FUEL AND ACORNS: EARLY NEOLITHIC PLANT USE FROM CUEVA DE CHAVES (NE SPAIN).

Marta ALCOLEA*, Pilar UTRILLA*, Raquel PIQUÉ**, Rafael LABORDA*, Carlos MAZO*

*University of Zaragoza, Spain. PPVE Research Group. Environmental Sciences Institute (IUCA).

**Autonomous University of Barcelona (UAB), Spain. AGREST Reasearch Group.

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Cueva de Chaves is a particularly important archaeological site for the Early Neolithic of the northeast Iberian Peninsula. This study focuses on the archaeobotanical analysis of wood charcoals and charred fruits from two Neolithic levels dated from 5678±50 to 5073±107 cal BC. Charcoal analysis reveals the exploitation of firewood resources in different environments. A great variety of woody taxa and plant formations dominated by pines and oaks has been documented. The location of the archaeological site in a mid-mountain environment favors a mixed exploitation of resources in the valley and the mountains. Mesophytes indicate a relative humid environment where xerophytic and thermophilous trees and shrubs have an important presence. Taxonomic richness documented in the settlement provides an idea of long-term settling and development of diversified activities. The dramatic increase of colonizing secondary formations in the earliest level of occupation can only be explained by human intervention. According to pollen information human activity in the environment is well-documented since Early Neolithic that reveal the presence of several herbaceous plants (Plantago, Rumex, Chenopodiaceae, Asphodellus, etc). Among charred seeds we have only documented the presence of abundant and well-preserved acorns (Quercus sp.) but the presence of crops has not been attested just by indirect archaeological evidences.

1. INTRODUCTION

The beginnings of farming and a sedentary lifestyle that led to a substantial impact on forest cover is an interesting topic from an archaeological perspective. Numerous studies are being conducted in the Mediterranean basin to understand the connection between Holocene climate change, cultural dynamics, and settlement patterns (González-Sampériz et al., 2009; López de Pablo and Jochim, 2010; Mercuri et al., 2011; Pérez-Olbiol et al., 2011; Cortés et al., 2012; Montes et al., 2015; Uzquiano et al., 2016). The aim of this work is to contribute to our knowledge of the environmental framework of the first farming communities in N-NE Iberia, discover which economic activities were linked to the management of forest resources, and evaluate the human impact on the landscape in small-scale terms.

In the central Pyrenees, where few open-air settlements are documented (Benavente and Andrés, 1989; Rey and Ramón, 1992), a series of occupations in caves and rock-shelters located in a mid-mountain area assemble the territory such as Cueva de Chaves (Baldellou and Castán, 1983), Espluga de la Puyascada (Baldellou, 1987) Cova Colomera (Oms et al., 2013) or Cova del Parco (Petit, 1996) (Figure 1). Although the spread of a farming lifestyle involved a significant change in man's relationship with the environment, agricultural societies were still closely linked to the availability of resources – including plant resources. The first farmers needed the forest for wood and fodder. In the same manner, farming requires at least a partial clearance of existing vegetation and its replacement by cultivated fields (Roberts, 1989). The location in a mid-mountain area that marks a transition between biogeographic environments favoured a mixed exploitation and resource management.

Despite the importance of forest resources for these human communities, archaeobotanical studies are still scarce in certain areas and often limited to palaeoenvironmental reconstructions. As a result, the results are not integrated into an archaeological discussion of the settlements. Some recent studies integrating plant remains analyses in N-NE Iberia have provided valuable information about subjects such as farming and livestock practices (Allué et al., 2009; Antolín et al., 2010), occupation of mountain areas by the first farmers (Lancelotti et al. 2014; Gassiot et al., 2016), and firewood management (Obea et al. 2011; Ruiz-Alonso and Zapata, 2015).

This paper focuses on the study of charred plant macro-remains (wood charcoal and fruit/seeds) that appear in the Cueva de Chaves (Huesca, Spain). This site is one of the most important Neolithic sites in the Iberian Peninsula and was regrettably destroyed by unauthorised works. The present study has a dual purpose. Firstly, wood charcoal analysis provides valuable paleoenvironmental information for the vicinity of the site during the various moments of occupation. Secondly, a study of wood and fruit/seed that complements other bioarchaeological (Castaños, 2004; Zapata et al., 2008) and not bioarchaeological studies (Utrilla et al., 2008; Baldellou, 2011; Domingo; 2014; Mazzuco et al, 2015), provides information about the economic activities in the settlement and the different uses of plant resources during the Neolithic.

2. GEOGRAPHICAL SETTING

The Cueva de Chaves (663 m asl) is located in a mid-mountain environment between the central Pyrenees and the Ebro basin. This territory includes highly variable ecosystems as a result of marked topographic, climatic, and geographic gradients. It has a mouth 60 m wide and 30 m high and a south-eastern orientation that opens in a ravine known as the Solencio (a rugged landscape in the Sierra de Guara – the highest range in the Pre-Pyrenees central sector: see Figure 1). Current vegetation in the Sierra de Guara reveals a contrast between the northern and southern slopes. The external mountain ranges of the Pre-Pyrenees feature Mediterranean vegetation and climate with a continental influence and a significant summer aridity. At present the climax vegetation is a dense holm oak (*Quercetum rotundifoliae subas. rhamnetosum infectoriae*) that is very affected by fire and anthropogenic action, as well as significant rosemary bush on rocky and dry cliffs (*Rosmarino Lithospermetum*). Deciduous forest communities are restricted to moist ravines along water courses. Kermes oak accompanied by juniper take advantage of the poor and rocky soil to form permanent communities at the base of the external mountain ranges. Currently, sub-Mediterranean taxa, especially boxwood, grow above 1000 m asl. The most thermophilous taxa (*Phillyrea latifolia, Asparagus acutifolius, Micromeria fruticosa, Rosmarinus officinalis*, etc) are restricted to dry and sunny cliffs. Oak groves (*Buxo-Quercetum pubescentis subas. quercetosum subpyrenaicae*) form the climax forest community on the northern slopes of the Sierra de Guara. Atlantic pine forests (*Buxo-Quercetum pubescentís subas. arenario-*

pinetosum) grow spontaneously over the 1500 m asl (Monserrat-Martí, 1987). These environments are excellent habitats for goats, deer, roe deer and wild boar.

3. ARCHAEOLOGICAL BACKGROUND AND SITE DESCRIPTION

The Cueva de Chaves (Huesca, Spain) is one of the most important Iberian Neolithic settlements. The first farming communities in N-NE Iberia founded permanent open-air settlements such as La Draga (Bosch et al., 2000, 2011), Plansallosa, (Bosch and Aliaga, 1998), Guixeres de Vilobí (Oms et al., 2014), Alonso Norte (Benavente and Andrés, 1989) or El Torrollón (Rey and Ramón, 1992) (Figure 1). In the central Pre-Pyrenees, where few open-air settlements are documented, a series of occupations in caves and rock-shelters have been found with complementary functions such as habitats, storage, stabling, or burial (Baldellou and Castán, 1987; Baldellou, 1987; Petit, 1996; Oms et al., 2013).

It has been the object of archaeological excavation from 1984 under the direction of Vicente Baldellou (Museum of Huesca) and Pilar Utrilla (University of Zaragoza). The Neolithic deposit was destroyed in 2007 following unauthorised works. There have been many periods of occupation in the cave (Solutrean, Magdalenian, Bronze Age and sporadic visits in historical times) but in this paper we focus on the Neolithic layers. The Neolithic occupation is located in a 110 m long hall that is well lit by sunlight for the first 50 m of its length. The site was partially excavated (almost 100m^2) before its destruction and a living space with numerous fireplaces and storage structures was uncovered (Figure 2). Numerous studies have focused on certain elements of material culture and lifestyle (Utrilla et al. 1999; 2008; Cava, 2000; López-García and López Saez, 2000; Castaños, 2004; Ramón, 2006; Utrilla and Baldellou, 2007; Zapata et al., 2008; Baldellou, 2011; Ureña et al. 2011; Gamba et al. 2012; Baldellou, et al. 2012; Domingo, 2014; Mazzuco et al., 2015; Sánchez, 2016).

