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Climatic and environmental conditions from the Neolithic to the Bronze Age (7000–3000 BP) in the Iberian Peninsula assessed using small-mammal assemblages

Les conditions climatiques et environnementales du Néolithique à l'âge du bronze (7000–3000 BP) dans la péninsule Ibérique évaluées en utilisant les petits mammifères

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A B S T R A C T

We have analyzed the palaeoenvironment and palaeoclimate of the beginning of the Holocene in the Iberian Peninsula on the basis of the small-mammal assemblages from three sites within the geography of the Iberian Peninsula: Mirador (Sierra de Atapuerca, Burgos), Colomera (Sant Esteve de la Sarga, Lleida) and Valdavara-1 (Becerreá, Lugo). These associations reveal that the palaeoenvironment was more humid than today in the sites under study, and the landscape was dominated by woodland and woodland margins in all the studied layers. Further, the climatic conditions were stable, but with winters colder than at present, above all in the Mediterranean area. Finally, our data have been compared with other environmental and climatic proxies, showing that human activities exerted little impact on the palaeoenvironmental conditions that occurred from 7000 to 3000 BP in the Iberian Peninsula.

R É S U M É

Nous avons analysé le paléoenvironnement et le paléoclimat du début de l'Holocène dans la péninsule Ibérique, sur la base des assemblages de petits mammifères provenant de trois sites situés dans celle-ci : Mirador (Sierra de Atapuerca), Colomera (Sant Esteve de la Sarga, Lleida) et Valdavara-1 (Becerreá, Lugo). Ces associations révèlent que le paléoenvironnement était plus humide qu'aujourd'hui dans les sites étudiés, et le paysage dominé par des forêts et marges de forêts dans tous les niveaux étudiés. En outre, les conditions

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climatiques étaient plus ou moins stables, mais avec des hivers plus froids qu'à l'heure actuelle, surtout dans la région méditerranéenne. Finalement, nos données ont été comparées avec d'autres, environnementales et climatiques, ce qui a permis d'établir que les activités humaines avaient peu d'influence sur les conditions paléoenvironnementales entre 7000 à 3000 BP dans la péninsule Ibérique.

1. Introduction

The Holocene climate in the Iberian Peninsula is known mainly from different scientific studies (palaeobotany, sedimentology, mineralogy, isotopes, solar variability), which can obtain new palaeoenvironmental and palaeoclimatic data either from continental records alone (Bastida et al., 2013; Carrión, 2002; Carrión et al., 2010a,b; Domínguez-Villar et al., 2011; Fletcher and Sánchez-Goñi, 2008; Fletcher and Zielhofer, 2013; García-Amorena et al., 2011; Gómez-Paccard et al., 2013; Jiménez-Moreno et al., 2013; López Sáez et al., 2005; López-Merino et al., 2012; Luzón et al., 2011; Pérez-Lambán et al., 2014; Perez-Obiol et al., 2011; Sancho et al., 2011) or from continental records in conjunction with marine records (Cacho et al., 2001; Fletcher and Zielhofer, 2013; Mayewski et al., 2004). This period is characterized by major changes in the vegetation and rapid oscillations in the climate (Cacho et al., 2001; Domínguez-Villar et al., 2012; Fletcher and Zielhofer, 2013; Jiménez-Moreno et al., 2013; Mayewski et al., 2004).

However, the Holocene is understudied in the Iberian Peninsula, especially in terms of small-mammal studies, and for this reason we want to provide a broader reference framework for interpreting the Holocene in the region (Fig. 1).

Recently, studies of small mammals in the Holocene have started to become more abundant. These studies have involved palaeoenvironmental and palaeoclimatic reconstructions (Bañuls-Cardona and López-García, 2009; Bañuls-Cardona et al., 2013; Cuenca-Bescós et al., 2009; López-García et al., 2011), which have been useful for characterizing the small changes that occurred at the beginning of the Holocene.

