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Woody macroremains from the Acheulian site of Torralba: Occurrence and palaeoecology of *Pinus* cf. *sylvestris* in the Middle Pleistocene of the Iberian Peninsula

Les bois fossiles du gisement acheuléen de Torralba : présence et paléoécologie de Pinus cf. sylvestris *dans le Pléistocène moyen de la péninsule Ibérique*

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ABSTRACT

The pieces of wood extracted by the Marquis of Cerralbo at the Acheulian site of Torralba constitute one of the few materials from this famous locality that have not been subjected to detailed study by researchers. Over a century after their extraction, the present paper provides the first anatomical results of these 34 woody remains. The results highlight the presence of the taxon *Pinus sylvestris–nigra* group (*Pinus* cf. *sylvestris*) at the site, thus constituting one of the few and oldest references attributable to the aforementioned taxon for the Iberian Peninsula. The anatomical diagnosis confirms the existence of Middle Pleistocene landscapes with pine woods at elevations at least 200 m lower than at present in the site area. From a taphonomic point of view, the wood samples exhibit the typical morphologies of woody macroremains preserved in continental sedimentary environments, and there was no evidence at all that they had previously been manipulated by man.

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RÉSUMÉ

Les fragments de bois extraits par le marquis de Cerralbo sur le site acheuléen de Torralba constituent l'un des rares matériaux de cette célèbre localité qui n'aient pas fait l'objet d'une étude détaillée par des chercheurs. Celle-ci ayant été réalisée sur un siècle depuis leur extraction, cet article fournit les premiers résultats anatomiques de ces 34 restes de bois. Les résultats soulignent la présence du taxon du groupe *Pinus silvestris–nigra* (*Pinus* cf. *sylvestris*) sur le site, constituant donc l'une des peu nombreuses et plus anciennes références attribuables au taxon susmentionné pour la péninsule Ibérique. La diagnose anatomique confirme l'existence, au Pléistocène moyen, de paysages de forêts de pins à des altitudes d'au moins 200 m inférieures à ce qui est observé actuellement dans

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la région du site. D'un point de vue taphonomique, les échantillons de bois montrent les morphologies typiques de macrorestes ligneux conservés dans des environnements sédimentaires continentaux, et il n'y a aucune preuve qu'ils aient été précédemment manipulés par l'homme.

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1. Introduction

The Torralba site (Soria, Spain) constitutes one of Europe's most famous and significant prehistoric sites. Discovered in 1888 when large bones of *Palaeoloxodon* were uncovered during construction of the Madrid-Zaragoza-Barcelona railway line, the first systematic excavation was conducted from 1909 to 1911, and the first published results became internationally relevant (Cerralbo, 1913). The Acheulian lithic industry and the ancient fauna found in the site's sediments attracted the attention of numerous European investigators, and intense research was initiated therein as from the start of the XXth century (Carbonell et al., 1987). Although geomorphological studies have provided relevant data in recent decades (Pérez-González et al., 1997a), the lithic industry and megafauna discovered (e.g., *Elephas* (*Palaeoloxodon*) *antiquus, Equus caballus torralbae, Dicerorhinus hemitoechus* or *Bos* cf. *primigenius*) have constituted the main object of study in the last century (Carbonell et al., 1987; Villa, 1990). Likewise, there has been heated debate over the possible relationships between man and the genesis of the site. Thus, in contrast with the classical interpretation stating that the site was unequivocally a hunting ground and was used to dismember large mammals (e.g., Biberson, 1968; Cerralbo, 1913; Freeman and Howell, 1982; Howell et al., 1962), more recent research has indicated that other aspects of a taphonomic or paleontological nature should also be considered, like, for instance, hunting of small mammals or scavenging (e.g., Binford, 1987; Klein, 1987; Shipman and Rose, 1983).

Together with the remains of fauna and the lithic industry, Cerralbo also found 34 fragments of wood, which are now included in the Cerralbo collection; referring thereto, he only mentioned that "*they were found among the bones of Elephas meridionalis and present some signs of having been used by primitive man*" (Howell et al., 1962). During the XXth century, there have been ongoing studies at the site. However, although there have been new excavations at Torralba both in the 1960s and 1970s (Howell et al., 1962; Pérez-González et al., 1997b), no data have been published on new woody remains at the site. Therefore, one century after their discovery, we still do not know any specific data on the botanic macroremains found at the site.

The principal aims of the present study are: (I) To perform taxonomic identification of the samples belonging to the Cerralbo collection. (II) To establish a framework for the palaeophytogeographical interpretation of these results. (III) To macroscopically analyse the samples to carry out taphonomic considerations.

2. Material and methods

We analysed 34 fragments of wood from branches or trunk parts, contained in the National Archaeological Museum (Madrid, Spain). A brief morphological description of these remains had previously been provided by Howell et al. (1962). We obtained the necessary authorisation to perform traditional micrographic analysis. A total of 6 macroremains was selected: n^{os} 2725, 2726, 2744, as well as three that were not numbered (called C1, C2 and C3). Fragments measuring approximately 1 × 1 × 2 cm were processed with a microtome to provide thin sections approximately 20 μm thick. These were placed in a watch glass containing distilled water, stained with safranin, and then washed with distilled water and alcohol. They were then submerged in xylol. Finally, a few drops of a Euquit fixer were added. The taxonomic identifications were made using a transmission light microscope at magnifications of 100×, 200×, and 400×. To identify these wood samples, we used a reference wood collection from the *U.D. Botánica, U.D. de Tecnología de la Madera* and the *U.D. de Anatomía de la Escuela Técnica Superior de Ingenieros de Montes* (Botany, Wood Technology and Anatomy Teaching Units of the Higher School of Forestry Engineering) (Madrid, Spain), as well as wood anatomy atlases (Greguss, 1955; Jacquiot, 1955; Peraza, 1964; Schweingruber, 1990). The other 28 woody remains (n^{os} 2746, 2729, 2734, 2752, 2738, 2733, 2745, 2747 and 2743, together with another 19 that did not bear an identification number) were studied by means of incident light microscope at magnifications of 100 ×, 200 ×, and 400 ×, and we were able to make some taxonomic appreciations of a more general nature.

Some authors indicate that identification at the species level of wood from montane Iberian pines (including *Pinus sylvestris, Pinus nigra* and *P. uncinata*) is highly problematic (Carcaillet and Vernet, 2001; Schweingruber, 1990). However, others indicate the existence of diagnostic features that can be used for this purpose (García and Guindeo, 1988; Greguss, 1955; Jacquiot, 1955; Peraza, 1964), especially when the number of macroremains is large and well preserved, and when young wood is avoided (Figueiral and Carcaillet, 2005; Mutz et al., 2004). With these premises in mind, we conducted all the anatomical studies possible in order to provide the highest degree of taxonomic differentiation of the samples. Likewise, the total absence of references by Cerralbo to the precise place and characteristics of wood deposits greatly limits the taphonomic analyses.

3. Geological setting

The Torralba archaeological site is located in the Iberian Range (41° 8′13″ N, 2° 30′9″ W), specifically in the Masegar river valley, at an altitude of 1113 m asl and approximately 156 km from Madrid; it is named after the nearby village of Torralba del Moral (Falguères et al., 2006) (Figs. 1 and 3).

