp.		60	30.00	40	11.02			4	20	12.82	21	8.11	145	13.46
cf. *Pistacia* sp.		16	8.00	4	1.10				7	4.49	20	7.72	47	4.36
Quercus sp. evergreen				49	13.50			1	1	0.64	4	1.54	55	5.11
Quercus sp.				13	3.58				1	0.64	9	3.47	23	2.14
cf. *Quercus* sp.				2	0.55								2	0.19
Rosa sp.		7	3.50						1	0.64	2	0.77	10	0.93
Salix-Populus				2	0.55						1	0.39	3	0.28
cf. *Salix-Populus*											1	0.39	1	0.09
Taxus baccata				2	0.55				1	0.64	4	1.54	7	0.65
Ulmaceae				4	1.10								4	0.37
Total fragments	12	200	100	363	100	36	37	14	156	100	259	100	1077	100
Total taxa	2	4		15		1	2	3	6		10		16	

angiosperms or conifers taxonomical rank, due to its fragmentation level and/or its preservation degree. In addition, several wood charcoal fragments have the *confer* mention (*cf.*), referring to those ones presenting very nearby anatomical elements to a botanical genus but are not well preserved or are too small to be clearly identified. In the same way, excluding angiosperms or conifers taxonomical rank, we have identified wood charcoal fragments to the family or genus rank, due to the incomplete anatomical observation.

Stratigraphic Unit IV from Abric del Pastor has yielded abundant wood charcoal material, mostly quite small. The size separation of samples in four fractions (>4 mm, 2–4 mm, 1–2 mm and <1 mm) in order to study the fragmentation degree, has provided a high concentration of remains in 1–2 mm and 2–4 mm sizes groups (almost 87% of total remains) (Fig. 3). Furthermore, as the smallest fragments (<1 mm) contain high number of undetermined angiosperms, in greater fragments (>4 mm and 2–4 mm) there is a higher representation of gymnosperms, most of them identified to genus (*Juniperus* sp.; *Ephedra* sp.), but also to species (*Taxus baccata*) or even species type (*Pinus* type *sylvestris-nigra*). (Fig. 4).

The effects of several pre-depositional and post-depositional processes have been observed in charcoal analysis, like the presence of radial cracks in some Fabaceae and *Juniperus* sp. fragments (Fig. 5A), reaction wood in *Salix-Populus* (Fig. 5B), as well as tension wood in *Pinus* type *sylvestris-nigra* (Fig. 5C). Finally, some taxa show varying degrees of vitrification, a phenomenon of fusion and homogenisation of the charcoal cellular walls (Fig. 5D). In addition to this, biogenic alterations caused by fungi, bacteria, insects and other microorganisms are present in numerous charcoal fragments from Abric del Pastor leading to deterioration of the organic material. Wood-rotting fungi have caused changes in cell wall structures, like the wavy appearance of decomposed cells observed in some angiosperms (Fig. 5E). Furthermore, hyphae growing activity has been observed in most of the samples penetrating tracheids via bordered pits, within the vessels (Fig. 5F) or as a mass of mycelia (Fig. 5G). Finally, several types of microorganisms (Fig. 5H and I) and microscopic structures (Fig. 5J–L) have been recognised in wood charcoal with different micromorphological features. As an example, the presence of a pluricellular microorganism has been detected in the radial section of a *Pinus* typus *sylvestris-nigra* showing 4 or 6 extremities (Fig. 5I).

4.2. Combustion structure charcoal

Lithostratigraphic unit IVc has yielded 200 wood charcoal remains from a charcoal accumulation located in the outer area of the rock shelter (H4). The nature of this charcoal accumulation could not be ascertained based on field observation. The botanical identification of this material has provided a minimum of 4 taxa: *Juniperus* sp. (Juniper), *Pistacia* sp. (Pistachio tree), *Rosa* sp. (Rose) and Cistaceae (Rock-rose family). Despite the diversity of taxa, around 90% of the charcoal is constituted by Juniper and Pistachio tree (Fig. 6).

Furthermore, four different combustion features were detected in lithostratigraphic unit IVd (H8, H9, H10 and H11). Wet sieving sediment from the first three hearths yielded a lower quantity of charcoal remains (n = 36 in H8, n = 37 in H9 and n = 14 in H10), with a maximum of 3 taxa and the strong presence of *Juniperus* sp. in all of them. In addition to this, H11, located above of H4, has yielded 156 wood charcoal remains with a minimum of 6 taxa: *Juniperus* sp., *Pinus* tp. *sylvestris-nigra*, *Pistacia* sp., *Quercus* sp. evergreen, *Rosa* sp. and *Taxus baccata* (Fig. 7).

4.3. Scattered charcoal

We have obtained a higher variety of taxa in the scattered charcoal assemblage compared with the single combustion actions. Even though the small sample size from lithostratigraphic unit IVb doesn't allow a detailed quantitative interpretation, the charcoal remains of Maloideae of the *Sorbus* type (Rosaceae family), *Ephedra*

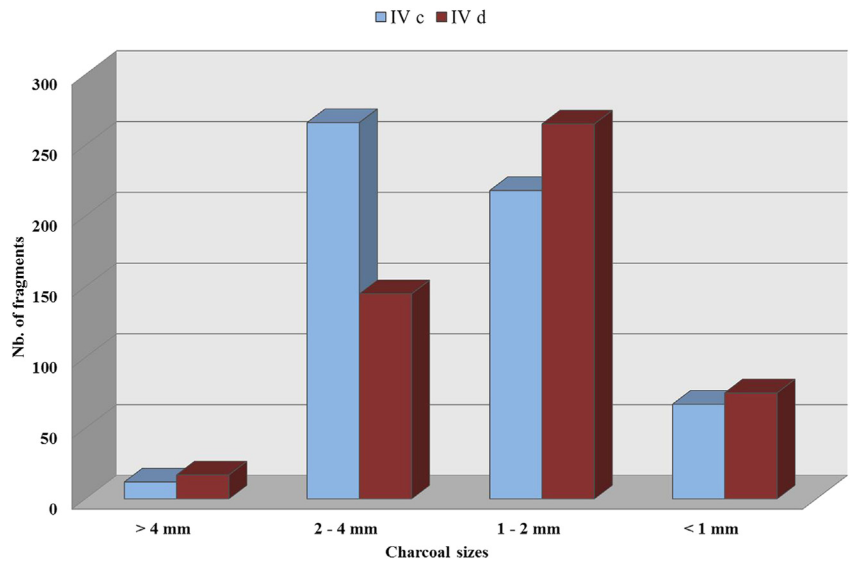

Fig. 3. Charcoal fragmentation degree in S.U. IV.