In this paper, our study of small mammals is focused chronologically on the Early and Middle Holocene. The aim is to characterize the environmental and climatic conditions of the period by the study of small mammals, and compare our results with other data in order to establish natural or human causes that influenced these results.

To this end, the small-mammal data chosen belong to archaeological sites situated in different climatic zones of the Iberian Peninsula. We have taken new small-mammal data from the Neolithic layers of Mirador cave and the data from the Bronze Age layer (MIR4) published in Bañuls-Cardona et al. (2013), as well as other small-mammal data published from Colomera cave (Sant Esteve de la Sarga, Lleida) (Bañuls-Cardona and López-García, 2009; López-García et al., 2010) and Valdavara-1 cave (Becerreá, Lugo) (López-García et al., 2011). The faunal assemblages used here are included in the small-mammal studies of three Middle Holocene sites (from the Early Neolithic to the Bronze Age) that correspond to 11 different layers dated to between 7000 and 3000 ka BP: six layers from the Early Neolithic (MIR24, MIR19, MIR18 and MIR17 of Mirador cave, CE12 and CE13-14 of Colomera cave), two layers from the Middle-Late Neolithic (MIR9 and MIR5 of Mirador cave) and finally three layers from the Bronze Age (MIR4 of Mirador, VUU of Valdavara-1 and EE1 of Colomera cave).

2. Material and methods

The new data of this paper are from Mirador cave (Sierra de Atapuerca, Burgos). For this paper, layers MIR5, MIR9, MIR17, MIR18, MIR19 and MIR24 have been analyzed. From these layers, 1154 remains (NR) have been identified, with a minimum number of individuals (MNI) of 706. Nine small-mammal taxa have been identified: *Sorex* gr. *coronatus-araneus*, *Crocidura russula*, *Myotis myotis-blythii*, *Miniopterus schreibersii*, *Microtus arvalis*, *Microtus agrestis*, *Microtus* (*Terricola*) *duodecimcostatus*, *Apodemus sylvaticus* and *Eliomys quercinus* (Table 1).

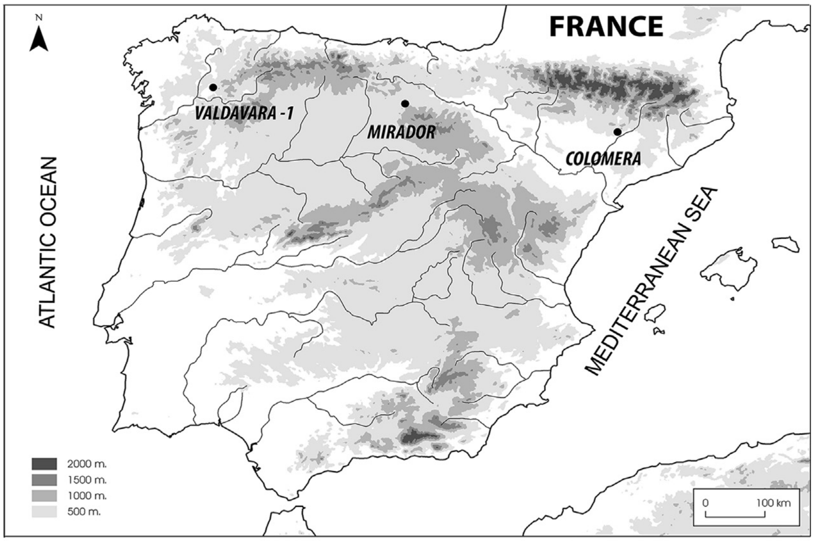
2.1. Palaeontological study

The small mammals belonging to levels MIR5, MIR9, MIR17, MIR18, MIR19 and MIR24 of Mirador cave (Sierra de Atapuerca, Burgos) have been identified by systematic palaeontology. For Soricidae, we used mandibles and isolated teeth (Cuenca-Bescós et al., 2008; López-García, 2008; Reumer, 1984); for chiropters, the mandibles, isolated teeth and humeri (Bruijn and Rumke, 1974; Menu and Popelard, 1987; Sevilla, 1988); for Arvicolinae, the first lower molars (Cuenca-Bescós et al., 2008; López-García, 2008, van der Meulen, 1973); while for *Apodemus sylvaticus* and *Eliomys quercinus* identification relied on isolated teeth (Cuenca-Bescós et al., 2008; López-García, 2008; Damms, 1981; Pasquier, 1974).

