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Lighting the dark: Wood charcoal analysis from Cueva de Nerja (Málaga, Spain) as a tool to explore the context of Palaeolithic rock art

Éclairer l'obscurité : analyse de charbon de bois de Cueva De Nerja (Málaga, Espagne) comme outil pour l'exploration du contexte de l'art pariétal paléolithique

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ABSTRACT

This study examines 100 charred plant macroremains from the inner galleries of Cueva de Nerja in order to better understand the context of Palaeolithic rock art and obtain information about possible lighting systems. The remains were retrieved on the surface, very close to Palaeolithic cave paintings, and also from inside possible points of fixed lighting. The predominant wood-type is *Pinus* sp., especially *Pinus* tp. *sylvestris/nigra*. The taphonomic alterations recorded are attributable to the combustion process (vitrification and cracks), the possible gathering of dead wood (fungal hyphae/mycelia), the use of branches and twigs (reaction wood) and the burning of resinous taxa (resin marks). The identification of a vegetative bud of *Pinus sylvestris* furnishes information about the use of tree branches, as well as the time of year at which the Cueva de Nerja may have been frequented by prehistoric groups.

RÉSUMÉ

Cette étude examine 100 macrovestiges de plantes carbonisées provenant des galeries intérieures de Cueva De Nerja, afin de mieux comprendre le contexte de l'art pariétal paléolithique et d'obtenir des informations sur les possibles systèmes d'éclairage. Les restes ont été récupérés en surface, très près des peintures paléolithiques de la caverne, et également à l'intérieur des possibles lieux d'éclairage fixe. Le type de bois prédominant est *Pinus* sp., particulièrement *Pinus* tp. *sylvestris/nigra*. Les altérations taphonomiques enregistrées sont attribuables au processus de combustion (vitrification et fissures), à un possible ramassage de bois mort (hyphes/mycéliums de champignons), à l'utilisation de branches et de brindilles (bois de réaction) et à la combustion de taxons résineux

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(marques de résine). L'identification d'un bourgeon végétatif de *Pinus sylvestris* documente l'utilisation de branches d'arbre, ainsi que l'époque au cours de laquelle la Cueva de Nerja a pu être fréquentée par les groupes préhistoriques.

1. Introduction

The study of decorated caves from the Upper Palaeolithic has focused mainly on iconographic issues. However, a decorated cave used and frequented by prehistoric communities provides an opportunity for archaeological analysis (Clottes, 1993; Moure and González-Morales, 1988; Rouzaud, 1978) in which any evidence of human activity may potentially yield archaeological informations. The natural and physical environment in which human activity takes place is itself a crucial subject for analysis (Delannoy et al., 2012; Pastoors and Weniger, 2011).

Analysis of wood charcoal from archaeological contexts provides valuable information on human activities carried out in underground settings, because vestiges of wood charcoal are among the most frequently-recorded types of remains in the interior of certain decorated caves. Apart from taxonomical identification, with its palaeoclimatic and palaeo-ethnobotanical implications, taphonomic and dendrological analysis of these remains can furnish information about the combustible material used by humans, through the examination of three fundamental factors: calibre, degree of humidity and physiological state prior to combustion (Théry-Parisot, 2001). Findings yield valuable socioeconomic information about the way prehistoric groups procured provisions, and about the use and management of locally available natural resources (Carrión, 2005b; Marguerie and Hunot, 2007; Théry-Parisot et al., 2010).

Nevertheless, surprisingly little research has focused on the anthracological analysis of plant remains found inside caves containing Pleistocene art. This neglect may stem from the fact that the floors of decorated caves have generated scant interest until relatively recent times, and may also reflect the traditional focus of archaeobotany on palaeoenvironmental studies and habitat contexts.

This study analyses charcoal remains found in the interior galleries of the Cueva de Nerja, collected at the foot of Palaeolithic graphic manifestations, on the path leading to decorated areas, as well as inside possible points of fixed lighting (Medina and Romero, 2011; Medina et al., 2012), with the aim of determining the plant elements preserved at these locations, including their identification, their physiological and phenological state, the calibre of the wood burnt, etc. A further aim is to contribute new information concerning the composition of the plant landscape of the prehistoric exokarst and the ways in which humans exploited their immediate environments.

The charcoal remains analysed here are thought to be the residues of combustion probably stemming from the illumination needed to use and decorate the innermost parts of the cave in the prehistoric period. This view is based on the following grounds:

- the location, distribution and arrangement of the remains undoubtedly indicate human activity;
- the various sites at which charcoal has been recorded are isolated contexts within the karstic system;
- other types of material emanating from the outside world are not observed at these sites;
- the chronology with respect to the Upper Palaeolithic dating of most fragments by anthracological analysis confirms their prehistoric antiquity;
- the analysed remains cannot constitute the raw material used to create rock art, because all the Palaeolithic art recorded in the chambers from which these fragments came is painted in red (Sanchidrián, 1994).

2. Cueva de Nerja: archaeological background

The Cueva de Nerja is located in the district of Maro (Nerja, Málaga). The mouth of the cave is 940 m from the current coastline and 158 m above sea level on the southwestern flank of the Sierra Almijara. The rock is dolomitic marble from the Triassic belonging to the Alpujarra Complex of the Baetic Ranges. Its UTM coordinates are 30S VF26, x = 424.695, y = 4.069.025 (Fig. 1) (Carrasco et al., 1998; Jordá et al., 2011).

The cave has a surface area of approximately 35,484 m^2, a volume of 264,379.33 m^3 and a length of 4843 m. It is accessed from the outside via three openings, two of them natural in the form of rounded sinkholes, and the other an artificial entry, created by perforating the sedimentary deposits covering a section of the access vaults sealed in the Holocene (Del Rosal et al., 2009; Liñán et al., 2009).

The outermost chambers contain a wide range of Quarternary clastic deposits where various sedimentary sequences are in evidence, encompassing the isotopic stages OIS 3a, OIS 2 and the first part of OIS 1. Human occupation of the living quarters of the cave has been dated to a period between the Gravettian (29,940–28,580 cal. BP) and the Chalcolithic (4830–3600 cal. BP) (Jordá and Aura, 2009; Jordá et al., 2011; Sanchidrián and Márquez, 2005).

An earlier anthracological study carried out by Badal focussed on material emanating from the Sala del Vestíbulo ("Entrance Chamber"). Unlike the present study, Badal's paper examined charcoal found in an outer section of the cave's living quarters, which was affected by solar radiation during the day; the remains were collected from a chamber lacking any cave art and as part of a stratigraphic sequence. The diagram summarising the results encompasses Gravettian levels, where *Pinus nigra* can be seen to occur with notable frequency, accompanied by Leguminosae; in the layers ascribed to the Solutrean, Leguminosae start to overtake *Pinus nigra*, although the latter

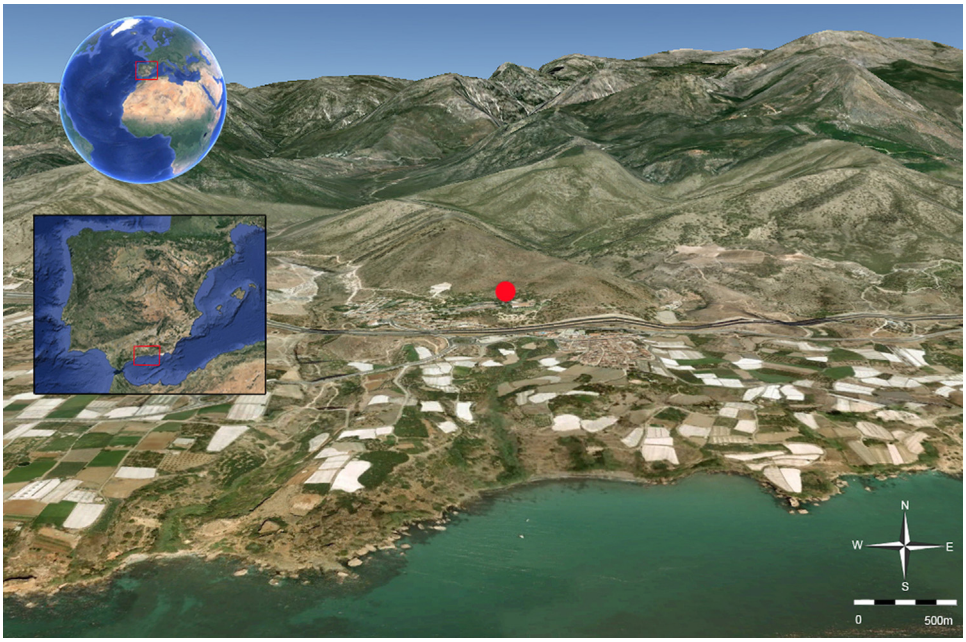

Fig. 1. (Color online.) Location of the studied area.
Fig. 1. (Couleur en ligne.) Localisation de la zone d'étude.
Modified from Google Earth.