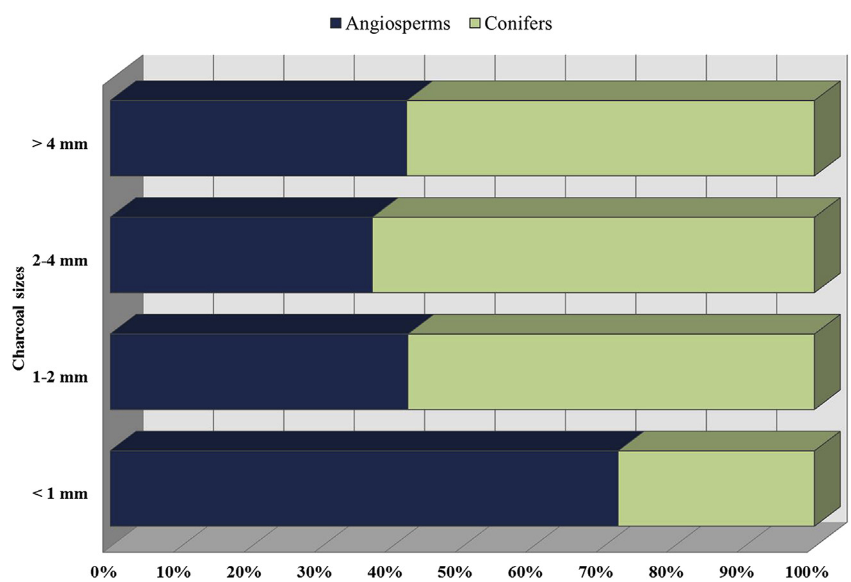

Fig. 4. Proportion of angiosperms and conifers in the four fractions from S.U. IV.

sp. (Joint pine) and some undetermined angiosperms show a coherent paleoflora image together with lithostratigraphic units IVc and IVd results.

The other lithostratigraphic units that compose the charcoal analysis results show an anthracological spectrum made up, at least, of 15 taxa for IVc and 10 taxa for IVd. Qualitative nuances and palaeoeconomical inferences for IVc and IVd will be discussed below. Nevertheless the scattered charcoal data assemblage presents *Juniperus* sp. as dominant taxon, closely followed by Mediterranean forest shrubby taxa like *Pistacia* sp., *Rosa* sp., Maloideae of the *Sorbus* type and *Quercus* sp. evergreen (Fig. 8). This spectrum is completed with minor percentages of other conifer species like *Pinus* type *sylvestris-nigra* (Scots-black pine) and *Taxus baccata* (Yew); as well as some kind of shrubs with a more xerophilous nature, like *Ephedra* sp., Euphorbiaceae (spurge family) or the only fragment of Monocotyledonaeae type Poaceae (cf. *Stipa tenacissima*) found in S.U. IV. The low presence of river bank species like *Fraxinus* sp. (Ash), *Salix-Populus* (Willow-Poplar) and Ulmaceae (the Elm family) indicate the existence of moisture areas near the site.

5. Discussion

As the study of Abric del Pastor's charcoal record is currently in progress, our study focuses on preliminary results from S.U. IV, specifically on subunits IVb, IVc and IVd, which have provided enough charcoal material to propose three kind of data: the palaeoecological, the palaeoeconomical and the taphonomical approach. The field methodology applied based on the palimpsest dissection allows obtaining more accurate archaeobotanical data about the palaeolandscape and firewood exploitation strategies during single human occupation episodes.

5.1. Palaeoecological approach based on the scattered assemblage: landscape and wooded formations

The charcoal analysis in Abric del Pastor shed light on the characterisation of the landscape indicating the prevalence of dry meso-supramediterranean conditions (mean annual temperature 8–17 °C and mean annual precipitation between 350 and 600 mm)

