LATE PLEISTOCENE ENVIRONMENTAL DYNAMICS AND HUMAN OCCUPATION IN SOUTHWESTERN EUROPE

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Abstract: This paper focuses on palaeoenvironmental conditions and climate variability during the Upper Late Pleistocene (c. 28,000-11,700 cal BP) in SW Europe (Iberian Peninsula) and their influence on human settlement patterns. All the palaeoenvironmental and archaeological sequences available for this period are analysed, together with a new palaeoenvironmental study related to a key deposit: Verdeospesoa mire (northern Iberian Peninsula). The multiproxy analysis (pollen, spores, non-pollen palynomorphs, magnetic susceptibility, organic content and macrocharcoal) of this sequence, with the support of six Accelerator Mass Spectrometry (AMS) radiocarbon dates, shows the climatic variability of that period, with some dry/cold and humid/temperate episodes. While in vast regions of central and northern Europe very few archaeological sites of this age are known, in the Iberian Peninsula no occupations gaps have been detected in all this period, supporting the idea of SW Europe as a glacial refugium for human groups during the worst periods of the Upper Late Pleistocene.

Key words: Palaeoenvironment; Climate variability; Human occupation; Upper Late Pleistocene; Southwestern Europe; Glacial refugia.

1. Introduction

The humans-climate relationship is an issue of interest for palaeoenvironmental and archaeological studies (Banks et al., 2008; Gamble et al., 2004; Straus, 2012, 2015), taking into account that climate is a key factor for understanding the subsistence strategies, settlement patterns, and mobility of past societies (Desbrosse and Koslowski, 1988; Büntgen et al., 2011; Schmidt et al., 2012; Barton et al., 2013; Posth et al., 2016). In this sense, the causal relationship between climate fluctuation and human adaptations (in a wide sense) has long been debated (Ruff, 1994, Blockley et al., 2000). However, the link between abrupt climate changes and human mobility has only emerged in the last decade (Blockley et al., 2006). The study of this connexion is of particular interest during the Pleistocene, when glacial-interglacial succession could have influenced humans' adaptive strategies.

In the context of SW Europe, climate-human mobility links have been explored for the Holocene, relating some abrupt climate changes and cultural dynamics: e.g. the 8200 cal BP cold event and the spread of agriculture in the Mesolithic-Neolithic transition (Berger and Guilaine, 2009; González-Sampériz et al., 2009; Cortés et al., 2012), and the 4200 cal BP event and the Chalcolithic-Bronze Age transition (Fabián-García et al., 2006; Magny et al., 2009; Lillios et al., 2016). However, the relationship between climate variability and human mobility during the Upper Palaeolithic has not been explored in detail until the last decade (Gamble et al., 2004; Finlayson et al., 2006; Carrión et al., 2008; Schmidt et al., 2012; Maier et al., 2016).

The reconstruction of Pleistocene climate fluctuations from southern European terrestrial records is, however, a difficult task. The reasons are varied. On the one hand, the scarcity of available records, their resolution, difficulty in comparing reconstructions based on different proxies, and the problems of correlating their changes with Greenland ice cores, are some examples. On the other hand, the different sensitivity of each deposit to archive the signals of different climatic conditions should also be taken into account (Moreno et al., 2014).

The final stage of the Late Pleistocene (Upper Late Pleistocene, ULP) in SW Europe is a palaeoenvironmentally interesting period. At a pan-European scale, palynological, isotope and speleothems recording the end of the last glacial cycle indicate an unstable climate with large temperature and precipitation fluctuations, leading to the alternation of cold and dry episodes with other more humid and temperate phases (Dansgaard et al., 1993; Cronin, 1999; Andersen et al., 2006; Carrión et al., 2010). However, these continental-scale fluctuations are not registered in all regions of Europe, and differences in both intensity and timing make local reconstructions a challenge (Moreno et al., 2012).

The ULP is also interesting regarding human occupation dynamics. The European archaeological record reveals a relatively low number of archaeological sites and remarkable geographical gaps (Street and Terverger, 1999; Terverger and Street, 2002; Gamble et al., 2005; Blockley et al., 2006; Banks et al., 2008). The data suggest certain abandonment of central and northern European territories during the coldest phases, mainly during the Last Glacial Maximum (LGM, c. 23,000-18,000 cal BP), and the concentration of archaeological sites in southern territories (Gamble et al., 2004; Bocquel-Appel et al., 2005; Straus, 2015). These data led to the hypothesis that SW Europe was a "refugium" area for humans during the worse climate periods

(Straus et al., 2002; Maier et al., 2016; Straus, 2016), likely influencing the ancient hunter-gatherer adaptive models to environmental conditions and the development of different techno-cultures in Europe such as the Gravettian, Solutrean and Magdalenian (Straus, 2010; Fu et al., 2016).

The available palaeo-proxy and archaeological data from c. 28,000 to 11,700 cal BP in the Iberian Peninsula are brought together here in order to shed light on the discussion about the link between climate fluctuation and human mobility during the ULP. To support the discussion, new proxy data, including pollen, non-pollen palynomorphs, magnetic susceptibility, loss-on-ignition and macrocharcoal, from the Verdeospesoa mire (Northern Iberian Peninsula) will be presented. This new record is key for three reasons: i) its biogeographical position between the Atlantic and Mediterranean regions of the Iberian Peninsula, acting as a crossroad between low latitudes in SW Europe and the Mediterranean region, hence being a refuge of biological resources in glacial times (Straus, 2015); ii) while palaeoenvironmental records from marine cores are abundant in the Atlantic margin and Bay of Biscay (Sánchez-Goñi et al., 2002; Naughton et al., 2007; Salgueiro et al., 2010; da Silva-Oliveira, 2012; Martínez-García et al., 2014), this new record is one of the few high-resolution continental records for the Iberian Peninsula, covering the c. 27,300-11,700 cal BP period; and iii) most Late Pleistocene proxy data in the Iberian Peninsula come from archaeological sites, offering information about the period of human occupation only, and not continuous pictures.

2. Study area and study site

The Iberian Peninsula is very sensitive to climate change, because it is one of the Mediterranean regions with the highest level of environmental heterogeneity and biological diversity, endowing it with one of the world's richest flora and biodiversity (Rivas-Martínez, 1987; Médail and Quézel, 1997; Castroviejo, 2002; Sainz-Ollero and Moreno, 2002; Costa-Tenorio et al., 2005; Myers et al., 2000). This environmental heterogeneity was also clearly defined in the past, as deduced from both palaeoenvironmental (Carrión et al., 2010) and genetic studies (Hewitt, 2000; 2003; Tzedakis et al., 2013), suggesting the existence of biological glacial refugia in the Quaternary favouring the survival of a number of temperate flora (González-Sampériz et al., 2010).

Verdeospesoa mire (43º 03´ 18´´ N/2º 51´ 41´´ W, 1015 m) is located in the Basque Country (Cantabrian region, Northern Iberia), on the western slopes of Gorbea mountain. It forms part of the Basque Mountains, a mountain range parallel to the coastline which limits the progressive arrival of Atlantic influences, favouring a complex and rich floristic diversity (Aseginolaza et al., 1996). It belongs to the municipality of Orozko (Gorbeia Natural Park), and occupies a small flat area of approximately 516 m^2, on a geological substratum consisting of Lower Cretaceous microconglomerate sandstones (Fig. 1A, 1B). The nearest meteorological station describes humid and cool conditions, with mean annual precipitation of 1350 mm on 196 rainy days, without a summer drought, and a mean annual temperature of 12ºC (Euskalmet, 2011).

The intensive pastoral exploitation of this place during the last decades determines the current vegetation of the surrounding areas (Fig. 1C). The local vegetation of the mire is formed by hygrophilous plants, typical of peatlands, like *Drosera rotundifolia* L, *Narthecium ossifragum* L. (Huds), *Ranunculus flammula* L. and *tetralix* L. In the vicinity, shrublands are the dominant plant communities, called Atlantic heaths, including *Calluna vulgaris* (L.) Hull., *Erica vagans* L., *E.*

arborea L., etc. The most common herbaceous communities are pasturelands formed by *Agrostis curtisii* Kerguélen, *Festuca rubra* L., *Danthonia decumbens* (L.) DC., *Gallium saxatile* L., etc. The main forests in the area are acidophilous. Acidophilous beech forests consist of beech (*Fagus sylvatica* L.) with *Ilex aquifolium* L. and *Vaccinium myrtillus* L. Some acidophilous forests of *Quercus robur* L. are also located in the slopes of Gorbea Mountain, with *Fraxinus excelsior* L., *Corylus avellana* L., *Castanea sativa* Mill., *Acer campestre* L., *Tilia platyphyllos* Scop. and *Ulmus glabra* Huds. (Aseguinolaza et al., 1996).

3. Material and methods

3.1. Compiling archaeological records

Gravettian, Solutrean and Magdalenian Iberian archaeological sites with human occupations have been compiled. Following Aura et al. (2012), radiocarbon dates from rock art, dates with a standard deviation larger than 350 years, dates contradicting their stratigraphic position, and dates from poorly-defined archaeological levels have been rejected. When three or more radiocarbon dates were available for the same archaeological level, only the oldest and the youngest have been selected, in order to situate the human occupations of every archaeological level. A total of 417 radiocarbon dates from 108 archaeological sites are considered (Fig. 1E, Supplementary appendix).

In order to infer demographic patterns, we use the summed probability distribution (SPD) curves of the valid radiocarbon dates, the most widely-accepted tool as a proxy record of prehistoric occupation so far (Gamble et al., 2005; Shennan and Edimborough, 2007; Buchanan et al., 2008; Williams, 2012; Crema et al., 2016). The analysis has been performed with the Oxcal software (version 4.2), and calibrated to the 2 sigma range (95.4% probability) with the INTCAL13 calibration curve (Reimer et al., 2013). This software additionally uses Bayesian statistics to model the dates.

3.2. Compiling proxy records

High-resolution proxy records from Iberian lakes, peatlands, speleothems, caves and marine cores with at least one quantitative climate variable (temperature, precipitation, vegetation or lake level) and with high chronological resolution and available age-depth models have been compiled. The proxy data have been compared with the NGRIP δ^{18} curve, which is the basis of the Late Glacial stratotype (Björck et al., 1998) (Fig. 1D, Fig. 2).

3.3. Verdeospesoa record

A 243 cm long core was retrieved from the Verdeospesoa mire using a Russian peat sampler (GYK type, 50 cm length; 5 cm in diameter). The lower portion of the core (180-235 cm depth), comprising Pleistocene chronologies, is the interval considered in this work. Samples were taken every 1-2 cm. The chronology is based on six Accelerator Mass Spectrometry (AMS) radiocarbon dates on plant remains and bulk material (Table 1). The dates were calibrated using CALIB 7.1 with the IntCal13 curve (Reimer et al., 2013). An age-depth model was performed by fitting a smooth spline curve (Type=4; smooth=0.1) using CLAM 2.2 (Blaauw, 2010) (Fig. 3).

Magnetic susceptibility (MS onwards) measurements were taken every 0.5 cm using a Bartington MS2E high-resolution surface scanning sensor connected to an MS3 meter (Dearing and Jones, 2003). An air measurement (zero-reading) was carried out before and after each sample reading to correct for drift using the Multisus software. Samples were also analysed for loss-on-ignition (LOI). They were dried for 24 h at 105 ºC, subsequently transferred to porcelain crucibles, and then ignited at 550 ºC for 4 h. The weight loss was measured after each stage in order to quantify the organic matter (OM) content (Heiri et al. 2001). LOI is expressed as a percentage of weight loss in dried sediment.

Palynological samples were treated chemically (HCl, KOH, HF) following Moore et al. (1991), together with a density separation using Thoulet solution (Goeury and de Beaulieu, 1979). Pollen grains were identified with the help of different keys and pollen atlases, such as Faegri and Iversen (1989), Moore et al. (1991) and Reille (1992), and the reference collection in the CSIC Archaeobiology Laboratory (Madrid). Non-pollen palynomorphs were identified according to van Geel (1978, 2001, 2006) and van Geel et al (1981, 1989, 2003). Pollen counts of up to 500 grains of total land pollen per sample were identified and counted. Pollen of aquatic or wetland plants as well as spores and non-pollen palynomorphs (NPP) were excluded from the pollen sum. The pollen and summary diagrams (Figs. 4 and 6) have been plotted against age using TGview (Grimm, 2004). Four local pollen assemblage zones (LPAZ 1, 2, 3 and 4) were separated on the basis of agglomerative constrained cluster analysis of incremental sum of squares (Coniss) after the square-root transformation of percentage data (Grimm, 1987).

Ordination by principal components analysis (PCA) was performed on the fossil dataset using the C2 1.5 software (Juggins, 2007), since an initial detrended correspondence analysis (DCA) pointed to a linear response of species data to environmental gradients (ter Braak and Prentice, 1988). Samples were square-root transformed for a better comparability. Analyses were processed with all pollen and non-pollen palynomorph taxa with values larger than 2%. According to the zonation obtained by Coniss, samples were classified into groups and expressed using different symbols (Fig. 5). In the PCA scatter plot, taxa are shown as distance biplot arrows, and the direction of the arrow indicates the direction in which the values of the corresponding taxa increase.

Macrocharcoal samples were sub-sampled (1 cm^3) along the entire core following standard procedures (Whitlock and Larsen, 2001). The samples were soaked in a 10 % NaOH solution for 24 h to disaggregate organic silts, then in a 6 % H_2O_2 solution (24 h) to bleach the remaining non-charcoal organic material and thus make charcoal identification easier (Rhodes, 1998). Charred particles were isolated using wet sieving with a 150 µm mesh (Clark, 1988; Ohlson and Tryterud, 2000; Carcaillet et al., 2001). Charcoal concentration was expressed as Charcoal Accumulation Rate (CHAR; particles cm^{-2} $year^{-1}$) based on the sediment accumulation rate (year cm-1) (Fig. 6).

4. Results and discussion

4.1. Late Pleistocene environmental changes in SW Europe: local or supra-regional signatures?

4.1.1. Dry and cold climate conditions (c. 27,300-23,750 cal BP) during Greenland Stadial 3 (GS-3)

The lower part of the Verdeospesoa record (bottom of LPAZ 1) shows a landscape characterized by the major presence of open areas (Fig. 4). The main herbaceous communities comprise grasslands (Poaceae, Fabaceae, Cardueae, *Aster*, Apiaceae) and xerophytic taxa (*Juniperus*, *Artemisia*, Caryophyllaceae, Chenopodiaceae, *Centaurea*). Trees are mainly pines, with maximum values of 21.6%. However, these conifers would not be the dominant forests in the vicinity of the peat bog, since studies of current pollen rain indicate that only values over 60% indicate the presence of local pine forests (López-Sáez et al., 2013). In this case, these woodlands would probably form a band of vegetation located above the deciduous forest. The local forest was mainly formed by mesophilous trees, such as deciduous *Quercus*. However, their values (< 20%) suggest an open forest of oak trees, with other deciduous trees such as hazel, birch, alder and ash. At this time, the reduced local forests allowed intense erosive processes, reflected in the MS curve (Fig. 6) with two main peaks at c. 26,600 cal BP and 24,740 cal BP. The PCA analysis shows for this part of the sequence negative values in PCA-1 and PCA-2, suggesting dry and cold climatic conditions. The PCA-3 analysis shows greater variability, in relation with the forest cover (Fig. 6).

This dry and cold phase coincides with the proposed Greenland Stadial-3 (Rasmussen et al., 2014), dated in NGRIP core to between c. 27,500 and 23,300 cal BP. All northern Iberian palaeoenvironmental records display the same trends as in Verdeospesoa, as in the study of speleothems at El Pindal (Moreno et al., 2010a), the sedimentological record in Lake Enol (Moreno et al., 2010b) and the micro-vertebrates in the caves of Askondo (García-Ibaibarriaga et al., 2015) and Santimamiñe (Rofes et al., 2014), which indicate lower temperatures and lower water availability. The dominance of xerophytic taxa is also recorded on the southern slopes of the Pyrenees, at the palaeo-lake of El Portalet and in Banyoles Lake (NE Iberia), where pine forests locally reach higher values (approx. 40%) than in the Cantabrian region (González-Sampériz et al., 2006, Pérez-Obiol and Julià, 1994). In the NW of the Iberian Peninsula, the analysis of marine sequences indicates that the Greenland Stadial-3 phase was characterized by cold Sea Surface Temperatures (SST) and high values of steppic pollen (Naughton et al., 2007), confirming the same trend as in northern Iberia. In the northern and southern plateaux of central Iberia, the palynological records from Fuentillejo and Villarquemado (Vegas et al., 2010; González-Sampériz et al., 2013), and the palaeoclimatic reconstruction based on calcite $\delta^{18}O$ from Eagle Cave in central Iberia (Domínguez-Villar et al., 2013) also attest cold and dry conditions at this time, which seems to be the general trend throughout south-west Europe.

4.1.2. Warmer and wetter climate conditions (c. 23,750-21,800 cal BP) during Greenland Interstadial 2 (GI-2)

The multiproxy study of Verdeospesoa mire reflects significant palaeoenvironmental changes in a short episode c. 23,750-21,800 cal BP (middle part of LPAZ 1), which seems to be related to Greenland Interstadial 2 (Rasmussen et al., 2014). This phase is dated in NGRIP core between c. 23,300-22,900 cal BP. However, in northern Iberia its duration appears to have been longer, since these relatively more humid conditions seem to last until c. 21,800 cal BP.