The settlement is interpreted as a clear case of colonisation with an ex novo establishment in an unoccupied place for thousands of years by groups who left Early Neolithic materials. The vast site contains a dwelling with distinct and separate functions in various areas and it was a stable settlement (Baldellou and Utrilla, 1999; Utrilla and Domingo, 2014). It is included within the *Cardial* cultural tradition that developed in the NE Iberian Peninsula during the sixth millennium cal BC, and is contemporary with other coastal sites such as Guixeres de Vilobí (Oms et al., 2014) and El Cavet (Martins et al., 2015) in Catalonia, or Cendres (Bernabeu and Fumanal, 2009) and Cova de l'Or (Martí, 2011) in eastern Spain (Figure 1).

Despite the continuity of human occupation shown by radiocarbon dating, the existence of two distinct archaeological layers is clearly documented – both dated to the sixth millennium cal BC and which correspond to two moments of occupation (Baldellou, 2011; Baldellou et al., 2012; Utrilla, 2012). The *Cardial* phase (level Ib) was dated to between 5799-5550 and 5478-5063 cal BC (5614-5479 cal BC in short-lived samples) (Table 1). The level lies on a stalagmitic crust that was perforated to open a variety of holes used as silos, hearths, and storage containers. This level was very rich in archaeological material: pottery; faunal remains; lithic tools; bone industry; painted pebbles; and a large set of shells (*Collumbellae, Dentalium, Cardium, Pecten*) and bone ornaments (perforated canid canines or marble rings) (Baldellou et al., 2012). The *Late Cardial* phase (level Ia) is more recent with five radiocarbon dates between 5474-5079 and 5281-4845 cal BC. An impoverishment of archaeological remains for level Ib is observed in lithic tools, bone industry, ornaments, and painted pebbles (Baldellou, 2011). This can be related with a change in the function of the occupied area (Sánchez, 2016). The frequency of pottery decorations with cardial impressions decreases although remains significant, while the rate of non-cardial impressions and incisions increases. However, continuity remains in both archaeological layers regarding the morphology of vessels. The presence of several burials in different funerary contexts is documented in level Ia (Utrilla et al., 2008).

The presence of two particularly interesting structures in the settlement should be noted (Figure 2). The first is the 86A hearth (1.50 m. maximum diameter and 20 cm depth), located in the habitation area. This fireplace contained charcoal fragments (n = 76), nut fragments (79), faunal remains (24), ceramic fragments (9), flint blades (5), rock crystal (2), a *Dentalium,* and ashes. An acorn was directly radiocarbon dated to 5471-5303 cal BC. The second structure of special interest is a male burial grave with bound hands holding the shins. The grave was covered with white pebbles (296) that came from the nearby Solencio cave, ochre, and a layer of white ash and wood charcoal (255) that probably resulted from burning an offering. The grave belongs to the recent level but is located outside the habitation area. It was directly radiocarbon dated to 5308-5057 cal BC (Utrilla et al., 2008).

4. MATERIALS AND METHODS

4.1. *Wood charcoal analysis*

Charcoal was hand collected by sieving the sediment during fieldwork. A total of 1397 wood charcoal fragments were analysed. The majority of the remains were scattered across the surface of both levels (n = 1066). Although the interpretation of archaeological charcoal depends on a complex interaction of many parameters (such as climatic, societal, settlement, and sedimentary factors) (Thèry et al., 2010) several authors have pointed out that the wood charcoal is the result of consecutive combustion events and so is a good indicator of palaeoecological conditions (Uzquiano, 1997; Chabal et al., 1999; Badal, 2003). Wood charcoal from two structures that represent isolated events were also studied – the 86A pit (n = 76) and the male burial grave (n = 255).

For the taxonomic identification of specimens, each fragment was manually broken using the method described by Vernet (1973). The anatomical patterns of each wood species were observed in three sections (transverse, tangential, and radial). For anthracological analysis, a metallographic dark/bright field incident-light microscope (Nikon Optiphot) was used with magnification factors of 40 to 1000x. Botanical identification was possible by referencing wood anatomy atlases for both non-charred (Greguss, 1959; Jaquiot et al., 1973; Schweingruber, 1990) and carbonised woods (Vernet et al, 2001). Nomenclature follows the guidelines in *Flora europaea* (Tutin et al., 1964).

4.2. Carpological material analysis

In the case of seeds, the often small size of these plant macroremains makes them virtually invisible and unnoticed if systematic and comprehensive sampling strategies are not applied. Unfortunately, no samples from the Cueva de Chaves Neolithic deposit were processed by water flotation.

Carpological material recovered during first excavations (1984-1986) was partially studied and the results published (Zapata et al., 2008). In the current work, the charred plant macroremains studied represent a total of 83 nut fragments that were identified using a stereoscopic microscope (Nikon SMZ-10) with magnification factors of 0.66 to 40x and specialised atlases (Schoch et al., 1988; Cappers et al., 2012). Our carpological study also involved a review of all plant remains recorded in the site inventory of materials: those already published and otherwise.

5. RESULTS

The study enabled the identification of 16 taxa that correspond to a minimum of 14 species (Table 2): *Acer* sp. (maple), *Arbutus unedo* (strawberry tree), *Buxus sempervirens* (boxwood), Fabaceae (legumes), *Juniperus* sp. (juniper), *Phillyrea*/*Rhamnus* (buckthorn/narrow-leaved vetch), *Pinus halepensis* (Aleppo pine), *Pinus sylvestris*-type (Scots/black pine type), *Pinus* sp. (pine), *Pistacia* sp. (mastic/terebinth), *Populus/Salix* (poplar/willow), *Prunus* sp., *Quercus* sp. deciduous (deciduous oak), *Quercus* sp. evergreen (evergreen oak), *Quercus* sp. and *Rosmarinus officinalis* (rosemary).

5.1. Scattered wood charcoal

In the earliest level (Ib) the most important taxon (33.3%) are cold mountain pines (*Pinus sylvestris*-type), although the thermomediterranean Aleppo pine (*Pinus halepensis*) also has a significant presence (19.2%). The second most commonly represented taxon (23.3%) at this level is deciduous oak (Deciduous *Quercus*). Varying percentages of Mediterranean elements (Evergreen *Quercus*, *Phillyrea/Rhamnus*, *Rosmarinus officinalis*) xeric and thermophilous were also documented.

In the more recent level (Ia) the percentages of both *Pinus* are similar although the total presence of pine decreases from nearly 60% to just over 30%. The best represented taxon (45.2%) in the Ia level is juniper (*Juniperus* sp.). The presence of taxa from deciduous forests is significantly reduced in level Ia, while Mediterranean taxa maintain their presence. Buckthorn/narrow-leaved vetch (*Phillyrea/Rhamnus*), rosemary (*Rosmarinus officinalis*), mastic/terebinth (*Pistacia* sp.) and strawberry tree (*Arbutus unedo*) are associated with Aleppo pine (*Pinus halepensis*) or evergreen oak (*Quercus* sp.evergreen) formations.

5.2. Wood charcoal associated with structures

The samples directly associated with structures show some differences in their taxonomic composition regarding the scattered charcoal. The 86A hearth shows the lowest presence of coniferous wood (21%). The anthracological record is dominated by mesophilous taxa that characterises Holocene deciduous forests (*Acer* sp., *Quercus* sp. deciduous, *Prunus* sp.) although closely followed by shrubby taxa linked to forest degradation (*Arbutus unedo*, *Buxus sempervirens*, *Rosmarinus officinalis*). The sample from the male burial grave reveals considerable levels of coniferous (83.3%), especially *Pinus* spp., and *Quercus* spp. (10.5%).

5.3. Carpological material

All the charred remains recovered correspond to *Quercus* spp. (acorns) (Table 3) – either isolated cotyledons or whole acorns with two cotyledons and even the pericarp (fruit wall) perfectly preserved (Figure 3). These remains appear exceptionally well preserved but the cupule of the fruit has not been preserved in any of the cases and so it was not possible to determine the species to which they belong. The present study identified 83 nut fragments, 33 belonging to level Ib, 13 to level Ia, and 37 to hearth 86A. If we add these 37 to the 42 in this structure published by L. Zapata (Zapata et al., 2008), then a total of 79 acorn fragments recovered from the structure appear mixed with wood charcoal that was directly radiocarbon dated in 5471-5303 cal BC. The remaining charred cotyledons were scattered across the surface at both levels. The acorns documented in the Cueva de Chaves totalled 151 cotyledons or cotyledon fragments.