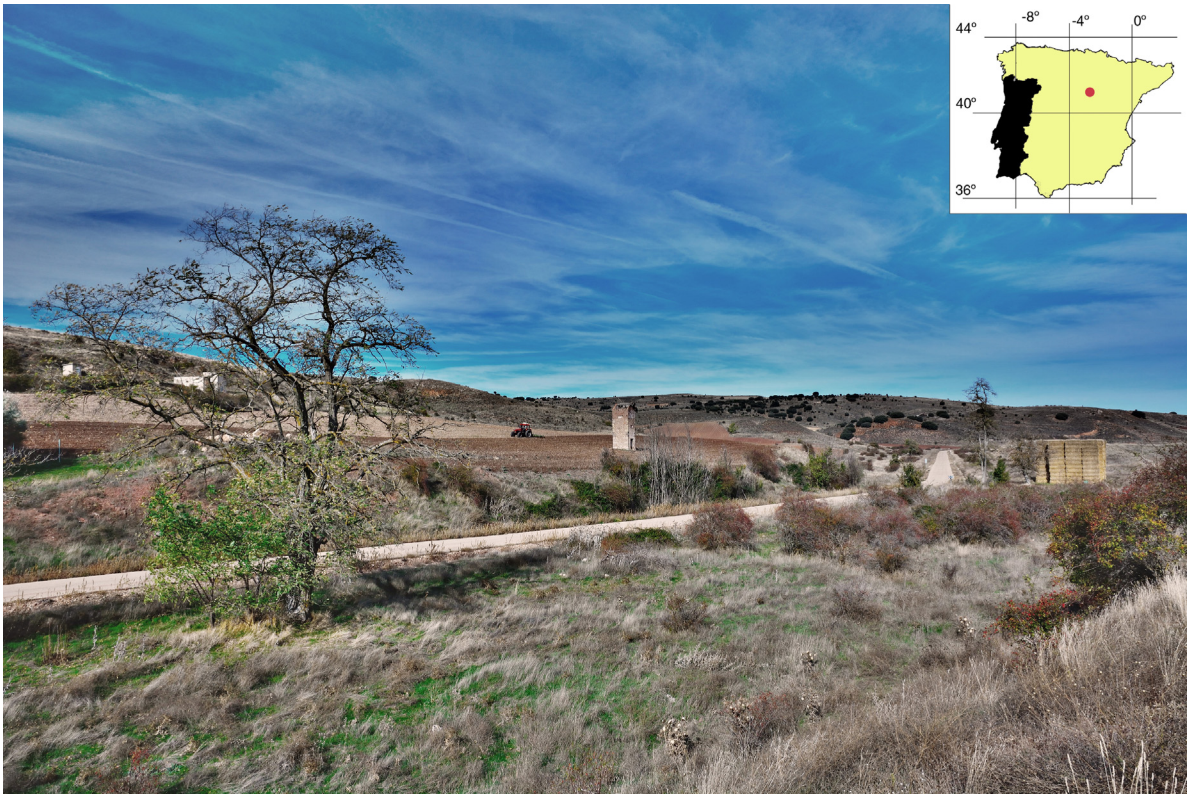

Fig. 1. Location of the Torralba site and current panoramic view thereof.

Fig. 1. Vue panoramique et localisation du site de Torralba.

From a geological point of view, it lies at the intersection of structures at the eastern end of the Central System where this meets the Iberian Range and the Almazán Tertiary basin. The site is located in the so-called Conquezuela polje, which is developed on an anticlinal structure, partially faulted on the northeastern side, which presents different Neogene corrosion surfaces and Pleistocene fluvial terraces (Pérez-González et al., 1997a).

The outcropping rocks in the area pertain principally to the Triassic, Buntsandstein, Muschelkalk and Keuper facies, and different outcrops were observed in the area with materials from the Jurassic and the Cretaceous (Benito et al., 1991). Quaternary deposits emerge in the area, both at the Torralba site and at the nearby site, during a period considered to be contemporaneous with Ambrona, and principally comprise detritic slope deposits and loams of shallow lacustrian origin (Pérez-González et al., 1997a).

Butzer (1965) considers that, due to their similarities, the neighbouring archaeological sites of Torralba and Ambrona should be included in the same stratigraphic formation known as the Torralba Formation. Other authors, however, maintain that these sites do not constitute one single stratigraphic unit (Agudo and Serrano, 1992; Pérez-González et al., 1997a, 1997b); this idea that they make up different units arises from study of the geomorphological evolution of the Conquezuela-Ambrona-Torralba polje.

The valley's evolution is a complex one, with an initial Quaternary capture of the Conquezuela polje by a tributary of the Duero river, giving rise to the Ambrona surface, at an elevation of 1140–1130 m asl, a plane that demarcates the deposit of the lacustrian and fluvial levels in relation to the Ambrona archaeological site. Subsequently, or coetaneous with the lower levels of Ambrona, a second capture of the polje occurred, caused by the headward erosion of the Masegar river, which eroded the Ambrona surface. This was followed by the construction of stepped terraces with relative elevations of +1 m, +7–9 m, +15 m, +22 m y +35 m. (Pérez-González et al., 1997a). The lacustrian, colluvial and alluvial materials making up the Torralba site are inserted at the 35 m level, evidencing the fact that the two sites are of different ages, as the latter one is related to the evolution of the Masegar river valley, whereas Ambrona is related to the so-called Ambrona surface (Pérez-González et al., 1997a).

4. Chronology of the setting

For a long time, it had been maintained that the Torralba and Ambrona sites were contemporaneous. Thus, Butzer (1965) initially proposed the same chronology for both sites, mainly because of the coincidence of their macrofaunas, which defined the same morphosedimentary unit, the so-called "Torralba Formation"; for this reason they came to be considered as twin sites. According to this author, sedimentological studies show that both sites present an age previous to the Holsteinian (Mindel–Riss) interglacial. The same chronology and stratigraphic consideration of the Torralba Formation was subsequently assumed by other authors (Howell et al., 1995). Recent geological studies, however, clearly show that Torralba was formed subsequently to what is known as the Lower Complex of Ambrona, given the aforementioned stratigraphic position, which indicates a more recent chronology (Falguères et al., 2006; Pérez-González et al., 1997a). As for the faunistic data, the existence both in Torralba and in Ambrona of large mammals such as *Elephas* (*Palaeoloxodon*) *antiquus, Stephanorhinus hemitoechus, Equus caballus torralbae* and *Bos primigenius*, enable these faunas to be clearly related to the Middle Pleistocene (Pérez-González et al., 1997b). Likewise, the lithic industry found in Torralba is related to the industrial complexes characteristics of the Acheulian of the Middle Pleistocene (Butzer, 1965; Carbonell et al., 1987; Howell et al., 1962; Pérez-González et al., 1997b). A more recent study based on combined ESR/U-series (US) methods conducted in Ambrona determines that the Lower Complex of Ambrona (AS1 to AS6) presents an age of between 314 and 366 ka, which points out that the top of the sequence was deposited during a coeval period with the OSI 9 or maybe with the end of OSI 11 (Falguères et al., 2006).

Considering the fauna, the lithic industry and their stratigraphic position in relation to the Ambrona site, as well as the dating of the latter, we can conclude that Torralba can be considered as a site from the Middle Pleistocene, subsequent to the Lower Complex of Ambrona, that is to say, probably with an approximate age of between 314–366 ka and 117 ka (Carbonell et al., 1987; Falguères et al., 2006; Pérez-González et al., 1995–1997).