At this time, the climate seems to be warmer and humid in Verdeospesoa mire. There is a significant increase in arboreal pollen (reaching 60%), with the dominance of mesophilous trees such as deciduous *Quercus* and pioneers like hazel. The only occurrence of hornbeam in c. 23,745-23,580 cal BP and the first presence of beech (Fig. 4) is detected in this period. This more forested landscape is the reason for the lesser intensity of erosive processes at the local scale (Fig. 6), probably motivated by more humid conditions, as shown by the increase in hygrophytic taxa and ferns, positive values of PCA-1 (wetter environment) and PCA-3 (forested environment) (Fig. 5). In spite of being a more humid and temperate phase, the presence of xerophytic taxa is reflected in the diagram, reaching maximum values of 10% (Figs. 4 and 6), which is however less intense than in the previous GS-3 phase.

This short episode is not well recorded in many regions of the Iberian Peninsula, mainly because of its relatively short duration, so it is hard to detect in non high-resolution multiproxy analysis. Only the speleothems in El Pindal (Moreno et al., 2010a), the palaeoenvironmental reconstructions based on microvertebrates from Askondo and Santimamiñe (Rofes et al., 2014; García-Ibaibarriaga et al., 2015) and the Fuentillejo maar lacustrine record (Vegas et al., 2010) show this slight climatic amelioration.

4.1.3. Drier and cold climate conditions (c. 21,800-16,800 cal BP) in Greenland Stadial 2 (GS-2)

A new drier and cold phase is detected in the Verdeospesoa record in c. 21,800-16,800 cal BP (top of LPAZ 1). This phase seems to roughly correspond to Greenland Stadial 2 (Rasmussen et al., 2014) dated in NGRIP core to c. 22,900-14,700 cal BP, including the LGM (23,000-18,000 cal BP) as well as the Mystery Interval (18,000-14,500 cal BP) documented in numerous regional sequences (González-Sampériz et al., 2017). In northern Iberia, the Verdeospesoa record indicates that herbs are now again the dominant vegetation, with grasslands and xerophytic taxa the main components. This greater presence of non-forested areas is defined by the negative values documented in PCA-3 (Fig. 6). At this time, deciduous forests of mainly hazel and deciduous *Quercus* show a regressing trend. All this is reflected in the negative values of PCA-1, indicating dry environmental conditions. Very significant in this sense is the increase in microcharcoal c. 21,480-18,000 cal BP, when particles reach a maximum of 175 particles cm^{-2} $year^{-1}$. These values are not extremely high, but they are very significant since they are the highest in the whole sequence. This event is a clear indication of the occurrence of fires in the environment, favoured by the aforementioned more arid climatic conditions.

Those unfavourable climatic conditions are also recorded in a large number of palaeoenvironmental records in the Iberian Peninsula, favoured by their longer chronology and intensity, as at Askondo, Santimamiñe, Kiputx IX, El Mirón and El Pindal caves in northern Iberia (Cuenca-Bescós et al., 2008, 2009; Straus and González-Morales, 2009; Moreno et al., 2010a; Straus et al., 2011; Castaños et al., 2014; Rofes et al., 2014; Stevens et al., 2014; García-Ibaibarriaga et al., 2015). In Lake Enol the climate was still cold, but slight warming with higher water availability and shorter periods of ice coverage has been suggested (Moreno et al., 2010b). On the southern slopes of the Pyrenees, this dry phase related to GS-2 is also documented in Lake Estanya (Morellón et al., 2009) by shallow lake levels and reduced organic productivity, in a landscape dominated by steppic grasses, according to pollen records from Estanya, El Portalet and Banyoles (Pérez-Obiol and Julià, 1994; González-Sampériz et al., 2006, 2017). A similar trend is recorded on the northern Plateau (El Portalón, López-García et al., 2010), in central Iberia (Eagle Cave, Domínguez-Villar et al., 2013), and on the southern plateau (Fuentillejo lacustrine record, Vegas et al., 2010). The marine sequences analysed on the Atlantic seaboard of the Iberian Peninsula and in the Alborán Sea also indicate that the LGM was a cold and relatively dry period, although probably not as dry as Heinrich Event 2 (Rocoux et al., 2001; Naughton et al., 2007; Fletcher and Sánchez-Goñi, 2008; Salgueiro et al. 2010; Naughton et al., 2016).

4.1.4. Humid and cold climate conditions (c. 16,800-11,500 cal BP) during the Greenland Interestadial 1 (GI-1) and the Greenland Stadial 1 (GS-1)

LPAZ 2 is characterized by a new and very evident improvement in the climate. Forests rapidly expand, mainly formed by mesophilous trees such as deciduous *Quercus* and hazel. Also noteworthy is the increase in the representation of two species that are very dependent on humidity: beech and linden (Fig. 4). In this phase, c. 16,715-16,690 cal BP, the first presence of walnut is detected. Pines, with a certain regional presence from the beginning of the sequence, now show a downward trend. From this moment, two previously-documented steppic taxa, juniper and *Artemisia*, disappear at the same time as a massive increase in the general values of hydro-hygrophilous taxa, reflecting more humid and possibly temperate conditions. Statistical PCA analyses also reflect this situation, with PCA-1 indicating positive values, affecting higher humidity, while PCA-3, with positive values, indicates a higher index of forest cover. Although other Iberian and European sequences record an initial warm and humid phase (GI-1, Bölling/Allërod) and another dry and cold episode (GS-1, Younger Dryas) previous to the onset of the Holocene (Pèlachs et al., 2012, Rasmussen et al., 2014; González-Sampériz et al., 2017), in Verdeospesoa mire only a clear humid and colder phase, is evident, probably because of a lower sedimentation rate and lower resolution in this part of the stratigraphy.

The increasing humidity during this phase (c. 16,800-11,500 cal BP) is clearly defined by the onset of growth in some speleothems in SW Europe. This is the case of stalagmites in Chauvet, Villars (Genty et al., 2006) and El Pindal caves (Moreno et al., 2010a). In the same way, palaeoclimatic reconstructions at Santimamiñe (Rofes et al., 2014), El Mirón (Stevens et al., 2014) and Lake Enol (Moreno et al., 2010b) show clearly warmer conditions than before, reflecting a supra-regional trend. In the Pyrenean region, this phase is represented by the deglaciation period documented in El Portalet c. 17,800-12,500 cal BP, where it is also possible to see a significant increase in arboreal pollen values (González-Sampériz et al., 2006) and in Lake Banyoles (Pérez-Obiol and Juliá, 1994) and Estanya (Morellón et al., 2009). Also in NW Iberia, the La Roya lake (Muñoz-Sobrino et al., 2013) indicates cold but more humid conditions. In central Iberia, the speleothem record from Eagle Cave shows low $\delta^{18}O$ values, interpreted as wetter periods, with the moisture source potentially contributing in part to the variability of this proxy (Domínguez-Villar 2013).

4.2. Settlement patterns in the Iberian Peninsula during the ULP

Before the period considered here, the Iberian Peninsula was occupied by hunter-gatherers during the Middle Paleolithic (Arsuaga et al., 2012; Ríos et al., 2013, Navazo and Carbonell, 2014) and Early Upper Paleolithic (Zilhão, 2006; Straus, 2010; Altuna et al., 2011). However, the present objective is to define the relationships between climate and human settlement patterns during the ULP, particularly in the time of the Gravettian, Solutrean and Magdalenian technocomplexes.

4.2.1. Gravettian (c. 32,000-23,400 cal BP)

Available records show a degree of asymmetric distribution both in the chronology and in the geographical distribution of Iberian Gravettian sites. Two main settlement concentrations have been identified (northern and Atlantic coasts), with few sites in the Mediterranean area, a significant scarcity in southern and inner Iberia, and an absence of well-dated archaeological sites in the Pyrenean region (Fig. 7).

The Cantabrian region in northern Iberia is the area in which archaeological research has detected the highest concentration of Gravettian archaeological sites and obtained the most radiocarbon dates, with 12 well-dated deposits and 22 radiocarbon dates (Fig. 7). Taking into account the chronology (Supplementary appendix), this region seems to be the area where the Gravettian lasted longer (Calvo and Prieto 2012). The main curve of Gravettian radiocarbon dates for sites with or without Noailles burins, La Gravette points and microgravettes, develops c. 32,000-23,400 cal BP (Fig. 7).

In the Mediterranean region, a total of six Gravettian archaeological sites and 13 radiocarbon dates are documented (Fig. 7). Faced with the traditional hypothesis that indicated the late development of the Gravettian groups, new research points to a chronological development similar to that proposed for the main Gravettian nucleus of northern Iberia (Villaverde and Román, 2004, Vega and Martín, 2006) and earlier than in other regions. In this area, this technocomplex seems to have developed between the oldest well-dated deposit of Finca Doña Martina (c. 31,312-30,795 cal BP; 800 years after the initial Gravettian in the north) and the youngest at Arbreda (c. 24,868-23,658 cal BP; 250 years before the end of the northern Gravettian). In this case, no concentration of archaeological sites is detected, since those six sites are located along the whole Mediterranean coast, from the north (Arbreda) to the south (Finca Doña Martina).

In southern Iberia, only the archaeological sites of Nerja (dated c. 29,400-27,800 cal BP) and Vale Boi (c. 29,300-25,700 cal BP) have been documented, so it is difficult to explore the settlement distribution and chronology of the Gravettian in this region in depth because of this scarce record (two sites and only 7 radiocarbon dates).

On the Atlantic coast of Portugal, most of the Gravettian sites are located in an interesting concentration in its central sector, where eight archaeological sites (19 radiocarbon dates) have been recorded (Fig. 7). In this case, the duration of the Gravettian in any of its identified facies (ancient Gravettian, Fontesantian and early Gravettian) is shorter than in the north and Mediterranean regions, because it is dated c. 30,886-29,484 cal BP in Caldeirao and c. 25,175-24,271 cal BP in Alecrim (Zilhão, 1997).

Finally, only two archaeological sites are known in inner Iberia: El Palomar (31,000-25,600 cal BP) and Peña Capón (25,800-23,600 cal BP). In the same way as in southern Iberia, it is difficult to infer any clear settlement beyond the indubitable presence of groups of hunter-gatherers in inner Iberia during the Gravettian (Alcaraz-Castaño et al., 2012).

4.2.2. Solutrean (c. 27,800-18,300 cal BP)

During the Solutrean, in northern Iberia the available archaeological record shows, as in the Gravettian, an interesting nucleus, with a total of 17 well-dated deposits (43 radiocarbon dates). Some of the sites were already occupied during the Gravettian and also contain Solutrean occupations, probably showing some kind of cultural continuity (Calvo and Prieto, 2012). In addition, other new sites are added to the Solutrean archaeological record, and this is the region in the whole Iberian Peninsula where most deposits have been identified (Fig. 7). Their chronological framework is dated between the oldest Hornos de la Peña Level C (c. 25,153-23,555 cal BP) and the youngest record from the Solutrean Level IV in Cueva del Ruso, (c. 20326-19255 cal BP), with a short overlapping period with the preceding Gravettian technocomplex. In this period, in the Pyrenean area the first well-dated deposit, Chaves, has a chronology of c. 24,422-22,947 cal BP.

In the Mediterranean region, the archaeological record shows a clear increase in the number of sites, from 6 in the Gravettian to 11 in the Solutrean. Whereas some were already cited in the Gravettian record, the others (a total of eight) are new Solutrean sites, all concentrated in the southern part of the Mediterranean coast (Fig. 7). The Solutrean in this region is dated between Level IV in Cueva Ambrosio (26,030-25,595 cal BP) and Level II (ext) in Cueva Beneito (c. 19,930-19,148 cal BP). Thus, this technocomplex seems to develop earlier and last longer than in the north.

The previously recorded sites in southern Iberia, Vale Boi and Nerja, also have Solutrean occupations, as well as such new sites as Cueva del Gato and Gorham´s Cave. In total four archaeological sites (13 radiocarbon dates) whose chronology covers from Level V (9) in Nerja (c. 25,863-25,042 cal BP) to Nerja Level V (8i) dated c. 19,938-18,303 cal BP), suggesting a longer duration of this technocomplex than in the Mediterranean region.

In the central Atlantic coast of Portugal, seven Solutrean sites (11 radiocarbon dates) are known, compared with eight in the Gravettian. They are all concentrated at the mouth of the Tagus and Mondego rivers (Fig. 7). The chronological framework begins in Cabeço do Porto Marinho Level III inf. dated c. 27,590-26,210 cal BP (which is the oldest radiocarbon date in the whole Iberian Solutrean) and finishes in Level 9 at Buraca Grande (c. 22,151-21,024 cal BP), so it seems to be a shorter-lasting technocomplex than in the other Iberian regions.

Finally, in the inner Iberian Peninsula, 4 archaeological sites are recorded, contrasting with the Gravettian, for which only two deposits have been identified, with chronologies between c. 25,817-25,263 cal BP in Peña Capón Level 4, which is one of the oldest Gravettian dates in the whole Peninsula, and c. 21,881-21,328 cal BP in Maltravieso. In this case, the scarcity of radiocarbon dates and the distance between them reveal clear discontinuity in the probability density curve (Fig. 7), which is probably far from the archaeological reality (Alcaraz-Castaño et al., 2013, 2017).

4.2.3. Magdalenian (c. 21,300-11,300 cal BP)

As in the previous periods, Magdalenian hunter-gatherer groups found northern Iberia to be one of the most suitable areas to live at the end of the Pleistocene. A large number of archaeological sites have been recognized; in sum 35 sites (116 radiocarbon dates) have been recorded (Fig. 7). The Magdalenian in this region is the earliest in the whole of Iberia, dated c. 21,288-20,733 cal BP in Level 26 at El Mirón, and it lasted until El Castillo Level 6 and c. 12,548-11,695 cal BP. Thus, this technocomplex covers a long period of c. 9000 years, overlapping with the last Solutrean occupations in this region. In addition, those sites are distributed in all northern areas, from the east to the west, with the first well-dated archaeological sites in the NW region, such as Valdavara 1, 2, 3 (Alonso et al., 2012) and Cueva Eiros (Fabregas et al., 2010). In the contiguous Pyrenean area, in contrast with the previous scarcity of sites, this is the best represented period in the Upper Paleolithic with 5 archaeological sites, in a chronological framework from the oldest level of Montlleó Sect. B c. 20,662-20,071 cal BP to Forcas I Level 10 c. 13,010-127,41 cal BP.

In the Mediterranean region, during the Solutrean an interesting concentration was detected in the Valencia region, but Magdalenian settlement seems to be concentrated at higher latitudes, in the northeast (Fig. 7) (Fullola et al., 2012). Further south in the Valencia region only the site of Cendres is known. The Mediterranean Magdalenian covers from Cova Gran de Santa Linya Level EA-3 dated c. 20,502-20,030 cal BP to Molí del Salt Level A dated c. 12,945-12,707 cal BP, very close to the chronology of the Pyrenean region. As mentioned above, in southern Iberia well-dated Upper Paleolithic archaeological sites are very scarce (Fig. 7). In the case of the Magdalenian, only the sites of Nerja and Vale Boi (also with Gravettian and Solutrean) occupations have been documented, with a chronological framework from Vale Boi Level Z1 dated c. 19,125-18,903 cal BP to Nerja Level T-17 c. 13,754-13,491 cal BP.

On the central Atlantic coast of Portugal, as in previous periods (Bicho and Haws, 2012), an interesting concentration consists of six archaeological sites (34 radiocarbon dates) relatively close to each other, in a chronological framework from Level 5 in Cabeço do Porto Marinho dated c. 20,203-18,853 cal BP to Lapa dos Piceiros upper Level E at c. 11,979-11,306 cal BP. Finally, in inland Iberia, this is the best represented period in the ULP in terms of number of archaeological sites, because 12 Magdalenian sites (35 radiocarbon dates) are known (Fig. 7), with a chronology from Legintxiki Level Ia dated c. 18,428-17,731 cal BP to Peña del Diablo 1 Level 2 (c. 13,013-12,250 cal BP).

4.3. A human glacial refugium in the Iberian Peninsula during the ULP?

Palaeoenvironmental and archaeological records in the Iberian Peninsula reveal an interesting pattern: the continuous presence of hunter-gatherer groups during the ULP with no apparent gaps because of the different climatic episodes.

The occupation of the Iberian Peninsula during the Upper Gravettian (c. 28,000-23,700 cal BP) took place in the dry and cold conditions of the GS-3, attested in different sites (Fig. 8). Nonetheless, in this period a total of 30 archaeological sites, including 66 radiocarbon dates from 52 archaeological levels, have been recorded (Fig. 9), attesting the presence of human hunter-gatherer groups in the Iberian Peninsula but with a certain degree of heterogeneity in their location. The main area in which the settlements are concentrated are the Cantabrian region in northern Iberia (the most-densely occupied area in the Iberian Peninsula in the ULP) and the Atlantic coast (concentration close to the mouth of the Tagus and Mondego rivers), with scattered occupations along the Mediterranean coast. The available data suggest that settlement in these environments near the coast was favoured by more temperate conditions owing to the oceanic influence. In those regions, although the climate was cold and dry, it was probably less severe than in inner Iberia (Carrión et al., 2010), where only two well-dated sites are currently known. Nevertheless, the presence of settlements in inland territories, like El Palomar and Peña Capón, suggest some kind of occupations. In those inner areas, the traditional interpretation of the lack of archaeological sites is that this was a mostly uninhabited area during the coldest stages of the Upper Paleolithic due to harsh environmental and climatic conditions (Straus et al., 2000; Delibes and Díez, 2006). However, recent findings could induce some reinterpretations about the inland occupation during the Gravettian in term of human adaptation (Alcaraz, 2015).