6. DISCUSSION

6.1. Palaeoecology and Neolithic landscape

The anthracological diagram reveals a forested landscape in the earliest level (Ib) (Figure 4). The spectrum is dominated by pine forests and mixed forest with oak. The influence of Mediterranean conditions is noticeable with numerous evergreen oaks accompanied by Mediterranean shrubs (*Arbutus unedo*, Fabaceae and *Phillyrea/Rhamnus*). Some changes in the charcoal record were documented in the most recent level (Ia). This deposit shows an increase in number and variety of shrubby and Mediterranean taxa (*Arbutus unedo*, *Buxus sempervirens*, Fabaceae, *Pistacia* sp., *Phillyrea/Rhamnus* and *Rosmarinus officinalis*) (Figure 4). Apparently, pioneer species expanded and caused secondary formations dominated by these shrubby taxa. The presence of certain species such as *Juniperus*, Ericaceae (*Arbutus unedo*), Fabaceae and

Lamiaceae (*Rosmarinus officinalis*) indicates the existence of open areas favourable to the development of these heliophilous taxa.

Spore-pollen content for the Cueva de Chaves Neolithic levels is low and so our knowledge of the paleoenvironment is limited (López-García, 1992) and this makes a reconstruction of forest landscape more difficult (Carrión et al., 2009). According to pollen data from the settlement (López-García, 1992; López-García and López-Sáez, 2000) at the earliest level (Ib) the landscape was a slightly open forest (AP 40-60%) dominated mainly by pines (*Pinus*) (Figure 5). However, the presence of evergreen oak (*Quercus ilex-coccifera*) and mesophytes such as maple (*Acer*), alder (*Alnus*), lime (*Tilia*), and hazel (*Corylus*) is well documented. In the most recent level (Ia) a development of the forest (AP 85%) and the first presence of cereal pollen grains is observed. Human impact on the environment is noticeable from the Neolithic with the presence of herbaceous taxa (*Plantago, Rumex, Chenopodiaceae, Asphodellus*, etc.) and microcharcoal that reveals local deforestation possibly related to farming and livestock.

According to pollen information provided by other pollen-sequences in this region, a relevant shift in the vegetation landscape composition in the central Pyrenees took place after 8.2 cal BP (ca. 6200-6000 cal. BC) (Pérez-Sanz et al., 2013; Pérez Sanz, 2014). Deciduous forests replaced pine in high altitude pollen sequences (Montserrat, 1992; González-Sampériz et al., 2006; Pèlachs et al., 2007; Pérez-Sanz et al., 2013). In mid-mountain areas, Estanya pollen-sequence (670 m asl) reveal the spread of semi-deciduous and evergreen *Quercus* (Pérez-Sanz, 2014). The Mid-Holocene period reflects more seasonal conditions that affect Mediterranean-influenced sequences and a well-established Mediterranean dry season vegetation landscape (Pérez-Sanz, 2014; Montes et al., 2015). Mid- Holocene records are unavailable for the most arid zones of the central Ebro basin, but data suggests a strong aridity in this area that caused intense erosion and a retreat of vegetation cover (Davis, 1994). The influence of Mediterranean conditions led to a marked regionalisation of the landscape and evergreen and semi-deciduous oak woodland acquired a special relevance associated with thermophytes and warm-loved taxa (Valero-Garcés et al., 2000; González-Sampériz et al., 2008). This transformation in the vegetation landscape coincides with the Mid-Holocene global atmospheric adjustment (Roberts et al., 2011) and an increase in human activities associated with the arrival of Neolithic cultures (Revelles, i.p.). Crisis aridity may have influenced Neolithic landscape in the central Ebro valley as suggested by several authors (Utrilla y Rodanés, 1997; López-Sáez et al., 2006).

The information provided by charcoal and pollen is complementary. Charcoal analysis provides valuable paleoenvironmental data about the immediate surroundings of the settlement, while palynology provides a vision of vegetation at a regional level. Both approaches give us information about the palaeoecological context of the settlement. A knowledge of the plant species present in the prehistoric environment is important because it enables us to infer the environments through their ecological characteristics. However, the level of determination in the pollen record is often insufficient to distinguish between species of the same family, which is particularly important when a species has differing ecological requirements. Pine species documented in the Cueva de Chaves through pollen grains have been the subject of controversy in some publications regarding their attribution to *Pinus halepensis* or *P. sylvestris*-type (López-García, 1992; López-García and López-Sáez, 2000; López-Sáez et al., 2006). Wood charcoal analysis shows that in the environment surrounding the Cueva de Chaves various pine species with contrasting ecological needs coexisted simultaneously. Aleppo pine is more resistant to aridity than black or Scots pine. Holocene environmental changes meant that the *Pinus sylvestris*-type (including *Pinus nigra* subsp. *laricio*, *Pinus sylvestris* and *Pinus uncinata*) that requires cold and humid conditions was restricted to mountainous areas (Franco-Múgica et al., 2001; Rubiales et al., 2010; Roiron et al., 2013) (although it sometimes survives in landscapes alongside Mediterranean pines in NE Iberia). This species can survive within its ecological tolerance limits (Allué, 2002; Badal, 2004; Alcolea, i.p.), a fact which is favoured by the location of the Cueva de Chaves in a mid-mountain or transitional area.

6.2. Management of vegetal resources

Woody plants were exploited in the surroundings of the settlement for various purposes. Archaeobotanical macro-remains from archaeological contexts are anthropogenic records and reflect the taxa consumed by humans according to their needs. A study of wood charcoal and seed remains provides data on resource management and settlement activities. Undoubtedly, the best documented plant use in the Cueva de Chaves is the use of wood as fuel. Although firewood can be collected for specific uses following various selection criteria, the most important criterion in its selection is local availability. Wood charcoal appearing in archaeological contexts is often a good reflection of the surrounding vegetation.

Neolithic settlements become more permanent and the tasks developed within were more diversified than in previous organisational systems. Taxonomic richness documented in Cueva de Chaves at both levels of the settlement suggests long-term and diversified activities. Among the functions of the settlement we can emphasise economic activities that involved the use of firewood (as revealed by faunal and traceological studies) (Castaños, 2004; Domingo, 2014; Mazzuco et al., 2015) and used the cave to store and process food, protect livestock, or process animal skins. These activities may imply the selection of certain fuels for their high tannin content (such as oak, pine, juniper fruit, strawberry leaves or terebinth) for smoking and tanning (Obón and Rivera, 1991).

Pinewood reaches levels of more than 50% in the earliest level (Ib) and was the most commonly used wood. Oak (Deciduous *Quercus*) (23.3%) and evergreen oak (Evergreen *Quercus*) (8.8%) were the second most commonly used firewoods. Finally, some Mediterranean plants (*Arbutus unedo*, Fabaceae, *Juniperus* sp., *Phillyrea/Rhamnus*, *Rosmarinus officinalis*) are documented with varying percentages (Table 2 and Figure 4). The competition between pinewood and oak and shrub formations is reflected by anthracological sequences from transitional areas of the western and eastern Pyrenees (such as Atxoste, Mendandia, Kampanoste Goikoa, Balma Margined, or Cova 120). The general trend in wood consumption reveals a large exploitation of oak forests and Mediterranean formations by Neolithic populations in parallel with their massive expansion during the Holocene (Allué, 2002; Obea et al. 2011; Ruiz-Alonso and Zapata, 2015). A significant increase in consumption of juniper is documented in the most recent level (Ia) of the Cueva de Chaves charcoal record (Figure 4). Different species of this genus cannot be distinguished from each other using wood anatomy (Schweingruber, 1990). Currently, in the central pre-Pyrenees up to four species of *Juniperus* can be found in the same area: Corsican juniper (*Juniperus phoenicea*); cade (J. *oxycedrus*); common juniper (*J. communis*); and Spanish juniper (*J. thurifera*) (Ferrández, 2003). Overall, *Juniperus* is a heliophilous genre that colonises secondary formations of soils that have been degraded either by natural conditions (such as climate or a composition that prevents the development of other formations), or by human activities (such as clearing for farming and grazing). This change in land use is not reflected in the Cueva de Chaves pollen record (Figure 5) (López-García, 1992) and may have two main causes.