5. Results

5.1. Wood identification

The analysis performed using traditional micrographic techniques (De Palacios, 1997; Schweingruber, 1990) of the 6 woody fossil remains revealed the following diagnostic features:

Description. *Transverse section*: homoxylous wood with perfectly delimited growth rings and polygonal tracheids with an approximate diameter of 28.6 μm. Abrupt transition from early (average of tracheids 34 μm) to the late wood (average of tracheids 20 μm). Physiological longitudinal resiniferous channels (average 102.2 μm) preferentially located (93.2%) in the summer wood and transition zones (Fig. 2, A, D). *Radial section*: ray-tracheids with rarely isolated dentations (only 20%). Most of these are sharp (80%), although they can also be found in varying degrees of bluntness (Fig. 2, B). The length of the dentations is variable (average 6.27 μm, up to 12 μm), reaching the centre of the lumen on several occasions, and even interconnecting. Cross-fields from parenchyma cells to tracheids with one large window-like pit (average 22 μm), sometimes 2 (Fig. 2, C). Spiral thickenings absent. *Tangential section*: heterogeneous woody rays uniseriate or pluriseriate, generally short, up to 9 cells, (Fig. 2, E), with the presence of some pluriseriate ones in which transversal resiniferous channels can be observed. Areolate pits on the radial walls of the longitudinal tracheids arranged in uniseriate rows, in no case biseriate.

Identification. This homoxylous wood with resiniferous channels, ray-tracheids walls with well-developed teeth and one or two window-like pits is characteristic of the genus *Pinus*, in fact of the *P. sylvestris* group including *P. sylvestris* L., *P. nigra* Arnold and *Pinus uncinata* Ramond ex DC. (Greguss, 1955; Schweingruber, 1990). Some features observed were quite different from those of *P. uncinata*. On one hand, the diameter of the channels was much greater than that established for the latter taxon (average 80–90 μm), and their preferential (92.3%) location in summer and transition wood does not coincide with the preferential location of these elements in spring wood in *P. uncinata* (García and Guindeo, 1988; Peraza, 1964). On the other hand, we did not observe remains of epithelial cells after the preparations had been made. The characteristics of the dentations of the ray-tracheids are among the most commonly mentioned diagnostic criteria in the literature (De Palacios, 1997; García and Guindeo, 1988; Greguss, 1955; Jacquiot, 1955; Peraza, 1964). The height of the dentations was frequently over half the diameter of the lumen, both characteristics of *Pinus sylvestris* leaving columnar formations (De Palacios, 1997; Greguss, 1955). Approximately 80% of the projections were pointed, compared with 20% which were blunt, once again features established for *P. sylvestris* (García and Guindeo, 1988; Greguss, 1955; Jacquiot, 1955; Peraza, 1964). Finally, 80% of the dentations were not isolated, further suggesting *P. sylvestris* (García and Guindeo, 1988; Peraza, 1964).

Studies with reflected light microscopy

Description. Homoxylous wood with longitudinal tracheids and the presence of pits on the radial walls arranged in uniseriate rows. Uniseriate rays (some pluriseriate ones), generally short (number of cells lower than 12s). Cross-fields from parenchyma cells to tracheids with one or two large window-like pits. Identification. From the set of characters observed, we only deduced that all the wood fragments analysed correspond to the genus *Pinus*, and within this, to some of the species: *P. sylvestris, P. nigra* or *P. uncinata* (Greguss, 1955; Schweingruber, 1990).

All the wood samples can therefore be identified with certainty as pertaining to the *Pinus sylvestris* group. Taking into account the set of characters described and defended by some authors (De Palacios, 1997; García and Guindeo, 1988; Greguss, 1955; Jacquiot, 1955; Peraza, 1964), the 6 samples analysed exhibit characters that coincide with the wood described for the taxon *P. sylvestris*. However, the difficulty involved in differentiating among the wood fragments of the group, particularly on considering diagnosis with small-sized fragments, with no possibility of avoiding early wood (Figueiral and Carcaillet, 2005; Mutz et al., 2004), suggests to assign tentatively our samples to the taxon *P.* cf. *sylvestris*.

6. Discussion

6.1. Taphonomic considerations

Making taphonomic considerations of the wood samples from the Cerralbo collection clearly presents limitations resulting from the scant data regarding the conditions thereof at the site of extraction. It is not a simple task to

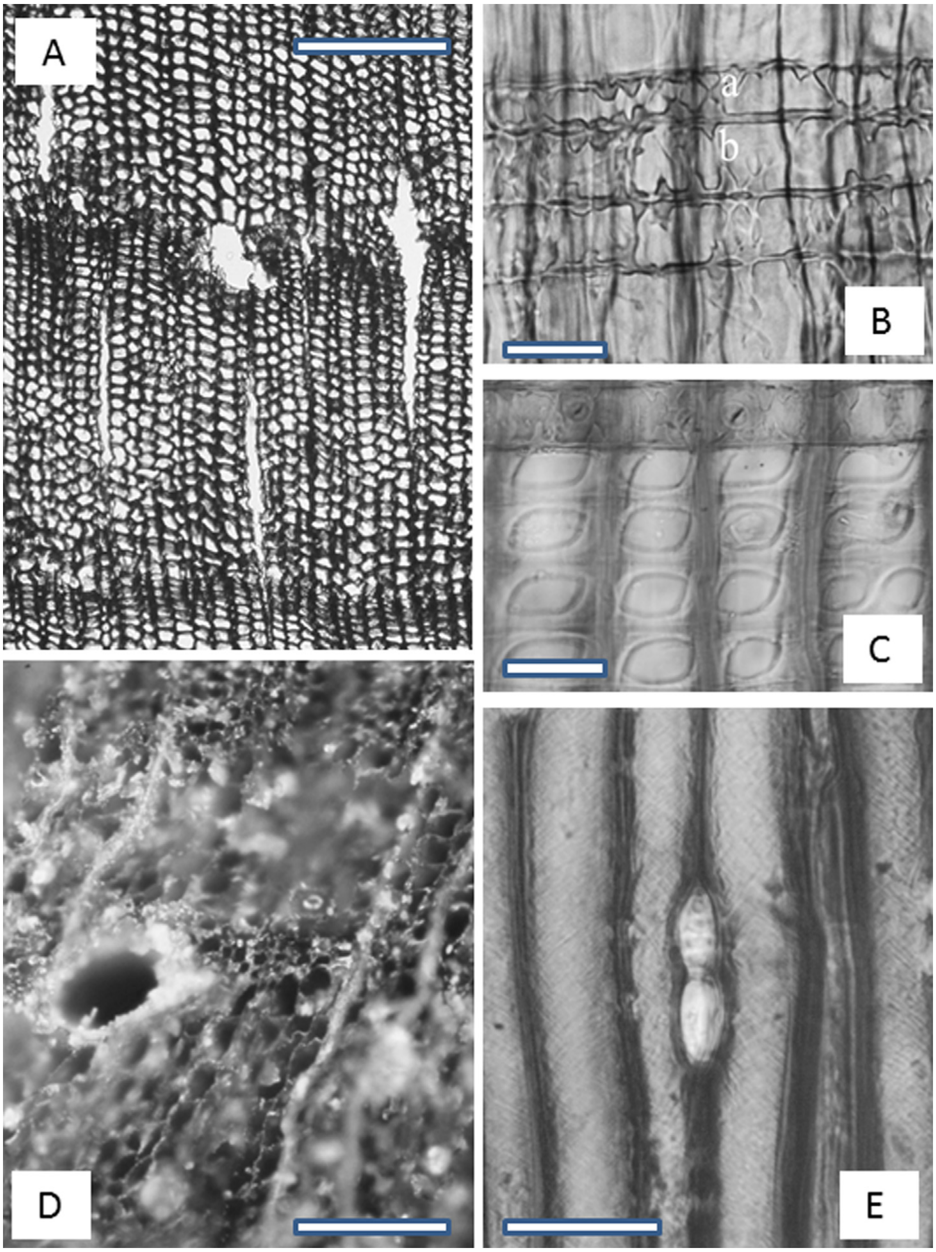

Fig. 2. **A**. Transversal Section. Homoxylous wood with resiniferous channel without remains of epithelial cells. **B**. (a) Conspicuous dentations of the tracheids; (b) teeth of ray-tracheids mostly sharp. **C**. Radial section. Cross-fields with one (two) large window-like pit. **D**. Transversal section examined by reflected light microscopy, showing a resiniferous channel. **E**. Longitudinal Section. Uniseriate ray two cells long. Scale bars: A: 250 μm; B: 40 μm; C: 30 μm; D: 12 μm; E: 125 μm.