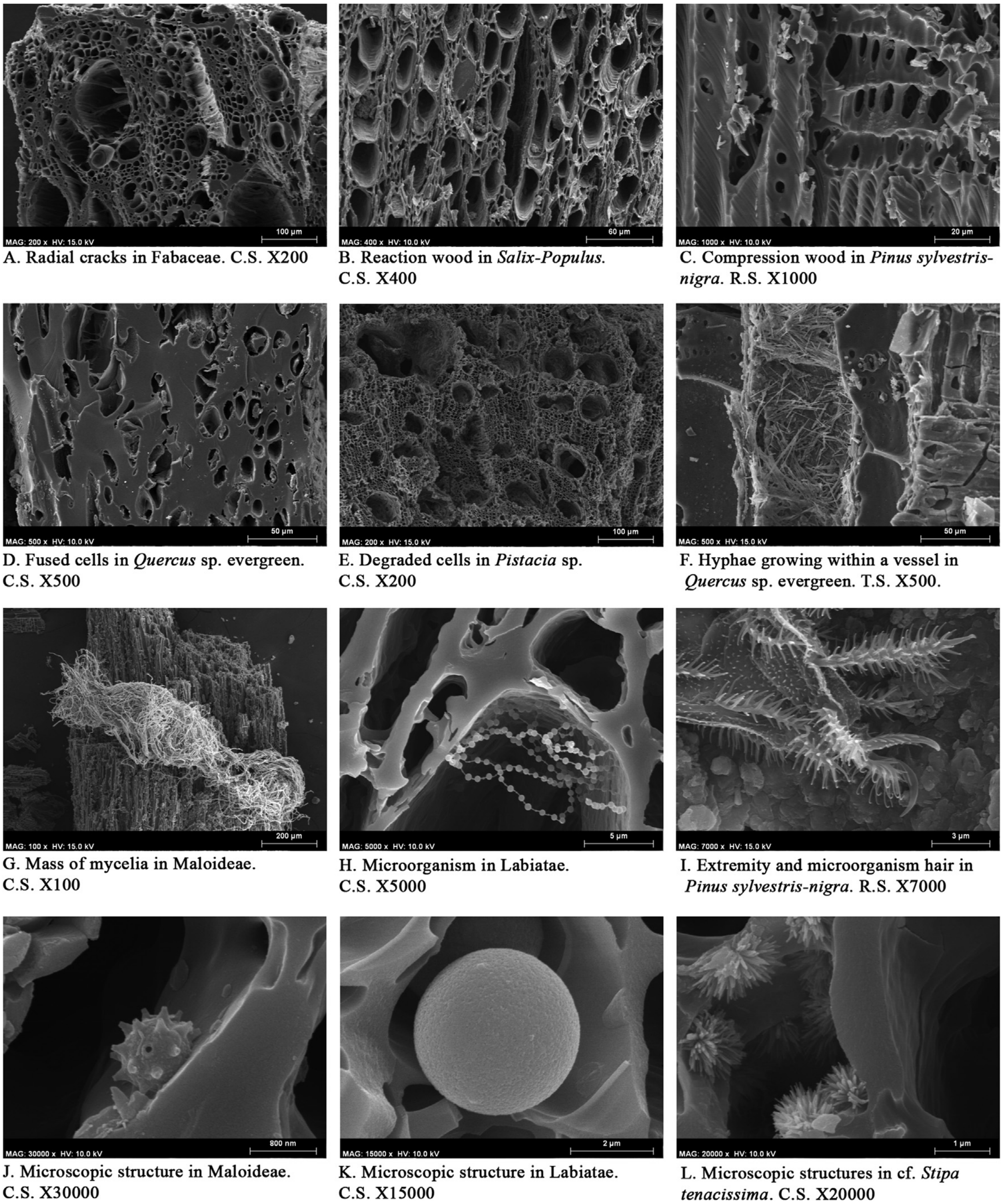

Fig. 5. SEM images of pre-depositional and post-depositional processes on some taxa identified at Abric del Pastor (C.S.: Cross section, T.S.: Tangential section and R.S.: Radial section).

(Rivas-Martínez, 1987). The location of the rock shelter in a shaded abrupt slope of a gorge generated a patchy landscape with several wooded formations, most of them reflected in the wood charcoal assemblage (Fig. 9). According to this, the identified flora in Abric del Pastor reflects the existence of abundant plant biomass at the site's surroundings and therefore a constant availability of woody plants to Neanderthal groups in eastern Iberia. Charcoal analyses from MIS 4-3 sites between 0 and 800 m a.s.l. in southern Iberia show a predominance of cryophilous pines (*Pinus sylvestris-nigra*) and juniper (Badal et al., 2012; Carrión, 2012). Besides cryophilous taxa, there are lower proportions and diversity of shrubs (mostly Fabaceae), possibly indicating the presence of open, grassy landscapes. Abundance of flora, the presence of Mediterranean mixed forest taxa (with sclerophyllous and deciduous species) and thermophilous taxa such as *Pistacia* sp., *Quercus* sp. evergreen or *Taxus baccata*, in addition to low proportions of *Pinus* type *sylvestris-nigra*, support the hypothesis of a chronological framework corresponding to a warm period of MIS 5, probably MIS 5a or MIS 5c, pending new TL datacions. The local palaeoflora, corresponding to the meso-supramediterranean bioclimatic belt, places the site within slightly cooler and drier bioclimatic conditions than present (meso-mediterranean bioclimatic belt).

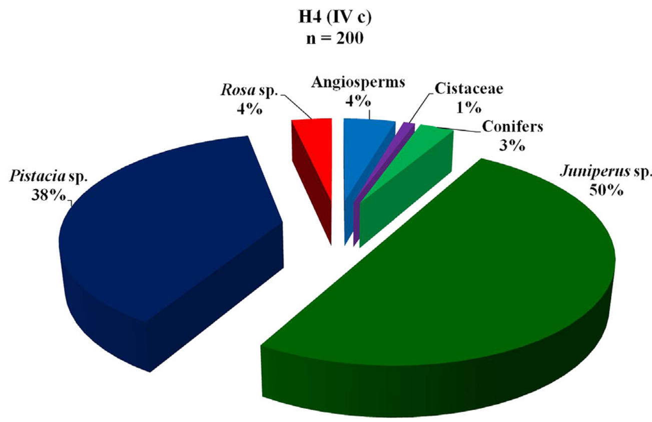

Fig. 6. Frequency of the identified taxa in H4.

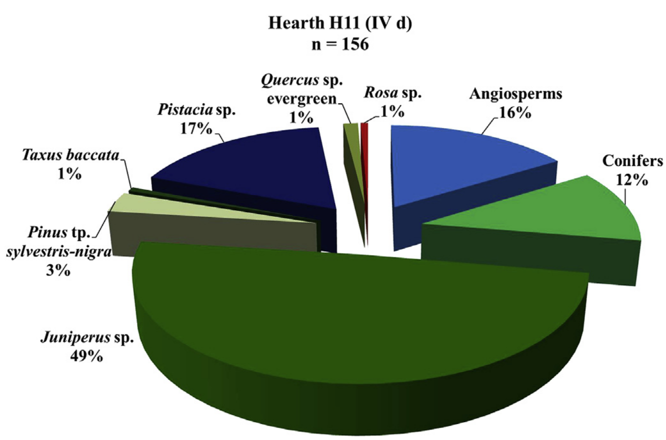

Fig. 7. Frequency of the identified taxa in H11.