Overlapping with the Gravettian (and the subsequent Magdalenian), the Iberian Solutrean (c. 27,800-18,300 BP) developed during the cold and dry conditions of the GS-3 (c. 27,300-23,750 cal BP) and GS-2 (c. 21,800-16,800 cal BP, including the LGM), with the interruption of a short warmer episode in the GI-2 (c. 23,750-21,800 cal BP), as evidenced by palaeoenvironmental records (Fig. 8).

In spite of the prevalence of those general worse conditions, archaeological data point to a clear increase in the occupation of the Iberian Peninsula, from 30 to 44 archaeological sites, 52 to 93 archaeological levels and from 66 to 107 archaeological radiocarbon determinations (Fig. 9). A significant increase in the probability density of radiocarbon data is noticeable in c. 23,700-22,500 cal BP, in a time near the short warmer episode of the GI-2 (Fig. 8), whereas large territories in central and northern Europe were practically abandoned (Jochim et al., 1999; Gamble et al., 2004; Bocquet-Appel et al., 2005; French and Collins, 2015).

In order to explain this, some kind of mobility of hunter-gatherer groups from the north (with extreme conditions) to the more temperate south may be proposed. The LGM in central and northern Europe was characterized by intensely dry and cold conditions, with a re-advance of glaciers (Rinterknecht et al., 2006; Ivy-Ochs et al., 2008; Ballantyne, 2010). Latitudes above 50 °N were severely affected by the Scandinavian Ice Sheet (SIS), or at least experienced periglacial environments (van Vliet-Lanoë et al., 2004). This situation must have conditioned human settlement patterns, since periglacial environments sustain a low biomass, which may prevent systematic utilization by prehistoric human groups (Banks et al., 2008). In contrast, while in the Iberian Peninsula, climate conditions were equally unfavourable, as explained above, they were probably less severe. This would have been an advantage for the human occupation of Iberia, which may have acted as a glacial refugium during the worst climatic episodes in the ULP. Following Banks et al (2008), Solutrean hunter-gatherer groups faced a relatively high level of ecological risk because of the climate and they occupied wide regions, allowed by their cultural adaptation. In this context, geographical barriers like the Pyrenees were not obstacles to the occupation of other ecological niches.

This dominance of severe conditions would condition the geographic distribution of archaeological sites in the Iberian Peninsula. In the same way as in the Gravettian, most Solutrean sites are located in coastal environments, mainly in the north, Mediterranean area and Atlantic coast. In those areas, the milder climate (in comparison with inner territories) favoured the availability of food resources of both marine (Aura et al., 2016) and terrestrial origin, i.e. biomass of ungulates (Bocquet-Appel and Demars, 2005; Straus, 2015). Few Solutrean archaeological sites are located in inner Iberia, with a more continental climate (González-Sampériz et al., 2010) shown by the prevalence of steppic pollen taxa and low lake productivity in Fuentillejo maar (Fig. 8). However, new finds of Solutrean deposits in the interior probably indicate the organized occupation of the Iberian plateaux in this period (Baena and Carrion 2002; Tapias et al., 2012; Alcaraz-Castaño et al., 2013; Alcaraz-Castaño et al., 2017).

The Magdalenian technocomplex developed in the Iberian Peninsula from c. 21,300-11,300 cal BP, during the dry and cold conditions of the GS-2 (c. 21,800-16,800 cal BP), the warmer GI-1 (16,800-12,900 cal BP, Bølling-Allerød) and the cold GS-1 (c. 12,900-11,700 cal BP, Younger Dryas). As stated above, neither GI-1 nor GS-1 are recorded in Verdeospesoa mire, but they are clearly defined in other Iberian (Pèlachs et al., 2012, González-Sampériz et al., 2017) and European sequences (Rasmussen et al., 2014). Available data suggest that the two severe climate phases (GS-2 and Younger Dryas) were not as cold and dry as the previous GS-3, as seen in the downward trend of xerophytic taxa in the Siles lagoon (Fig. 8) (Carrion, 2002).

At this time, the Magdalenian settlement pattern shows a new increase in the number of archaeological sites, reaching 69 sites and 244 radiocarbon dates from 200 archaeological layers (Fig. 9). This is therefore probably the best-known prehistoric technocomplex in the Upper Palaeolithic (Fullola et al., 2012). During the development of this prehistoric culture, a first increasing trend is observed in the probability curve from the first stages of this technocomplex, c. 20,000-17,600 cal BP (Fig. 8), coinciding with the end of the LGM, in c. 23,000-18,000 cal BP. As in the previous Solutrean, this increasing trend must be correlated with extreme conditions in central and northern Europe, as the Iberian Peninsula received populations from other uninhabitable European regions. The area in which this increasing trend is most obvious is northern Iberia, and to a lesser extent the Pyrenean area.

After that time, a new and larger increase in the probability curve of radiocarbon data is detected c. 15,500 to 13,000 cal BP (Fig. 8). In this case, while population in northern, Pyrenean and Mediterranean areas displays some stability, the Atlantic coast of Portugal, and inner and southern Iberia show noticeable increments in the probability curve of radiocarbon data, indicating more consistent occupation of those regions (Fig. 8). This coincides with the end of the GS-2 and the GI-1, which were not as cold as previously and with more water availability, highlighting once again the great capacity of mobility and adaptation to changing environmental situations displayed by ULP hunter-gatherer groups.

5. Conclusions

A broad analysis of the climate at the end of the Pleistocene (ULP, 28,000-11,700 BP) in the Iberian Peninsula shows a first dry and cold period c. 27,300-23,750 cal BP, a second warmer phase with a certain component of steppic vegetation and higher water availability c. 23,750-21,800 cal BP, a new drier but temperate episode c. 21,800-16,800 cal BP with incidence of natural fires, and, a final stage which seems to reflect the deglaciation period from c. 16,800 cal BP, with the gradual passage to warmer and humid conditions before the beginning of the Holocene. In northern areas, climate changes were more subdued than in the south, where deposits seem to have been more sensitive to environmental changes.

The analysis of settlement patterns in the Iberian Peninsula in this chronological framework suggests a relatively intense occupation, with no apparent interruptions in this part of SW Europe during the MIS-2 (c. 28,000-11,700 cal BP), but with a clear geographic distribution of sites. In the Gravettian, Solutrean and Magdalenian technocomplexes, which developed during the different climatic phases, most of the settlements were located near coastal environments. The availability of prey, marine resources and suitable raw materials, combined with the less severe conditions favoured the occupation of those regions. However, continental regions with more severe climatic conditions, like inner Iberia, were also occupied during those periods, although in the present state of our knowledge it seems that population density was lower.

A global analysis of the environmental conditions and archaeological record shows that, in SW Europe (Iberian Peninsula), less severe climatic conditions than in north and central Europe allowed intense human occupation of Iberia by hunter-gatherer groups. This supports the hypothesis that this, the south-westernmost corner of Europe, was a glacial refugium for humans in the ULP, highlighting the mobility strategies and adaptations of hunter-gatherer groups in SW Europe.

CRediT author statement

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TABLE AND FIGURE AND CAPTIONS

Figure 1. Location of the Verdeospesoa mire and the other sites mentioned in the text. A, location of the site, B, image of Verdeospesoa mire, C, location of the palaeoenvironmental deposits mentioned in the text, D, current local vegetal communities near Verdeospesoa mire, E, archaeological sites considered in this analysis.

Fig. 2. Palaeoenvironmental sequences mentioned in the text and its chronological distribution.

Figure 3. Age-depth model of Verdeospesoa mire. Lines connecting each plotted point are interpolated sediment-accumulation rates.

Figure 4. Palynological diagram of Verdeospesoa mire. Taxa with lower values are exagered (grey line, 5%).

Figure 5. Scores for axis PCA-1, PCA-2 and PCA-3 for pollen types of all study sites.

Figure 6. Synthetic pollen diagram, CHAR, MS, OM and variation of factor scores (F1 to F3) against age (cal yr BP) and climatic events from Verdeospesoa mire. Mesophilous trees (*Alnus*, *Betula*, *Corylus*, *Fagus*, *Fraxinus*, *Juglans*, deciduous *Quercus*, *Salix*, *Tilia*), Pines (*Pinus sylvestris* type, *P. pinaster*), Xerophytic taxa (*Juniperus*, *Artemisia*, Chenopodiaceae, *Centaurea*, Cichorioideae), Hydro-hygrophytic taxa and ferns (Ranunculaceae, Cyperaceae, Filicales monolete undiff., Filicales trilete undiff., *Polypodium vulgare*, *Pteridium aquilinum*), Uppland herbs (Poaceae, Fabaceae, Caryophyllaceae, Cardueae, *Aster*, Apiaceae).

Figure 7. Archaeological sites and summed probability distribution of radiocarbon dates during the Gravettian, Solutrean and Magdalenian.

Figure 8. Selected high resolution terrestrial and marine records compared with the NGRIP curve and radiocarbon dates in the MIS-2.

Figure 9. Evolution of the number of archaeological sites, radiocarbon dates and archaeological layers of the Gravettian, Solutrean and Magdalenian technocomplexes.

Table 1. Radiocarbon dates (AMS C^{14} dating) from the peat bog of Verdeospesoa calibrated using Calib Radiocarbon Calibration program 7.1. The maximum probability interval is used to construct the age-depth model at 2 σ ranges.

Supplementary Data. Appendix A. Appendix A. Supplementary data. Radiocarbon dates of the archaeological sites mentioned in the text and with standard deviations < 350 years. GRA: Gravettian, SOL: Solutrean: MG: Magdalenian. Material: B: Bone, CH: Charcoal, S: Shell, T: Teeth, OS: Organic Sediment.

Nº.	**Site**	**Complex**	**Layer**	**Lab. Code**	**Material**	**Age (C-14 years BP)**	**Age (cal BP)**	**Med. Prob.**	**References**
1	Abauntz	MGD	E	Ly 1965	B	15800 ± 350	19948-18348	19111	Utrilla et al., 2015
	Abauntz	MGD	E	OxA-5983	B	13500 ± 160	16776-15798	16265	Utrilla et al., 2015
	Abauntz	MGD	2r	Cams-9918	CH	12340 ±60	14718-14088	14348	Utrilla et al., 2015
	Abauntz	MGD	2r	OxA-5116	CH	11760 ±90	13763-13431	13591	Utrilla et al., 2015
2	Abrigo de Ángel 1	GRA	10 inf.	GrA-16961	CH	25330 ± 190	29938-28869	29391	Utrilla & Domingo, 2002
3	Abrigo del Cuco	GRA	III	GrA-32097	B	23400 ± 250	27968-27193	27593	Rasines & Muñoz, 2012
4	Aitzbitarte III	GRA	III	Ua-11147	B	20405 ± 130	27134-26310	26729	Altuna et al., 2011
	Aitzbitarte III	GRA	IV	UA-25965	B	22420 ± 290	27310-26078	26710	Altuna et al., 2011
	Aitzbitarte III	GRA	II	Ua-37959	B	19765 ± 220	24318-23219	23790	Altuna et al., 2011
	Aitzbitarte III	GRA	III	UA-11150	B	18400 ± 215	22735-21745	22239	Altuna et al., 2011
5	Aitzbitarte IV	SOL	III	GrN-5993	B	17950 ± 150	22191-21315	21738	Altuna, 1972
6	Alecrim	GRA	6	Wk-25514	B	21794 ± 170	26415-25736	26032	Bicho et al., 2012
	Alecrim	GRA	6	Beta-203513	B	20510 ± 150	25175-24271	24703	Bicho et al., 2012
7	Alexandre	MGD	IIIb	GrN-123448	CH	15370 ± 110	18853-18384	18638	Utrilla et al., 2006
8	Alonsé	MGD	m	GrA-21536	CH	15069 ± 90	18558-18045	18311	Montes, 2005
	Alonsé	MGD	m	GrA-21537	CH	14840 ± 90	18308-17828	18053	Utrilla & Montes, 2007
9	Altamira	GRA	8	GrA-27739	B	21930 ± 100	26415-25917	26132	Lasheras et al., 2012
	Altamira	GRA	8	GrA-32765	B	21910 ± 90	26370-25912	26110	Lasheras et al., 2012
	Altamira	SOL	7	GrA-32761	B	19630 ± 80	23926-23387	23652	Lasheras et al., 2012
	Altamira	SOL	7 med.	GrA-30325	B	19060 ± 90	23298-22636	22950	Lasheras et al., 2012
	Altamira	SOL	7 sup.	GrA-30324	B	18750 ± 100	22885-22403	22611	Lasheras et al., 2012
	Altamira	SOL	3	GifA-90045	B	18540 ± 320	23141-21613	22395	Soto-Barreiro, 2001
	Altamira	MGD	MG inf	I-12012	CH	15910 ± 230	19766-1814	19212	González-Sainz, 1989
	Altamira	MGD	MG (sup)	GifA-90047	B	14520 ± 260	18320-16984	17666	González-Echegaray, 1996
10	Anecrial	GRA	3n	GrA-12016	CH	24410 ± 110	28735-28149	28463	Bicho et al., 2012
	Anecrial	GRA	2b	OxA-11235	B (Capra)	23410 ± 170	27844-27374	27601	Bicho et al., 2012

	Anecrial	SOL	1	GrA-1219	CH	20520 ± 100	25087-24360	24706	Almeida et al., 2007
11	Antoliñako Koba	GRA	Lmbk sup/Smbk	Beta-230279	B	27520 ± 190	31629-31053	31326	Aguirre, 2012
	Antoliñako Koba	GRA	Lmbk sup/Smbk	Beta-215542	B	26080 ± 200	30820-29746	30359	Aguirre, 2012
	Antoliñako Koba	GRA	Lab	Beta-233766	B	22640 ± 120	27303-26578	26973	Aguirre, 2012
	Antoliñako Koba	SOL	Lmc	GrN-23785	B	19280 ± 120	23560-22899	23225	Aguirre, 2012
	Antoliñako Koba	SOL	Lmc	Beta-230284	B	19020 ± 120	23282-22543	22897	Aguirre, 2012
	Antoliñako Koba	SOL	Lmb	Beta-251301	B	17340 ± 100	21244-20625	20918	Aguirre, 2012
	Antoliñako Koba	MGD	Lgc inf	GrN-23783	B	14680 ± 80	18077-17631	17865	Aguirre, 2012
	Antoliñako Koba	MGD	Lgc inf	Beta-230281	B	14580 ± 70	17963-17557	17760	Aguirre, 2012
12	Arbreda	GRA	D	GrA-47323	B	22630 ± 100	27274-26595	26967	Soler et al., 2012
	Arbreda	GRA	E	Gif-6420	CH	20130 ± 220	24868-23658	24209	Delibrias et al., 1987
	Arbreda	SOL	C	GrA-47330	B	19480 ± 80	23726-23130	23469	Soler et al., 2012
	Arbreda	SOL	B	GrA-47320	B	18860 ± 80	22957-22486	22716	Soler et al., 2012
	Arbreda	SOL	C	Gif-6419	B	17720 ± 290	22187-20677	21428	Delibrias et al., 1987
	Arbreda	SOL	B	Gif-6418	CH	17320 ± 290	21705-20182	20923	Delibrias et al., 1987
13	Arlanpe	SOL	III	Beta-238178	B	17060 ± 80	20827-20328	20578	Ríos et al., 2008
14	Askondo	GRA	-	Beta-303671	B	23760 ± 110	28049-27622	27823	Ríos & Gárate, 2012
	Askondo	SOL	4	Beta-316473	B	17490 ± 90	21432-20836	21127	Ríos& Gárate, 2012
15	Atxoste	MGD	h2	GrA-19503	B	12540 ±80	15139-14312	14808	Utrilla et al., 2010
	Atxoste	MGD	g	GrA-19502	B	12200 ±90	14491-13733	14097	Utrilla et al., 2010
	Atxoste	MGD	f2	GrA-19554	B	12070 ±60	14086-13762	13917	Utrilla et al., 2010
	Atxoste	MGD	f	GrN-26667	B	11960 ±180	14331-13393	13825	Utrilla et al., 2010
	Atxoste	MGD	f	GrN-26666	B	11910 ±170	14171-13398	13758	Utrilla et al., 2010
	Atxoste	MGD	VIIc	GrA-22900	B	11800 ±60	13749-13482	13633	Utrilla et al., 2010
	Atxoste	MGD	h	GrA-19870	B	11730 ±80	13744-13423	13554	Utrilla et al., 2010
	Atxoste	MGD	VIIb	GrA-22865	B	11720 ±70	13729-13428	13541	Utrilla et al., 2010
	Atxoste	MGD	VIIc	GrA-23107	B	11690 ±80	13729-13365	13518	Utrilla et al., 2010
16	Balma Gai	MGD	I	Gif-956330	-	12240 ± 110	14713-13795	14189	García-Arguelles et al., 2001
	Balma Gai	MGD	II	GifA-10029	-	11170 ± 160	13302-12725	13021	García-Arguelles et al., 2001
17	Balma Griera	GRA	III	AA-8649	B	21255 ± 350	26149-24589	25529	Fullola et al., 1994
18	Balma Guilanyà	MGD	Ej	Beta-185066	CH	12180 ± 50	14228-13870	14069	Casanova et al., 2006
	Balma Guilanyà	MGD	Ej	UBAR-367	CH	11460 ± 230	13749-12829	13305	Casanova et al., 2006