Fig. 2. **A**. Plan transversal. Bois constitué de trachéïdes avec canaux résinifères sans cellules bordières. **B**. (a) Trachéides transversales dentées ; (b) dents en général aiguës et très développées. **C**. Section radiale. Champs de croisement avec une (deux) ponctuations de type pinoïde. **D**. Section transversale observée par réflexion, montrant un canal résinifère. **E**. Plan tangentiel. Rayons ligneux unisériés. Échelles : A : 250 μm ; B : 40 μm ; C : 30 μm ; D : 12 μm ; E : 125 μm.

differentiate the different organs of the wood into twigs, branches or trunks (Chapman, 1994). The great similarity in anatomical microstructure and the natural variability in the wood resulting from seasonal, climatic and developmental variations prevents easy adscription to one or another anatomical component. All the wood fragments from the Cerralbo collection possess very narrow sections, with rings very close together, which would likely indicate quite thin fragments of twigs or branches. However, we cannot rule out the possibility that some of the fragments could correspond to disarticulated remains of trunks that were broken down into small components due to the disintegration process during the biostratinomic phase. Neither can we rule out the possibility of occasional fragmentation during the extraction processes. In all cases the remains possess no bark, which might have been lost during the dispersal and biodegradation processes.

Although we cannot provide an accurate consideration regarding the possible displacements of the Torralba wood fragments, studies conducted on macroremains indicate displacements of a maximum of only 10 km in continental environments, which would appear to indicate conditions of at least a relative regional autochthony (MacGinitie, 1969; Rich, 1989). In the wood fragments from the Cerralbo collection, there are no signs of wear or abrasion. In most cases, they present surfaces with the typical irregularities found in wood fragments, and caused by natural fragmentation (natural death of the parent tree, breakage by the weight of snow, animals, etc.) and it could be stated that their dispersal was very likely caused by simple flotation (Gastaldo, 1986, 1989). We therefore believe that it cannot be said that these wood fragments were manipulated by man, as suggested both by Cerralbo (1911) and by Howell et al. (1962).

The state of the wood fragments has remained essentially unaltered since their original composition; we found no evidence of carbonification and most of them preserve their original colouring and weight. This preservation most likely results from early burial of the fragments which, under anoxic condition, prevented biodegradation processes. In some of the wood fragments, however, there is evidence of carbonization on the outside. This is the case of samples: without number (ref. 75/24/61 and showcased at the Archaeological Museum), n° 2751 (ref. 75/24/58), n° 2724 (ref. 75/24/43) and n° 2722 (both fragments). To these must be added another 10 contained in bags with no reference at all. Considering the sedimentary environment in which the wood fragments were found, we believe that the carbonization must have occurred during the biostratinomic phase. Analysis of these wood fragments did not provide us with sufficient elements to discern whether these carbonization processes are anthropic or natural. With the data available, we cannot establish whether they are all from the same parent tree or from different individuals. In the fossil diagenetic phase, lithostatic pressure flattened the pieces and caused cracks and fractures in most of them. Neither did we find signs of sedimentary infilling that might indicate processes of taphonomic reworking.

6.2. Palaeovegetation at the Torralba site in the Middle Pleistocene

Diagnosis of the wood samples from the excavation by the Marquis of Cerralbo reveals the presence in the centre of the Peninsula of the taxon *Pinus* cf. *sylvestris* for the Middle Pleistocene. This finding confirms the results of previous pollen analyses performed at the site, which indicate that the *P. sylvestris* typology makes its appearance therein (Menéndez Amor and Florschütz, 1959). According to these authors, these analyses reveal a set of hygrophilous or mesohygrophilous taxa such as *Salix, Corylus, Alnus, Betula* together with the so-called *Quercetum mixtum*. The appearance of these taxa might be related to valley-bottom environments, or shaded ones and those presenting a high phreatic level. Although on occasions the pines could be associated with more of less hygrophilous environments, they generally occupy large areas on the surrounding moorlands, constituting more or less open formations comprising quite high percentages of Gramineae and Chenopodiaceae (Menéndez Amor and Florschütz, 1959). It was subsequently pointed out that these pine pollen percentages were variable, although an invariable number of species represented was typically observed (Freeman and Butzer, 1966; Howell et al., 1962). The most recent and complete palynological study in the area was performed by Ruiz-Zapata et al. (2003) at the Loma del Saúco; it presents two pollen levels, C and B. At pollen level "C" or below, situated at a depth of between 100 and 40 cm, a dominance of tree pollen can be observed, with *Pinus* and *Juniperus* mainly represented, together with the more or less continuous presence of *Castanea, Juglans, Corylus, Alnus* and, to a lesser extent, of *Betula, Fagus* and deciduous *Quercus*. At the next level, "B", at a depth of between 40 and 20 cm, there is a noteworthy increase in *Juniperus* and a simultaneous decrease in *Pinus* pollen, along with the disappearance of the mesohygrophillous species, except for *Betula*, a fact that has been associated with an evident drop in temperature and moisture in the area (Ruiz-Zapata et al., 2003).

From an ecological point of view, the appearance of the species *P. sylvestris* fits perfectly within the floristic assemblage described, both due to its hydric requirements (it grows in valley-bottoms or on slopes) and to its tolerance to cold periods, which must have occurred, judging by the palaeovegetation described. At the present time, the nearest villages are those situated in the Ministra Mountains, at an altitude of 1309 m asl (Bermejo and Martínez-García, 1997), and at an elevation of 200 m higher than the site, which provides clear evidence of its presence at clearly lower elevations than the present time for the Middle Pleistocene represented in Torralba.

The nearby site of Ambrona (Pérez-González et al., 1997a, 1997b) shows certain similarities with Torralba. According to Howell et al. (1995), two associations appear in the so-called Lower Complex. On one hand, the *Pinus*-sedge association, characterised by a high frequency of tree pollen (mainly pine 75–79%) and reeds (up to 10–25%). On the other, the Gramineae–Chenopodiaceae association, characterised by AP values (40–60%), less than 5% of Juncaceae and a high frequency of gramineae (20–35%) and Chenopodiaceae (3% or over). Grasses and chenopods, with a wide range of herbaceous species, were dominant in the valleys and highlands (NAP usually 40–90%). Some tree taxa appear, such as willows and oaks, but very poorly with regard to pollen percentages. Furthermore, in the so-called Upper Complex, Howell et al. (1995) describe a variant of the *Pinus*–Juncaceae association, with an AP of 96–98% and some rare deciduous species like oak (1.5%) and elm (0.7%). Once again, a moderately cold and moist glacial phase appears, supported by geomorphological evidence. The most recent study in Ambrona by Ruiz-Zapata et al. (2003) highlights in its four pollen zones the presence of vegetation dominated mainly by *Pinus, Juniperus* and Poaceae, with the presence of mesohygrophilous taxa and riparian elements such as *Castanea, Corylus, Juglans* and *Ulmus* with the occasional presence of *Betula*.