The first explanation is a small-scale change in the landscape. Agriculture practices and livestock farming imply significant changes in vegetation cover. Despite the fact that use-wear analysis (Domingo, 2014; Mazzuco et al., 2015) shows evidence of farming in both Neolithic levels, cereal pollen is only documented in the most recent level (Ia) (López-García, 1992). Mazzuco et al. (2015) argues that during the earliest occupation of the Cueva de Chaves (level Ib) cultivated fields were located far from the settlement due to the hilliness of the cave's surrounding landscape. However, the presence of cereal pollen in level Ia could be related the presence of nearby cereal crops as cereal pollen does not travel far (Iversen, 1949). This hypothesis agrees with the proliferation of heliophilous and pioneer taxa during phase Ia (Figure 4). Firewood collection was carried out in the open landscape and secondary woodland formations following deforestation and farming practices as revealed by the anthracological diagram.

The second explanation for the dramatic increase of juniper in level Ia may be due to a specific use of wood. Researchers interpret a decline in the importance of the settlement as a habitat (revealed by a smaller variety of tasks being performed) in this second phase of human occupation as caused by material scarcity (Baldellou et al., 2012; Sánchez, 2016). Other functions of the cave, such as the stabling of livestock or burial, may have gained importance. Juniper forms open communities favourable for extensive grazing and the existence of pastures and winter sprigs of juniper are an essential addition to the diet of sheep and goats (Blanco et al., 1997). Ethnographic studies show that livestock was fed from tree fodder when grazing was impossible and this hypothesis has been formulated for several archaeological contexts in Iberian Neolithic caves according to the archaeobotanical remains (Rasmussen, 1993; Badal, 1999; Zapata et al., 2003; Allué, 2004; Rodríguez et al., i.p.). Fodder was stored for animals and newborns during the coldest months. Although juniper is not highly valued as livestock feed, juniper formations (e.g. *Juniperus phoenicea*) in the central Pyrenees were used to feed livestock and its ash was added as a mineral supplement to cow and sheep feed (Villar and Ferrández, 2000).

This could explain some overrepresentation of this taxon – although the possibility that it became more common in the environment during this period cannot be excluded.

Both explanations may be complementary. It has also been proposed that the use of aromatic species could be related to funerary practices (Picornell, 2012). Wood charcoal found at the male burial is dominated by aromatic species – especially juniper and pine with high resin contents (Table 2 and Figure 6). In any event, as a sudden change occurs in a very short period of time that cannot be explained just by climatic causes, it is necessary to look for other causes, such as anthropogenic causes or changes in fuel management strategies following a change in the occupation patterns of the site between Ia and Ib.

6.3. Contribution of charred plants to Neolithic subsistence

Oak forests near the cave were also exploited for acorns (*Quercus* sp.). A total of more than 100 charred cotyledons (Table 3) and acorns have been collected from both Neolithic levels, and this confirms the palaeoeconomical importance of these wild fruits in the Cueva de Chaves. Acorns have also been documented at many other NE Iberian Neolithic cave sites where gathering wild fruits has been suggested as a common activity among early farmers in the Neolithic (as documented at La Draga or La Dou) (Antolín, 2013; Antolín and Jacomet, 2015 and references therein) (Figure 1).

The carpological analysis carried out on wild fruit remains has not enabled the type of *Quercus* to be identified. Numerous species of this genus currently grow in the Sierra de Guara: *Quercus coccifera, Q. ilex, Q. faginea, Q. petraea, Q. pyrenaica, Q. suber, Q. pubescens.* Acorns are nutritionally comparable with cereals and suitable for both human and animal consumption, as well as being high in protein, carbohydrates, fat, and fibres. Their roasted presence inside hearth 86A has been interpreted as a clear sign that they formed part of the diet of Neolithic inhabitants of Cueva de Chaves (Zapata et al., 2008). Only *Quercus* sp. deciduous accompanied by shrubby taxa has been documented inside the 86A structure (Table 2 and Figure 6). However, according to wood charcoal information both evergreen and deciduous oaks were commonly found during Neolithic times in the immediate vicinity of the site. Sweet acorns (e.g. *Quercus ilex*) can be eaten raw and several methods of preparation are known from historical, experimental, and ethnographic examples (Mason, 1992; 2000; Rosenberg, 2008; Mason and Nesbitt, 2009; Šálková et al., 2011; Antolín, 2013; Ayerdi et al., 2016).

These acorns are the only carpological remains documented in this record. Archaeobotanical samples from Iberian Neolithic caves usually contain crop grains;

although the presence of other elements is not usually documented (Zapata et al., 2004). Cultivated plants were integrated into human subsistence yet farming activities near the Cueva de Chaves is only documented with indirect proof: large pottery vessels; silos, quern-stones (Baldellou, 2011); lithic tools with cereal use-wears (Domingo, 2014; Mazzuco et al, 2015); caries in buried humans (Utrilla et al., 2008); and *Cerealia* pollen (López-García, 1992).

In addition to plant gathering and farming, hunting and livestock are well documented in the Cueva de Chaves through archaeozoological studies (Castaños, 2004). Faunal remains are abundant at both levels (12,754 bones and 593 recognisable NMI) and have a similar composition (Figure 7). Ovicaprine livestock (*Ovis/Capra*) was the most important, followed by bovine (*Bos taurus*) and porcine (*Sus domesticus*). Among wildlife species, deer (*Cervus elaphus*) was the most hunted followed by wild goat (*Capra pyrenaica*) and wild boar (*Sus scrofa*). Taphonomic analysis has revealed that lagomorphs (*Oryctolagus cuniculus*) do not seem to have an anthropic character.

A mixed exploitation and mountain/valley type resource management was favoured by the location of the site in a mid-mountain area that marks a transition between biogeographic environments. In the Cueva de Chaves, farming probably took place on the plains or well-orientated slopes, while mountainous areas provided forest resources such as fodder and wood for firewood or timber. This type of woodland exploitation is documented in other nearby sites with similar locations such as Cova de la Guineu (Barcelona) (Allué et al., 2009). Aridity intensification and human impact (fires, deforestation, farming, pastoralism) caused a rapid transformation of the forest landscape in the immediate settlement vicinity. This change is also reflected in the different land uses as a consequence of a change in the occupation patterns of the site between Ia and Ib.

7. CONCLUSIONS

Archaeobotanical studies reveal that the main uses of plants in the Cueva de Chaves are as a source of energy and human and livestock feed. The Neolithic inhabitants of the Cueva de Chaves exploited tree and shrub layers of the deciduous forest, as well as the sclerophyllous taxa typical of Mediterranean climates that grow in certain favoured areas. The location of the site in a mid-mountain area that marks the transition between biogeographic environments, and the long duration of developed activities favours a mixed exploitation with mountain/valley type resource management and the use of different plant communities.

Wild fruit are integrated into human subsistence in the Early Neolithic as revealed by the large volume of well-preserved acorns. The existence of crops is only documented by indirect evidence. Taxonomic richness documented in the settlement and wood charcoal analysis suggests a long-term settlement and the development of diversified activities. Changes in the wood charcoal record between two occupation phases reflects a variation in vegetal resource exploitation strategies. The results of anthracological studies suggest a change in the function of the excavated area in which raising livestock gains importance coinciding with the general trend observed in other charcoal contexts of the western Mediterranean. Farming practices benefit from the open landscape – especially in the most recent level of occupation with the spread of colonising secondary formations and well-known anthropogenic indicators. This idea is supported by studies of the faunal assemblage and pollen analysis.