Coniferous taxa indicate the existence of an open landscape prevailing over the middle and high area of the gorge. Considering that *Pinus* type *sylvestris-nigra* is sporadically present in the charcoal record, *Juniperus* sp. would certainly be the most dominant and available conifer near the site, attending its highest values (Fig. 10A). This could be attributed to thermofilous taxa (like *Juniperus oxycedrus* or *Juniperus phoenicea*) and also to cryophilous junipers (like *Juniperus communis* or *Juniperus thurifera*), whose present-day range covers from thermomediterranean to supramediterranean belts under dry or semiarid bioclimatic conditions (Costa et al., 2005). Nowadays, *Pinus sylvestris* and *Pinus nigra* can be found above 1000–1200 m a.s.l. on the supramediterranean or oromediterranean mountains of Iberia, but *P. sylvestris* requires cooler conditions and mostly grows in the oromediterranean belt under its greater cryophilous nature (Rivas-Martínez, 1987; Roiron et al., 2013). This taxon has been recorded in another Iberian Middle Paleolithic site belonging to MIS 5 chronology, Cueva del Camino, under high mountain climatological conditions (Arsuaga et al., 2012). In addition to this, many Middle Palaeolithic sites with later chronologies (mostly MIS 3 sites) show the dominance of *Pinus* type *sylvestris-nigra* (Théry-Parisot, 2002; Uzquiano, 2008; Allué et al., 2012; Badal et al., 2012; Uzquiano et al., 2012), indicating a widespread of cryophilous pines communities throughout MIS 4-3 and its lower presence during MIS 5 (Moncel et al., in press). In consonance with this, ongoing charcoal analysis in El Salt, a MIS 3 Paleolithic site close to Abric del Pastor, also supports the high presence of this taxon in the local area. Considering the milder environment that the anthracological assemblage from Abric del Pastor reveals and the scarcity of cryophilous pines remains, it's probable that the *Pinus* type *sylvestris-nigra* registered reflects the feeble presence of *Pinus nigra* in the surroundings. However, these two pine species are hardly anatomically distinguishable (Roiron et al., 2013; Moncel et al., in press) and both of them could jointly grow at the supramediterranean belt to the south of latitude 40°N (Rubiales et al., 2010; Badal et al., 2012).

Angiosperms have a strong presence in subunits IVc and IVd, indicating forested areas at lower height in the shaded slope. The presence of a Mediterranean mixed-likely forest is drawn by *Quercus* sp. evergreen, attributed to *Quercus rotundifolia* and/or

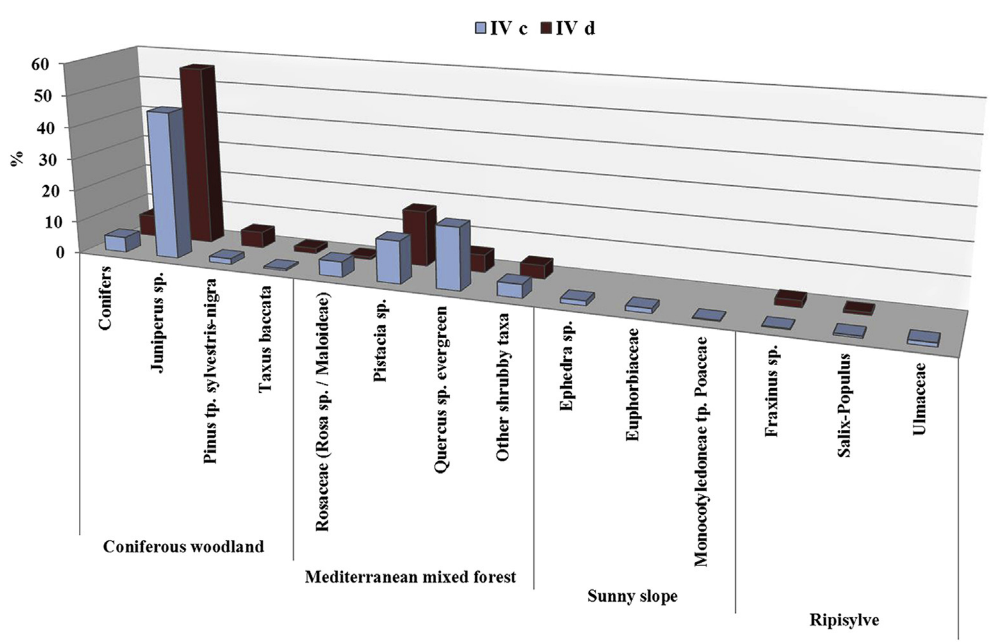

Fig. 8. Firewood supply areas in lithostratigraphic units IVc and IVd.