Mediterranean taxa such as *Olea* or evergreen *Quercus* also appear, with abundant Poaceae and continuous high percentages of Ericaceae and Rosaceae. Throughout the whole diagram, one can appreciate different phases of decreases or changes in temperature and moisture, perhaps associated with local variations in hydric availability, which in turn generate local variations in the percentages of mesohygrophilous elements. In the final zone, pollen zone IV, one can observe the development of a monospecific forest of *Pinus*, the subsequent degradation of which gives rise to a phase of almost exclusive dominance of *Juniperus*, with wide-ranging steppic elements and a decrease in aquatic species, values indicative of a drop in mean humidity and temperature in the basin (Ruiz-Zapata et al., 2003).

6.3. Occurrence of the Pinus sylvestris group in the Middle Pleistocene of the Iberian Peninsula

The appearance of the *Pinus sylvestris* group (*P.* cf. *sylvestris*) at the Torralba site constitutes the first evidence based upon wood fossils of this taxon for the Middle Pleistocene on the Iberian Peninsula. The only macroremains previously referring to this taxon are some charcoals attributable to *Pinus sylvestris*-type, with an age of over 300 ka, from the Cuesta de la Bajada site (González-Sampériz et al., 2010). Together with Torralba, only the Mealhada and Villaverde sites (Andrade, 1944; Menéndez Amor and Florschütz, 1959) presented the *P. sylvestris* pollen typology have been previously cited for the Iberian Peninsula for this part of the Pleistocene.

Several sites, however, reflect the presence of pines and more or less open pine forests, during the Middle Pleistocene in which there are varying degrees of steppic conditions. In the central-north of the Peninsula, at the Atapuerca site (Galería, pollen zone IV) (Fig. 3, B), dated between 256–200 ka (Berger et al., 2008), a phase can be detected in which *Pinus*, *Asteraceae* (*Liguliflorae*) and *Poaceae* are well represented, with high percentages of non-tree pollen (García Antón and Sainz Ollero, 1991). Deciduous and evergreen oaks practically disappear, as do the Mediterranean taxa present in other zones of the diagram, like *Pistacia* and *Olea*. Nevertheless, the site as a whole does not appear to reflect conditions that are too xeric and/or steppic. For the centre of the Peninsula, Menéndez Amor and Florschütz (1959), describe the flora of the Villaverde site (Fig. 3, C), the age of which, according to the authors, is similar to that of the Torralba and Ambrona sites, for which the existence of pines has been mentioned, in a steppic environment with the presence of taxa such as *Quercus* or *Juglans*. In Villacastín (Fig. 3, D) dated as MIS 6, open-mosaic vegetation appears with the presence of tree taxa such as *Pinus* or *Juniperus* with more or less steppic open zones, herbaceous vegetation and patches of *Quercus* (Carrión et al., 2007). The last notable site in the centre of the Peninsula is the so-called Pinedo Formation (river Tagus) (Fig. 3, E), which also presents a mosaic-like vegetation with *Pinus* and *Quercus* with the presence of both Mediterranean taxa (e.g., *Olea*, Cistaceae) and temperate ones (e.g., *Betula, Castanea, Alnus*) (Martín-Arroyo et al., 1995; Ruiz-Zapata et al., 2004).

In the Northeast of the Peninsula, one can mention the Mindel–Riss Pla de les Presses site (Fig. 3, F), where a somewhat similar set of species can be found, with *Pinus*, *Betula*, *Artemisia* and *Quercus*, all these taxa also being present in Torralba (Pérez-Obiol et al., 1986). The Val d'en Bas (Fig. 3, F) site, dated at over 250 ka, also presents a floristic assemblage in which *Pinus* and *Abies* appear together with mesophytes like *Quercus* evergreen, *Carpinus*, *Tilia* or *Corylus*, all of these associated with a phase of the interglacial (Cros et al., 1986). Finally, the Northeast of the Peninsula exhibits the Pla de l'Estany site, dated between 190–170 ka (Fig. 3, F); it also registers a cold steppic phase with the spread of *Pinus*, Poaceae and Asteraceae (Burjachs, 1990). Also? in the North-East of the Peninsula, the Cuesta de la Bajada site (Fig. 3, G) provides similar data, showing steppic conditions with the presence of macroremains of *Juniperus thurifera* and *P. sylvestris*-type for an age > 300 ka (> MIS 9) and conditions that are also steppic in an open landscape for MIS 6 dominated by herbaceous species and with the isolated presence of *Pinus* (González-Sampériz et al., 2010; Santonja et al., 2000).

In the South-East of the Peninsula, the Padul sequence (Fig. 3, H) includes in its base the Mindel–Riss interglacial and the Riss interglacial, also showing steppic phases in which cold open landscapes appeared to alternate with temperate phases (Florschutz et al., 1971). Similar results were obtained from the marine sequences, for which there is a good general correlation with the continental ones. In the Southwest of the Peninsula, the sites of uncertain age (Mindel–Riss/Riss) of Mealhada (Fig. 3, I), San Pedro de Muel, Ribeira do Penegral and Alpiarça (Fig. 3, J), Porto Covo Sines (Morgavel), Ribeira da Provença, Samourqueira and Vila Nova de Milfontes (Fig. 3, K) (Andrade, 1944; Teixeira, 1943; Zbyszewski, 1958) present a microthermal and/or hygrophilous set of species in which *Pinus, Betula*, Ericaceae and *Quercus* frequently appear. At all these sites, pine species belonging to the *Pinus sylvestris* group might have made up a part of their communities, despite being close to the coast and far from their current distribution ranges. However, the possibility cannot be ruled out that *Pinus pinaster* also formed a part thereof. Thus, the marine records showing the presence of *Pinus* (e.g., the MD95-2042, MD01-2447, MD01-2443 cores in Desprat et al., 2006; Roucoux et al., 2006; Sánchez-Goñi et al., 1999) (Fig. 3, L) coincide in general terms with the data presented by the continental sequences, highlighting the fact that in the colder phases of the Middle Pleistocene, steppic or pseudo-steppic formations with a presence of pine trees were widespread.