19	Berroberria	MGD	D inf	OxA-949	-	11900 ± 130	14050-13464	13733	Barandiarán, 1990
	Berroberria	MGD	D inf	OxA-978	B	11600 ± 130	13725-13184	13429	Barandiarán, 1990
20	Bora Gran	MGD	-	OxBGA-2153	B	13080 ± 90	15974-15331	15675	Nadal, 1998
	Bora Gran	MGD	-	OxBga-2222	B	12830 ± 80	15620-15077	15305	Nadal, 1998
21	Buendía	MGD	N1C	Beta-212776	CH	14840 ± 50	18226-17875	18044	Cacho et al., 2012
	Buendía	MGD	-	UtC-4006	CH	14380 ± 90	17817-17228	17526	Cacho et al., 2012
22	Buraca Escura	GRA	3	OzA-5523	B	22700 ± 240	27481-26423	26998	Bicho et al., 2012
	Buraca Escura	GRA	2	OxA-5524	B	21820 ± 200	26512-25714	26063	Bicho et al., 2012
23	Buraca Grande	GRA	9B	GifA-93048	CH	23920 ± 300	28602-27546	28021	Bicho et al., 2012
	Buraca Grande	SOL	9	Gif-9502	CH	17850 ± 200	22151-21024	21603	Aubry et al., 2001
	Buraca Grande	MGD	-	OxA-5522	B	13050 ± 100	15953-15286	15626	Bicho and Haws, 2012
	Buraca Grande	MGD	2	GifA-96307	B	11390 ± 110	13444-13065	13237	Bicho and Haws, 2012
24	Cabeço do Porto Marinho	SOL	III inferior	SMU-2475	CH	22710 ± 350	27591-26208	26969	Bicho et al., 2012
	Cabeço do Porto Marinho	MGD	5	Wk-3126	CH	16180 ± 290	20203-18853	19523	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	9	SMU-2634	CH	15420 ± 180	19055-18264	18676	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	8	SMU-2476	CH	15410 ± 195	19082-18202	18664	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	9	Wk-3127	CH	15040 ± 210	18739-17817	18274	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	13	ICEN-687	CH	12220 ± 110	14666-13778	14148	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	12	ICEN-689	CH	11810 ± 110	13944-13889	13638	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	13	SMU-2011	CH	11680 ± 60	13708-13675	13509	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	14	ICEN-545	CH	11160 ± 280	13575-12546	13029	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	15	SMU-2637	CH	11110 ± 130	13194-12723	12961	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	16	ICEN-690	CH	10940 ± 210	13259-12516	12851	Bicho and Haws, 2012
	Cabeço do Porto Marinho	MGD	17	SMU-2636	CH	10160 ± 80	12098-11403	11816	Bicho and Haws, 2012
25	Caldeirao	GRA	Jb	OxA-5542	B	26020 ± 320	30886-29484	30235	Bicho et al., 2012
	Caldeirao	SOL	H	OxA-2511	B	20530 ± 270	25414-24054	24732	Zilhão, 2000
	Caldeirao	SOL	H	OxA-1939	B (Capra pyrenaica)	19900 ± 260	24561-23258	23941	Zilhão 2000
	Caldeirao	SOL	Fc	OxA-2510	B	18840 ± 200	23242-22325	22723	Zilhão, 1997
26	Casa da Moura	GRA	1b	TO-1102	B (Canis lupus)	25900 ± 220	30705-29535	30132	Straus et al., 1998
27	Cendres	GRA	XVIc	Beta-189078	CH (P. nigra)	25850 ± 260	30721-29426	30071	Villaverde & Román, 2012
	Cendres	GRA	XVIc	Beta-287537	CH	25500 ± 140	30143-29202	29605	Villaverde & Román, 2012
	Cendres	GRA	XVIa	Beta-142283	CH (P. nigra)	24240 ± 220	28710-27828	28272	Villaverde & Román, 2012

	Cendres	GRA	XV	Beta-303419	CH	23350 ± 100	27752-27381	27570	Villaverde & Román, 2012
	Cendres	GRA	XVIa	Beta-287549	CH	21860 ± 100	26326-25869	26069	Villaverde & Román, 2012
	Cendres	GRA	XIV	Beta-142282	CH	21230 ± 80	25787-25327	25584	Villaverde & Román, 2004
	Cendres	GRA	XIV	Beta-287546	CH	20800 ± 110	25422-24616	25092	Villaverde & Román, 2012
	Cendres	SOL	XIIIb	Beta-118026	CH	18920 ± 180	23272-22417	22794	Villaverde et al., 1999
	Cendres	SOL	XIIIb	Beta-118027	CH	18750 ± 130	22940-22374	22622	Villaverde et al., 1999
	Cendres	SOL	XIIb	Beta-118024	CH (P. nigra)	17230 ± 130	21166-20446	20784	Villaverde et al., 1999
	Cendres	MGD	XII	Beta-287541	CH	16030 ± 60	19554-19150	19352	Villaverde et al., 2012
	Cendres	MGD	XII	Beta-287840	CH	15630 ± 60	19011-18739	18871	Villaverde et al., 2012
	Cendres	MGD	XIIa	Beta-118023	CH	14850 ± 100	18337-17821	18066	Villaverde et al., 1999
28	Chaves	SOL	C1	GrN-12681	CH	19700 ± 310	24422-22947	23947	Utrilla et al., 2010
	Chaves	MGD	2b	GrN-15635	B	12950 ±70	15741-15239	15381	Utrilla et al., 2010
	Chaves	MGD	2b	GrN-14561	B	12660 ±70	15283-14730	15054	Utrilla et al., 2010
	Chaves	MGD	2a	GrN-12682	CH	12020 ±350	15128-13198	14014	Utrilla et al., 2010
29	Cobrante	SOL	3	GrA-22438	B	18540 ± 70	22579-22259	22419	Rasines, 2009
	Cobrante	SOL	4	GrA-22439	B	18260 ± 70	22347-21892	22129	Rasines, 2009
30	Colls	MGD	IV	GifA-95571	CH	12490 ± 120	15132-14171	14673	Fullola et al., 2012
	Colls	MGD	IV	GifA-95544	CH	12150 ± 120	14563-13730	14033	Casanova et al., 2006
	Colls	MGD	II	AA-8645	CH	10950 ± 120	13064-12691	12850	Bergadá, 1998
31	Cova Gran Sta. Linya	MGD	EA-3	Beta-233606	CH	16800 ± 80	20502-20030	20265	Mora et al., 2011
	Cova Gran Sta. Linya	MGD	6P	Beta-265984	CH	15120 ± 70	18580-18149	18380	Mora et al., 2011
	Cova Gran Sta. Linya	MGD	4P	Beta-259273	CH	14760 ± 70	18168-17739	17960	Mora et al., 2011
	Cova Gran Sta. Linya	MGD	S4H	Beta-187424	CH	13660 ± 50	16712-16249	16466	Fullola et al., 2012
32	Cualventí	MGD	E	GrA-21431	CH	15950 ± 70	19483-19012	19242	Uzquiano, 2014
33	Cueto de la Mina	SOL	V	Ua-3586	B	19110 ± 205	23521-22521	23023	Rasilla & Lana, 1994
	Cueto de la Mina	SOL	F	Ua-3588	B	17545 ± 205	21777-20668	21209	Soto-Barreiro 2003
	Cueto de la Mina	MGD	B	OxA-996	B (Antler)	11650 ± 190	13932-13092	13488	Soto-Barreiros, 2013
	Cueto de la Mina	MGD	B	OxA-969	B (Antler)	11630 ± 120	13737-13243	13460	Soto-Barreiros, 2013
34	Cueva Ambrosio	SOL	IV	Gif-9884	CH	21520 ± 120	26030-25596	25820	Ripoll et al., 2006
	Cueva Ambrosio	SOL	II.1	GifA-95576	CH	20150 ± 200	24838-23722	24228	Ripoll et al., 2006
	Cueva Ambrosio	SOL	II.1	GifA-95577	CH	19950 ± 210	24492-23489	24000	Ripoll et al., 2006
	Cueva Ambrosio	SOL	II.6	Gif-A-II.6	CH	19300 ± 190	23741-22751	23246	Jordá et al., 2012

	Cueva Ambrosio	SOL	II.g	Gif-9883	CH	19250 ± 70	23462-22932	23192	Ripoll et al., 2006
	Cueva Ambrosio	SOL	II.2	GifA-A-II.2	CH	19170 ± 190	23566-22592	23097	Jordá et al., 2012
	Cueva Ambrosio	SOL	II.4	Gif-A-II.4	CH	19110 ± 90	23378-22731	23018	Jordá et al., 2012
	Cueva Ambrosio	SOL	II	Gif-7276	CH	16500 ± 280	20584-19207	19907	Ripoll, 1988
35	Cueva Beneito	SOL	IV (ext)	Ua-32244	B	18275 ± 175	22485-21713	22128	Domenech et al., 2012
	Cueva Beneito	SOL	B2	Ly-3594	-	16560 ± 280	20650-19269	19980	Cascalheira, 2013
	Cueva Beneito	SOL	II (ext)	Ua-32243	B	16180 ± 140	19930-19148	19524	Domenech et al., 2012
36	Cueva del Gato	SOL	2	GrA-22505	CH	18650 ± 140	22900-22237	22524	Blasco & Rodanés, 2004
	Cueva del Gato	SOL	2	GrA-42226	B	17700 ± 70	21702-21130	21423	Blasco & Rodanés, 2004
37	Cueva del Ruso	SOL	IV	Beta-810	B	16410 ± 210	20326-19255	19802	Yravedra et al., 2010
38	Cueva Eiros	MGD	B	Beta-308859	-	12060 ± 50	14063-13763	13904	Fabregas et al., 2010
39	Cueva Morín	GRA	5a	Si-953	CH	20107 ± 350	25179-23380	24206	González-Echegaray & Freeman, 1978
40	Cueva Oscura	MGD	3a	Gif-5106	-	11670 ± 200	13956-13112	13510	Adán et al., 2005
41	Ekain	MGD	VIIb	I-12020	B	16510 ± 270	20571-19240	19919	Altuna & Merino, 1984
	Ekain	MGD	VIIb	I-12224	B	16030 ± 240	19934-18818	19344	Altuna & Merino, 1984
	Ekain	MGD	VIIc	I-12225	B	15970 ± 240	19869-18763	19278	Altuna & Merino, 1984
	Ekain	MGD	VIId	I-12266	B	15400 ± 240	19181-18081	18650	Altuna & Merino, 1984
	Ekain	MGD	VI	I-9240	-	12050 ± 190	14652-13466	13941	Altuna & Merino, 1984
42	El Castillo	GRA	14	Beta-298432	B	29740 ± 190	34202-33554	33875	Bernaldo de Quirós et al., 2012
	El Castillo	GRA	14	Beta-298433	B	29600 ± 180	34094-33454	33777	Bernaldo de Quirós et al., 2012
	El Castillo	GRA	12	Beta-298430	B	25920 ± 140	30604-29681	30170	Bernaldo de Quirós et al., 2012
	El Castillo	GRA	12	Beta-242617	B	24070 ± 150	28483-27782	28108	Bernaldo de Quirós et al., 2012
	El Castillo	SOL	10	Beta-242619	B	19260 ± 90	23494-22927	23204	Bernaldo de Quirós et al., 2012b
	El Castillo	SOL	10	OxA-971	B	16850 ± 220	20882-19768	20327	Sommer et al., 2008
	El Castillo	MGD	8	OxA-971	B	16850 ± 220	20882-19768	20327	Barandiarán, 1988
	El Castillo	MGD	8	Beta-242620	B	15160 ± 70	18620-18216	18427	Bernaldo de Quirós et al., 2012b
	El Castillo	MGD	6	-	B	12390 ± 120	15039-14072	14500	Barandiarán, 1988
	El Castillo	MGD	6	-	B	10310 ± 120	12548-11695	12117	Barandiarán, 1988
43	El Horno	MGD	1	GX-27457	B	12530 ± 190	15356-14049	14729	Straus et al., 2002
	El Horno	MGD	2	GX-27456	B	12250 ± 190	15038-13744	14285	Straus et al., 20012
44	El Linar	SOL	B3	GrA-21436	B	19680 ± 320	24427-22906	23686	Uzquano, 2014
	El Linar	MGD	C3	GrA-21435	B	14040 ± 60	17338-16797	17062	Uzquiano, 2014

45	El Mirón	GRA	128	GX-27113	CH	27580 ± 210	31757-31058	31368	González-Morales & Straus, 2012
	El Mirón	SOL	127	UG-7216	CH	19230 ± 50	23426-22942	23168	González-Morales & Straus, 2012
	El Mirón	SOL	126	GX-24471	B	18950 ± 350	23694-22064	22864	González-Morales & Straus, 2012
	El Mirón	SOL	121	GX-32655	B	18390 ± 300	22923-21505	22220	González-Morales & Straus, 2012
	El Mirón	SOL	313	GX-31194	B	17400 ± 270	21769-20349	21026	González-Morales & Straus, 2012
	El Mirón	MGD	26	GX-29439	B	17400 ± 80	21288-20733	20998	González-Morales & Straus, 2012
	El Mirón	MGD	117	GX-25857	CH	17050 ± 60	20767-20354	20566	González-Morales & Straus, 2012
	El Mirón	MGD	119	GX-25857	CH	16960 ± 80	20683-20194	20455	González-Morales & Straus, 2012
	El Mirón	MGD	Niche A	GX-30398	B	16600 ± 90	20300-19738	20029	González-Morales & Straus, 2012
	El Mirón	MGD	114	GX-28209	B	16460 ± 50	20052-19647	19860	González-Morales & Straus, 2012
	El Mirón	MGD	111	GX-23395	B	16370 ± 190	20220-19250	19758	González-Morales & Straus, 2012
	El Mirón	MGD	119.2	GX-32656	B	16320 ± 160	20090-19268	19704	González-Morales & Straus, 2012
	El Mirón	MGD	110	GX-23396	B	16130 ± 250	20053-18886	19460	González-Morales & Straus, 2012
	El Mirón	MGD	18	UG-3366R	B	16080 ± 40	19568-19239	19415	González-Morales & Straus, 2012
	El Mirón	MGD	21	UG-3364R	CH	16050 ± 40	19543-19212	19378	González-Morales & Straus, 2012
	El Mirón	MGD	312	GX-31932	B	15850 ± 170	19547-18778	19136	González-Morales & Straus, 2012
	El Mirón	MGD	17	GX-25853	CH	15700 ± 190	19454-18588	18976	González-Morales & Straus, 2012
	El Mirón	MGD	504	UG-7217	B	15740 ± 40	19125-18864	18975	González-Morales & Straus, 2012
	El Mirón	MGD	20	GX-24469	B	15530 ± 230	19361-18285	18793	González-Morales & Straus, 2012
	El Mirón	MGD	118	GX-31933	CH	15460 ± 190	19148-18298	18717	González-Morales & Straus, 2012
	El Mirón	MGD	26	OxA-22090	B	15430 ± 75	18853-18534	18698	González-Morales & Straus, 2012
	El Mirón	MGD	17	GX-32654	CH	15350 ± 80	18794-18430	18625	González-Morales & Straus, 2012
	El Mirón	MGD	116	GX-23416	B	15220 ± 100	18725-18234	18485	González-Morales & Straus, 2012
	El Mirón	MGD	16	GX-234115	B	15180 ± 100	18684-18166	18444	González-Morales & Straus, 2012
	El Mirón	MGD	503.1	UG-7799	CH	15120 ± 40	18544-18217	18383	González-Morales & Straus, 2012
	El Mirón	MGD	15	GX-23392	B	15010 ± 260	18783-17649	18239	González-Morales & Straus, 2012
	El Mirón	MGD	13	OxA-22089	B	14930 ± 70	18348-17939	18148	González-Morales & Straus, 2012
	El Mirón	MGD	108	GX-27114	CH	14850 ± 60	18257-17877	18057	González-Morales & Straus, 2012
	El Mirón	MGD	18	OxA-22091	B	14760 ± 70	18168-17739	17960	González-Morales & Straus, 2012
	El Mirón	MGD	5	GX-23397	B	14710 ± 160	18302-17517	17900	González-Morales & Straus, 2012
	El Mirón	MGD	10	GX-22347	CH	14620 ± 80	18008-17577	17798	González-Morales & Straus, 2012
	El Mirón	MGD	10	GX32381	B	13710 ± 70	16850-16285	16549	González-Morales & Straus, 2012