2.2. Palaeoenvironmental reconstruction

To produce the palaeoenvironmental reconstruction, we used the Habitat Weighting method (Andrews, 2006; modified by Blain et al., 2008; López-García et al., 2011). We took into account the geographical location of each species today, as all of them still exist in the Iberian Peninsula. We ascertained a percentage distribution for the habitat(s) preferentially occupied by each taxon, dividing the habitats into five categories defined according to a series of highly concrete environmental features: dry meadow, wet meadow, woodland, rocky areas and watercourse areas. "Dry meadow" consists of meadowland subject to seasonal climate change; "wet meadow" indicates evergreen meadowland with pastures and dense topsoil; "woodland"

A)



B)

LAYER	Laboratory number	Measured Radiocarbon age	2σ calibrated result BP	Mean of 2σ calibrated result BP
MIR4 (top)	Beta-154894	3020±40	3350-3140	4026
MIR4 (bass)	Beta-153366	3380±40	3720-3560	
MIR9	Beta-220912	5050±40	5920-5730	5825
MIR18	Beta-208132	6090±40	7180-7110 /7100-6880	7067
MIR19	Beta-182040	6130±50	7180-6870	6990
MIR24	Beta-220914	6080±40	7160-7120 /7030-6870	7880
	Beta-197386	7030±40	7960-7800	
EE1	Beta-241704	3630±40	4080-3840	3980
CE12	Beta-248523	6020±50	6990-6740	6870
CE13-14	Beta-240551	6120±40	7170-6940	7060
VUU	Beta-235727	4490±40	5340-4980	5130

Fig. 1. A) Geographic location of the sites under study. **B)** Radiocarbon dates measured of the layers chosen from each site, the calibrated dates 2σ (P = 95%) and the mean of the calibrated dates.

Fig. 1. A) Situation géographique des sites étudiés. **B)** Datations radiocarbone mesurées sur des couches choisies pour chaque site, datations radiocarbone calibrées 2σ (p = 95 %) et moyenne des datations calibrées.

ranges from leafy forests to woodland margins, with moderate vegetation cover; "rocky areas" refer to rocky habitats without vegetation cover; and "watercourse areas" include streams, lakes and ponds (Table 2).

2.3. Palaeoclimatic reconstruction

For the palaeoclimatic reconstruction, we used the Mutual Ecogeographic Range method (MER) (Blain, 2005; Blain et al., 2010; Blain et al., 2016). With this method, we defined the current distribution area of the faunal association, superimposing current distribution maps divided into 10 × 10 km UTM grids (Palomo and Gisbert, 2005). The resulting intersection indicates an area where the climatic characteristics are similar to those of our association. On the basis of this intersection, we calculated the MAT (mean annual temperature), MTC (mean temperature of the coldest month) and the MTW (mean temperature of the warmest month), as well as the MAP (mean annual precipitation). These climatic characteristics are obtained using current data relating to temperature and precipitation, collected between 1982 and 2012 (Climate_Data.org). The data obtained were compared with the present-day climate of this region of the Iberian Peninsula, enabling us to note the changes in temperature and precipitation with respect to this point of the Holocene period.

We have omitted certain taxa from the palaeoclimatic reconstruction. This applies to chiropters, because studies of chiropteran distribution are currently very scarce; in many cases their mobility makes it difficult to ascertain their present geographical distribution, which could thus falsify our data.