6.4. Pinus sylvestris–nigra group in the Middle Pleistocene in the forests of southwestern Europe

Despite the difficulty involved in dating the European sites of the Middle Pleistocene, there is an apparent correlation between the data from Torralba and those obtained at other sites of a similar age in SW Europe. An alternation of cold and warm phases during the Middle Pleistocene has been indicated in numerous sequences for the whole continent. For southern Europe, we found certain parallelisms in some sites where it is possible to find the set

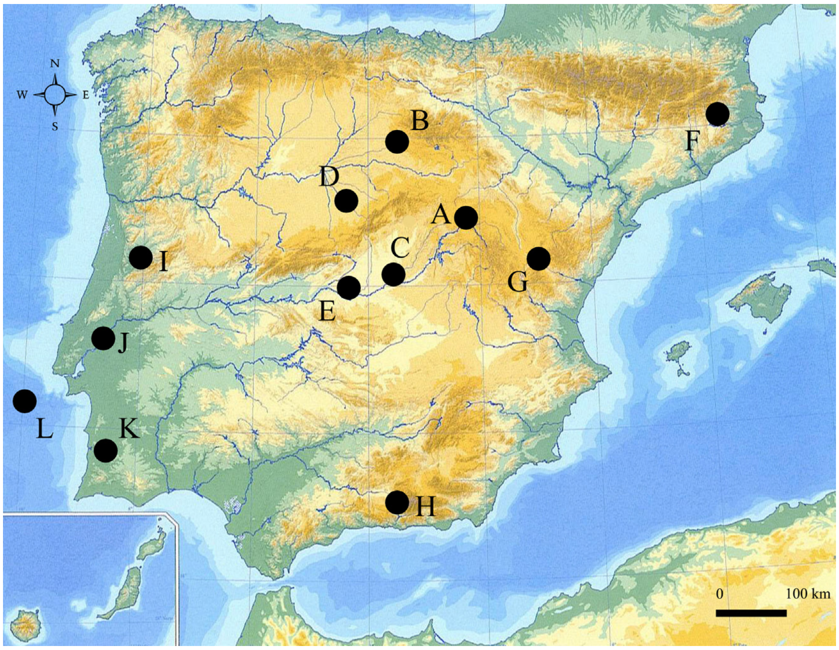

Fig. 3. Iberian sites cited in the text. **A**. Torralba and Ambrona (Howell et al., 1962; Menéndez Amor and Florschütz, 1959; Ruiz-Zapata et al., 2003). **B**. Villaverde (Menéndez Amor and Florschütz, 1959). **C**. Atapuerca (García Antón and Sainz Ollero, 1991). **D**. Villacastín (Carrión et al., 2007). **E**. Pinedo formation (Martín-Arroyo et al., 1995; Ruiz-Zapata et al., 2004). **F**. Val d'en Bas, Pla de les Preses and Pla de l'Estany (Burjachs, 1990; Cros et al., 1986, Pérez-Obiol et al., 1986). **G**. Cuesta de la Bajada (Santonja et al., 2000; González-Sampériz et al., 2010). **H**. Padul (Florschutz et al., 1971). **I**. Mealhada (Andrade, 1944). **J**. San Pedro de Muel, Ribeira do Penegral and Alpiarça (Andrade, 1944; Zbyszewski, 1958). **K.** Porto Covo Sines (Morgavel), Ribeira da Provença, Samourqueira and Vila Nova de Milfontes (Andrade, 1944; Teixeira, 1943). **L**. Marine cores MD95-2042, MD01-2447, MD01-2443 (Desprat et al., 2006; Roucoux et al., 2006; Sánchez-Goñi et al., 1999).

Fig. 3. Gisements ibériques mentionnés dans le texte. **A**. Torralba et Ambrona (Howell et al., 1962 ; Menéndez Amor et Florschütz, 1959 ; Ruiz-Zapata et al., 2003). **B**. Villaverde (Menéndez Amor et Florschütz, 1959). **C**. Atapuerca (García Antón et Sainz Ollero, 1991). **D**. Villacastín (Carrión et al., 2007). **E**. Pinedo formation (Martín-Arroyo et al., 1995 ; Ruiz-Zapata et al., 2004). **F**. Val d'en Bas, Pla de les Preses et Pla de l'Estany (Burjachs, 1990 ; Cros et al., 1986, Pérez-Obiol et al., 1986). **G**. Cuesta de la Bajada (González-Sampériz et al., 2010 ; Santonja et al., 2000). **H**. Padul (Florschutz et al., 1971). **I**. Mealhada (Andrade, 1944). **J**. San Pedro de Muel, Ribeira do Penegral et Alpiarça (Andrade, 1944 ; Zbyszewski, 1958). **K**. Porto Covo Sines (Morgavel), Ribeira da Provença, Samourqueira et Vila Nova de Milfontes (Andrade, 1944 ; Teixeira, 1943). **L**. Carottes marines MD95-2042, MD01-2447, MD01-2443 (Desprat et al., 2006 ; Roucoux et al., 2006 ; Sánchez-Goñi et al., 1999).

of species present in Torralba. Thus, cold, arid periods characterised by open vegetation have been highlighted at the Vallo di Diano site in southeast Italy, for periods of the Middle Pleistocene falling within isotopic stages 16 and 14 (Russo Ermolli and Cheddadi, 1997). In Italy, too, in the Valle di Castiglioni sequence, one can appreciate similar steppic conditions and phases of approximately 250.000 BP (Follieri et al., 1988). In southeastern France, the Terra Amata site, associated with the Torralba and Ambrona sites due to its lithic industry, also indicates the presence of *Pinus sylvestris*-type during this phase of the Pleistocene (Mourer-Chauviré and Renault-Miskovsky, 1980). Accompanying this species are *Alnus, Salix, Betula, Fagus, Picea* and *Abies*. These authors state that the non-Mediterranean taxa likely reduced their elevation as a result of changes in climatic conditions such as cold and moisture, often coming close to the coast. This type of vegetation for the Middle Pleistocene can also be found in the Greek sequence of Tenaghi Philippon, where one can observe that in zone 26 (isotopic stage 12) steppic conditions appear with a phase of *Artemisia*-Chenopodiaceae showing different values of *Pinus* and different deciduous species (Van der Wiel and Wijmstra, 1987). Similar situations occur at the site in zones 32, 30 and 28, where different steppic situations can be observed.

The appearance of *P.* cf. *sylvestris* at the Torralba site constitutes unequivocal evidence of the most extensive past distribution of montane pines during cold periods of the Pleistocene. Indeed, numerous fossil macroremains testify to these decreases in altitude of montane pines during the Upper Pleistocene or even the Holocene (Badal et al., 2013; Postigo-Mijarra et al., 2010). Interestingly, these notable decreases in elevation of *P. sylvestris* or *P. nigra* involved areas relatively close to the coast, thus testifying to a clear altitudinal descent of these species during the coldest periods of the last glacial–interglacial cycle. The presence of these species at lower elevations than the present is now evidenced by the existence of natural populations of *P. sylvestris* to be found today in certain parts of the Duero basin, such as the Cega River (Segovia), and at higher elevations, pine forests in Lillo (León), Velilla del río Carrión (Palencia), the Nevada, Cazorla, Baza and Gêres ranges (Costa Tenorio et al., 1997; Franco Múgica et al., 2000, 2001).

7. Conclusions

At the site, we identified 6 samples as *Pinus* cf. *sylvestris* and 28 as *Pinus sylvestris–nigra* group, confirming that this taxon formed a part of the pine forests recorded by the pollen analyses for the Middle Pleistocene (Acheulian) of the northern Iberian sub-plateau. Analysis of the available palaeoenvironmental information indicates that climatic variations could have caused the taxon to spread at medium or low elevations; together with other microthermal species, it would come to shape the plant landscapes in different parts of the Peninsula and of Europe during the Acheulian. This altitudinal decrease of pine forests during cold periods of the Middle Pleistocene helps to explain the presence of current relicts following phenomena of population fragmentations. On the contrary, we did not find any element to clearly indicate, as has previously been stated, that the woody remains from the site had clearly been worked by man. Neither the morphologies present nor the existence of carbonisations enable this to be unequivocally established. We therefore consider that these wood fragments present alterations and morphologies typical of this kind of fossil macroremains, which have been subjected to taphonomic transport processes from their place of production, lithostatic pressure and taphonomic disarticulation.

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References

Agudo, C., Serrano, E., 1992. Evolución geomorfológica del valle del arroyo de la Mentirosa (Alto Jalón, Soria). Estudios de Geomorfología en España. Actas de la II Reunión de Geomorfología, Murcia, España I, 291–298.