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FIGURE CAPTIONS

Figure 1. Location map of Cueva de Chaves: A) Location of the site (yellow star) in relation with the sites mentioned in the text and other important Early Neolithic sites from NE Iberia and South of France: 1. La Lámpara (Ambrona, Soria); 2. Peña Larga

(Cripán, Álava); 3. Mendandia (Saseta, Burgos); 4. Atxoste (Vírgala, Álava); 5. Los Cascajos (Los Arcos, Navarra); 6. Paternanbidea (Íbero, Navarra); 7. La Ambrolla (La Muela, Zaragoza); 8. Arba de Biel Sites (Biel, Zaragoza); 9. Esplugón (Sabiñánigo, Huesca); 10. El Torrollón (Usón, Huesca); 11. Coro Trasito (Tella-Sin, Huesca); 12. Espluga de la Puyascada (San Juan de Toledo, Huesca); 13. Els Trocs (Bisaurri, Huesca); 14.Forcas II (Graus, Huesca); 15. Cueva del Moro (Olvena, Huesca); 16. Cueva de las Brujas (Juseu, Huesca); 17. Cova Colomera (Sant Esteve de la Sarga, Lleida); 18. Cova del Parco (Alòs de Balaguer, Lleida); 19. Valmayor XI (Mequinenza, Zaragoza); 20. Plano del Pulido (Caspe, Zaragoza); 21. Pontet and Costalena (Maella, Zaragoza) and Botiquería dels Moros (Mazaleón, Teruel); 22. Ábrigo de Ángel 2 (Ladruñan, Teruel); 23. Grotte Gazel (Sallèles-Cabardès, Aude); 24. Pont de Roque-Haute (Portiragnes, Hérault); 25. Roc de Dourgne (Fontanès de Sault, Aude); 26. Balma Margineda (Andorra, La Vella, Andorra); 27. Plansallosa, (Tortellà, Girona); 28. La Draga (Banyoles, Girona); 29. Cova del Toll (Moià, Barcelona); 30. Cova del Frare (Matadepera, Barcelona); 31. Guixeres de Vilobí (Sant Martí Sarroca, Barcelona); 32. Can Sadurní (Begues, Barcelona); 33. Sant Pau del Camp (Barcelona, Barcelona); 34. El Cavet (Cambrils, Tarragona); 35. Cova del Vidre (Roquetes, Tarragona); 36. El Costamar (Cabanes, Castellón); 37. Cova de la Sarsa (Bocairent, Valencia); 38. Cova de l'Or (Beniarrés, Alicante); 39. El Barranquet (Oliva, Valencia); 40. Mas d'Is (Penàguila, Alicante); 41. Cova de les Cendres (Moraira, Alicante). B) Cave's mouth and its surroundings. C) Location of the site in relation to the Mediterranean Basin.

Figure 2. Cave plan (modified from Utrilla and Baldellou, 2001–2002): red square indicates excavated Neolithic habitation area with hearths and silos; the red circle indicates the Neolithic burial area. Images of the most important materials of the site: A. Reconstruction of pottery vessel decorated with cardium; B. Painted pebble; C. Quern.

Table 1. Radiocarbon dates after Baldellou et al., 2012. B(dom) (Bone domestic animal), B(hum) (Human bone), Ch (Charcoal), A (Acorn).

Figure 3. Acorns (*Quercus* spp.) with conservated pericarpe.

Figure 4. Anthracological diagram from Cueva de Chaves.

Table 2. Anthracological results.

Table 3. Carpological results. Number remains correspond to cotyledon or cotyledon fragment of acorns (*Quercus* spp.). Concent. (Concentration of plant macrorremains), Individual (Individual find), Sum (Sum of individual finds).

Figure 5. Pollen diagram redrawing after López-García, 1992 and López-García and López-Sáez, 2000.

Figure 6. Frequency of the identified taxa in Hearth 86A (1) and male burial (2).

Figure 7. Archaeozoological results after Castaños, 2004. Values expressed in NMI.

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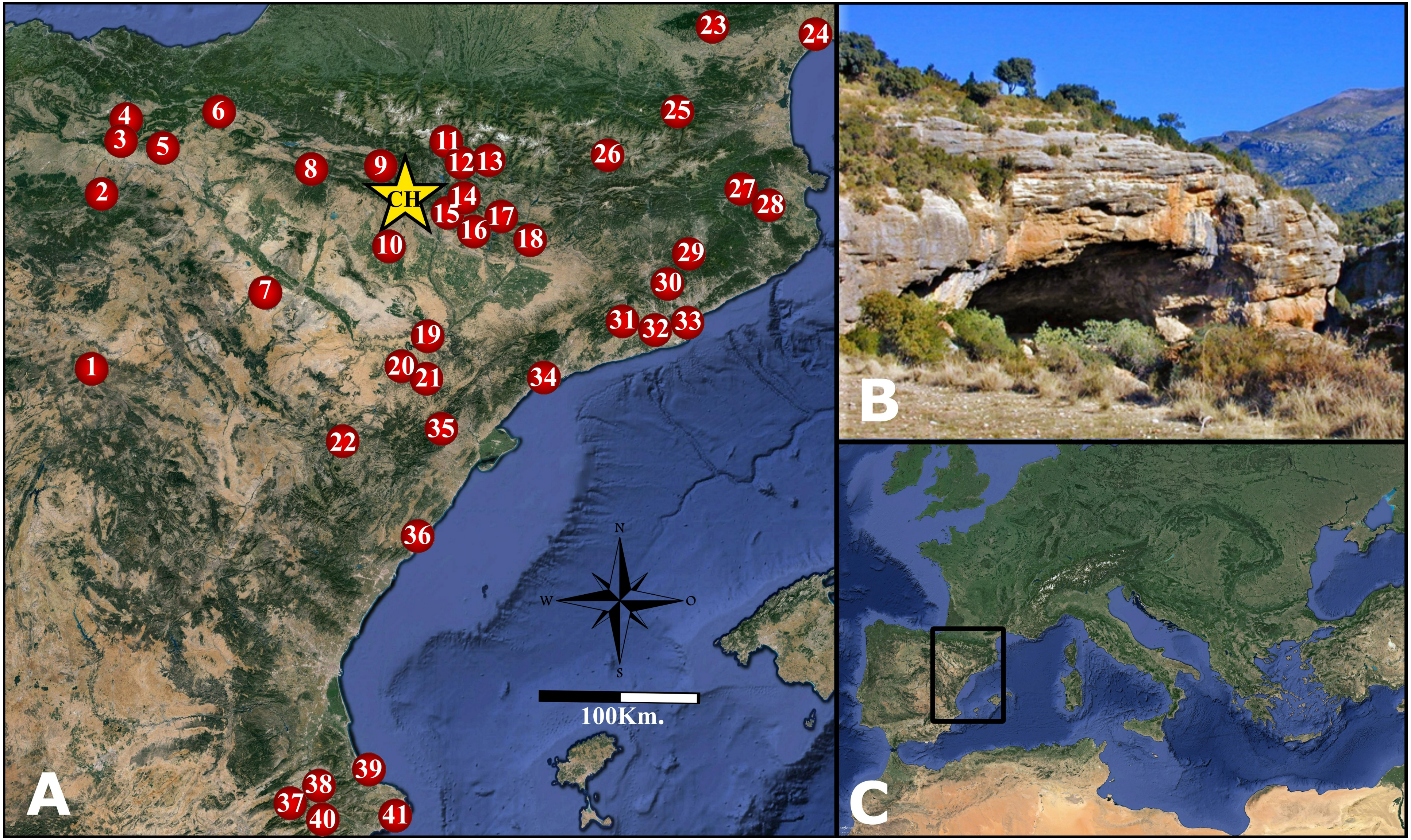