	El Mirón	MGD	4	GX-22703	B	13660 ± 70	16768-16228	16471	González-Morales & Straus, 2012
	El Mirón	MGD	7	UG-9286	B	13490 ± 70	16508-16011	16239	González-Morales & Straus, 2012
	El Mirón	MGD	12	GX-22132	CH	12970 ± 70	15764-15259	15508	González-Morales & Straus, 2012
	El Mirón	MGD	16	GX-28210	CH	12350 ± 180	15105-13847	14458	González-Morales & Straus, 2012
46	El Monte	MGD	-	Beta-245814	-	14660 ± 80	18051-17612	17841	Cacho et al., 2012
	El Monte	MGD	-	Beta-245813	-	13570 ± 70	16623-16120	16350	Cacho et al., 2012
47	El Palomar	GRA	IV	Beta-85410	B	26430 ± 210	31057-30240	30708	Peña & Vega, 2012
	El Palomar	GRA	V	Beta-185411	B	26230 ± 200	30930-29918	30525	Peña & Vega, 2012
	El Palomar	GRA	III	Beta-185409	B	21560 ± 110	26045-25646	25850	Peña & Vega, 2012
48	El Pendo	MGD	II	OxA-977	B	14830 ± 130	18264-17709	18047	Barandiarán, 1988
49	Entrefoces	MGD	B	Ly-2937	B	14690 ± 200	18373-17393	17875	González-Morales, 1990
50	Erralla	MGD	Va	I-12551	B	16270 ± 240	20198-19010	19634	Altuna et al., 1985
	Erralla	MGD	Va	I-12540	B	16030 ± 240	19934-18818	19344	Altuna et al., 1985
	Erralla	MGD	V	I- 12868	B	15740 ± 240	19592-18525	19032	Altuna et al., 1985
51	Finca Doña Martina	GRA	7b	VERA-5368	-	26990 ± 220	31312-30795	31047	Villaverde & Román, 2012
	Finca Doña Martina	SOL	04-may	VERA-510bHS	CH	19180 ± 90	23435-22842	23110	Zilhao et al., 2011
52	Forcas I	MGD	15	GrA-25979	B	14440 ± 70	17859-17385	17602	Utrilla et al., 2010
	Forcas I	MGD	14	GrN-17788	B	13010 ±320	16444-14293	15530	Utrilla et al., 2010
	Forcas I	MGD	14	GrA-33986	B	12600 ± 60	15215-14628	14955	Utrilla et al., 2010
	Forcas I	MGD	13d	GrA-32957	B	12440 ±50	14934-14217	14561	Utrilla et al., 2010
	Forcas I	MGD	13a	GrA-33987	B	12010 ± 60	14044-13735	13868	Utrilla et al., 2010
	Forcas I	MGD	10	GrA-32959	B	11015 ± 45	13010-12741	12879	Utrilla & Montes, 2008
53	Fuente del Salín	GRA	2	GX-27756	CH	22580 ± 100	27224-26553	26906	Cuenca, 2013
54	Fuente del Trucho	SOL	UA1	Beta-72393	B	19060 ± 80	23276-22652	22950	Utrilla et al., 2010
55	Galeria da Cisterna	MGD	3	GrA-11129	B (Capra sp)	11755 ± 80	13750-13444	13583	Trinkaus et al., 2011
	Galeria da Cisterna	MGD	3	GrA-9722	B	10820 ± 60	12808-12652	12722	Trinkaus et al., 2011
56	Gorhams ` Cave	SOL	III	Beta-184042	CH	18440 ± 160	22611-21884	22291	Finlayson et al., 2006
57	Hornos de la Peña	SOL	C	BM-1882R	B	20180 ± 310	25153-23555	24292	Bowman et al., 1990
58	Hort de la Boquera	MGD	II	OxA-13595	CH	12250 ± 60	14489-13967	14162	Fullola et al., 2012
	Hort de la Boquera	MGD	II	OxA-23645	CH	11775 ± 45	13729-13476	13603	Fullola et al., 2012
59	Kukuma	MGD	11	Ua-2625	B	11550 ± 130	13700-13106	13381	Baldeón & Berganza, 1997
60	La Boja	SOL	SW18E	VERA-5213	CH (Juniperus sp.)	20980 ± 110	25617-25031	25334	Lucena et al., 2012

	La Boja	SOL	SW18E	VERA-5366	CH (Juniperus sp.)	20980 ± 120	25637-25003	25332	Lucena et al., 2012
	La Boja	SOL	SW18C	VERA-5365	CH (Juniperus sp.)	19390 ± 100	23640-23022	23346	Lucena et al., 2012
	La Boja	SOL	SW18B2	VERA-5364-b	CH (Juniperus sp.)	17430 ± 70	21310-20801	21039	Lucena et al., 2012
	La Boja	SOL	SW18B2	VERA-5364-a	CH (Juniperus sp.)	16990 ± 70	20704-20255	20493	Lucena et al., 2012
	La Boja	SOL	SW18B1	VERA-5788	CH	16580 ± 70	20228-19755	20005	Lucena et al., 2012
61	La Garma A	GRA	F3	TO-11697	B	22200 ± 170	26965-26038	26431	Arias et al., 2007
	La Garma A	MGD	5	OxA-7181	B	13860 ± 100	17111-16415	16782	Arias et al., 2000
	La Garma A	MGD	Zone IV	OxA-8722	B	13610 ± 100	16777-16105	16410	Arias et al., 2011
	La Garma A	MGD	5	OxA-7204	B	13490 ± 110	16604-15907	16244	Arias et al., 2000
	La Garma A	MGD	Zone IV	AA-45581	B	13410 ± 120	16503-15780	16135	Arias et al., 2011
	La Garma A	MGD	3	OxA-7203	-	12070 ± 100	14203-13711	13926	Arias et al., 2000
62	La Paloma	MGD	6	OxA-974	B	14600 ± 160	18176-17468	17771	Barandiarán, 1988
	La Paloma	MGD	4	OxA-973	B	12860 ± 130	15803-14937	15365	Barandiarán, 1988
	La Paloma	MGD	4	OxA-975	-	12750 ± 130	15695-14628	15178	Barandiarán, 1988
63	La Pila	MGD	IV.4	Gif-90033	CH	12580 ± 190	15461-14100	14812	Uzquiano, 2014
	La Pila	MGD	IV.2	Gif-8147	CH	12160 ± 130	14658-13732	14056	Bernaldo de Quirós & Gutierrez, 1992
64	La Riera	SOL	12	GAK-6446	B	17210 ± 350	21731-19940	20788	Straus & Clark, 1986
	La Riera	SOL	17	GAK-6445	CH	16900 ± 200	20900-19894	20384	Straus & Clark, 1986
	La Riera	MGD	19	Q-2116	CH	15230 ± 300	19125-17791	18464	Straus & Clark, 1986
	La Riera	MGD	23	UCR-1274D	B	12620 ± 300	15846-13926	14873	Straus & Clark, 1986
65	La Viña	SOL	IX	OxA-21688	B (Cervus elaphus)	24680 ± 130	29011-28401	28714	Santamaria et al., 2012
	La Viña	MGD	IV	Ly-3316	B	13360 ± 190	16644-15455	16067	Santamaria et al., 2012
	La Viña	MGD	IV	Ly-3317	B	13300 ± 150	16434-15496	15986	Santamaria et al., 2012
66	Lagar Velho	GRA	GC3	OxA-9572	B	23170 ± 140	27693-27198	27455	Zilhão & Trinkaus 2000
	Lagar Velho	GRA	ls/ms boundary	Wk-9571	B	23042 ± 142	27615-27082	27361	Zilhão & Trinkaus 2000
	Lagar Velho	GRA	GC4	Beta-139361	B	22720 ± 90	27352-26707	27094	Zilhão & Trinkaus 2000
	Lagar Velho	GRA	us	OxA-8425	CH	22670 ± 160	27368-26548	26995	Zilhão & Trinkaus 2000
	Lagar Velho	GRA	ms	Wk-9256	CH (Pinus sp.)	22493 ± 107	27162-26464	26815	Zilhão & Trinkaus 2000
	Lagar Velho	GRA	us	OxA-10303	CH	22390 ± 280	27282-26067	26679	Pettitt et al., 2002
	Lagar Velho	GRA	6	OxA-8418	CH	22180 ± 180	26961-26012	26412	Zilhão & Trinkaus 2000
	Lagar Velho	GRA	GC3	OxA-9571	B	21130 ± 130	25760-25170	25476	Zilhão and Trinkaus 2000
	Lagar Velho	GRA	us	OxA-8426	CH	20570 ± 130	25195-24278	24773	Zilhão & Trinkaus 2000

	Lagar Velho	SOL	9	OxA-8419	CH	20200 ± 180	24861-23840	24282	Zilhão & Trinkaus 2000
67	Laminak II	MGD	-	CAMS-9918	CH	12340 ± 60	14718-14088	14348	Berganza & Arribas, 1994
	Laminak II	MGD	II	Ua-2362	B	11700 ± 140	13810-13237	13534	Berganza & Arribas, 1994
68	Lapa dos Coelhos	MGD	4	GrN-18377	CH	12240 ± 60	14459-13955	14147	Bicho and Haws, 2012
	Lapa dos Coelhos	MGD	3	GrN-1876	CH	11660 ± 60	13595-13341	13492	Bicho and Haws, 2012
69	Lapa dos Picaeiros	MGD	N	Wk-16417	B	16389 ± 111	20067-19510	19781	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	K	WK-31354	B	15035 ± 87	18508-18005	18268	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	E middle	Wk-10434	CH	12500 ± 160	15227-14106	14684	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	G	OxA-5527	CH	12320 ± 90	14817-14009	14345	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	F	Wk-6677	CH	12210 ± 100	14590-13775	14121	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	J	Wk-6678	CH	11880 ± 80	13951-13877	13689	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	F	Wk-4219	CH	11780 ± 90	13771-13442	13612	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	E middle	Wk-5431	CH	11700 ± 120	13761-13297	13532	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	E lower	Wk-4218	CH	11550 ± 120	13596-13119	13381	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	J	WK-10433	CH	10490 ± 110	12679-12053	12399	Bicho and Haws, 2012
	Lapa dos Picaeiros	MGD	E upper	Wk-4217	CH	10070 ± 80	11979-11306	11623	Bicho and Haws, 2012
70	Las Aguas	MGD	B4	GrA-21524	CH	15030 ± 60	18452-18045	18263	Uzquiano, 2014
	Las Aguas	MGD	B3	GrA-21525	CH	14550 ± 60	17930-17541	17732	Uzquiano, 2014
	Las Aguas	MGD	B1	GrA-21526	B	14440 ± 70	17859-17385	17602	Uzquiano, 2014
71	Las Caldas	SOL	15 (sala I)	Ua-15318	CH	20250 ± 235	25075-23798	24363	Corchón, 1999
	Las Caldas	SOL	16	Ly-2428	B	19510 ± 330	24246-22686	23487	Evin et al., 1983
	Las Caldas	SOL	12b (pasillo)	Ly-2426	B	19480 ± 260	24079-22825	23455	Evin et al., 1983
	Las Caldas	SOL	9 (pasillo)	Ly-2424	B	19390 ± 260	23983-22711	23348	Corchón, 1999
	Las Caldas	SOL	12t (pasillo)	Ly-2425	B	19030 ± 320	23730-22289	22947	Evin et al., 1983
	Las Caldas	SOL	18	Ly-2429	B	19000 ± 280	23589-22347	22907	Evin et al., 1983
	Las Caldas	SOL	7 (pasillo)	Ly-2423	B	18310 ± 260	22717-21492	22142	Jordá et al., 1992
	Las Caldas	SOL	11 (sala I)	UA-15316	B	18305 ± 295	22813-21402	22130	Corchón, 1999
	Las Caldas	SOL	3 (pasillo)	Ly-2421	B	18250 ± 300	22753-21305	22072	Jordá et al., 1992
	Las Caldas	SOL	XIVc (sala II)	Ua-4302	B	17380 ± 215	21605-20444	20996	Corchón, 1999
	Las Caldas	SOL	II-XIVc	Ua-4302	B	17380 ± 215	21605-20444	20993	Corchón, 1994
	Las Caldas	SOL	4 (pasillo)	Ly-2422	B	17050 ± 290	21366-19858	20576	Crochón, 2012
	Las Caldas	SOL	Pasillo 4	Ly-2422	B	17050 ± 290	21366-19858	20576	Corchón, 1999

	Las Caldas	MGD	XIII (sala II)	UA-4301	B	15165 ± 160	18751-18024	18414	Corchón, 1994
	Las Caldas	MGD	XII inf (sala II)	Ua-4300	B	14835 ± 130	18369-17715	18053	Crochón, 2012
	Las Caldas	MGD	XII (sala II)	Ua-2735	B	14495 ± 140	17997-17276	17661	Crochón, 2012
	Las Caldas	MGD	XI (sala II)	Ua-2734	B	13755 ± 120	17012-16254	16626	Crochón, 2012
	Las Caldas	MGD	VIc (sala II)	Ua-10190	B	13650 ± 140	16940-16077	16476	Crochón, 2012
	Las Caldas	MGD	IV/III (sala II)	Ly-2427	B	13400 ± 150	16585-15690	16123	Crochón, 2012
	Las Caldas	MGD	IIIb-IIIc (sala II)	Ua-10191	B	13185 ± 155	16244-15320	15823	Crochón, 2012
	Las Caldas	MGD	II (sala II)	Ua-10192	B	12960 ± 190	16099-14885	15500	Crochón, 2012
	Las Caldas	MGD	I	Ua-10193	B	12595 ± 125	15284-14260	14871	Corchón, 1995
	Las Caldas	MGD	II (sala II)	Ua-10194	B	12590 ± 120	15268-14270	14866	Corchón, 1995
72	Legintxiki	SOL	II	-	-	17025 ± 110	20846-20212	20534	Nuin, 1996
	Legintxiki	MGD	Ia	Ua-3397	B	14865 ± 140	18428-17731	18087	Nuin, 1996
73	Legunova	MGD	q	GrA-22089	CH	12500 ± 90	15107-14241	14705	Tejero et al., 2013
	Legunova	MGD	q	GrA-27846	CH	11240 ± 60	13240-12997	13107	Tejero et al., 2013
74	Llonín	SOL	IV	OxA-22698	B	19480 ± 110	23798-23087	23465	Aura et al., 2012b
	Llonín	SOL	IV	OxA-22700	B	19300 ± 110	23560-22934	23245	Aura et al., 2012b
75	Los Toros	MGD	a2/b	GrA-27867	B	14410 ± 70	17823-17331	17564	Utrilla et al., 2010
76	Malladetes	GRA	Inf	Beta-155607	CH (P. sylvestris)	25120 ± 240	29733-28640	29167	Villaverde & Roman, 2004
	Malladetes	SOL	VI	KN-I/915	CH	19370 ± 105	23625-22999	23321	Fortea & Jordá, 1976
77	Maltravieso	SOL	A	Poz-30460	CH	17930 ± 100	21993-21408	21720	Canals et al., 2010
	Maltravieso	SOL	A	Poz-30469	CH	17840 ± 90	21881-21328	21616	Canals et al., 2010
78	Martinarri	MGD	103	GrA-45940	B	11890 ± 50	13797-13561	13693	Soto et al., 2015
79	Molí del Salt	MGD	B2	GifA-101038	CH	12510 ± 100	15129-14230	14722	Fullola et al., 2012
	Molí del Salt	MGD	B1	GifA-101037	CH	11940 ± 100	14052-13553	13780	Fullola et al., 2012
	Molí del Salt	MGD	A	Beta-284213	CH	11800 ± 50	13749-13482	13636	Vaquero et al., 2012
	Molí del Salt	MGD	A	Beta-284214	CH	10940 ± 50	12945-12707	12789	Vaquero et al., 2012
80	Montlleó	MGD	Sect. B	OaX-X-2234-52	B	16900 ± 110	20662-20071	20381	Mangado et al., 2009
	Montlleó	MGD	Sect. C	OxA-X-2234-5	CH	15550 ± 140	19125-18517	18807	Mangado et al., 2009
	Montlleó	MGD	Sect. B	OxA-9017	CH	15440 ± 80	18871-18537	18707	Mangado et al., 2009
81	Nerja	GRA	V (11)	GifA-102023	CH (Pinus)	24730 ± 250	29375-28217	28775	Jordá & Aura, 2008
	Nerja	GRA	V ((13c)	Beta-131576	CH (Pinus)	24480 ± 110	28788-28233	28531	Arribas et al., 2004
	Nerja	GRA	V (13)	Beta-189080	CH (P. cf. pinea)	24200 ± 200	28657-27826	28236	Jordá & Aura, 2006