Andrade, M.M., 1944. Estudio polínico de algumas formaçoes turfolignitosas portuguesas. Publ. Mus. Lab. Min. Geol. Fac. Ciên. Porto 37 (2), 5–11.

Badal, E., Villaverde, V., Zilhao, J., 2013. The fire of Iberian Neanderthals. Wood charcoal from three new Mousterian sites in the Iberian Peninsula. Sagvntvm Extra 11, 77–78.

Benito, G., Gutiérrez Elorza, M., Sancho, C., 1991. Mapa geomorfológico, en Mapa Geológico de España, 1:50.000, nº 462. I.G.M.E.

Berger, G.W., Pérez-González, A., Carbonell, E., Arsuaga, J.L., Bermúdez de Castro, J.M., Ku, T.L., 2008. Luminiscence chronology of cave sediments at the Atapuerca paleoanthropological site, Spain. J. Hum. Evol. 55, 300–311.

Bermejo, E., Martínez-García, F., 1997. Vegetación. In: Ruiz de la Torre, J. (Ed.), Mapa Forestal de España, E 1:200.000. Sigüenza. Ministerio de Agricultura, Pesca y Alimentación, Madrid, pp. 71–96.

Biberson, P., 1968. Les gisements acheuliens de Torralba et Ambrona (Espagne). Nouvelles précicions. L'Anthropologie 72, 241–242.

Binford, L.R., 1987. Were there elephant hunters at Torralba? In: Nitecki, M.H., Nitecki, D.V. (Eds.), Evolution of Human Hunting. Plenum Press, New York/London, pp. 47–105.

Burjachs, F., 1990. Palinologia dels dòlmens de l' Alt Empordà i dels diposits quaternaris de la cova de l' Arbreda (Serinyà) i del Pla de l' Estany (Olot, Garrotxa). Evolució del paisatge vegetal i del clima des fa més de 140. 000 anys al NE de la Península Ibérica. Universitat Autònoma de Barcelona, Barcelona (PhD thesis).

Butzer, K.W., 1965. Acheulian Occupation Sites at Torralba and Ambrona Spain. Their Geology. Science 150, 1718–1722.

Carbonell, E., Díez, C., Enamorado, J., Ortega, A., 1987. Análisis morfotécnico de la industria lítica de Torralba (Soria). Cuadernos de Antropología-Etnografía 4, 201–216.

Carcaillet, C., Vernet, J.L., 2001. Comments on "The Full-Glacial forests of Central and Southeastern Europe" by Willis et al. Quat. Res. 55 (3), 385–387.

Carrión, J.S., Scott, L., Arribas, A., Fuentes, N., Gil-Romera, G., Montoya, E., 2007. Pleistocene landscapes in central Iberia inferred from pollen analysis of hyena coprolites. J. Quat. Sci. 22, 191–202.

Cerralbo De, M., 1911. Páginas de la historia patria por mis excavaciones arqueológicas. T.I., Torralba. Inédito.

Cerralbo De, M., 1913. Torralba, la plus ancienne station humaine de L'Europe? In: XIV Congrès international d'anthropologie, 1912., pp. 277–290.

Chapman, J.L., 1994. Distinguising internal developmental characteristics from external palaeoenvironmental effects in fossil wood. Rev. Palaeobot. Palynol. 81, 19–32.

Costa Tenorio, M., Morla, C., Sainz Ollero, H. (Eds.), 1997. Los bosques ibéricos: una interpretación geobotánica. Ed. Planeta, Barcelona, Spain, 572 p.

Cros, J., Pérez-Obiol, R., Roure, J., 1986. Primeres dades sobre la vegetació i el clima del Quaternari Mitjà a Olot (NE Península Ibérica). Collect. Bot. 16 (2), 365–369.

Desprat, S., Sánchez-Goñi, M.F., Turon, J.L., Duprat, J., Malaizé, B., Peypouquet, J.P., 2006. Climatic variability of Marine Isotope Stage 7: direct land–sea–ice correlation from a multiproxy analysis of a northwestern Iberian margin deep-sea core. Quat. Sci. Rev. 25, 1010–1026.

De Palacios, P., 1997. Anatomía de géneros y especies de coníferas del hemisferio norte. Universidad Politécnica de Madrid, E.T.S.I., Montes, Madrid (PhD thesis).

Falguères, Ch., Bahain, J.J., Pérez-González, A., Mercier, N., Santonja, M., Dolo, J.M., 2006. The Lower Acheulian site of Ambrona, Soria (Spain): ages derived from a combined ESR/U-series model. J. Archaeol. Sci. 33, 149–157.

Figueiral, I., Carcaillet, C., 2005. A review of Late Pleistocene and Holocene biogeography of highland Mediterranean pines (*Pinus* type *sylvestris*) in Portugal, based on wood charcoal. Quat. Sci. Rev. 24, 2466–2476.

Florschutz, F., Menéndez Amor, J., Wijmstra, T.A., 1971. Palynology of a thick Quaternary succession in southern Spain. Palaeogeogr. Palaeoclimatol. Palaeoecol. 10, 223–264.

Franco Múgica, F., Gómez-Manzaneque, F., Maldonado, J., Morla, C., Postigo-Mijarra, J.M., 2000. El papel de los pinares en la vegetación holocena de la península Ibérica. Ecología 14, 61–77.

Franco Múgica, F., García Antón, M., Maldonado, J., Morla, C., Sainz, H., 2001. The Holocene history of *Pinus* forests in the Spanish northern Meseta. The Holocene 11 (3), 343–358.

Follieri, M., Magri, D., Sadori, L., 1988. 250.000-year pollen record from Valle Di Castiglioni (Roma). Pollen Spores 30 (3–4), 329–356.

Freeman, L.G., Butzer, K.W., 1966. The Acheulean station of Torralba, Spain: a progress report. Quaternaria 8, 7–23.

Freeman, L.G., Howell, F.C., 1982. Acheulean hunters on the Spanish Meseta: Torralba and Ambrona reconsidered. 8lst Annual Meeting of the American Anthropological Association, Washington, D.C.

García, L., Guindeo, A., 1988. Anatomía e identificación de las maderas de coníferas españolas. A.I.T.M. Coimpress, Madrid, 142 p.

García Antón, M., Sainz Ollero, H., 1991. Pollen records from the middle Pleistocene Atapuerca site (Burgos, Spain). Palaeogeogr. Palaeoclimatol. Palaeoecol. 85, 199–206.

Gastaldo, R.A., 1986. Implications on the paleoecology of autochthonous Carboniferous lycopods in clastic sedimentary environments. Palaeogeogr. Palaeoclimatol. Palaeoecol. 53 (2–4), 191–212.

Gastaldo, R.A., 1989. Preliminary observations on phytotaphonomic assemblages in a subtropical/temperate holocene bayhead delta: Mobile Delta, gulf coastal plain, Alabama. Rev Palaeobot. Palynol. 58, 61–83.

González-Sampériz, P., Leroy, S.A.G., Carrión, J.S., Fernández, S., García-Antón, M., Gil-García, M.J., Uzquiano, P., Valero-Garcés, B., Figueiral, I., 2010. Steppes, savannahs, forests and phytodiversity reservoirs during the Pleistocene in the Iberian Peninsula. Rev. Palaeobot. Palynol. 162, 427–457.

Greguss, P., 1955. Identification of living Gymnosperms on the basis of xylotomy. Akadémiai Kiadò, Budapest.