continues to be well represented, with certain warmer species such as *Pinus halepensis, Pistacia terebinthus* and *Cneorum tricoccum* also emerging. The Magdalenian layers contain Leguminosae above all, although *Pinus nigra* is still present in low percentages. The Holocene levels are notable for the diversification of species, with warmer species such as the olive (*Olea europea var. sylvestris*) appearing and *Pinus nigra* continuing to decline, making a small recovery in the Epipalaeolithic or Early Holocene (Badal, 1996; Jordá et al., 2011; Rodríguez-Ariza and Montes, 2007).

In this same sequence, the most abundant charred plant macroremains are the bracts of pinecones and the shells of *Pinus pinea* pine nuts, while the percentages of woody remains coming from this species remain constant, never exceeding 15%. Such circumstances point to the socioeconomic management of this tree for the purpose of gathering of pine nuts, probably stemming from the high nutritional value of this fruit (Badal, 1998, 2001).

The interior galleries, which are the subject of this study and where sunlight does not penetrate, were also repeatedly used by prehistoric societies. Manifold indications of human activity have been recorded in these galleries: more than 100 graphic manifestations, anthropic modifications of the karstic geomorphology and numerous archaeological materials on the surface (flint, bones, ochre, ceramics and, above all, charred plant remains). At the time of writing, some twenty radiocarbon dating measurements have been made on charcoal fragments taken from the inner part of the cave. The majority of samples date back to the Upper Palaeolithic, with the Gravettian, Solutrean and Magdalenian periods all well represented. Up to now only two results have been ascribed to the Holocene (Romero et al., 2012; Sanchidrián, 1994).

3. Material and methods

For the purposes of this study, 100 charred plant fragments were selected from the inner galleries of the Cueva de Nerja, specifically from 14 geomorphically-defined sectors. Three percent of the remains were taken from the Galería del Fémur ("Femur Gallery") in the Sala de la Cascada ("Waterfall Chamber") (sector number 1). The remaining 97% were taken from the Sala del Cataclismo ("Cataclysm Chamber"). Moving clockwise and with the mouth of the cave at one's back, the relevant areas in this chamber were those known as: Plataforma (2), Cierva trilineal (3), Subida cierva (4), Corte moonmilk (5), Concavidad 15 (6), Camino a Fondo (7), Fondo (8), Pico-pato (9), Bitriangulares (10), Puente (11), Subida (12), Órganos (13) and Aledaños (14). Fig. 2 shows the sampled zones, together with a representation of the figurative rock art to be found in the Galerías Bajas (Lower Galleries) of Cueva de Nerja.

The number of fragments that have been analyzed is small due to the following reasons:

- there is a limited preservation of wood charcoal in both number and consistency because they are usually remains preserved on the surface and of Palaeolithic chronology;
- because our aim has been to carry out an integrated study where different analyses have been performed (taxonomic, taphonomic and dendrological); being one of the few studies on this problematic, it has been priorized to study fragments in detail rather than producing a higher number but not so thoroughly done.

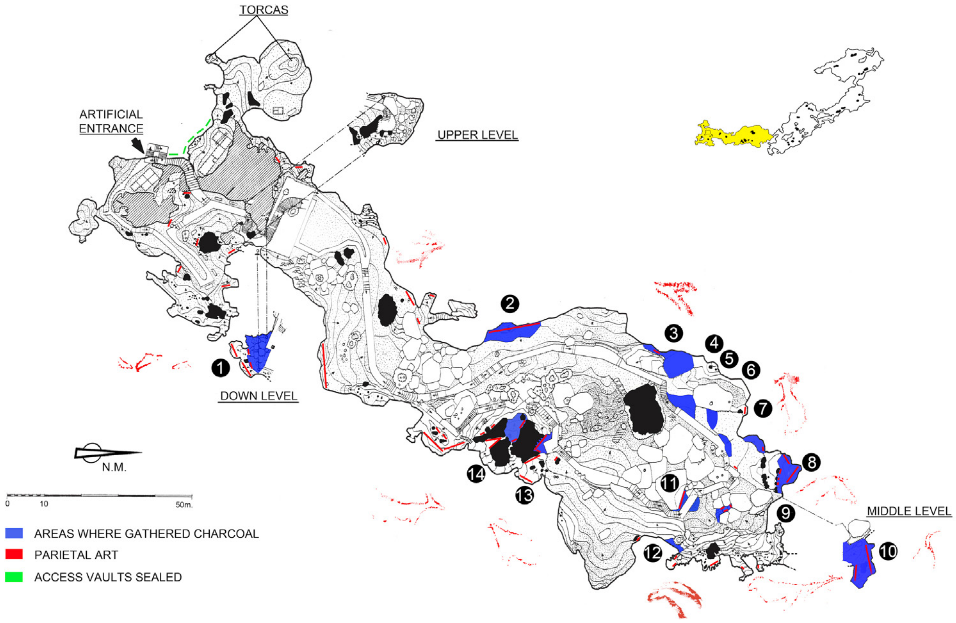

Fig. 2. (Color online) Topographic plan of the Lower Galleries of Cueva de Nerja with the location of the figurative rock art motifs and the sectors where wood charcoal has been sampled.
Fig. 2. (Couleur en ligne.) Plan topographique des galeries inférieures de Cueva De Nerja avec l'emplacement des motifs figuratifs d'art pariétal et des secteurs où du charbon de bois a été prélevé.

Modified from Ramírez et al., 1985 and Sanchidrián, 1994.

Most of the remains (92%) were found at surface level (Fig. 3) in the immediate vicinity of the Palaeolithic rock art, both grouped together in small charcoal clusters and spread about on the cave floors in a scattered and individualised way. The remaining fragments (8%) were located in the interior of natural and/or artificial cavities, full of sediment, that occur in karstic speleothems (flowstones, stalagmites, etc.), which were interpreted as possible fixed lighting points (Medina and Romero, 2011; Medina et al., 2012). These small depressions are also found very near places with Pleistocene art, as well as on the access route to decorated areas.

Fig. 3. (Color online) Photograph of the wood charcoal remains on the surface in sector number 7.
Fig. 3. (Couleur en ligne.) Photographie d'un assemblage de charbon de bois visible en surface dans le secteur numéro 7.

The recovery of remains located on the surface was carried out individually by removing each fragment directly, after general and macroscopic photographs of the area of provenance had been taken, along with its planimetric coordinates. To retrieve the fragments of charcoal found in the cavities, a micro-excavation of one quarter of the cavities' sedimentary deposits was carried out (Fig. 4). Pieces large enough to be subjected to anthracological study (larger than 2 mm) and dating by AMS (greater than 50 mg) were isolated. Meanwhile, part of the sampled sediment was subjected to flotation, with the aim of identifying more charcoal particles not visible to the naked eye.

The classification of the plant macroremains proceeded by the following stages.