	Nerja	SOL	V (9)	GifA-102021	CH (Pinus)	21140 ± 190	25863-25042	25475	Aura et al., 2006
	Nerja	SOL	V (8c)	UBAR-98	CH	17940 ± 200	22279-21165	21720	Jordá et al., 1990
	Nerja	SOL	V (8i)	UBAR-157	CH	15990 ± 260	19938-18752	19303	Jordá et al., 1990
	Nerja	MGD	VI (N.8)	GAK-8966	CH	13780 ± 340	17619-15727	16673	Pellicer & Acosta, 1997
	Nerja	MGD	VI (N.9)	GAK-8976	CH	13330 ± 270	16836-15224	16020	Pellicer & Acosta, 1997
	Nerja	MGD	M (16)	UGRA-98	CH	12270 ± 220	15130-13721	14340	Jordá et al., 1990
	Nerja	MGD	V (6)	UBAR-155	CH	12190 ± 150	14818-13725	14127	Jordá et al., 1990
	Nerja	MGD	V (7)	UBAR-156	CH	12130 ± 130	14576-13628	14010	Jordá et al., 1990
	Nerja	MGD	V (5)	Ubar-154	CH	11930 ± 160	14159-13439	13780	Jordá et al., 1990
	Nerja	MGD	M (16)	UGRA-147	CH	11930 ± 150	14124-13456	13777	Jordá et al., 1990
	Nerja	MGD	M (16e)	Ubar-97	CH	11850 ± 190	14138-13291	13696	Jordá et al., 1990
	Nerja	MGD	T-17	Beta-193273	CH	11810 ± 40	13754-13491	13646	Sanchidrián & Marquez, 2005
82	Parco	MGD	XI	GofA-95552	CH	14300 ± 150	17843-16991	17409	Fullola et al., 2012
	Parco	MGD	VII	GifA-95542	CH	14040 ± 140	17480-16591	17055	Fullola et al., 2012
	Parco	MGD	VI	AA-8644,T459	CH	13950 ± 150	17396-16430	16915	Bergadá, 1998
	Parco	MGD	V	GifA-95565	CH	13890 ± 130	17232-16370	16825	Bergadá, 1998
	Parco	MGD	VII	GifA-95547	CH	13720 ± 140	17020-16170	16577	Fullola et al., 2012
	Parco	MGD	II-XII	OxA-23650	CH (Pinus)	13475 ± 50	16430-16018	16216	Fullola et al., 2012
	Parco	MGD	II	OxA-10798	CH	13175 ± 60	16055-15617	15833	Mangado et al., 2006
	Parco	MGD	III	OxA-17730	CH	13095 ± 55	15949-15433	15711	Fullola et al., 2012
	Parco	MGD	III	GifA-95564	CH	13070 ± 140	16066-15235	15652	Bergadá, 1998
	Parco	MGD	IV	AA-8643, T458	B	12900 ± 130	15850-15043	15434	Fullola et al., 2012
	Parco	MGD	II	OxA-10797	CH	12460 ± 60	15004-14235	14612	Fullola et al., 2012
	Parco	MGD	Ib	OxA-8656	CH	11430 ± 60	13412-13134	13270	Bergadá, 1998
	Parco	MGD	Ic	OxA-8657	CH	11270 ± 90	13316-12944	13137	Bergadá, 1998
83	Parpalló	SOL	T6	OxA-22651	B	19020 ± 100	23228-22562	22896	Zilhão, 2010
	Parpalló	SOL	T11	OxA-18510	B (Capra pyrenaica)	18510 ± 100	22615-22089	22386	Davidson, 1974
	Parpalló	SOL	4.25-4.00	Birm-521	B	17900 ± 340	22431-20798	21647	Davidson, 1974
84	Peña Capón	GRA	4	Beta-246878	T	21220 ± 120	25817-25263	25566	Alcaraz-Castaño et al., 2012
	Peña Capón	GRA	2	Beta-246880	T	19930 ± 110	24281-23670	23982	Alcaraz-Castaño et al., 2012
	Peña Capón	SOL	4	Beta-246878	T	21220 ± 120	25-817-25263	25566	Alcaraz-Castaño et al., 2012
	Peña Capón	SOL	3	Beta-246879	T	19980 ± 110	24335-23733	24039	Alcaraz-Castaño et al., 2012

85	Peña de Estevanvela	MGD	VI	Beta-228871	CH	14450 ± 80	17881-17380	17615	Cacho et al., 2012
	Peña de Estevanvela	MGD	VI	Beta-197378	CH	14200 ± 50	17486-17099	17291	Cacho et al., 2012
	Peña de Estevanvela	MGD	IV	Beta-290780	CH	12530 ± 60	15118-14370	14809	Cacho et al., 2012
	Peña de Estevanvela	MGD	III	Beta-232939	CH	12440 ± 50	14934-14217	14561	Cacho et al., 2012
	Peña de Estevanvela	MGD	III	Beta-232940	CH	12070 ± 40	14062-13772	13912	Cacho et al., 2012
	Peña de Estevanvela	MGD	II	Beta-197376	OS	11700 ± 70	13723-13405	13524	Cacho et al., 2012
	Peña de Estevanvela	MGD	II	Beta-155116	CH	11400 ± 120	13466-13055	13247	Cacho et al., 2012
	Peña de Estevanvela	MGD	I	Beta-287754	CH	11330 ± 50	13279-13083	13178	Cacho et al., 2012
	Peña de Estevanvela	MGD	I	Beta-290779	CH	10640 ± 60	12715-12435	12618	Cacho et al., 2012
86	Peña del Diablo 1	MGD	2	GrN-21014	CH	10760 ± 140	13013-12250	12674	Cacho et al., 2012
87	Peña del Perro	MGD	2c	GrN-20962	CH	12140 ± 180	14799-13565	14066	Straus et al., 2002
88	Praile Aitz	GRA	VI	GrA-28025	B	25320 ± 140	29766-28974	29375	Peñalver, 2014
	Praile Aitz	GRA	VI	Beta-341896	B (Cervus elaphus)	22900 ± 110	27492-27003	27259	Peñalver, 2014
	Praile Aitz	SOL	V (Vestíbulo)	GrA-24687	B	19330 ± 150	23673-22886	23278	Peñalver, 2014
	Praile Aitz	SOL	V (Vestíbulo)	Beta-162879	B	17850 ± 70	21859-21390	21633	Peñalver, 2014
	Praile Aitz	MGD	IV (vestíbulo)	GrA-24688	B	15810 ± 110	19391-18824	19075	Peñalver, 2014
	Praile Aitz	MGD	IV (vestíbulo)	GrA-20462	B	14700 ± 100	18149-17612	17887	Peñalver, 2014
	Praile Aitz	MGD	III (vestíbulo)	Beta-341897	B (Raginfer tarandus)	12920 ± 50	15664-15434	15434	Peñalver, 2014
89	Rambla Perea	SOL	-	-	CH (Juniperus sp.)	19180 ± 90	23435-22842	23110	Zilhao et al., 2010
90	Rascaño	MGD	5	BM-1455	-	16433 ± 130	20152-19512	19827	González-Echegaray & Barandiarán, 1981
	Rascaño	MGD	4	BM-1453	B	15988 ± 195	19772-18841	19292	González-Echegaray & Barandiarán, 1981
	Rascaño	MGD	3	BM-1452	-	15173 ± 160	18758-18032	18423	González-Echegaray & Barandiarán, 1981
	Rascaño	MGD	2.3	BM-1451	-	12896 ± 137	15871-15001	15419	González-Echegaray & Barandiarán, 1981
	Rascaño	MGD	2.1	BM-1450	-	12282 ± 164	14983-13780	14331	González-Echegaray & Barandiarán, 1981
91	Ratla del Bubo	SOL	II	Ly-5219	CH	17360 ± 180	21481-20497	20960	Soler et al., 1990
	Ratla del Bubo	SOL	II	Ly-5809	CH	17360 ± 80	21226-20680	20943	Soler et al., 1990
92	Salemas	SOL	VS	ICEN-376	B	20250 ± 320	25237-23616	24384	Zilhão, 1997
	Salemas	SOL	VS	ICEN-385	B	19220 ± 300	23847-22479	23159	Zilhão, 1997
93	Santa Catalina	MGD	III	Ua-13877	B	12424 ± 90	15004-14145	14543	Berganza, 1992
	Santa Catalina	MGD	II	Ua-13876	-	12405 ± 90	14974-14123	14508	Berganza, 1992
94	Santa Maira	SOL	II-12	Beta-317412	CH (P. nigra/silvestris)	19910 ± 100	24242-23664	23960	Aura & Jordá, 2012
95	Santimamiñe	MGD	Csn-Carm 41	Beta-240904	B (Red deer)	14670 ± 70	18047-17641	17855	López-Quintana & Guenaga Lizau, 2011

	Santimamiñe	MGD	Csn-Carm 41	Beta-240905	B	14650 ± 80	18039-17603	17830	López-Quintana & Guenaga Lizau, 2011
	Santimamiñe	MGD	Slnc 20	Beta-240902	B (Red deer)	12790 ± 70	15551-15036	15243	López-Quintana & Guenaga, 2011
96	Socuevas	MGD	V	Beta-312040	B	12040 ± 50	14042-13756	13888	Soto et al., 2015
	Socuevas	MGD	V	Beta-282216	B	11540 ± 50	13467-13281	13378	Soto et al., 2015
	Socuevas	MGD	IV	Beta-282215	B	11530 ± 50	13462-13276	13371	Soto et al., 2015
	Socuevas	MGD	V	Beta-312041	B	11530 ± 50	13462-13276	13371	Soto et al., 2015
97	Sopeña	GRA	III	Beta-198144	B	21020 ± 100	25628-25106	25376	Pinto, 2012
98	Suao	MGD	8	GX-27593	CH	15110 ± 90	18597-18095	18364	Bicho and Haws, 2012
	Suao	MGD	6	GX-27589	CH	14380 ± 90	17817-17228	17526	Bicho and Haws, 2012
	Suao	MGD	9	GX-27594	CH	12590 ± 80	15222-14430	14912	Bicho and Haws, 2012
	Suao	MGD	5	GX-27591	CH	12590 ± 100	15239-14329	14888	Bicho and Haws, 2012
	Suao	MGD	7	GX-27590	CH	12410 ± 80	14954-14138	14511	Bicho and Haws, 2012
	Suao	MGD	7	GX-27592	CH	10900 ± 70	12957-12691	12777	Bicho and Haws, 2012
99	Terra do Manuel	GRA	2s	ETH-6038	CH	21770 ± 210	26482-25651	26020	Zilhão, 1997
100	Tito Bustillo	MGD	1b-c	OxA-6260	B	14550 ± 110	17993-17448	17725	Uzquiano, 2014
	Tito Bustillo	MGD	1a/b	OxA-6258	-	13520 ± 110	16651-15949	16286	Moure, 1997
	Tito Bustillo	MGD	1b-c	OxA-6259	-	12850 ± 90	15677-15086	15341	Moure, 1997
101	Urtiaga	MGD	F inf.	GrN-5817	B	17050 ± 140	20938-20178	20565	Altuna, 1972
102	Valdavara 1	MGD	4	Beta-257849	B	15120 ± 70	18580-18149	18380	Alonso et al., 2012
103	Valdavara 2	MGD	4	Beta-235726	B	14630 ± 70	18004-17604	17810	Alonso et al., 2012
104	Valdavara 3	MGD	5	Beta-235728	B	13770 ± 70	16934-16364	16646	Alonso et al., 2012
105	Vale Almoinha	SOL	5SIII	ICEN-71	CH	20380 ± 150	25024-24095	24509	Zilhão, 1997
	Vale Almoinha	SOL	5AIII	Oxa-5676	CH	19940 ± 180	24415-23547	23989	Zilhão, 1997
106	Vale Boi	GRA	4	Wk-24762	CH	24769 ± 180	29264-28407	28808	Bicho, 2008
	Vale Boi	GRA	3	Wk-13686	B	22470 ± 235	27293-26185	26768	Bicho et al., 2010
	Vale Boi	GRA	D4	Wk-26803	S	21896 ± 186	26559-25799	26130	Bicho et al., 2010
	Vale Boi	GRA	3	Wk-16415	S	21830 ± 195	26512-25731	26071	Bicho, 2008
	Vale Boi	SOL	C4	Wk-26800	CH	20620 ± 160	25290-24374	24831	Cascalheira, 2013
	Vale Boi	SOL	D2	Wk-26802	CH	20570 ± 158	25241-24327	24775	Bicho et al., 2010
	Vale Boi	SOL	B1	Wk-17840	CH	20340 ± 160	24996-24035	24455	Bicho, 2008
	Vale Boi	SOL	C1	Wk-24763	CH	19533 ± 92	23839-23189	23536	Bicho, 2008
	Vale Boi	SOL	B6	Wk-25765	S	18859 ± 90	22970-22478	22716	Bicho, 2008

	Vale Boi	SOL	Vertiente 2	Wk-12130	B	18410 ± 165	22583-21857	22258	Bicho & Stiner, 2006
	Vale Boi	SOL	Vertiente 2	Wk-12131	CH	17634 ± 110	21682-20968	21324	Bicho, 2008
	Vale Boi	MGD	Z1	Wk-31088	Tooth	15660 ± 86	19125-18726	18903	Pereira et al., 2016
107	Vergara	MGD	D	GrN.A-8403	T (Horse)	14000 ± 100	17355-16623	16999	Cacho et al., 2012
108	Zatoya	MGD	IIB	GrN-23998	B	12205 ±90	14512-13775	14106	Barandiarán & Cava, 2008
	Zatoya	MGD	II	Ly-1400	B	11840 ± 240	14355-13124	13704	Barandiarán & Cava, 1994
	Zatoya	MGD	II	Ly-1399	-	11480 ± 270	13841-12743	13328	Barandiarán & Cava, 1994

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Figure 1

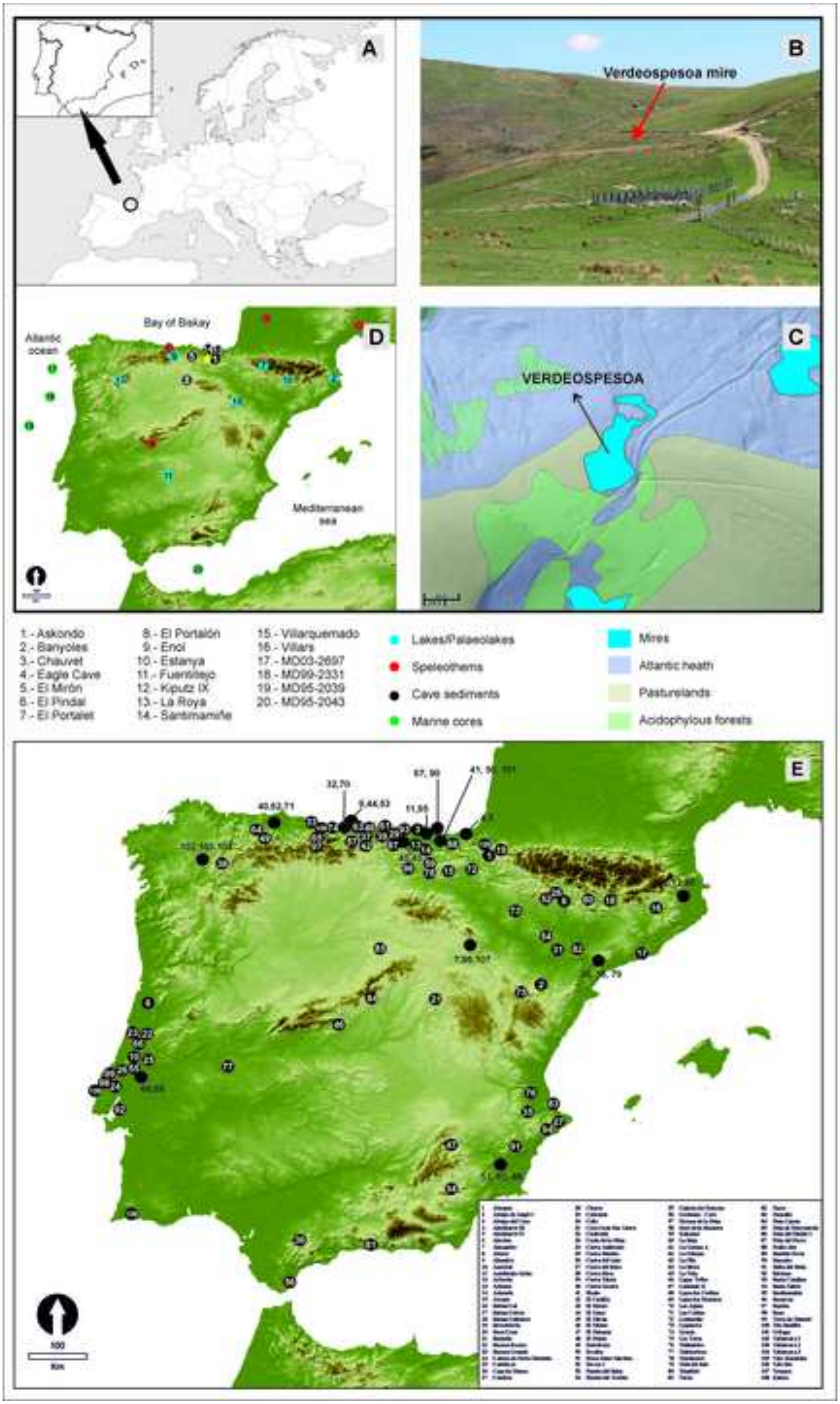

A
B
Verdeospesoa mire
C
VERDEOSPESOA
D
Bay of Biskay
Atlantic ocean
Mediterranean sea
1.- Askondo
2.- Banyoles
3.- Chauvet
4.- Eagle Cave
5.- El Mirón
6.- El Pindal
7.- El Portalet
8.- El Portalón
9.- Enol
10.- Estanya
11.- Fuentillejo
12.- Kiputz IX
13.- La Roya
14.- Santimamiñe
15.- Villarquemado
16.- Villars
17.- MD03-2697
18.- MD99-2331
19.- MD95-2039
20.- MD95-2043
Lakes/Palaeolakes
Speleothems
Cave sediments
Marine cores
Mires
Atlantic heath
Pasturelands
Acidophylous forests
E
40,62,71
32,70
9,44,53
11,55
67, 90
41, 95, 101
102, 103, 105
7,56,107
100
Km