Howell, F.C., Butzer, K.W., Aguirre, E., 1962. Noticia preliminar sobre el emplazamiento acheulense de Torralba (Soria). Excavaciones Arqueológicas en España 1:38.

Howell, F.C., Butzer, K.W., Freeman, L.G., Klein, R.G., 1995. Observations on the Acheulean occupation site of Ambrona (Soria province, Spain) with particular reference to recent investigations (1980-1983) and the lower occupation. Jahrbuch des Römisch-Germanischen Zentralmuseum Mainz 38, 33–81.

Jacquiot, C., 1955. Atlas d'anatomie des bois des conifères. Centre technique du bois, Paris, 133 p.
Klein, R.G., 1987. Reconstructing how early people exploited animals: problems and prospects. In: Nitecki, M.H., Nitecki, D.V. (Eds.), The Evolution of Human Hunting. Plenum Press, New York, pp. 11–45.
MacGinitie, H.D., 1969. The Eocene Green River flora of northwestern Colorado and northeastern Utah, 83. Univ. Calif. Publ. Geol. Sci.
Martín-Arroyo, T., Ruiz-Zapata, B., Pérez-González, A., 1995. Reconstrucción paleoclimática y paleoambiental durante el Pleistoceno Medio en el valle del río Tajo: primeros datos polínicos. In: Aleixandre, T., Pérez-González, A. (Eds.), Construcción de Paleoambientes y cambios climáticos durante el Cuaternario. Monografías, 3. Centro de Ciencias Ambientales, CSIC, Madrid, pp. 347–361.
Menéndez Amor, J., Florschütz, F., 1959. Algunas noticias sobre el ambiente en el que vivió el hombre durante el gran interglaciar en dos zonas de ambas Castillas. Estud. Geol. 15, 277–283.
Mourer-Chauviré, C., Renault-Miskovsky, J., 1980. Le paléoenvironment des chasseurs de Terra Amata (Nice, Alpes-Maritimes) au Pléistocène moyen. La flore et la faune de grands mammifères. Geobios 13, 279–287.
Mutz, R., Guilley, E., Sauter, U.H., Nepveu, G., 2004. Modelling juvenile-mature wood transition in Scots pine (*Pinus sylvestris* L.) using nonlinear mixed-effects models. Ann. Forest Sci. 61, 831–841.
Peraza, C., 1964. Estudio de las maderas de coníferas españolas y de la zona norte de Marruecos. Ministerio de Agricultura. Instituto Forestal de Investigaciones y Experiencias, Madrid, 112 p.
Pérez-González, A., Santonja, M., Mora, R., Soto, E., Sesé, C., Ruiz-Zapata, M.B., Alexaindre, T., Villa, P., Gallardo, J., 1995–1997. 1995-1997. Investigaciones recientes (1990–1997) en los yacimientos achelenses de Ambrona y Torralba (Soria, España). O Arqueólogo Português 13/15, 11–34.
Pérez-González, A., Santonja, M., Gallardo, J., Aleixandre, T., Sesé, C., Soto, E., Mora, R., Villa, P., 1997a. Los yacimientos pleistocenos de Torralba y Ambrona y sus relaciones con la evolución geomorfológica del Polje de Conquezuela (Soria). Geogaceta 21, 175–178.
Pérez-González, A., Santonja, M., Mora, R., Sesé, C., Soto, E., Aleixandre, T., Villa, P., Gallardo, J., 1997b. Ambrona y Torralba. Actividad y procesos naturales. In: Rodríguez Vidal, J. (Ed.), Cuaternario Ibérico. AEQUA, Huelva, pp. 235–247.
Pérez-Obiol, R., Roure, J.M., Mallarach, J.M., 1986. Study of climatic changes during the recent Quaternary in the northeastern iberian peninsula on the basis of pollen analysis. In: López Vera, F. (Ed.), Quaternary climate in western Mediterranean. Universidad Autónoma de Madrid, Madrid, pp. 297–305.
Postigo-Mijarra, J.M., Gómez-Manzaneque, F., Morla Juaristi, C., Zazo, C., 2010. Palaeoecological significance of Late Pleistocene pine macrofossils in the lower Guadalquivir Basin (Doñana natural park, southwestern Spain). Palaeogeogr. Palaeoclimatol. Palaeoecol. 295, 332–343.
Rich, F.J., 1989. A review of the taphonomy of plant remains in lacustrine sediments. Rev. Palaeobot. Palynol. 58, 33–46.
Roucoux, K.H., Tzedakis, P.C., de Abreu, L., Shackleton, N.J., 2006. Climate and vegetation changes 180,000 to 345,000 years ago recorded in a deep-sea core off Portugal. Earth Planet. Sci. Lett. 249, 307–325.
Ruiz-Zapata, M.B., Pérez-González, A., Santonja, M., Gil García, M.J., Dorado Valiño, M., Valdeolmillos Rodríguez, A., 2003. Vegetación mesopleistocena del poljé de Conquezuela (Soria). Polen 13, 5–17.
Ruiz-Zapata, M.B., Dorado, M., Valdeolmillos, A., Gil-García, M.J., Martín-Arroyo, T., Pérez-González, A., 2004. Registro paleoambiental y paleoclimático de Pleistoceno Medio y Superior en depósitos fluviales del Valle del Río Tajo (Toledo). Miscelánea en Homenaje a Emiliano Aguirre, vol. II. Paleontología, Museo Arqueológico Regional, Alcalá de Henares, Spain, pp. 507–518.
Russo Ermolli, E., Cheddadi, R., 1997. Climatic reconstruction during the Middle Pleistocene: a pollen record from Vallo Di Diano (Southern Italy). Geobios 30 (6), 735–744.
Sánchez-Goñi, M.F., Eynaud, F., Turon, J.L., Shackleton, N.J., 1999. High resolution palynological record off the Iberian margin: direct land–sea correlation for the Last Interglacial complex. Earth Planet. Sci. Lett. 171, 123–137.
Santonja, M., Pérez-González, A., Villa, P., Sesé, C., Soto, E., Mora, R., Eisenman, V., Dupré, M., 2000. El yacimiento paleolítico de Cuesta de la Bajada (Teruel) y la ocupación humana de la zona oriental de la Península Ibérica en el Pleistoceno medio. Scripta in Honorem a Enrique Llobregat. Inst. Alicantino de Cultura Juan Gil-Albert, Alicante, Spain, pp. 79–101.
Schweingruber, F.H., 1990. Anatomie europäischer Hölzer. Paul Haupt, Bern und Stuttgart.
Shipman, P., Rose, J., 1983. Evidence of butchery and hominid activities at Torralba and Ambrona; an evaluation using microscopic techniques. J. Archaeol. Sci. 10 (5), 465–474.
Teixeira, C., 1943. Note sur les argiles à végétaux de Porto-Covo. Com. Serv. Geol. Portugal 14, 1–5.
Van der Wiel, A.M., Wijmstra, T.A., 1987. Palynology of the lower part (78-120 m) of the core Tenaghi Philippon II, Middle Pleistocene of Macedonia, Greece. Rev. Palaeobot. Palynol. 52, 73–88.
Villa, P., 1990. Torralba and Aridos: elephant exploitation in Middle Pleistocene Spain. J.Hum.Evol. 19 (3), 299–309.
Zbyszewski, G., 1958. Le Quaternaire du Portugal. Bol. Soc. Geol. Port. XIII, 3–227 (IX pl. Lisboa).