3.1. Macroscopic recording

The remains were described by external physical observation using a stereoscopic microscope (Nikon SMZ 1500 7.5-30x). The parameters recorded were:

- *external morphology*, i.e. whether they were rounded or angular, and whether they displayed new or ancient cracking;
- *adhered sediment*, which was described in terms of its coloration, size and the compactness of its granules;
- *the consistency* of the fragments, scoring them high when they were difficult to crack, medium when they cracked

Fig. 4. (Color online) Photograph composition of wood charcoal and ashes in a natural concavity in sector 13.
Fig. 4. (Couleur en ligne.) Photographie d'un assemblage de charbon de bois et de cendres dans une concavité naturelle du secteur 13.

easily but did not disintegrate and low when cracking caused them to crumble into numerous particles;
- *the weight and dimensions* of all the remains.

All the fragments were also photographed in detail with a Nikon D200 digital camera connected to the stereoscopic microscope, with the aim of recording the initial morphology prior to cracking.

3.2. Taxonomic analysis

For taxonomic identification, the anatomical and biometric properties of the wood's three physical sections were recorded. Clean cuts were carried out on each fragment to obtain the three sections needed for analysis: transversal, tangential and radial (Chabal, 1997). Classification of each specimen was determined by comparing and checking with various reference sources in the wood anatomy field (García et al., 2002; Schweingruber, 1990; Vernet et al., 2001), and by using the charcoal reference collection held at the University of the Basque Country's Archaeobotanical Laboratory.

An Olympus BX50 light microscope was used with light reflected to a light-dark reflection field at magnifications between 50 and 500. A supplementary Nikon Eclipse 50i

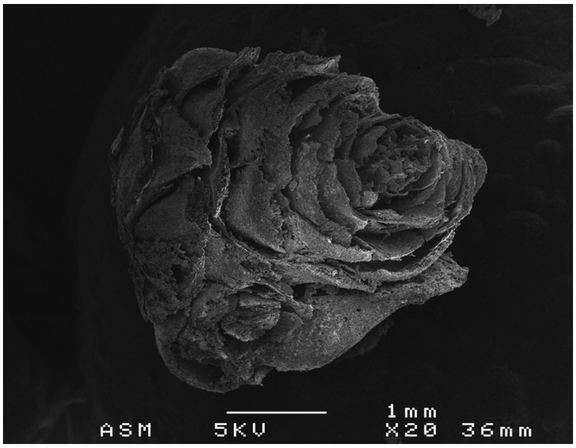

Fig. 5. SEM photograph of the remain identified as vegetative shoot of *Pinus sylvestris*.
Fig. 5. Photographie MEB du bourgeon végétatif de *Pinus sylvestris*.

microscope was also used with magnifications of between 40 and 1000, as well as a Nikon Coolpix 8400 digital camera for taking macro-photographs of the internal structure of the charcoal. Some specimens were also observed and photographed with SEM.

3.3. Taphonomic analysis

Although there are broader definitions of taphonomy (Théry-Parisot et al., 2010), this study will use the term to refer to microscopic analysis (using the equipment mentioned above) of the anomalies present in the internal structure of the wood charcoal.

The anatomical alterations observed were classified, according to their nature and origin, as: alterations caused by *combustion* (vitrification, cracks and the collapse of cells); by *entomofauna and microorganisms* (fungal hyphae/mycelia, insect degradation and compartmentalization), by *mechanical action* during the growth of the tree (knots, reaction wood and compression wood) and *other alterations* (traumatic resinous channels, tyloses, the sinuosity and eccentricity of the rings and the presence of bark and resin marks).

The definition of these alterations and their possible implications have been discussed by a number of authors, including: Schweingruber (1996, 2007), Scheel-Ybert (1998), Blanchette (2000), Théry-Parisot (2001), Allué (2002), Carrión (2005a, 2005b), Marguerie and Hunot (2007), Allué et al. (2009), Euba et al. (2010), McParland et al. (2010), Moskal-del Hoyo et al. (2010), Caruso-Fermé (2012), Martín (2012), Théry-Parisot and Henry (2012), Henry and Théry-Parisot (2014).

4. Results

Gross observation reveals that the dimensions and shapes of anthracological material recovered from the inner galleries of Cueva de Nerja are highly varied. The largest fragment by volume is 2 cm high, 1.2 cm wide, 1.1 cm deep and weighs 0.579 g. The remains generally

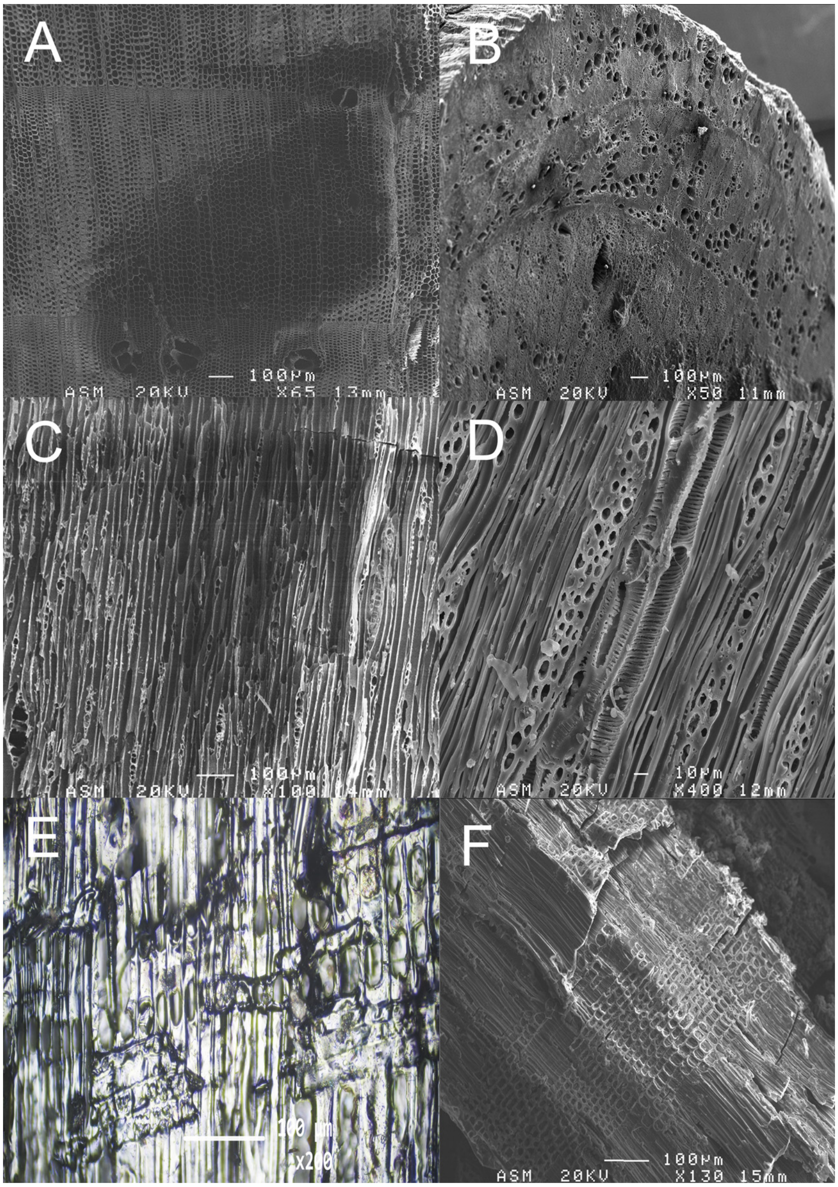

Fig. 6. Transversal section (A), tangential (C) and radial (E) of *Pinus* tp. *sylvestris/nigra*. Transversal section (B), tangential (D) and radial (F) of cf. Leguminosae. SEM photographs, except (E) with incident light microscopy.