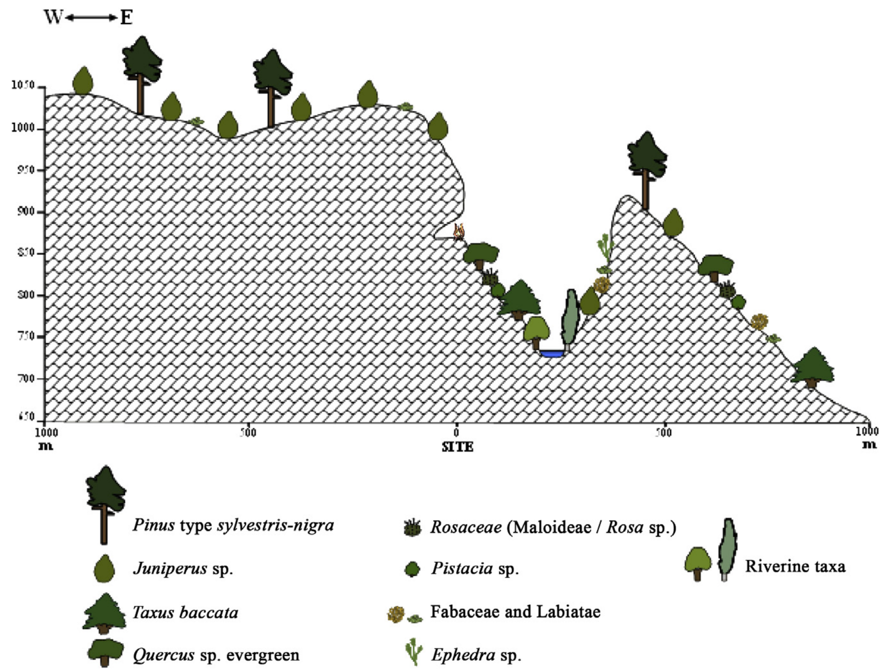

Fig. 9. Hypothetical reconstruction of wooded formations and supply areas nearby Abric del Pastor site.

Quercus coccifera, which are present nowadays until the supramediterranean belt (Fig. 10B). This taxon dominates the Mediterranean mixed forest formation, associated to spiny deciduous species like *Crataegus monogyna*, *Rosa* sp., *Sorbus* sp. that are represented at Abric del Pastor by the Maloideae and *Rosa* sp. record. Additionally, *Pistacia* sp., probably *Pistacia terebinthus* attending its higher adaptability to meso-supramediterranean conditions than *Pistacia lentiscus* (Costa et al., 2005), would be an integrated part of this forest component, just like other shrubby taxa as Labiatae, Fabaceae and Cistaceae families. The favourable climatic conditions together with the phreatic moisture and a suitable topography allowed the mixed forest growth, which currently has

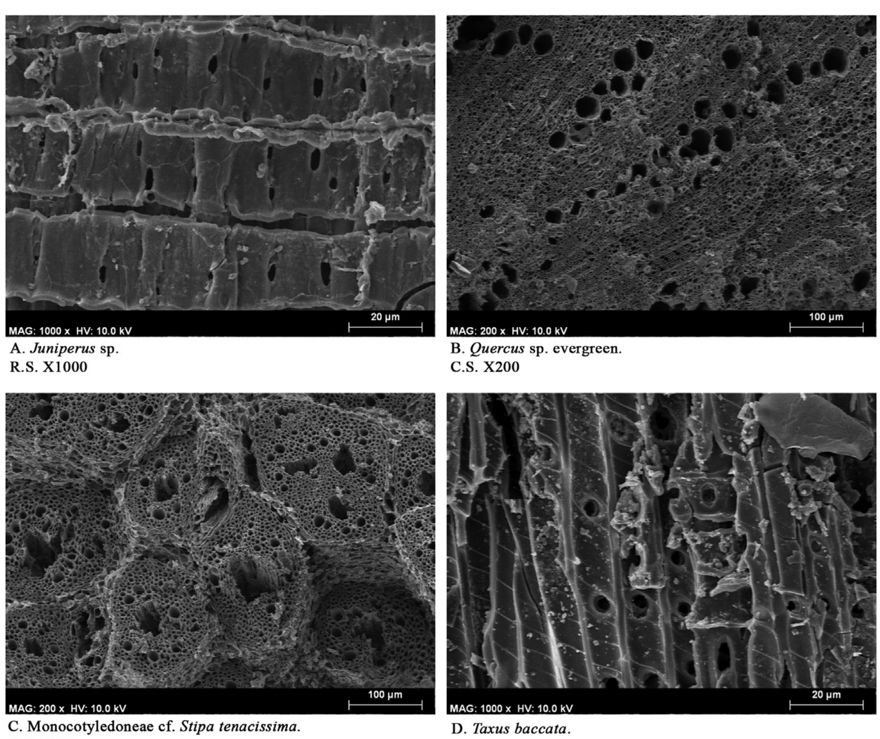

Fig. 10. SEM images of some identified taxa at Abric del Pastor (C.S.: Cross section, T.S.: Tangential section and R.S.: Radial section).

a eurosiberian and thermophilous relic natural flora representation in Font Roja Natural Park, 15 km far away from Abric del Pastor (Costa, 1999; Laliga and Soler, 2011).

The poorest values come from small xerophytic shrubs species (*Ephedra* sp., Euphorbiaceae and Monocotyledoneae cf. *Stipa tenacissima*) whose optimal ecological slot could be on the sunny slope of the gorge, owing its lower humidity requirements (Fig. 10C). Several riverine taxa would be present at the bottom of Benisaidó river valley and in contact with the mixed forest communities, being a fitting habitat to the development of rushes, reeds and diverse kinds of climbing plants (Elhaï, 1968; Costa et al., 2005).

Although subunits IVc and IVd provides a broad wooded taxa that enables the partial knowledge of different vegetation assemblages in the area including open forest, closed-mixed forest and riverside species, some considerations must be taken into account. Undetermined angiosperm wood charcoals (39 in IVc and 46 in IVd) can't be included in a specific wooded formation, as they represent a wide group of flowering plants. Similarly, the Fabaceae fragments remain difficult to interpret climatologically, as it isn't possible to determine what type or types of genus are involved, based on anatomical wood charcoal observation. Finally, some taxa like *Fraxinus* sp., *Salix-Populus* or *Taxus baccata* (Fig. 10D) could inhabit sheltered areas such as the bottom of valleys or higher moisture refugia zones, besides coniferous woodland or ripisylve formations.

5.2. *Palaeoeconomical approach based on the concentrated assemblage: firewood gathering in a diverse wooded environment*

Charcoal from combustion structures of Abric del Pastor show constant firewood gathering patterns focused on the most available coniferous species (Juniper), closely followed by Mediterranean mixed forest taxa, mainly *Quercus* sp. evergreen, *Pistacia* sp. and Rosaceae species. Shrub communities must have grown near the site in appreciable quantity as they were used as a reiterated burnable resource too.