Moreover, we have used a classification of taxa according to chorotypes established by Sans-Fuentes and Ventura (2000), Real et al. (2003) and López-García et al. (2010b). A chorotype can be defined as a group of species whose distributions in space overlap more than expected at random. Chorotype 1 (CH-1) refers to species with Euro-Siberian requirements; this implies a mean summer temperature lower than 20 °C, a mean annual temperature that should be between 10 and 12 °C, and a mean annual precipitation higher than 800 mm. Chorotype 2 (CH-2) refers to Euro-Siberian species that nonetheless tolerate Mediterranean conditions, with a mean annual precipitation greater than

Table 1
Minimum number of individuals (MNI) and percentage of minimum number of individuals (MNI%).
Tableau 1
Nombre minimum d'individus (MNI) et pourcentage du nombre minimum d'individus (MNI %).

Taxa	Mirador														Colomera						Valdavara-1	
	MIR4		MIR5		MIR9		MIR17		MIR18		MIR19		MIR24		EE1		CE12		CE13-14		VUU	
	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%	NMI	NMI%
Crocidura russula	19	19.8	6	6.7	17	32.1	16	12.5	21	11.4	6	5.1	8	6.0	1	2.3	3	4.3	2	2.4	2	3.4
Sorex coronatus-araneus	6	6.3	4	4.5	5	9.4	9	7.0	21	11.4	4	3.4	3	2.2								
Sorex sp.																					1	1.7
Erinaceus europaeus																					1	1.7
Talpa occidentalis																					4	6.8
Rhinolophus sp.																					1	1.7
Myotis myotis					2	3.8			3	1.6			4	3.0								
Myotis nattereri																					1	1.7
Miniopterus schreibersii					2	3.8			1	0.5	1	0.9	2	1.5								
Arvicola sapidus																					2	3.4
Iberomys cabrerae															1	2.3	2	2.9	1	1.2	2	3.4
Clethrionomys glareolus																					1	1.7
Micromys minutus																					1	1.7
Chionomys nivalis															6	14.0	11	15.9	24	28.9	1	1.7
Microtus arvalis	21	21.9	20	22.5	3	5.7	18	14.1	16	8.6	9	7.7	22	16.4	5	11.6	4	5.8	4	4.8	1	1.7
Microtus agrestis	14	14.6	37	41.6	13	24.5	34	26.6	26	14.1	22	18.8	15	11.2	3	7.0	7	10.1	7	8.4	1	1.7
Microtus (Terricola) lusitanicus																					17	28.8
Microtus (Terricola) duodecimcostatus	17	17.7	14	15.7	1	1.9	18	14.1	21	11.4	11	9.4	24	17.9	1	2.3	4	5.8	5	6.0		
Apodemus sylvaticus	18	18.8	8	9.0	1	1.9	32	25.0	73	39.5	58	49.6	56	41.8	22	51.2	32	46.4	36	43.4	16	27.1
Glis glis																					6	10.2
Eliomys quercinus	1	1.0			9	17.0	1	0.8	3	1.6	6	5.1			4	9.3	6	8.7	4	4.8	1	1.7
Total	96	100	89	100	53	100	128	100	185	100	117	100	134	100	43	100	69	100	83	100	59	100

Table 2
Distribution of the taxa by habitat: the abbreviations are as follows: R, Rocky; WA, Water; OD, Open Dry; OH, Open Humid; WO, Woodland. Distribution of the taxa by chorotype: CH-1, Chorotype 1 (species with Euro-Siberian requirements); CH-2, Chorotype 2 (Euro-Siberian species that nonetheless tolerate Mediterranean conditions); CH-3, Chorotype 3 (species with strictly Mediterranean requirements); CH-4, Chorotype 4 (generalist species).
Tableau 2
Répartition des taxons par habitat. Les abréviations sont les suivantes : R, milieux rocheux ; WA, milieux aquatiques ; OD, milieux ouverts et secs ; OH, milieux ouverts et humides et WO, forêts. Répartition des taxons par chorotype. Les abréviations sont les suivantes : CH-1, chorotype 1 (espèces ayant des exigences euro-sibériennes) ; CH2, chorotype 2 (espèces euro-sibériennes qui tolèrent néanmoins des conditions méditerranéennes) ; CH-3, chorotype 3 (espèces strictement méditerranéennes) et CH-4, chorotype 4 (espèces généralistes).