A
B
C
CH
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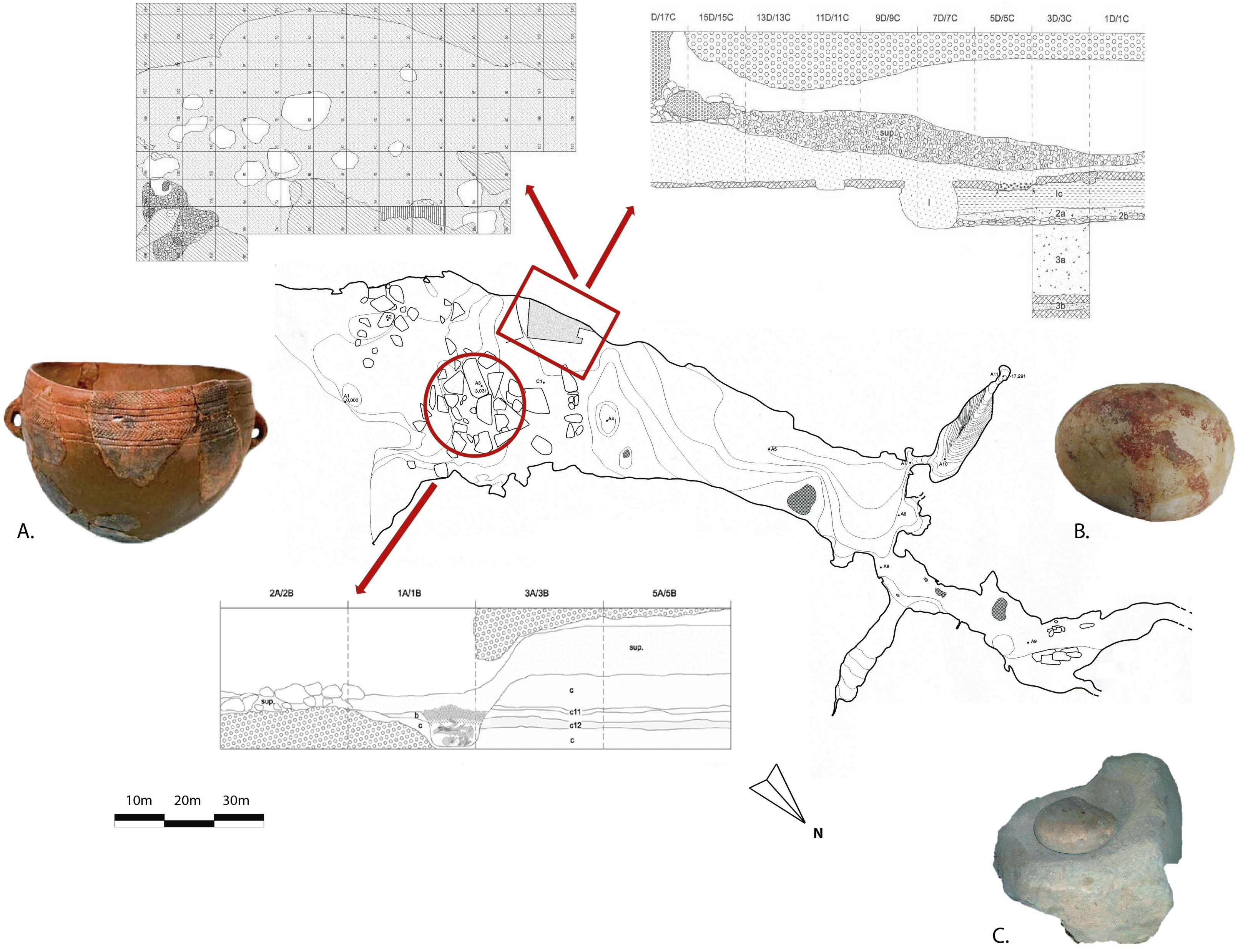
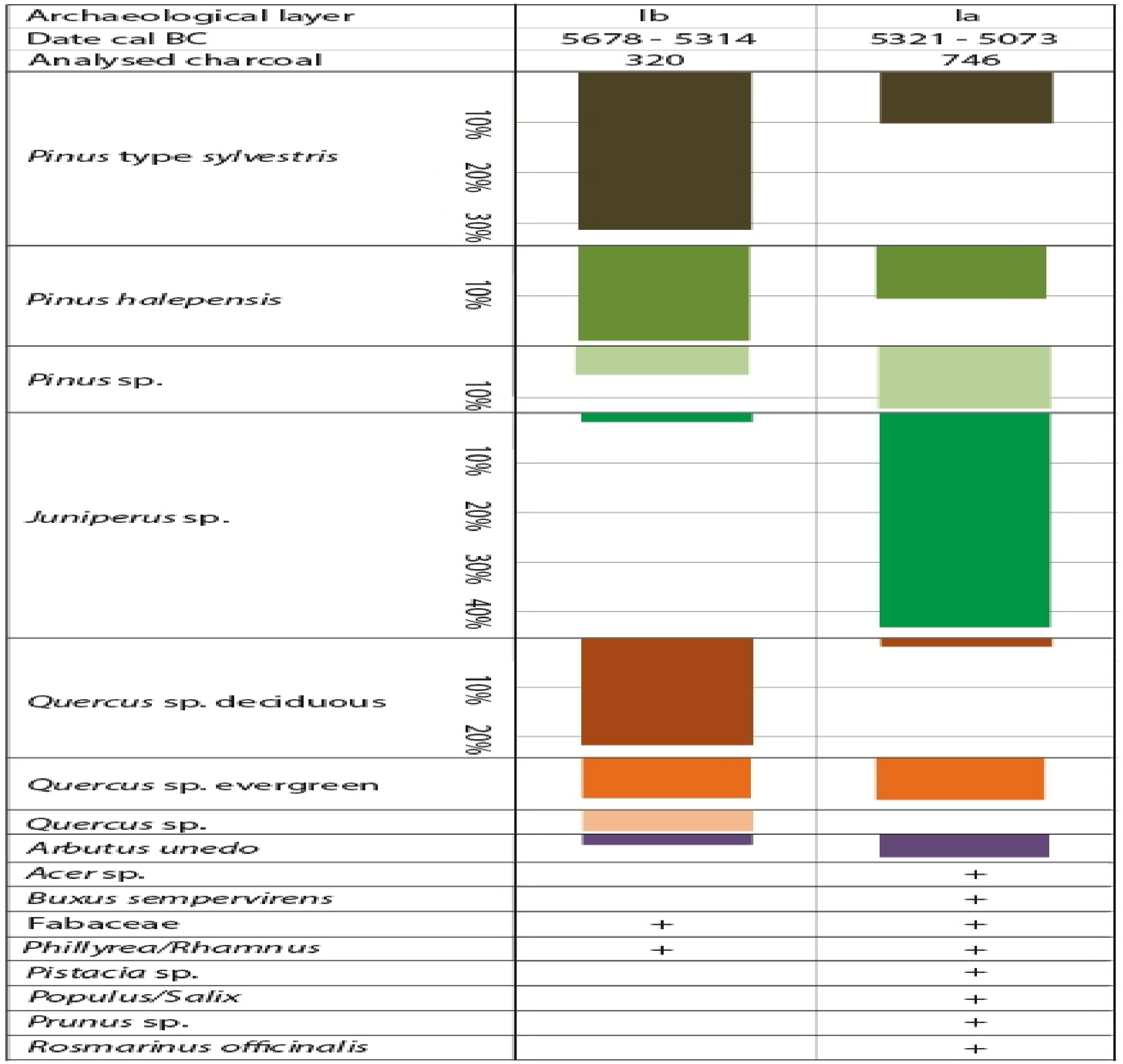
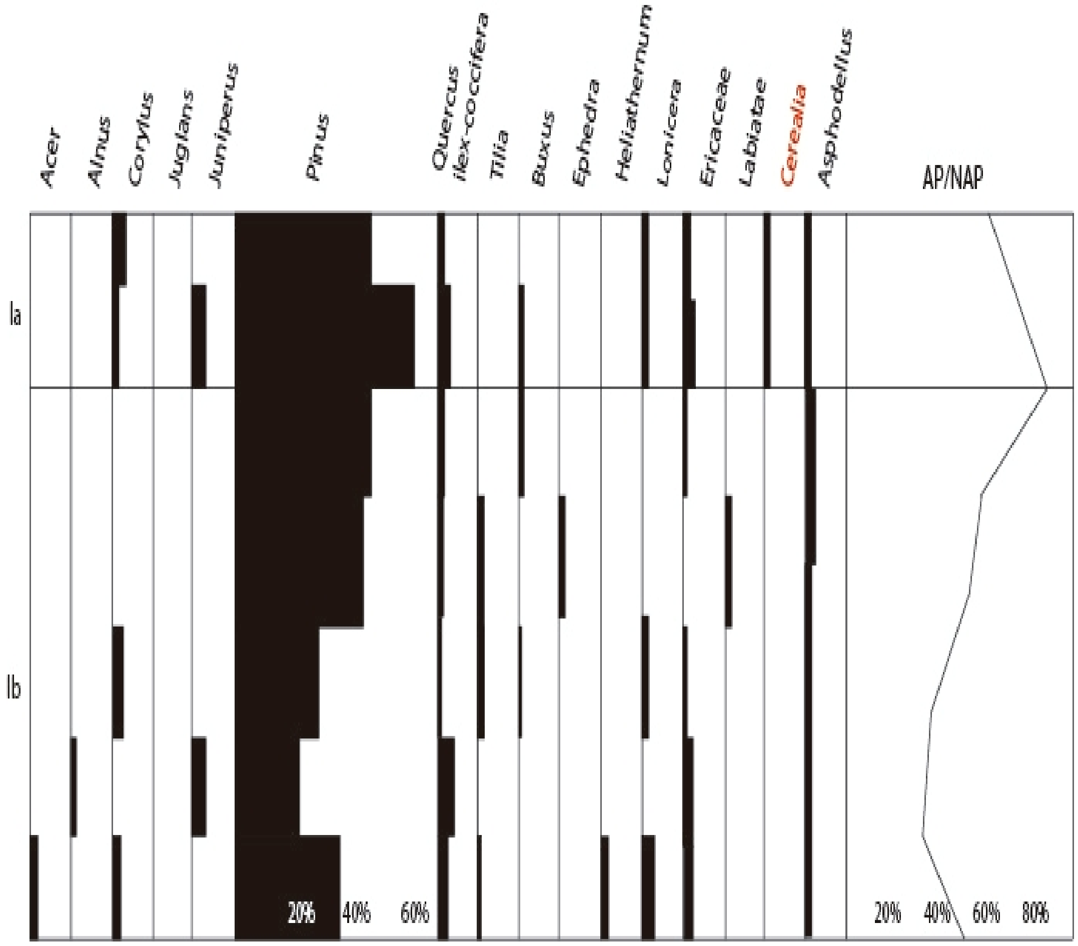