Fig. 6. Coupe transversale (A), tangentielle (C) et radiale (E) de Pinus tp. *sylvestris/nigra*. Coupe transversale (B), tangentielle (D) et radial (F) de cf. Leguminosae. Photographies au MEB, excepté pour (E) en photomicroscopie de lumière incidente.

range between 1 and 1.5 cm in height, width and depth. Owing to the type and singularity of the context, however, very small pieces of little more than 1 mm at their largest were analysed. As far as the morphology is concerned, remains with recent cracking were recorded, while others were found to have highly aged and eroded surfaces. The consistency was generally low (67% of the remains) and the majority had sediment adhering (dolomitic sand, moonmilk, etc.), depending on the part of the cave from which they had been removed.

With regard to taxonomic identification, all the remains were woody specimens, with the sole exception of sample number 8, from the Fondo sector (8), which was classified as a vegetative shoot of *Pinus sylvestris* (Fig. 5). Of the woody fragments, 82% belonged to the Gymnosperms group. *Pinus* sp. was the genus that occurred most frequently, comprising some 80% of the analysed remains. The most commonly-occurring anthracological type was *Pinus* tp. *sylvestris/nigra* (Fig. 6A, C and E), with a frequency of 64%. The taxa identified as *Pinus* cf. *Pinus* tp. *pinea/pinaster* accounted for 3% of the total; 10% of the remains were Leguminosae (Fig. 6B, D and F), while 2% were indeterminate angiosperms and 6% are indeterminate. The results for each sector are provided in Table 1.

Table 1
Plant macroremains identified and frequency in the different sectors of the cave.
Tableau 1
Macro-restes de plantes identifiées et fréquence dans les différents secteurs de la grotte.

Taxa identified	Sectors														No.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Gimnosperms															
Pinus tp. *sylvestris/nigra*		13		1	11	4	1	3	4	3	4	1	1		46
Pinus cf. *Pinus* tp. *sylvestris/nigra*		4	1	1	2			1	3		3		2		17
Shoot of *Pinus sylvestris*								1							1
Pinus cf. *Pinus* tp. *pinea/pinaster*		3													3
Pinus sp.	1	4						2	4	2					13
Gymnosperm	2														2
Angiosperms															
Leguminosae		2						1	1						4
cf. Leguminosae		5												1	6
Indeterminate angiosperm									1				1		2
Taxa indeterminate								2	1	3					6
Total	3	31	1	2	13	4	1	10	14	8	7	1	4	1	100

As far as taphonomic alterations are concerned, vitrification (Fig. 7C and E) was the most frequent (83%). However, the degree to which it was present was very slight, enabling the anatomical structure of most charcoal fragments to be observed. Cracks were also common, being encountered in 65% of cases (Fig. 7C). Alterations caused by fungal hyphae/mycelia were detected in 61% of the remains analysed (Fig. 7A and B). Alterations stemming from mechanical actions during the life of the tree were also documented: of the 100 fragments, 49 displayed indications of reaction wood (Fig. 7D) and three were knots in the wood. Moreover, 80% of the fragments studied exhibited resin marks, above all in their longitudinal planes (Fig. 7f). Table 2 shows the taphonomic alterations examined, their frequency and their distribution throughout the various sectors of the cave.

5. Discussion

Anthracological analysis of the plant remains recovered from the inner areas of Cueva de Nerja enabled the investigation of the materials chosen to penetrate into the deepest parts of the cave, probably linked to the lighting systems used.

5.1. Wood used in the inner most parts of Cueva de Nerja

Taxonomic analysis confirmed the predominant use of wood from *Pinus* sp. and, in particular, *Pinus* tp. *sylvestris/nigra* together with other, scarcely present, species such as Leguminosae for fire-making in the decorated parts of the cave.

Table 2
Taphonomic alterations observed and their frequency in the different sectors of the cave.
Tableau 2
Altérations taphonomiques observées et leur fréquence dans les différents secteurs de la grotte.

Anatomical alterations	Sectors														No.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
By mechanical action															
Knot		1					1						1		3
Reaction wood		16	1	1	7	2	4	1	6	2	1	6	2		49
Compression wood															
By entomofauna and microorganisms															
Fungal hyphae/myceliums	3	16	1	1	13	3	4	1	10	1	1	4	3		61
Insect degradation															
Compartmentalization															
By combustion															
Vitrification	2	22	1	1	13	4	8	1	13	6	1	7	4		83
Crack	2	22	1	1	10	3	5	1	8	3		7	2		65
Collapse of cells															
Other alterations															
Resin marks	3	21	1	2	13	4	8	1	11	5	1	7	3		80
Traumatic resinous channels															
Tyloses															
Sinuosity of the rings															
Eccentricity of the rings															
Bark															
Total	10	98	5	6	56	16	30	5	48	17	4	31	15		341

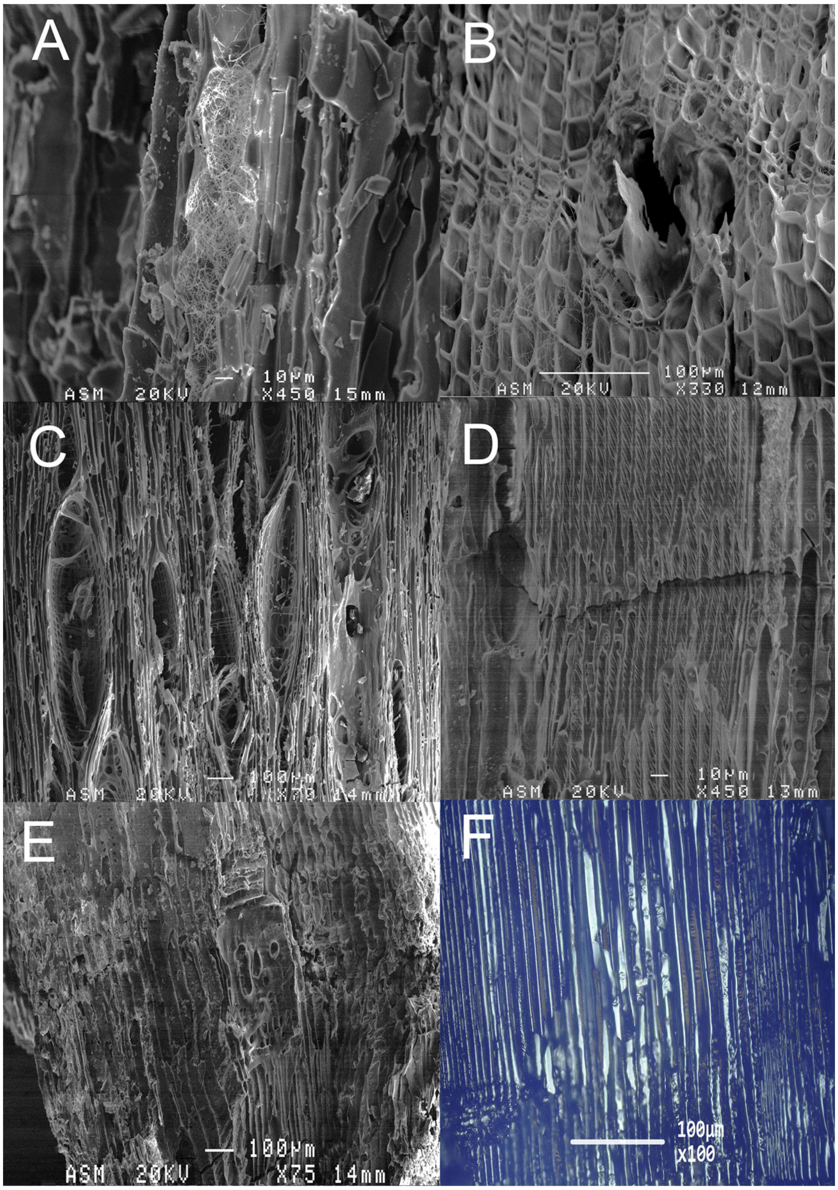

Fig. 7. (Color online) Taphonomic alterations found in this study: hyphae/mycelium in tangential (A) and transversal section (B), cracks and vitrification in tangential section (C), reaction wood in radial section (D), vitrification in radial section (E) and resin stigma in longitudinal pores (F) of several *Pinus* tp. *sylvestris/nigra* fragments. SEM photographs, except (F) with incident light microscope.