Fireplace function and occupation patterns are anthropogenic factors that lead into the question of charcoal accumulation. In agreement with Chabal (1997), the successive firewood gathering accumulations represent the majority of woody biomass in the surrounding area for long–term activities (succession of combustion features), but the superposition of archaeological deposits from successive short-term occupations or just the mixture of charcoal in the same level by fireplaces cleaning tend to hinder single gathering distinctions (Théry-Parisot et al., 2010; Mallol et al., 2013). In consonance with this, both H4 and H11, located one above the other in the limit of the excavation area (A6-B6 squares), contain a high amount of wood charcoal remains compared with H8, H9 and H10 located inside of the rock shelter in a more protected area. Consequently, the diversity of taxa reflected in charcoal analysis of H4 and H11 can be read in the following ways: a) In both of them, the results could reflect the last firewood hearth feeding and, therefore, they are the consequence of a single varied and non-selective gathering at the surroundings; b) They could reflect reiterative burning episodes which required constant firewood feeding dominated by *Juniperus* sp. and *Pistacia* sp. Here, the variety of taxa would be the effect of several relighting during short-term occupations; c) It can be linked to the fireplace function due to its position in the site. A marginal hearth could imply a more lasting use over time than central hearths which could develop a punctual use, and finally d) It can be explained by a differential cleaning pattern of combustion remains. In this way, central fireplaces would be more exposed to cleaning activities than those placed outside main activities areas. Furthermore, an external fireplace could consume a greater quantity of firewood as it would be more exposed to wind drafts.

5.2.1. *Fuelwood gathering vs. other purposes*

The weak presence of riverine taxa at Abric del Pastor suggests that physiological state of the wood, particularly the moisture content, determines firewood selection strategies demonstrated by ethnographical studies (Smart and Hoffman, 1988; Henry et al., 2009, 2014). According to the Principle of Least Effort (Shackleton and Prins, 1992; Chabal, 1997), all the species existing in a reduced area were equally available and collected by past human groups. In consonance with this criterion, availability, abundance and proximity seem to be stronger decisive factors for fuel purposes than specific selection (Badal and Heinz, 1991; Chabal, *op. cit.*; Théry-Parisot et al., 2010).

On the other hand, S.U. IV shows a taxonomically rich assemblage and it might reflect an extensive use of species for other purposes, apart from combustible function. Some of these woods would be used for toolmaking or tool handles and could be selected according to their characteristics: mechanical properties, size, diameter, impermeability, resistance, etc (Dufraisse, 2014). Unfortunately, the perishable nature of wood doesn't allow us to document that important part in the lifestyle of hunter-gatherer societies, but we can infer the use of wood resources in their environment in order to supply their daily needs.

In addition to this, *Pistacia* genus and Rosaceae family (both Maloideae and Rosoideae subfamilies included) produce edible fruits in Fall-Winter season (Bazile-Robert, 1983). Carpological remains haven't yet been observed in S.U. IV of Abric del Pastor, but the anthracological presence of these taxa could be also related to the collection of fruits as available natural resource used in other Palaeolithic sites (Lev et al., 2005; Pryor et al., 2013; Sistiaga et al., 2014).

5.2.2. *Local resource management at Abric del Pastor*

As the wood charcoal record shows, hunter-gatherers from Abric del Pastor made use of a great variety of firewood employed in fireplaces during alternative frequentation and exploitation of various plant communities, despite the high *Juniperus* sp. gathering which would supply the most part of firewood collection. A slight aspect during S.U. IV is the more varied supply areas in IVc compared with the IVd ones, as sunny slope shrubs (such *Ephedra* sp. and Euphorbiaceae) only appear in IVc charcoal record, indicating little nuances in gathering among distinct occupation episodes or differential preservation in wood charcoal (Fig. 11).

Anthracological data at Abric del Pastor reveal the existence of abundant plant biomass in a Last Interglacial environment where Neanderthal groups must had a detailed knowledge of their surrounding resources, as it has been also documented in lithic and faunal remains from the site. While in S.U. IV the flint lithic record has been ascribed to 4 different raw material types obtained within a 17 km maximum radius from the site (Molina et al., 2010; Machado et al., 2013), a total of 243 *Testudo hermanni* remains (Mediterranean tortoise) have been collected from this level (Sanchis et al., in press). These faunal remains are directly connected with palaeoecological results, as Mediterranean tortoise is a thermophilous species with shrub communities landscape preferences. Nevertheless they are also connected with Stratigraphic Unit IV fireplaces, given the high number of burning carapace fragments observed from the upside-down cooking on Abric del Pastor hearths (Morales and Sanchis, 2009). Also, remains of *T. hermanni* have been documented in other MIS 5 warm Mediterranean sites like Bolomor cave (Fernández Peris et al., 2012), Cueva Negra (Martínez Valle, 2009), Cova del Rinoceront (Luján and Borràs, 2009) or Abri aux Puces (Slimak et al., 2010).

Other plant processing material could had been well-exploited during daily routes by the inhabitants from Abric del Pastor, on

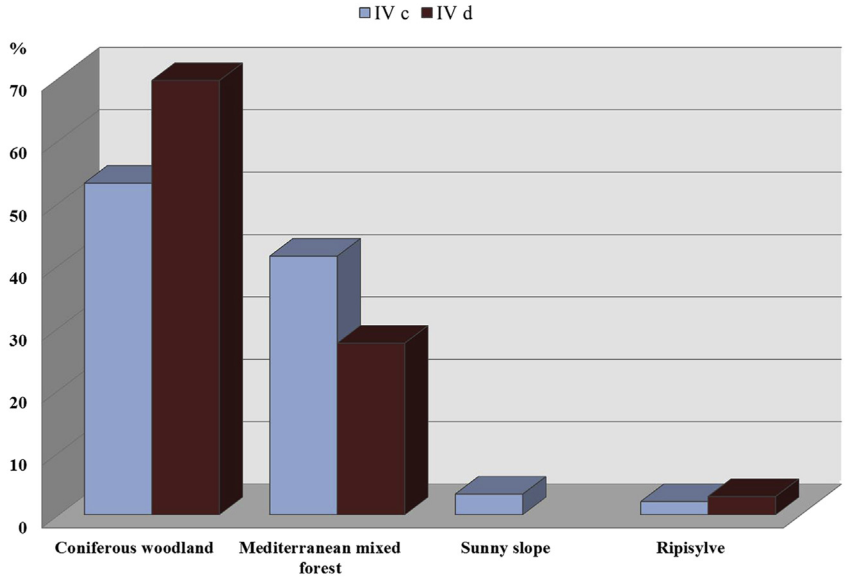

Fig. 11. Firewood supply areas in IVc and IVd.