D/17C
15D/15C
13D/13C
11D/11C
9D/9C
7D/7C
5D/5C
3D/3C
1D/1C
sup
Ic
2a
2b
3a
3b
A.
B.
2A/2B
1A/1B
3A/3B
5A/5B
sup.
c
c11
c12
b
C.
10m
20m
30m
N

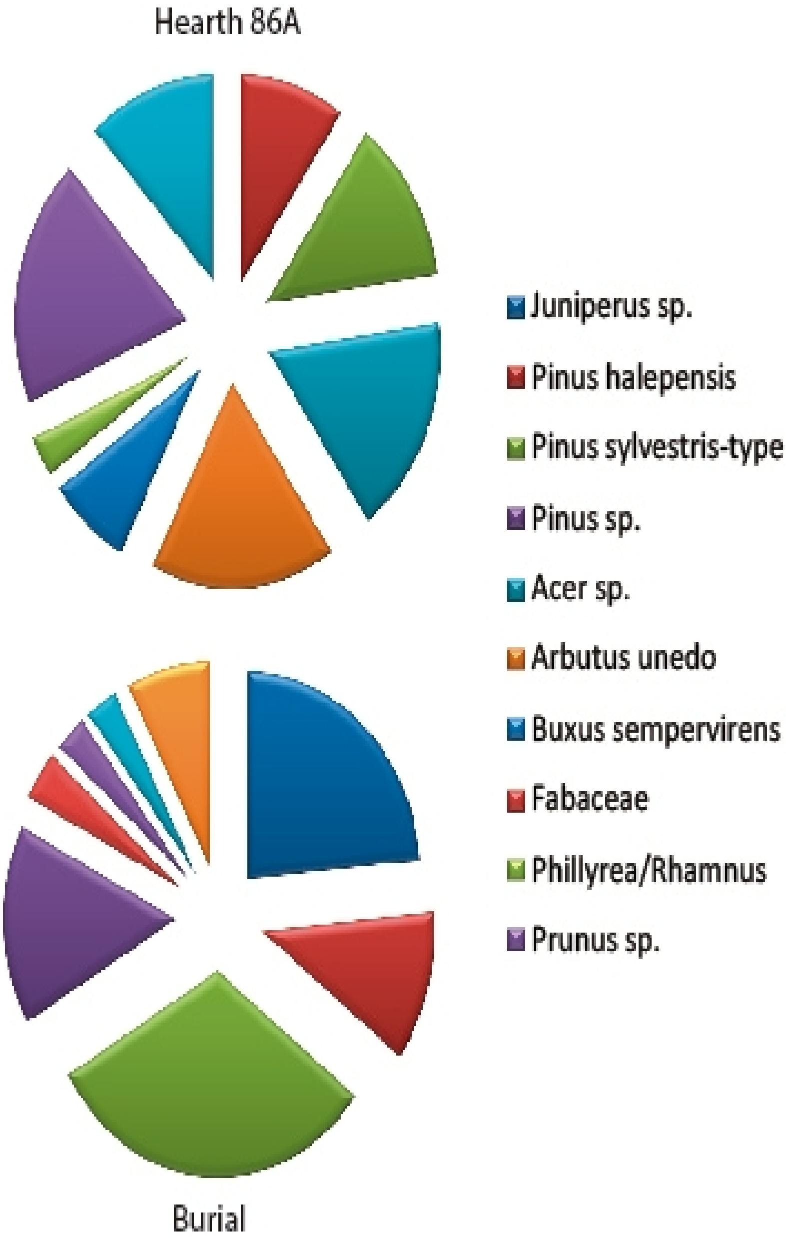

1 cm

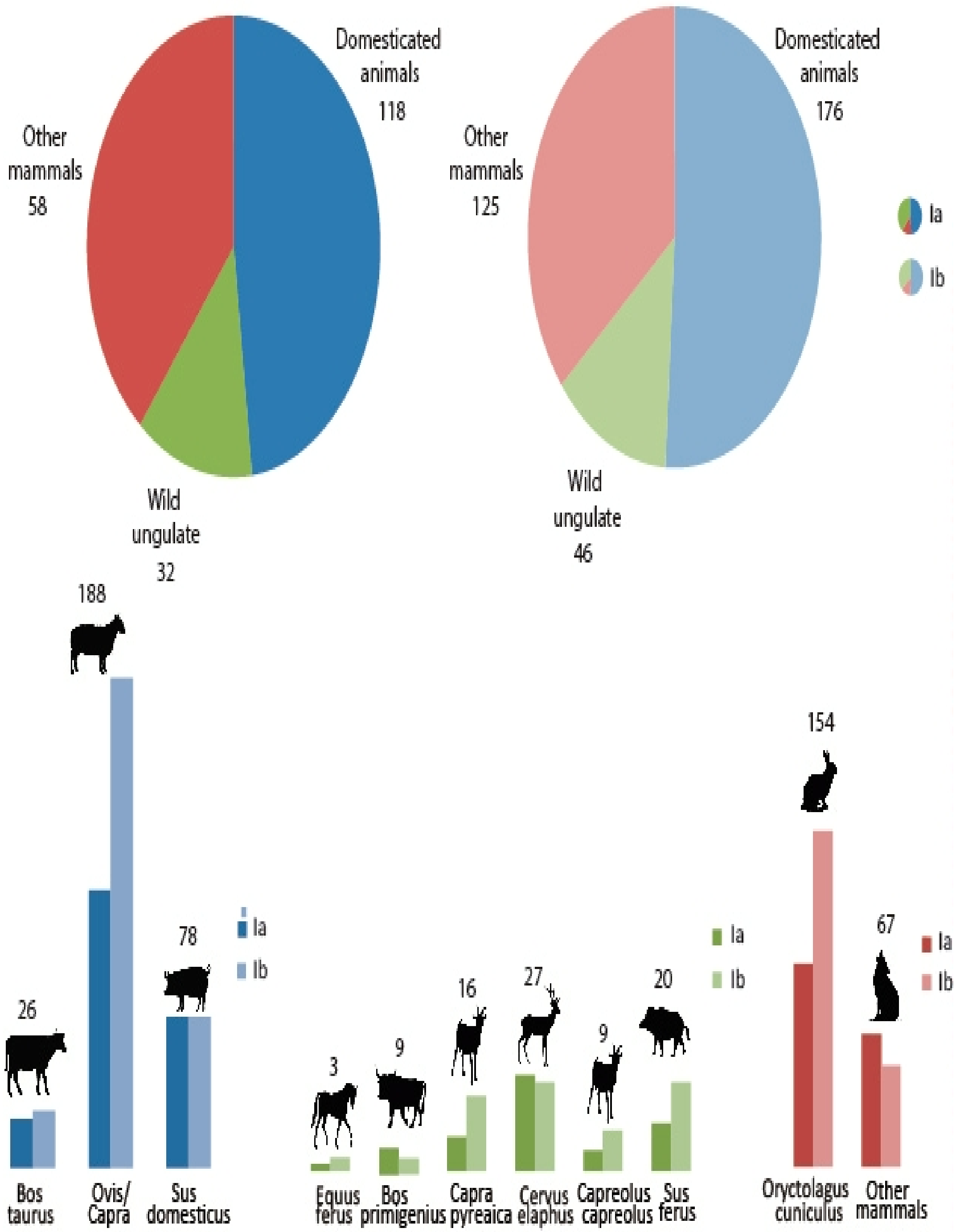


Archaeological layer
Date cal BC
Analysed charcoal
Ib
5678 - 5314
320
Ia
5321 - 5073
746
Pinus type sylvestris
Pinus halepensis
Pinus sp.
Juniperus sp.
Quercus sp. deciduous
Quercus sp. evergreen
Quercus sp.
Arbutus unedo
Acer sp.
Buxus sempervirens
Fabaceae
Phillyrea/Rhamnus
Pistacia sp.
Populus/Salix
Prunus sp.
Rosmarinus officinalis
10%
20%
30%
40%



Acer
Alnus
Corylus
Juglans
Juniperus
Pinus
Quercus ilex-coccifera
Tilia
Buxus
Ephedra
Heliathernum
Lonicera
Ericaceae
Labiatae
Cerealia
Asphodellus
AP/NAP
Ia
Ib
20%
40%
60%
20%
40%
60%
80%


Hearth 86A
Juniperus sp.
Pinus halepensis
Pinus sylvestris-type
Pinus sp.
Acer sp.
Arbutus unedo
Buxus sempervirens
Fabaceae
Phillyrea/Rhamnus
Prunus sp.
Burial



Domesticated animals 118
Other mammals 58
Wild ungulate 32
Domesticated animals 176
Other mammals 125
Wild ungulate 46
Ia
Ib
188
26
78
Bos taurus
Ovis/ Capra
Sus domesticus
3
9
16
27
9
20
Equus ferus
Bos primigenius
Capra pyreaica
Cervus elaphus
Capreolus capreolus
Sus ferus
154
67
Oryctolagus cuniculus
Other mammals

Archaeological level	Reference	Date BP	Date BC	Date cal BP	Date cal BC	Type of sample
Ia	CSIC-381	6120±70	4170±70	7023±107	5073±107	Ch
Ia	GrA-26912	6230±45	4280±45	7141±86	5191±86	B(hum)
Ia	CSIC-379	6230±70	4280±70	7134±97	5184±97	Ch
Ia	GrN-13603	6260±100	4310±100	7160±113	5207±113	Ch
Ia	GrN-13605	6330±70	4380±70	7270±80	5321±80	Ch
Ib	GrN-13602	6330±90	4380±90	7260±101	5314±101	Ch
Ib	GrA-34256	6335±40	4385±40	7260±40	5310±40	Ch
Ib	GrA-28341	6380±40	4430±40	7336±55	5386±55	B
Ib	GrA-34257	6410±40	4460±40	7350±50	5401±50	Ch
Ib	CSIC-378	6460±70	4510±70	7373±58	5423±58	Ch
Ib	UCIAMS-66317	6470±25	4520±25	7385±40	5435±40	B(dom)
Ib	GrN-13604	6490±40	4540±40	7400±45	5443±45	Ch
Ib	GrA-34258	6530±40	4580±40	7455±25	5505±25	Ch
Ib	GrA-38022	6580±35	4630±35	7484±31	5534±31	B(dom)
Ib	GrN-12683	6650±80	4700±80	7530±60	5581±60	Ch
Ib	GrN-12685	6770±70	4820±70	7630±50	5678±50	Ch

Archaeological assemblage	**Level Ib**		**Level Ia**		**Hearth 86A**		**Burial**	
Sample type	**Scattered charcoal**		**Scattered charcol**		**Concentration**		**Concentration**	
Radiocarbon date cal BC	**5678±50 5314±101**		**5321±80 5073±107**		**5386±55**		**5191±86**	
Taxa	**Nº**	**%**	**Nº**	**%**	**Nº**	**%**	**Nº**	**%**