Fig. 7. (Couleur en ligne.) Altérations taphonomiques observées : hyphes/mycéliums de champignons en section tangentielle (A) et transversale (B), fissures et vitrification en section tangentielle (C), bois de réaction en section radiale (D), vitrification en section radiale (E) et marques de résine dans les pores longitudinaux (F) de plusieurs fragments de *Pinus* tp. *sylvestris/nigra*. Photographies au MEB, excepté pour (F) en photomicroscopie de lumière incidente.

The properties of pinewood as a woody fuel are only too well known. Numerous historical, ethnographic and experimental accounts confirm its suitability for making fire and light, and especially for making torches. Its high flammability and usefulness in lighting were known to antiquity (Segura and Torres, 2009). Some ethnographic analogies relating to the pre-Hispanic Mayan people suggest a semantic correlation between burning pinewood torches during ritual ceremonies in caves and the modern use of candles (Morehart et al., 2005). By the same token, experimental studies have confirmed the benefits of pinewood for lighting, stemming above all from its molecular arrangement and the resin it contains (made up largely of terpene hydrocarbons with a high calorific value), which helps in igniting the wood, yielding a flame that combines high levels of durability and radiation (Théry-Parisot and Thiébault, 2005); these factors make it eminently suitable for use as a fuel in caves of the size of the Cueva de Nerja.

While pine was present in all the sectors studied, in four of them it was found in combination with Leguminosae. Bushy species such as leguminous plants generally burn well owing to their small size, and burn better and faster than large pieces, especially when dry; this accounts for their use in burning as a means of starting fires (Chabal, 1997).

The various lighting techniques employed by prehistoric societies to overcome the utter darkness of caves (torches, fires and stone lamps) (Beaune, 2000) may have involved the use of woody fuels. No traditional lamps have been recorded to date at the Cueva de Nerja, but the use of portable lighting would be indispensable to penetrate and move around the cave, as well as to light the fixed fires of the cavities (Medina and Romero, 2011; Medina et al., 2012). Perhaps torches played a fundamental role in this cave, since they are eminently suitable for wandering around especially large caves, exploring new areas and throwing light in all directions (Beaune, 2000; Rouzaud, 1990). A large number of the charcoal fragments found on the floor of the cave probably stem from wandering humans carrying torch-like burning objects. To increase the flame's luminosity it would have been sufficient to move it swiftly in the air so as to oxygenate the fire. Such an action unleashes a scattering of numerous charcoal fragments in the vicinity, as confirmed by experiments carried out by one of the authors (MAM-A) and the Cueva de Nerja archaeological team.

Interestingly, anthracological data available for the internal archaeological contexts of other caves with Pleistocene art yield similar taxonomic information. The 122 charcoal fragments studied at the Chauvet Cave have been identified as *Pinus* tp. *sylvestris/nigra* (Théry-Parisot and Thiébault, 2005). Also, 130 fragments identified at the Réseau Clastres have been characterized as *Pinus sylvestris* except for an indeterminated hardwood remain (Clottes, 1995). The torch remains found in this Gallery have been identified as *Pinus* (Clottes, 1993). Small groups of charcoal fragments found in the Tête du Lion Cave in the excavation at the foot of the main panel were identified as *Pinus sylvestris* (Combier, 1984). Besides, 116/258 fragments from Cosquer Cave belonged to and indeterminated conifer (although authors point out that they might be *Pinus sylvestris*) and the other 142 remains were identified as *Pinus sylvestris* (Clottes et al., 2005). Moreover, one of the charcoal particles found in the exploration of the Sala de las Pinturas ("Paintings Chamber") of the Cueva de Etxeberri (Garate et al., 2012), was identified as Gymnosperm wood with vitrification marks (L. Zapata, unpublished work). The remains of coniferous wood burning, probably *Taxus* or *Juniperus*, were detected in the pink earthenware lamp found in the Lascaux cave (Delluc and Delluc, 1979; Leroi-Gourhan et al., 1979). Likewise, in Aldène cave some fragments from *frottis de torche* have been identified as conifer wood (juniper, *Juniperus communis*) (Perles, 1977).

The taxa identified in this study were also identified in the sedimentary sequence of the outer occupied chamber known as Vestíbulo (Badal, 1996, 1998; Jordá et al., 2011).

Data are available for 12 ^{14}C-AMS samples of wood charcoal found on the floor or in fixed lighting points in two areas decorated with Pleistocene art in the Cueva de Nerja chambers included in this study: Cascada and Cataclismo. Of the 100 fragments analysed in this study, nine have also been dated. Fig. 8 shows the results of dating up to now in the sectors analyzed in this paper. Of these, five yield dates going back to the Gravettian and the Solutrean, periods in which *Pinus nigra* is the most widely-recorded taxon in habitation contexts. Two dating results point to the Magdalenian period, while the last indicates a Holocene chronology. *Pinus nigra* is scarcely represented at all in the anthracological picture of the Vestíbulo chamber in these more recent periods. The three remaining dating results were derived without anthracological determination. They all relate to the Upper Palaeolithic: one is Gravettian, another is Solutrean and the last is Magdalenian.

A recent survey of Late Quaternary dynamics of pinewoods in the Iberian mountains (Rubiales et al., 2010) indicates that the landscape of the Baetic System around the time of the Late Glacial period was dominated by herbaceous plants (chiefly Poaceae and *Artemisia*) alternating spatially and temporally with wooded landscapes where pine was the dominant taxon, together with evergreen *Juniperus* and deciduous *Quercus*. Forests predominated in the landscapes of the Late Glacial and two distinct models emerge, reflecting the palaeobotanical data available: on the one hand, there is a clear predominance of pine trees throughout the period at between 500 and 1350 metres above sea level in the interior and north-eastern regions of the Baetic System and, on the other hand, the growing presence of *Quercus* in the western regions, owing to the effect of Atlantic air currents flowing through the Genil valley, and in the milder climatic conditions of the Late Glacial interstadial. Pine trees may also have been present at altitudes higher than these zones.

Pending the palynological findings from the Quaternary clastic deposits of the Cueva de Nerja (research in progress), palaeo-palynological data from nearby sites were analysed in order to gain for a picture of the flora that predominated at these altitudes. Studies of this sort carried out at Cueva de Bajondillo (Torremolinos, Málaga), 75 km to the west of Nerja, show the presence of *Pinus pinea/halenpensis* and *pinaster* from at least the end of the Solutrean to the start of the Holocene (Cortés et al., 2008; López-Sáez et al., 2007). Investigations carried out at the Abrigo 3 site at the Complejo del Humo (Málaga), located 46 km to the west of Nerja, suggest that pine trees were abundant throughout the Upper Palaeolithic, with coastal pines (*Pinus pinea* and *Pinus halepensis*) in areas close to the site and highland pines (*Pinus nigra* and *Pinus sylvestris*) in the mountainous foothills bordering the coast (López-Sáez et al., in press).

5.2. Physiological condition of the gathered wood

Of the 13 taphonomic alterations assessed in this study only six have been documented: knots, reaction wood, fungal hyphae/mycelia, vitrification, cracks and resin marks. With the exception of knots, which were only detected in three fragments from three different contexts, the other anomalies occurred with high frequency and were present in almost all sectors.