behalf of the climbing plants which often reside within damp environments like closed mixed forests (*Lonicera* sp., *Smilax* sp., *Tamus communis*, *Clematis* sp.) or various kind of rushes in riparian communities (*Phragmites* sp., *Juncus* sp.). Despite the lower preservation of these botanical remains, a monocot fragment of Poaceae type (cf. *Stipa tenacissima*) has been recorded in lithostratigraphic unit IVc. Recently, evidence of the remains of fibers and plant tissues point to the probable monocots use to make cordage in Abri du Maras (Hardy et al., 2013), or as recurrent preparation of grass beds related to hearth areas in Esquilleu cave (Cabanes et al., 2010). Despite the presence of only one fragment, Neanderthal groups from Abric del Pastor could be collecting feather grass (*Stipa tenacissima*) for bedding near combustion structures, for cordage or for basket production. The monocot fragment presented here could be the evidence of a perishable material much more common in hunter-gatherer societies than archaeological record indicates, being an essential element for daily life.

5.3. Taphonomical approach: impact of pre- and post-depositional processes on charcoal preservation

5.3.1. Combustion and mechanical processes

The small size of wood charcoal remains has often been observed in several Middle Palaeolithic sites (Dibble et al., 2009; Marquer et al., 2010; Ronchitelli et al., 2011; Badal et al., 2012; Uzquiano, 2012). Although Chabal (1997) established the same fragmentation pattern for all species during combustion, various post-depositional processes converge in the final preservation of wood charcoal (Chrzazvez et al., 2014). Atmospheric and edaphic factors such as wind, surface exposure, sediment moisture or rainfall, along with anthropogenic actions like trampling, sweeping, hearth cleaning or reworking, can break and scatter charcoal assemblages (Marquer et al., 2010; Théry-Parisot et al., 2010). Other limiting factors in charcoal preservation include intense burning events, fireplace function or recurrent human occupations (Mallol et al., 2013). According to Scott (1989), the presence of growth rings in gymnosperm taxa increase fragmentation processes. However, we have observed a higher volume of small fragments in angiosperm taxa, probably due to its porous anatomy and a different reaction pattern when exposed to heat (Braadbaart and Poole, 2008) or to stronger bioturbation processes in this kind of woods (Singh, 2012). Recent experiments (Chrzazvez et al., 2014) have shown that porous woods with large vessels or radial pore files (angiosperms) produce more fragments than homogenous wood (gymnosperms) or porous wood with small isolated vessels. Furthermore, this fragmentation variability tends to be more significant in the small fraction (1–2 mm and <1 mm). These taphonomic observations are related to the misinterpretation of charcoal scarcity or absence in those archaeological sites where the larger fragments have disappeared. According to this, the study of the very thin fraction of the sediment is absolutely required in Palaeolithic sites in order to obtain a more complete picture of the vegetation.

Regarding the observed alterations, radial cracks have been generally interpreted as green wood burning but experimental combustions showed that they aren't necessarily correlated with the moisture content (Théry-Parisot and Henry, 2012) and that they may be due to internal stress during combustion, constituting a pre-depositional phenomenon (Théry-Parisot et al., 2010). On the other hand, several mechanical alterations have been identified among the analysed samples. The glossy appearance of the charcoal affected by vitrification has been generally considered as a result of high temperature burning (Prior and Alvin, 1983), recharring, diagenetic processes, biological or chemical degradation and physical compression (Braadbaart and Poole, 2008; McParland et al., 2010). Recent experiments using *Fraxinus, Populus, Pinus pinaster* and *Quercus* evergreen (Henry, 2011) point to the influence of combustion duration, a reducing atmosphere and the chemical composition of the wood prior to combustion. These data are in disagreement with the hypothesis of temperature rising or the use of waterlogged wood. Further experimental work should be carried out to narrow down the possible causes of the phenomenon. In any event, vitrification is likely related to other factors besides combustion conditions and water absorption rates.

5.3.2. Biogenic alterations

Fungal and insect attacks detected in Abric del Pastor charcoal have been identified in other Mousterian sites like Cueva Antón or Abrigo de la Quebrada (Badal et al., 2012) and in many other chronologies and areas (Moskal et al., 2010; Carrión et al., 2012). Although several anthracologists have observed anatomical alterations caused by fungal attack (Théry-Parisot, 2001; Badal and

Carrión, 2004; Allué et al., 2009), few researchers (Moskal et al., 2010; Henry, 2011; Chrzazvez et al., 2014; Henry and Théry-Parisot, 2014) have investigated the preservation of these alterations after combustion and their possible relationships with fuel collecting strategies (green wood vs. dead wood). Even though their initial moment of attack is difficult to determine, biodegradation may have been produced before (previously to deadwood gathering or during storage period) or after burning event, since the deposition of charcoal, considering that acari and fungi form part of the soil habitat where they live as decomposers (Clausen, 1996; Blanchette, 2000; Schmitt et al., 2005; Moskal et al., *op. cit.*). Accordingly, experimental studies with conifers have shown that fungal decay features are preserved on charcoal fragments after combustion processes under laboratory conditions (Henry and Théry-Parisot, *op. cit.*) and occur in the same way as in decayed wood from natural contexts (Moskal et al., *op. cit.*). In addition, microscopic criteria established for unburned wood are not always useful for charred wood observation, as combustion sometimes causes anatomical alterations (Braadbaart and Poole, 2008). Biogenic alterations (cellular deformations caused by hyphae and microorganisms presence) observed on angiosperm and gymnosperm samples from the Abric del Pastor charcoal assemblage were identified mostly on cross and radial sections, in agreement with experimental studies (Henry, 2011).