Figure 2

Click here to access/download;Figure;Fig. 2.jpg

	N.	Site	Location	Archive	Altitude (m. asl)	Proxy	References
Terrestrial	1	Askondo	Cantabrian Region	Cave sediments	248	Small vertebrates	García-Ibaibarriaga et al., 2015
	2	Banyoles	Pyrenean area	Lake sediments	173	Pollen, Calcite $\delta^{18}O$, $\delta^{13}C$	Pérez-Obiol and Julià, 1994; Valero-Garcés et al., 1998
	3	Chauvet	Ardèche	Speleothems	240	Calcite $\delta^{18}O$, $\delta^{13}C$	Genty et al., 2006
	4	Eagle Cave	Central Iberia	Speleothems	500	Calcite $\delta^{18}O$	Domínguez-Villar et al., 2013
	5	El Mirón	Cantabrian Region	Cave sediments	250	$\delta^{13}C$, $\delta^{15}N$, Small mammals, Pollen	Cuenca-Bescós et al., 2009, 2012; Straus et al. 2011, Stevens et al., 2014
	6	El Pindal	Cantabrian Region	Speleothems	24	Calcite $\delta^{18}O$, $\delta^{13}C$	Moreno et al., 2010a
	7	El Portalet	Pyrenean area	Lake sediments	1802	Pollen	González-Sampériz et al., 2006
	8	El Portalón	Northern Plateau	Cave sediments	1040	Small vertebrates	López-García et al., 2010
	9	Enol	Cantabrian Region	Lake sediments	1075	Calcium content	Moreno et al., 2010b
	10	Estanya	Pyrenean area	Lake sediments	670	Lithology	Morellón et al., 2009
	11	Fuentillejo	Southern Meseta	Lake sediments	600	Lithology, Pollen	Vegas et al. 2010
	12	Kiputz IX	Cantabrian Region	Cave sediments	350	$\delta^{13}C$, $\delta^{15}N$ bone collagen	Castaños et al., 2014
	13	La Roya	NW Iberia	Lake sediments	1608	Pollen, Chironomids	Muñoz-Sobrino et al., 2013
	14	Santimamiñe	Cantabrian Region	Cave sediments	150	Small vertebrates	Rofes et al., 2014
	15	Villarquemado	Central Iberia	Lake sediments	980	Pollen, Lithology	González-Sampériz et al., 2013
	16	Villars	Dordogne	Speleothems	175	Calcite $\delta^{18}O$, $\delta^{13}C$	Genty et al., 2006
Marine	17	MD03-2697	Iberian margin	Marine sediments	-2164	Pollen	Naughton et al., 2007
	18	MD99-2331	Iberian margin	Marine sediments	-2110	Pollen	Naughton et al., 2007
	19	MD95-2039	Iberian margin	Marine sediments	-3381	Pollen	Roucoux et al., 2001
	20	MD95-2043	Alboran Sea	Marine sediments	-1108	Pollen	Sánchez-Goñi et al., 2002; Fletcher and Sánchez Goñi, 2008

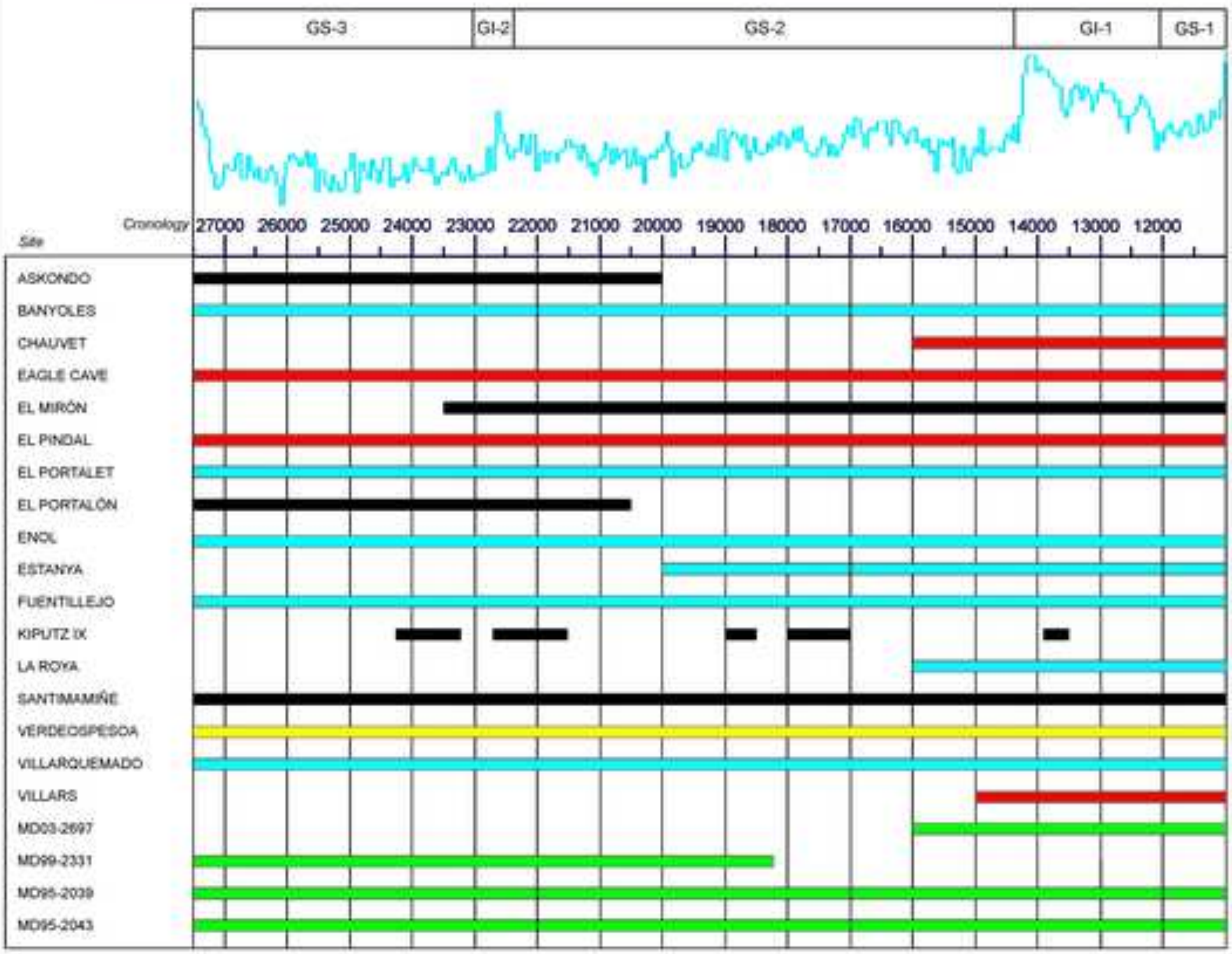


Figure 3 Click here to access/download;Figure;Fig. 3.pdf

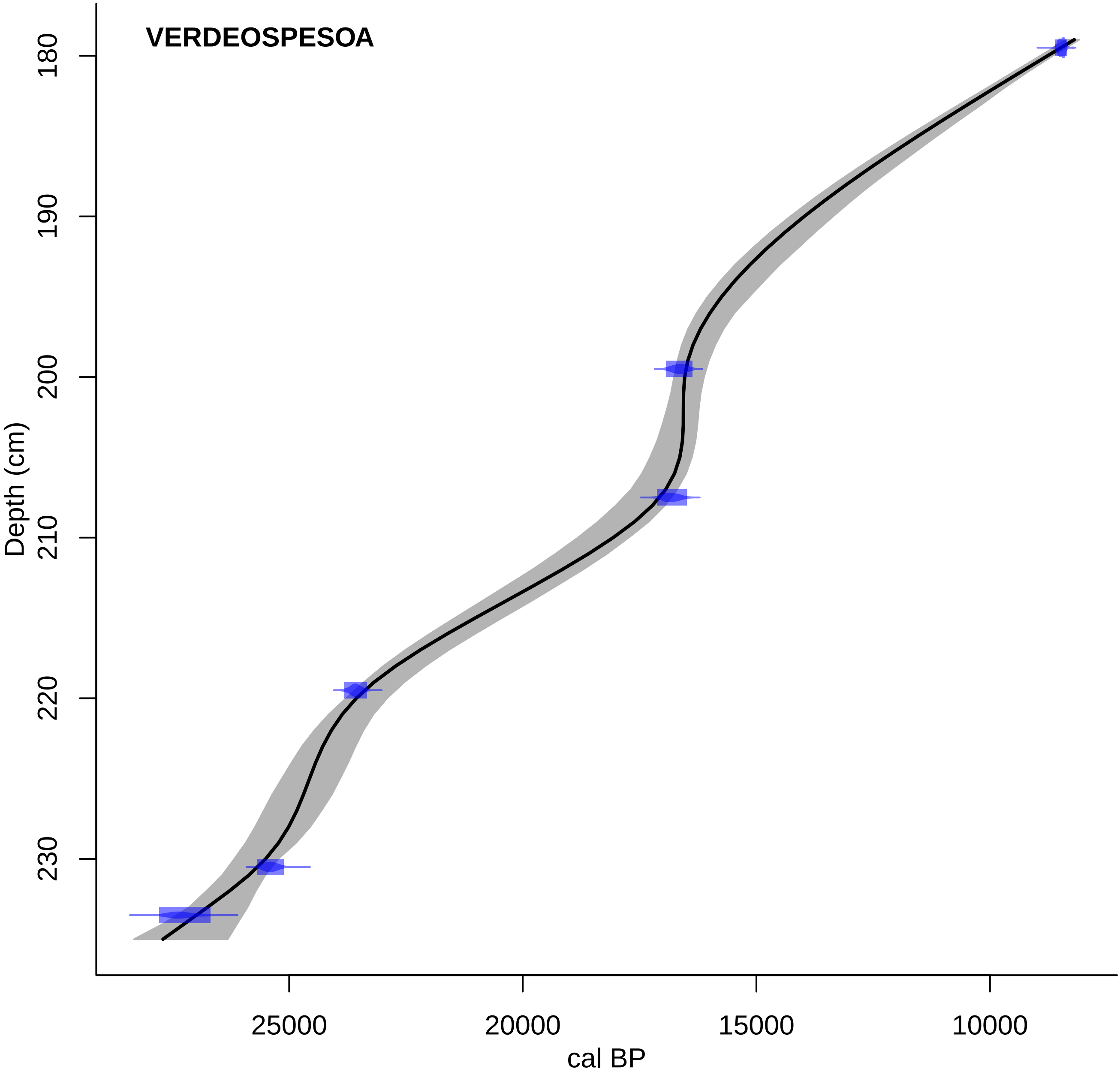


Figure 4

Click here to access/download;Figure;Fig. 4.jpg

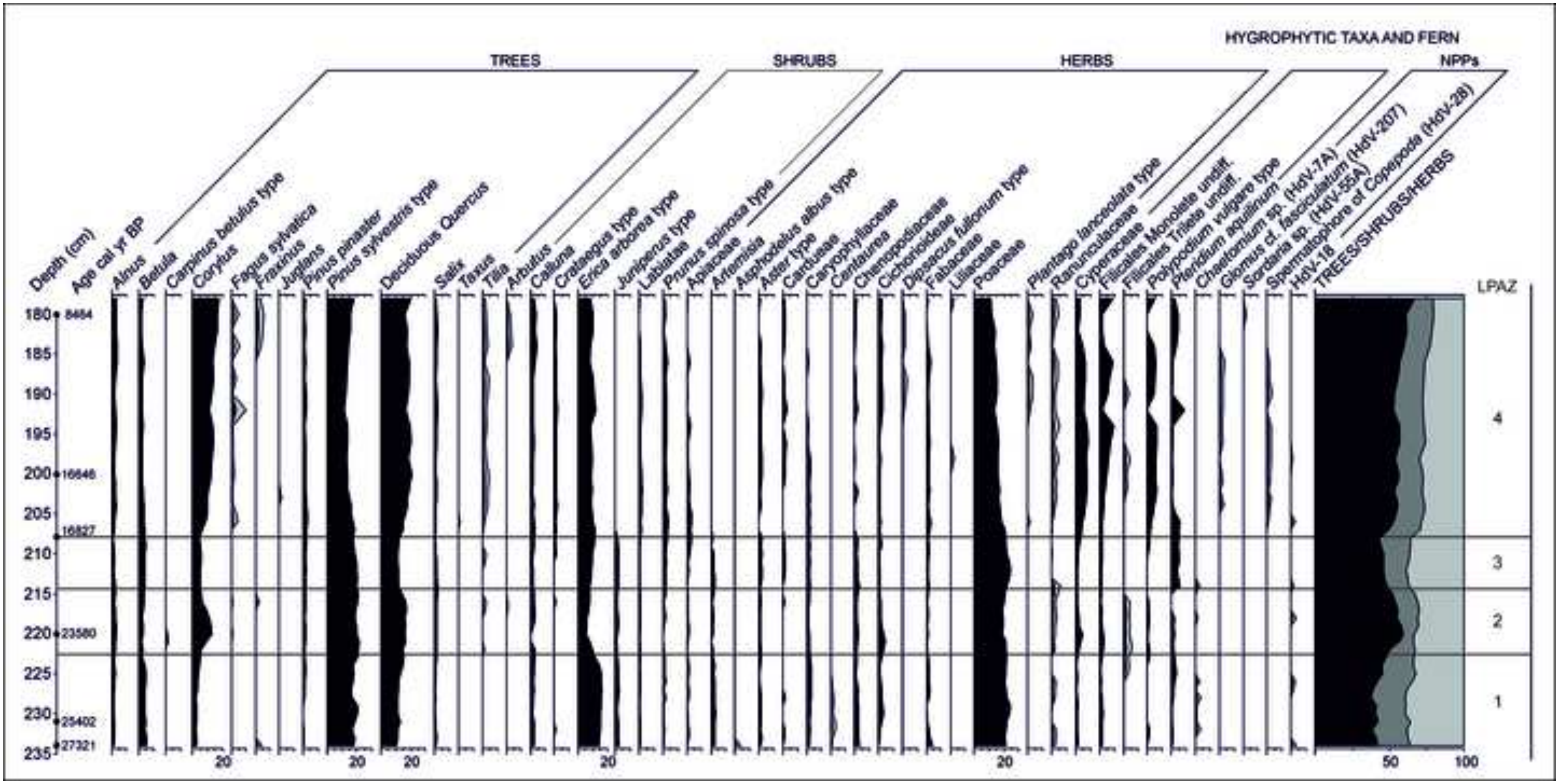
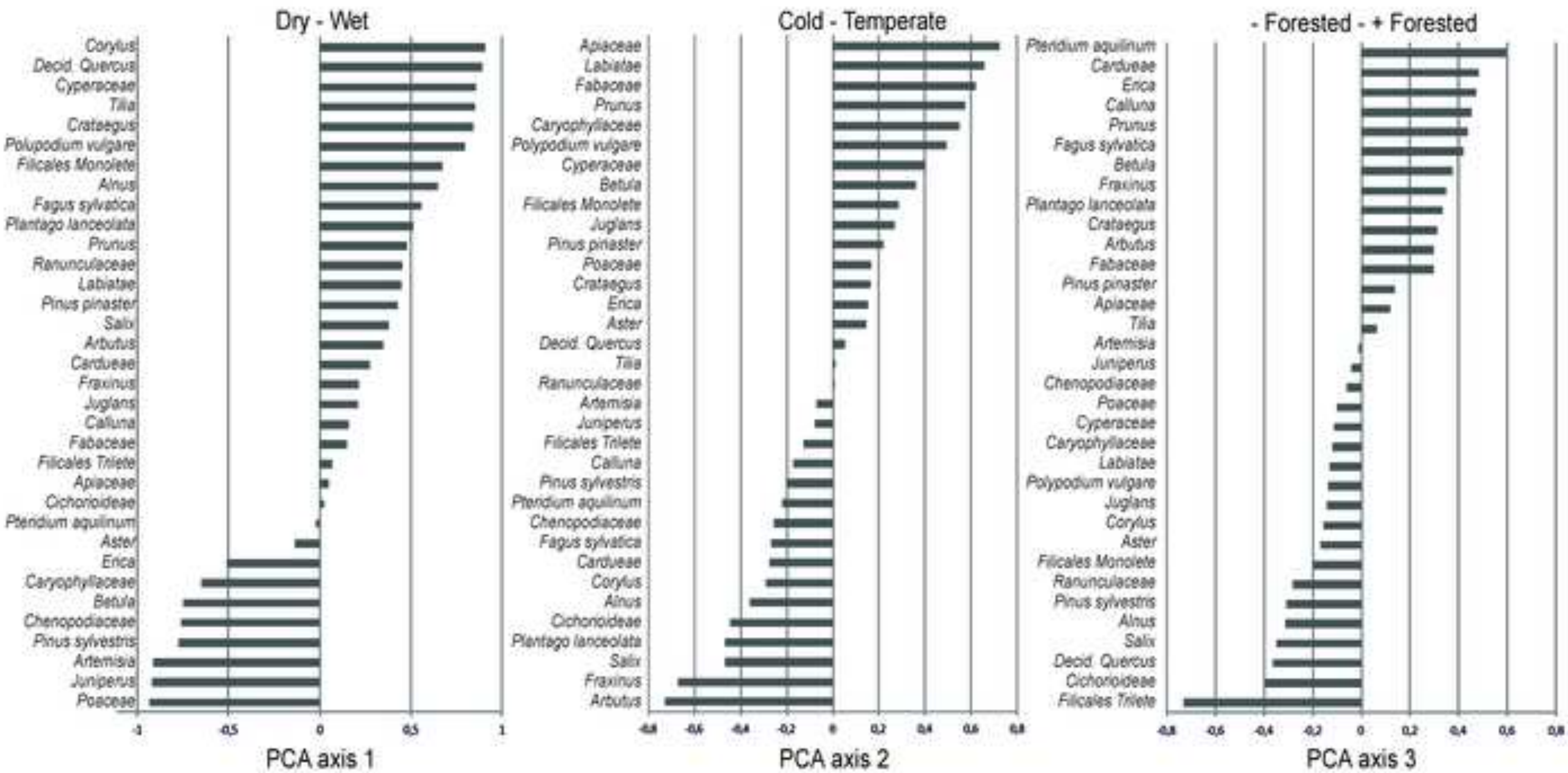
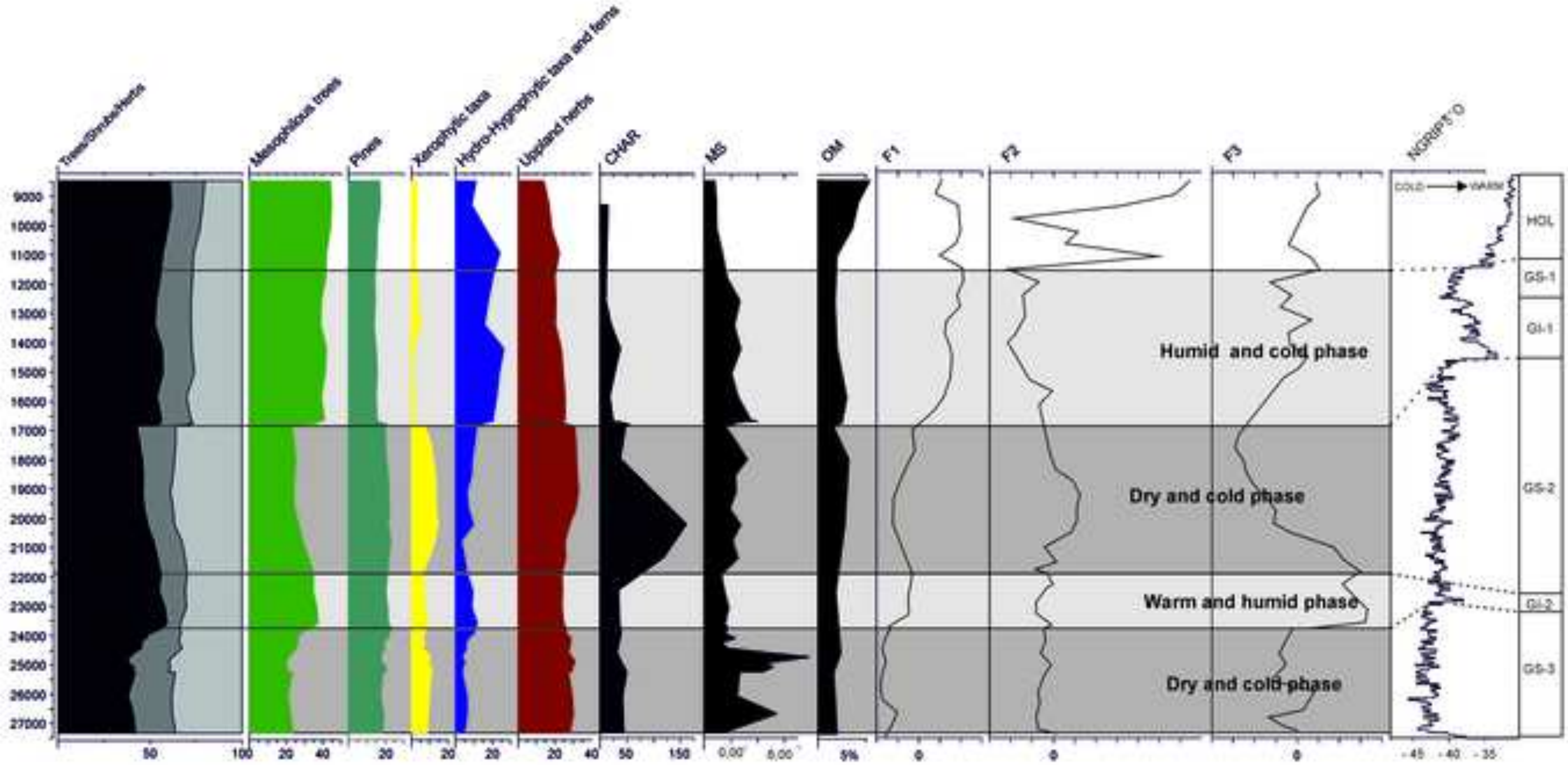