The purpose of identifying fungal hyphae in archaeological charcoal is to try to determine the state of the wood used as fuel, given that hunter-gatherer groups must commonly have used dead wood that had become detached from trees (Asouti and Austin, 2005; Carrión, 2005b). A high

SECTOR	14-C DATATION			TAXA IDENTIFIED	LOCATION		PARIETAL ART	MOTIF NUMBER (Sanchidrián, 1994)
	Laboratory reference	Conventional radiocarbon Age (B.P.)	2σ calibration calibrated result 95% prob. (INTCAL13)		Surface	Fixed lighting points		
1. Galería del Fémur	Beta-347462	5160 ± 30	Cal BC 4035 to 4020 (Cal BP 5985 to 5970)	*Pinus* sp.	■		■	Out of catalogue
2. Plataforma	Beta-347457	21900 ± 90	Cal BC 24285 to 24010 (Cal BP 26235 to 25960)	*Pinus* tp. *sylvestris/nigra*	■		■	Out of catalogue
3. Cierva trilineal	Beta-342842	13380 ± 60	Cal BC 14300 to 14000 (Cal BP 16250 to 15950)	*Pinus* cf. *Pinus* tp. *sylvestris nigra*	■		■	177
4. Subida cierva	Beta-342843	13920 ± 60	Cal BC 15110 to 14725 (Cal BP 17060 to 16675)	*Pinus* tp. *sylvestris/nigra*		■		
5. Corte moonmilk					■			
6. Concavidad 15	Beta-271211	23800 ± 140	Cal BC 26125 to 25730 (Cal BP 28075 to 27680)	*Pinus* tp. *sylvestris/nigra*		■		
7. Camino a Fondo				*Pinus* tp. *sylvestris/nigra*	■		■	Out of catalogue
8. Fondo	Beta-277745	35320 ± 360	Cal BC 38745 to 37085 (Cal BP 40695 to 39035)	Indeterminate		■	■	190-212
	Beta-298419	23880 ± 130	Cal BC 26205 to 25780 (Cal BP 28155 to 27730)	*Pinus* cf. *Pinus* tp. *sylvestris/nigra*	■		■	
9. Pico-pato	Beta-342844	13490 ± 50	Cal BC 14395 to 14165 (Cal BP 16345 to 16115)	*Pinus* cf. *Pinus* tp. *sylvestris/nigra*	■		■	223-226
10. Bitriangulares	Beta-271212	20980 ± 100	Cal BC 23605 to 23170 (Cal BP 25555 to 25120)		■		■	214-22
11. Puente	Beta-298418	12890 ± 60	Cal BC 13650 to 13260 (Cal BP 15600 to 15210)		■		■	188
12. Subida					■			
13. Órganos	Beta-306992	29650 ± 160	Cal BC 32070 to 31650 (Cal BP 34020 to 33600)	*Pinus* cf. *Pinus* tp. *sylvestris/nigra*		■	■	111-156
	Beta-277744	24130 ± 140	Cal BC 26535 to 25910 (Cal BP 28485 to 27860)		■		■	
14. Aledaños					■		■	94-103

Fig. 8. Summary of the radiometric data from the sectors that have been analyzed. Information is also included about their location in the cave and its relationship with rock art. Numbers in bold correspond to remains characterized before being dated.

Fig. 8. Résumé des données radiométriques des secteurs qui ont été analysés. L'information est également incluse au sujet de leur emplacement dans la grotte et de leurs relations avec l'art pariétal. Les numéros en gras correspondent aux restes caractérisés avant d'être datés.

proportion of the Nerja fragments (61%) exhibited fungal hyphae/mycelia. There is no conclusive consensus among specialists, however, regarding the dating of this contamination; it usually occurs in branches that have fallen and died, but can also take place while the tree is standing or even while the fuel is being stored (Moskal-del Hoyo et al., 2010; Théry-Parisot, 2001).

Alterations and phenomena prompted by the combustion process are widely present in the samples. Vitrification occurs in 83% of the fragments. The main causes of vitrification in burning wood are elevated humidity and high temperatures (Caruso-Fermé, 2012). Carrión (2005b) shares this view, adding that the restricted atmosphere, the slow combustion and the stable temperature, as well as the sudden interruption of carbonisation in the pyrolysis stage of combustion tend to contribute to the vitrified appearance of wood charcoal. Marguerie and Hunot (2007) add that rapid carbonisation at high temperatures, as well as the burning of small calibre twigs, tend to produce this phenomenon. Recent findings, however, appear to counter this view, suggesting that vitrification is not the outcome of combustion at high temperatures or with resinous or green wood (McParland et al., 2010). Scheel-Ybert (1998) argues that burning unseasoned wood and resinous taxa leads to greater vitrification, a proposal that perfectly fits the present findings.

Cracking, another alteration connected to the combustion process, was detected in 65% of the fragments analysed. The release of gases and water vapour from the wood in the first stages of carbonisation produces fissures, generally in the cross-sectional plane of the wood, although it can also occur in longitudinal sections (Fig. 7C). Théry-Parisot and Henry (2012) determine thanks to an experimental work with wood of wild *Pinus sylvestris* "...that the occurrence of radial cracks is not correlated with the moisture content. Therefore, the percentage of radial cracks in an archaeological sample is not a relevant indicator of the combustion of green wood in ancient hearths..." (p. 387) "...Nevertheless, the number of radial cracks (RC/cm2) could represent a new method that might help identifying the combustion of green wood in archaeological charcoal samples..." (p. 387). Nevertheless, as these authors indicate, it is necessary to test this method with archaeologic samples generally smaller and with a state of conservation lower, as well as with other species. A similar study has been presented by Caruso-Fermé and Théry-Parisot (2011) with Patagonian Andean Wood. Also, some authors have suggested that the frequency of radial cracks is linked to the internal anatomical structure of the wood, being commoner in species with large, dense radii, as well as the position of the fuel within the wood, with the frequency of the cracks being inversely correlated to proximity to the pith (Marguerie and Hunot, 2007).

A total of 80% of specimens exhibited visible signs of burnt resin. These marks take the form of brownish stains, similar to the colour of amber, generally located in the walls of the longitudinal vessels (Fig. 7F). All the taxa identified as *Pinus* sp. displayed these marks. It is hoped that the experimental work now under way will help to clarify the taphonomic information emerging from this observation and establish whether, for example, pieces with a high resin content were chosen or resin was added to the torches and lighting devices as both historians and ethnographers have suggested.

Another taphonomic alteration repeatedly recorded was reaction wood (49% of the fragments under examination). The presence of this anomaly is connected to a tree losing uprightness as a consequence of subsidence in the forest floor, the trunk leaning to one side, the presence of strong winds, the weight of large quantities of snow, etc. (Carrión, 2005b; Caruso-Fermé, 2012; Martín, 2012; Schweingruber, 1996, 2007). This alteration can also indicate the original location of the combustible wood within the log from which it comes, because it is associated with a pronounced curvature close to the pith or deriving from branches (Marguerie and Hunot, 2007).

The detection of certain taphonomic alterations, as mentioned above, also points to the use of branches. Vitrification often affects twigs and the reaction wood may indicate either the use of branches or the fragment's original position within the trunk, given that it is associated with a highly pronounced curvature (Marguerie and Hunot, 2007).

Moreover, the classification of one of the fragments from the Fondo sector of the Sala del Cataclismo (8) as a *Pinus sylvestris* vegetative bud also points to the use of branches and yields information about seasonality, since such buds only emerge in branches in autumn and winter (Ruiz de la Torre, 2006). When taken in conjunction with the result of dating one of the *Pinus* cf. *Pinus* tp. *sylvestris/nigra* charcoal fragments recovered a few centimetres away from the remains – 23,880 ± 130 BP – this information suggests that this sector of Cueva de Nerja was at least visited at some time in the aforementioned time interval and in the autumn-winter period.

6. Conclusions

Taxonomic and taphonomic analysis of 100 charred plant macroremains taken from the internal archaeological context of Cueva de Nerja indicates that Upper Palaeolithic groups used wood as a combustible material in order to penetrate the innermost parts of the cave; they tended to use small and medium-sized branches of pine, compatible with the anatomy of *Pinus sylvestris* (scots pine) and *Pinus nigra* (black pine). The reasons for the recurrent use of pine appear to be linked to its presence in the vicinity of the cave, as indicated by certain palaeobotanical markers, but also its properties as a fuel, above all the fact that it contains resin, a highly flammable substance. The identification of leguminous plants next to the pine fragments at a number of the sites examined suggests the combination of both fuels or perhaps the use of these bushy specimens for igniting fires. The presence of hyphae and mycelia in more than half the remains may indicate the use of dead wood. Alterations stemming from the combustion process, such as vitrification and cracking, are highly prevalent. The identification of a *Pinus sylvestris* vegetative bud yields information about the time of year in which the cave may have been used (autumn-winter).