Pre-depositional and post-depositional processes influence the botanical assemblage and may lead to a biased interpretation. On the one hand, post-depositional fragmentation behaves differently depending on taxa, and may lead to under/overrepresentation of some taxa (Chrzazvez et al., 2014). Thus, the systematical wet flotation is essential to recover the maximum possible number of taxa used by Neanderthal groups. The charcoal assemblage from Abric del Pastor shows the maximum number of taxa in the 2–4 mm and 1–2 mm size fractions. This is where the presence of several Mediterranean-mixed forest species (*Quercus* sp. evergreen, Maloideae, *Rosa* sp., Fabaceae or Labiatae) and riverside plants (*Salix-Populus* or Ulmaceae) was revealed. Despite the small size of wood charcoal in Abric del Pastor, only a low proportion of the sample (14% of the charcoal assemblage) has been identified until angiosperms or conifers rank, apart from the fragments with a *confer* mention due to a poor preservation or a too small size. This suggests the interest in analysing the thin fraction in Paleolithic sites, where the small size of plant macroremains has led to misinterpretations about charcoal scarcity. On the other hand, not all species exhibit biogenic alteration to the same degree and recent studies highlight new methodologies to better understand different resistance of taxa to fungal decay (Henry and Théry-Parisot, *op. cit.*). Moreover, we do not know if fragmentation affects all the charcoal remains in a sample equally or if stronger fragmentation occurs in strongly altered charcoal. In this regard, anatomical observation in the Abric del Pastor assemblage has enabled identification of a high proportion of undetermined angiosperm fragments exhibiting stronger microbial decay (deformed and collapsed cell walls in cross section) than gymnosperms fragments. Fungal spread within the ligneous structure by hyphae has been detected in numerous fragments, and this process causes weakening of the charcoal fragments with the modification of cellulose and/or lignin by depolymerisation (Blanchette, 2000), leading to a stronger fragmentation. Further studies on charcoal analysis from Abric del Pastor will focus on the effect of mechanical and biogenic processes in order to obtain a broader view on the differential preservation of taxa at the site. Finally, a quantitative approach (Henry, 2011) applied on a larger anthracological sample to study microscopic anatomical alterations will allow the formulation of hypotheses about the macroscopic state of wood prior to combustion and ultimately about different possible fuel collecting strategies of Neanderthal groups in Abric del Pastor.

6. Conclusions

The wood charcoal remains from Stratigraphic Unit IV at Abric del Pastor yielded new data on the environmental conditions during the early Middle Paleolithic in Eastern Iberia. Our conclusions are as follows:

1. Botanical identification shed light on the characterisation of the landscape in the mountains of Alcoy in the Upper Pleistocene prior to MIS 3 and supports a chronological framework within milder periods of MIS 5. Stratigraphic Unit IV is associated to dry meso-supramediterranean conditions (mean annual temperature 8–17 °C and mean annual precipitation between 350 and 600 mm) with coniferous taxa dominated by *Juniperus* sp., a Mediterranean mixed forest, xerophytic taxa and hygrophilous plants.
2. Neanderthal firewood gathering based on the anthracological assemblage shows that there was not a scarcity of wood nearby the site. The primary firewood used was *Juniperus* sp. followed by shrubby formations and a low use of riverine taxa. Other coniferous species, such as yew and scots pine, were sporadically used. Firewood provisioning was based on abundance, availability and proximity to the rock shelter, but little nuances in gathering patterns have been observed in lithostratigraphic unit IVc, which has registered more varied supply areas with the presence of sunny slope shrubs. This point is related to the succession of reiterative firewood gathering within a lithostratigraphic unit formation.
3. The size separation of the Abric del Pastor samples in 4 fractions for the study of the charcoal fragmentation degree has revealed a concentration of the macroremains in 2–4 mm and 1–2 mm fractions. From a qualitative point of view, angiosperm taxa seem to fragment more than conifer taxa, as higher volume of angiosperm fragments have been observed in the small fractions (1–2 mm and <1 mm). The small size of plant macroremains in many old Palaeolithic sites has led to misinterpretations about charcoal scarcity. Consequently, the study of the thin fraction of sediments is needed.
3. Fungal deterioration, microorganism attacks and mechanical features have been noticed during SEM analyses at higher magnifications. One remaining question is the affection degree of microorganisms and post-depositional processes in archaeological woods, as it can introduce bias into palaeobotanical and palaeoeconomical interpretations with differential preservation of taxa. Consequently, a quantitative approach will be pursued in future studies in order to calculate the proportion of altered/non-altered charcoals and establish different degrees of alteration among the anthracological assemblages.

Fieldwork at Abric del Pastor is ongoing and we hope that S.U. V and S.U. VI wood charcoal remains will provide new data about environmental changes through time and Neanderthal firewood management patterns.

Acknowledgements

This work was carried out in context of a Ph. D Thesis at the Department of Prehistory and Archaeology (University of Valencia) with the financial support of a VALi + d predoctoral grant to P. Vidal (ACIF/2013/260). Research for the present paper has been supported by the projects HAR2012-32703 and HAR2011-24878. The first author is broadly grateful to Dr. E. Badal for her helpful corrections of the manuscript, to M. Vidal and S. Bergin for helping with English corrections and to the team members for their help with field and soil samples extraction tasks. Finally, we thank the anonymous reviewers who helped to improve the manuscript.

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