Figure 5



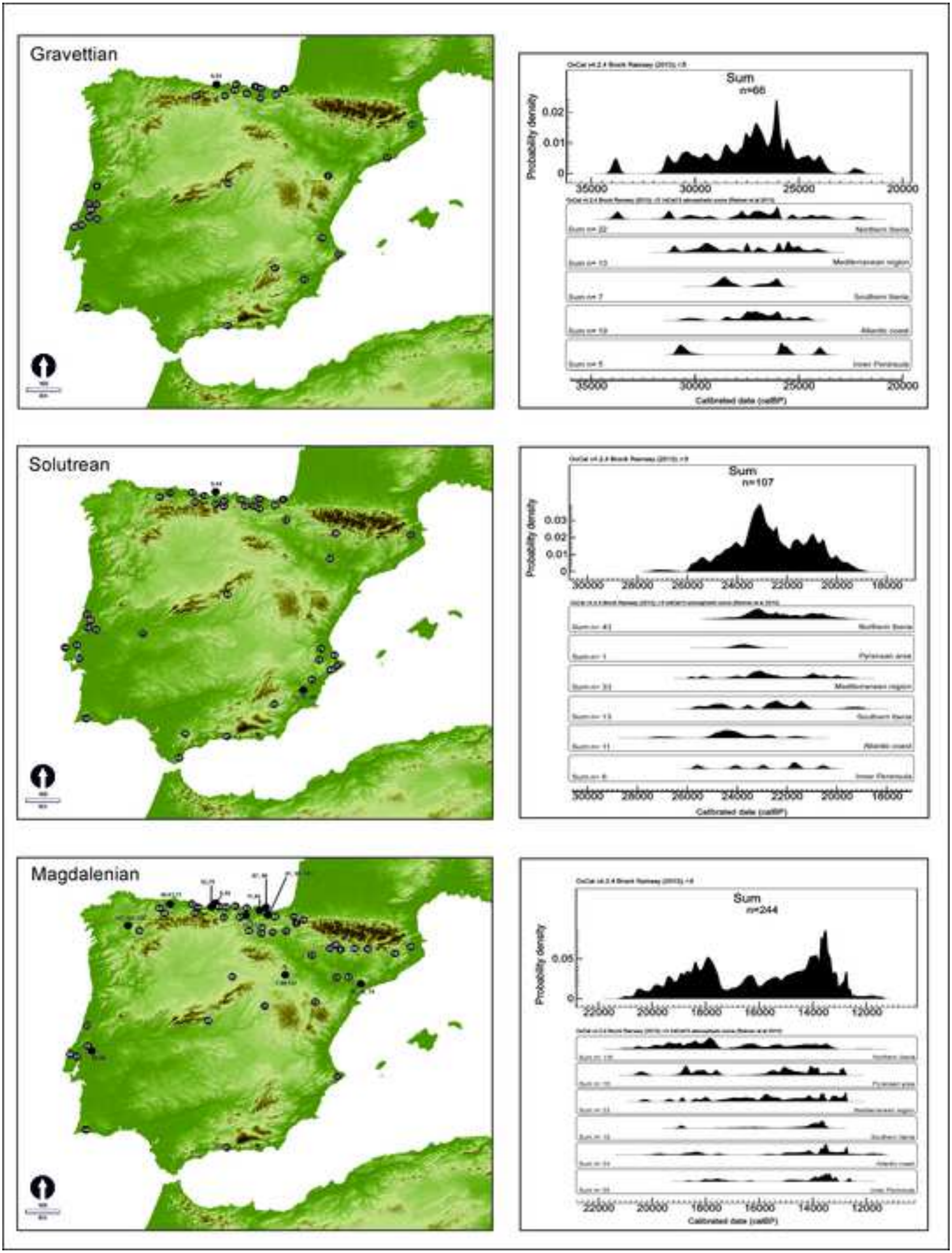
Dry - Wet
Corylus
Decid. Quercus
Cyperaceae
Tilia
Crataegus
Polupodium vulgare
Filicales Monolete
Alnus
Fagus sylvatica
Plantago lanceolata
Prunus
Ranunculaceae
Labiatae
Pinus pinaster
Salix
Arbutus
Cardueae
Fraxinus
Juglans
Calluna
Fabaceae
Filicales Trilete
Apiaceae
Cichorioideae
Pteridium aquilinum
Aster
Erica
Caryophyllaceae
Betula
Chenopodiaceae
Pinus sylvestris
Artemisia
Juniperus
Poaceae
-1
-0,5
0
0,5
1
PCA axis 1
Cold - Temperate
Apiaceae
Labiatae
Fabaceae
Prunus
Caryophyllaceae
Polypodium vulgare
Cyperaceae
Betula
Filicales Monolete
Juglans
Pinus pinaster
Poaceae
Crataegus
Erica
Aster
Decid. Quercus
Tilia
Ranunculaceae
Artemisia
Juniperus
Filicales Trilete
Calluna
Pinus sylvestris
Pteridium aquilinum
Chenopodiaceae
Fagus sylvatica
Cardueae
Corylus
Alnus
Cichorioideae
Plantago lanceolata
Salix
Fraxinus
Arbutus
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4
0,6
0,8
PCA axis 2
- Forested - + Forested
Pteridium aquilinum
Cardueae
Erica
Calluna
Prunus
Fagus sylvatica
Betula
Fraxinus
Plantago lanceolata
Crataegus
Arbutus
Fabaceae
Pinus pinaster
Apiaceae
Tilia
Artemisia
Juniperus
Chenopodiaceae
Poaceae
Cyperaceae
Caryophyllaceae
Labiatae
Polypodium vulgare
Juglans
Corylus
Aster
Filicales Monolete
Ranunculaceae
Pinus sylvestris
Alnus
Salix
Decid. Quercus
Cichorioideae
Filicales Trilete
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4
0,6
0,8
PCA axis 3

Figure 6



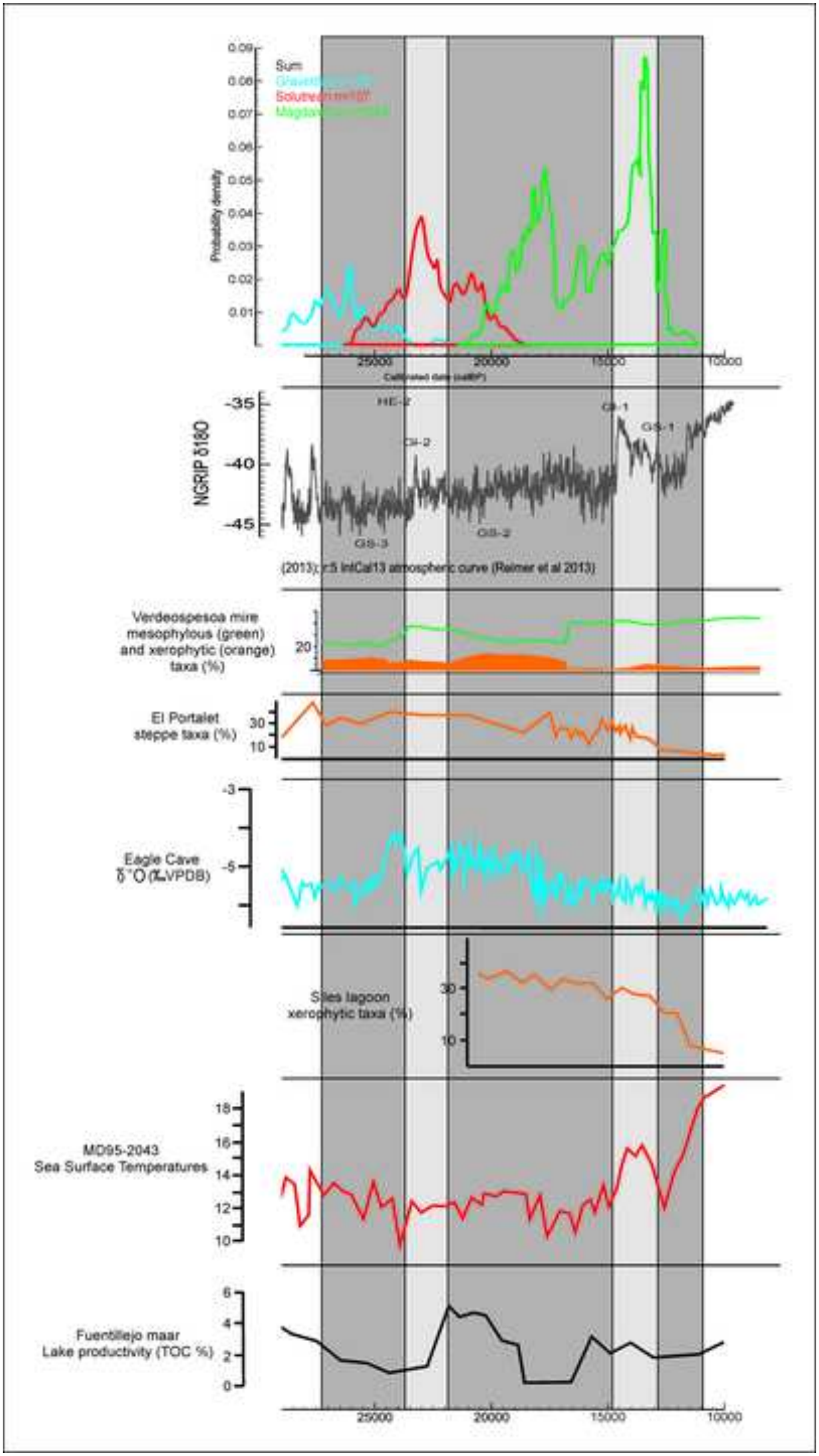
Trees/Shrubs/Herbs
Mesophilous trees
Pines
Xerophytic taxa
Hydro-Hygrophytic taxa and ferns
Upland herbs
CHAR
MS
OM
F1
F2
F3
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
21000
22000
23000
24000
25000
26000
27000
COLD
WARM
HOL
GS-1
GI-1
GS-2
GI-2
GS-3
Humid and cold phase
Dry and cold phase
Warm and humid phase
Dry and cold phase
50
100
20
40
20
20
20
20
40
50
150
0,00
5%
0
0
0
-45
-40
-35

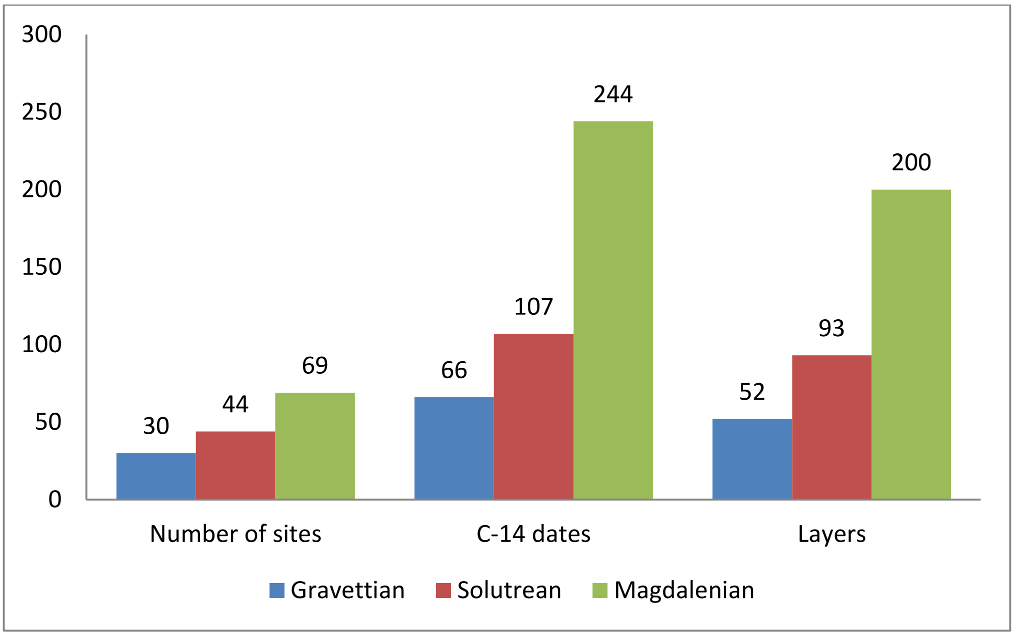
Figure 7



Gravettian
Sum
n=66
Probability density
0.02
0.01
0
35000
30000
25000
20000
Calibrated date (calBP)
Solutrean
Sum
n=107
Probability density
0.03
0.02
0.01
0
30000
28000
26000
24000
22000
20000
18000
Calibrated date (calBP)
Magdalenian
Sum
n=244
Probability density
0.05
0
22000
20000
18000
16000
14000
12000
Calibrated date (calBP)

Figure 8 Click here to access/download;Figure;Fig. 8.jpg




300
250
200
150
100
50
0
30
44
69
66
107
244
52
93
200
Number of sites
C-14 dates
Layers
Gravettian
Solutrean
Magdalenian

Depth Interval (cm)	Lab. Code	Material of sample	Age uncalibrated BP	Age cal BP	Median age (cal yr. BP)
179-180	Poz-63214	Bulk	7660 ± 80	8598-8341	8464
199-200	Poz-63217	Bulk	13770 ± 70	16934-16364	16646
207-208	Poz-66421	Plant remains	13890 ± 90	17133-16484	16827
219-220	CNA-2391	Bulk	19570 ± 60	23834-23332	23580
230-231	Poz-63215	Bulk	21050 ± 120	25684-25102	25402
233-234	CNA-2392	Plant remains	23050 ± 300	27777-26640	27321

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In relation with the submission of the manuscript entitled: LATE PLEISTOCENE ENVIRONMENTAL DYNAMICS AND HUMAN OCCUPATION IN SOUTHWESTERN EUROPE

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.
We understand that the Corresponding Author is the sole contact for the Editorial process. He/She is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

Sincerely,

On behalf of all authors

Sebastián Pérez Díaz

(corresponding author)