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References

Allué, E., 2002. Dinámica de la vegetación y explotación del combustible leñoso durante el Pleistoceno Superior y el Holoceno del Noreste de la Península Ibérica a partir del análisis antracológico. Universitat Rovira i Virgili, Tarragona (Tesis doctoral inédita).

Allué, E., Euba, I., Solé, A., 2009. Charcoal Taphonomy: The Study of the Cell Structure and Surface Deformations of *Pinus sylvestris* type for the Understanding of Formation Processes of Archaeological Charcoal Assemblages. J. Taphon. 7 (2–3), 57–72.

Asouti, E., Austin, P., 2005. Reconstructing Woodland Vegetation and its Exploitation by Societies, based on the Analysis and Interpretation of Archaeological Wood Charcoal Macro-Remains. Environ. Archaeol. 10, 1–18.

Badal, E., 1996. La vegetation du Paleolithique superieur et de l'Épipaleolithique aux alentours de la Cueva de Nerja. Actes du colloque de Périgueux 1995. Supplément à la Rev. d'Archéom., pp. 171–176.

Badal, E., 1998. El interés económico del Pino piñonero para los habitantes de la Cueva de Nerja. In: Sanchidrián, J.L., Simón, M.D. (Eds.), Las culturas del Pleistoceno superior en Andalucía. Patronato de la Cueva de Nerja, Málaga, pp. 287–300.

Badal, E., 2001. Leña para el fuego. In: Villaverde, V. (Ed.), De neandertales a cromañones. El inicio del poblamiento humano en las tierras valencianas. Universidad de Valencia, Valencia, pp. 105–106.

Beaune, S.A., 2000. Les techniques d'éclairage paléolithiques : un bilan/Paleolithic lighting technics: an overview. PALEO. 12, 19–27.

Blanchette, R.A., 2000. A review of microbial deterioration found in archaeological wood from different environments. Int. Biodeterior. Biodegrad. 46, 189–204.

Carrasco, F., Durán, J.J., Andreo, B., Liñán, C., Vadillo, I., 1998. Consideraciones sobre el karst de Nerja. In: Durán, J.J., López, J. (Eds.), Karst en Andalucía. Instituto Tecnológico Geo-Minero de España, Madrid, pp. 173–181.

Carrión, Y., 2005a. Dendrología y Arqueología: las huellas del clima y de la explotación humana de la madera. In: Molera, J., et al. (Eds.), Avances en Arqueometría, Actas del VI Congreso Ibérico de Arqueometría, Fundació Privada Girona. Universitat i Futur, Gerona, pp. 273–282.

Carrión, Y., 2005b. La vegetación mediterránea y atlántica de la península ibérica: nuevas secuencias antracológicas. Diputación provincial de Valencia, Valencia.

Caruso-Fermé, L., 2012. Modalidades de adquisición y usos de los recursos leñosos entre cazadores-recolectores patagónicos (Argentina): metodología y técnicas de estudio del material leñosos arqueológico. Universidad Autónoma de Barcelona, Barcelona (Tesis doctoral inédita).

Caruso-Fermé, L., Théry-Parisot, I., 2011. Experimentation and combustion properties of Patagonian Andean wood. SAGVNTVM Extra. 11, 39–40.

Chabal, L., 1997. Forêts et sociétés en Languedoc (Néolithique final Antiquité tardive). L'anthracologie, méthode et paléoécologie. Maison des sciences de l'Homme, Paris.

Clottes, J., 1993. Contexte archéologique interne. In: GRAPP (Ed.), L'Art pariétal paléolithique. Techniques et méthodés d'étude. Comité des travaux historiques et scientifiques, Paris, pp. 49–58.

Clottes, J., 1995. Les cavernes de Niaux. Art préhistorique en Ariège. Seuil, Paris.

Clottes, J., Courtin, J., Vanrell, J., 2005. Cosquer redécouvert. Seuil, Paris.

Combier, J., 1984. La grotte de la Tête-du-Lion à Bidon (Ardèche). In: Leroi-Gourhan, A. (Ed.), L'Art des Cavernes. Imprimerie Nationale, Ministère de la Culture, Paris, pp. 595–599.

Cortés, M., Morales, A., Simón, M.D., Bergadà, M.M., Delgado, A., López, P., López-Sáez, J.A., Lozano, M.C., Riquelme, J.A., Roselló, E., Sánchez, A., Vera-Peláez, J.L., 2008. Paleoenvironmental and cultural dynamics of the coast of Málaga (Andalusia, Spain) during the Upper Pleistocene and Early Holocene. Quat. Sci. Rev. 27, 2176–2193.

Del Rosal, Y., Lara, M.D., Tinaut, A., Garrido, A., 2009. La entomofauna en la Cueva de Nerja (Málaga). In: Durán, J.J., López, J. (Eds.), Cuevas Turísticas, cuevas vivas, II Congreso español sobre cuevas turísticas. Asociación Cuevas Turísticas Españolas, Madrid, pp. 91–100.

Delannoy, J.J., Geneste, J.M., David, B., Katherine, M., Gunn, R.G., Whear, R.L., 2012. Apports de la géomorphologie dans l'aménagement et la constrution sociale de sites préhistoriques. Exemples de la grotte Chauvet-Pont-d'Arc (France) et de Nawarla Gabarnmang (Australie). PALEO. 23, 85–104.

Delluc, B., Delluc, G., 1979. L'éclairage. In: Leroi-Gourhan, A., Allain, J. (Eds.), Lascaux inconnu. CNRS, Paris, pp. 121–142.

Euba, I., Allué, E., Palet, J.M., 2010. Alteraciones biológicas de la madera: el estudio de los materiales constructivos del yacimiento de Pleta de l'Estall Serrer (Valle del Madriu, Andorra). In: Saiz, M.E., et al. (Eds.), Actas del VIII Congreso Ibérico de Arqueometría. Seminario de Arqueología y Etnología Turolense, España, pp. 305–314.

Garate, D., Bourrillon, R., Ríos-Garaizar, J., 2012. La grotte ornée paléolithique d'Etxeberri (Camou-Cihige, Pyrénées-Atlantiques): datation du contexte archéologique de la « salle des Peintures ». Bull. Soc. Prehist. Fr. 109 (4), 637–650.

García, L., De Palacios, P., Guindeo, A., García, L., Lázaro, I., González, L., Rodríguez, Y., García, F., Bobadilla, I., Camacho, A., 2002. Anatomía e identificación de maderas de coníferas a nivel de especie. Fundación Conde del Valle de Salazar y Mundi-Prensa, Madrid.

Henry, A., Théry-Parisot, I., 2014. From Evenk campfires to prehistoric hearths: charcoal analysis as a tool for identifying the use of rotten wood as fuel. J. Archaeol. Sci. 52, 321–336.

Jordá, J., Aura, E., 2009. El límite Pleistoceno-Holoceno en el yacimiento arqueológico de la Cueva de Nerja (Málaga, España): nuevas aportaciones cronoestratigráficas y paleoclimáticas. Geogaceta 46, 95–98.

Jordá, J., Maestro, A., Aura, E., Álvarez, E., Avezuela, B., Badal, E., Morales, J.V., Pérez, M., Villalba, M.P., 2011. Evolución paleogeográfica, paleoclimática y paleoambiental de la costa meridional de la Panínsula Ibérica durante el Pleistoceno superior. El caso de la Cueva de Nerja (Málaga, Andalucía, España). Bol. R. Soc. Esp. Hist. Nat. 105 (1–4), 137–147.