Juniperus sp.	6	1.9	330	45.2			54	23.7
Pinus halepensis	61	19.2	79	10.8	7	9.2	28	12.3
Pinus sylvestris-type	106	33.3	80	10.9	9	11.8	72	31.6
Pinus sp.	17	5.3	86	11.8			36	15.8
Total Gymnospermae		**59.7**		**78.8**		**21.1**		**83.3**
Acer sp.			4	0.5	12	15.8		
Arbutus unedo	6	1.9	30	4.1	12	15.8		
Buxus sempervirens			9	1.2	5	6.6		
Fabaceae	4	1.3	4	0.5			8	3.5
Phillyrea/Rhamnus	4	1.3	5	0.7	2	2.6		
Pistacia sp.			3	0.4				
Populus/Salix			4	0.5				
Prunus sp.			10	1.4	14	18.4	6	2.6
Quercus sp. deciduous	74	23.3	14	1.9	8	10.5	6	2.6
Quercus sp. evergreen	28	8.8	68	9.3			18	7.9
Quercus sp.	12	3.8						
Rosmarinus officinalis			3	0.4	7	9.2		
Total Angiospermae		**40.3**		**21.2**		**78.9**		**16.7**
Total determinable	**318**		**730**		**76**		**228**	
Indeterminable	2		16				27	
Total charcoal	**320**		**746**		**76**		**255**	

Provenance	Sample number	Sample type	Grid square	Number remains	Reference
Hearth 86A	17	Concent.	5D	37	Present study
Hearth 86A	184-201	Concent.		42	Zapata et al., 2008
Level Ia	15	Sum	1C/1D 3C/3D	2	Present study
Level Ia	18	Individual	13A’	1	Zapata et al., 2008
Level Ia	35	Individual	1C/1D 3C/3D	1	Present study
Level Ia	39	Individual	14C’	1	Present study
Level Ia	42	Sum	8B’	2	Present study
Level Ia	57	Individual	10C	1	Zapata et al., 2008
Level Ia	58	Sum	12A’	5	Present study
Level Ia	69	Sum	12A’	2	Present study
Level Ia	95	Individual	13E/13 F/13G	1	Zapata et al., 2008
Level Ia	177	Sum	9E/9F	2	Zapata et al., 2008
Level Ia	386	Sum	10C	2	Zapata et al., 2008
Level Ia	388	Sum	15	2	Zapata et al., 2008
Level Ia	538	Sum	8D	5	Zapata et al., 2008
Level Ia		Individual	85B	1	Zapata et al., 2008
Level Ia		Sum		2	Zapata et al., 2008
Level Ib	4	Individual	12A	1	Present study
Level Ib	38	Sum	15A	2	Present study
Level Ib	41	Sum	10C’	4	Present study
Level Ib	45	Individual	10[a]	1	Present study
Level Ib	46	Individual	17A	1	Present study
Level Ib	48	Sum	10C’	2	Present study
Level Ib	49	Sum	17A	2	Present study
Level Ib	50	Sum	10C’	2	Present study
Level Ib	51	Sum	17D	4	Present study
Level Ib	52	Individual	15D/ 15E	1	Present study
Level Ib	54	Individual	10B’	1	Present study
Level Ib	59	Sum	12B	2	Present study
Level Ib	60	Sum	13A/ 13B	5	Present study
Level Ib	61	Sum	13B’	2	Present study
Level Ib	65	Sum	8C’	2	Present study
Level Ib	70	Individual	12A’	1	Present study
Level Ib	388	Sum	15	2	Zapata et al., 2008
Level Ib	810	Individual	13/15	1	Zapata et al., 2008
Level Ib		Sum	85B	2	Zapata et al., 2008
Level Ib		Individual	15B	1	Zapata et al., 2008