Leroi-Gourhan, A., Schweingruber, F.H., Girard, M., 1979. Les bois. In: Leroi-Gourhan, A., Allain, J. (Eds.), Lascaux inconnu. CNRS, Paris, pp. 185–188.

Liñán, C., Carrasco, F., Calaforra, J.M., Del Rosal, Y., Garrido, A., Vadillo, I., 2009. Control de los parámetros medioambientales en las Galerías Altas y Nuevas de la Cueva de Nerja (Málaga). Resultados preliminaries. In: Durán, J.J., López, J. (Eds.), Cuevas Turísticas, cuevas vivas, II Congreso español sobre cuevas turísticas. Asociación Cuevas Turísticas Españolas, Madrid, pp. 131–144.

López-Sáez, J.A., Alba, F., López, L., Pérez, S., in press. Historia de la vegetación en la costa de Málaga durante el Paleolítico medio y el superior. Análisis arqueopalinológico del Abrigo 3 del Complejo del Humo.

López-Sáez, J.A., López, P., Cortés, M., 2007. Paleovegetación del Cuaternario reciente: Estudio arqueopalinológico. In: Cortés, M. (Ed.), Cueva Bajondillo (Torremolinos), Secuencia cronocultural y paleoambiental del Cuaternario reciente en la Bahía de Málaga, Diputación de Málaga. Junta de Andalucía, Universidad de Málaga, Fundación Cueva de Nerja y Fundación Obra Social de Unicaja, Málaga, pp. 139–156.

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

Martín, M., 2012. A xestión do bosque e do monte dende a Idade do Ferro á época romana no noroeste da península Ibérica: consumo de combustibles e produción de manufacturas en madeira. Universidade Santiago de Compostela, Santiago de Compostela (Tesis doctoral inédita).

McParland, L.C., Collinson, M.E., Scott, A.C., Camobell, G., Veal, R., 2010. Is vitrification in charcoal a result of high temperature burning of wood? J. Archaeol. Sci. 37, 2679–2687.

Medina, M.A., Cristo, A., Romero, A., Sanchidrián, J.L., 2012. Otro punto de luz. Iluminación estática en los "santuarios" paleolíticos: el ejemplo de la Cueva de Nerja (Málaga, España). In: Clottes, J. (Ed.), L'art pléistocène dans le monde/Pleistocene art of the world/Arte pleistoceno en el mundo. IFRAO, Tarascon-sur-Ariège, pp. 105–121.

Medina, M.A., Romero, A., 2011. Iluminando el Paisaje Subterráneo: reflexiones iniciales y primeros resultados. In: Montalvo, E., Sebastián, M. (Eds.), El legado artístico de las sociedades prehistóricas: nuevos paradigmas de análisis y documentación. Universidad de Zaragoza, Zaragoza, pp. 49–52.

Morehart, C.T., Lentz, D.L., Prufer, K.M., 2005. Wood of the Gods: The ritual use of Pine (*Pinus* sp.) by the ancient lowland Maya. Soc. Am. Archaeol. 16, 255–274.

Moskal-del Hoyo, M., Wachowiak, M., Blanchette, R.A., 2010. Preservation of fungi in archaeological charcoal. J. Archaeol. Sci. 37, 2106–2116.

Moure, A., González-Morales, M.R., 1988. El contexto del arte parietal. La tecnología de los artistas en la Cueva de Tito Bustillo (Asturias). Trabajos de Prehistoria. 45, 19–49.

Pastoors, A., Weniger, G.C., 2011. Cave Art in Context: Methods for the Analysis of the Spatial Organization of Cave Sites. J. Archaeol. Res. 19, 377–400.

Perles, C., 1977. Préhistoire du feu. Masson, Paris.

Ramírez, F., Gutiérrez, J.M., Durán, J.A., 1985. Descripción de la cavidad. In: GES de la Sociedad Excursionista de Málaga (Ed.), La Cueva de Nerja. Sociedad Grupo de Espeleólogos Granadinos, Granada, pp. 50–79.

Rodríguez-Ariza, M.O., Montes, E., 2007. Origen y domesticación del olivo en Andalucía (España) a partir de los hallazgos arqueológicos de *Olea europea* L. In: I Congreso de la Cultura del Olivo. Instituto de Estudios Giennenses, Jaén, pp. 221–244.

Romero, A., Cristo, A., Medina, M.A., Sanchidrián, J.L., 2012. Datación del contexto arqueológico y frecuentación pleistocena en la Cueva de Nerja (Málaga, España). In: Clottes, J. (Ed.), L'art pléistocène dans le monde/Pleistocene art of the world/Arte pleistoceno en el mundo. IFRAO, Tarascon-sur-Ariège, pp. 1105–1122.

Rouzaud, F., 1978. La Paléospéléologie : l'homme et le milieu souterrain pyrénéen au Paléolithique supérieur. EHESS, Toulouse.

Rouzaud, F., 1990. Fréquentation humaine dans le monde souterrain durant la Prehistoire. In: Actes du II Colloque sur le patrimoine troglodytique CPIE. de Sireuil, 14–16 avril 1988. Les Cahiers de Commarque, Sireuil, pp. 29–31.

Rubiales, J.M., García-Amorena, I., Hernández, L., Génova, M., Martínez, F., Gómez, F., Morla, C., 2010. Late Quaternary dynamics of pinewoods in the Iberian Mountains. Rev. Palaeobot. Palynol. 162 (3), 476–491.

Ruiz de la Torre, J., 2006. Flora Mayor. Organismo Autónomo de Parques Nacionales, Madrid.

Sanchidrián, J.L., 1994. Arte Rupestre de la Cueva de Nerja. Fundación Cueva de Nerja, Málaga.

Sanchidrián, J.L., Márquez, A.M., 2005. Primeros resultados de la secuencia crono-estratigráfica de la Sala de la Torca de la Cueva de Nerja (Málaga, España). In: Sanchidrián, J.L., Márquez, A.M., Fullola, J.M. (Eds.), La cuenca mediterránea durante el Paleolítico Superior, 38. 000-10. 000 años. UISPP. y Fundación Cueva de Nerja, Málaga, pp. 272–282.

Scheel-Ybert, R., 1998. Stabilité de l'Écosystème sur le litoral sud-est du Brésil à l'Holocène supérieur (5500–1400 ans BP). PhD Thesis, Université Montpellier-2, Sciences et Techniques du Languedoc, Montpellier, France.

Schweingruber, F.H., 1990. Anatomie europäischer Hölzer- Anatomy of European Woods. Eidgenössische Forschungsanstalt für Wald, Schnee und Landscaft, Birmensdorf (Hrsg.), Paul Haupt, Bern und Stuttgart.

Schweingruber, F.H., 1996. Tree rings and environment. Paul Haupt, Bern.

Schweingruber, F.H., 2007. Wood Structure and Environment. Springer, Verlag, Berlin, Heidelberg, New York.

Segura, S., Torres, J., 2009. Historia de las plantas en el mundo antiguo. CSIC, Madrid.

Théry-Parisot, I., 2001. Économie des combustibles au Paléolithique. CNRS, Paris.

Théry-Parisot, I., Chabal, L., Chrzavzez, J., 2010. Anthracology and taphonomy from wood gathering to charcoal analysis. A review of the taphonomic processes modifying charcoal assemblages, in archaeological contexts. Palaeogeogr. Palaeoclimatol. Palaeoecol. 291 (1–2), 142–153.

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

Théry-Parisot, I., Thiébault, S., 2005. Le pin (*Pinus sylvestris*) : préférence d'un taxon ou contrainte de l'environnement ? Étude des charbons de bois de la grotte Chauvet. Bull. Soc. Préhist. Fr. 102 (1), 69–75.

Vernet, J.-L., Ogereau, P., Figueral, I., Machado, C., Uzquiano, P., 2001. Guide d'identification des charbons de bois préhistoriques et récents. Sud-Ouest de l'Europe: France, péninsule Ibérique et Îles Canaries. CNRS, Paris.