Taxa	Habitat weighting					Chorotypes			
	OD	OH	WO	RO	WA	CH-1	CH-2	CH-3	CH-4
Crocidura russula	0.5		0.5						X
Sorex coronatus-araneus		0.5	0.5				X		
Erinaceus europaeus		0.5	0.5					X	
Talpa occidentalis		0.5	0.5				X		
Talpa europaea		0.5	0.5				X		
Myotis myotis	0.25	0.25	0.5					X	
Myotis nattereri	0.25	0.25	0.5					X	
Miniopterus schreibersii	0.25	0.25	0.5						X
Arvicola sapidus					1				
Iberomys cabrerae		0.5	0.5						X
Cletrionomys glareolus			1			X			
Chionomys nivalis				1		X			
Microtus arvalis	0.5		0.5			X			
Microtus agrestis		0.5	0.5			X			
Microtus (Terricola) lusitanicus		0.5	0.5					X	
Microtus (Terricola) duodecimcostatus		0.5	0.5						X
Apodemus sylvaticus			1					X	
Micromys minutus			1				X		
Eliomys quercinus			0.5	0.5				X	
Glis glis			1			X			

600 mm. Chorotype 3 (CH-3) denotes generalist species, and finally Chorotype 4 (CH-4) denotes species with strictly Mediterranean requirements (Table 2).

3. Results and discussion

The Holocene is a warm and wet period, with some episodes with increased aridity and global climatic pulsations. However, there are many regional differences. Little is known about Holocene climatic variability from the continental records of Europe, and there is a need to gather more information from terrestrial sources whose reach across Europe is well known (Bernárdez et al., 2008; Leira and Santos, 2002). In the Iberian Peninsula, the detailed examination of high-frequency climatic variability in the present interglacial has focused mainly on ice cores and marine or continental records. Studies such as the Alboran sea (MD95-2043) core record off the Mediterranean coast have been carried out on marine deep-sea cores, using oxygen isotope curves (Cacho et al., 2001), while the record from core SMP02-3 from the Galician continental shelf off the NW Iberian Peninsula (Bernárdez et al., 2008) has also been used to understand the vegetation response to climate variability in the Holocene (Carrión, 2002; Fletcher and Zielhofer, 2013; Fletcher et al., 2008; Jiménez-Moreno et al., 2013; Morellón et al., 2009) (Fig. 2).

Our study focuses chronologically in particular on the Early and Middle Holocene, and in order to characterize this period climatically and environmentally on the basis of a small-mammal study, we have chosen sites with special geographic characteristics, because the Iberian Peninsula represents one of the largest and most diverse areas of Mediterranean-type climate in the Mediterranean region (Moreno et al., 2007).

a) Northern Spanish Meseta

Mirador cave (Sierra de Atapuerca, Burgos) is located 1033 m above sea level on the northeastern edge of the northern Spanish Meseta (Fig. 1), which currently has a continental Mediterranean climate or Cfb climate (according to the Köppen-Geiger system), with special characteristics: long, cold winters with moderate rainfall and short, warm summers (Kottek et al., 2006).

According to our taphonomic study of the small mammals from Mirador cave, the remains analyzed present slight signs of digestion. From these results, it can be surmised that the main animal responsible for the accumulation in the cave was a category 1 predator, a nocturnal bird of prey that displays an opportunistic trophic pattern and produces slight modifications of the bones it ingests (Andrews, 1990). The small mammals form an assemblage of great taxonomic variety, indicating that it was the work of an opportunistic hunter.

The results obtained from Mirador cave by the MER method show that the same climatic characteristics prevailed throughout the Holocene period, because the species represented in the layers studied did not undergo great changes. The temperatures are seen to undergo minimal changes of less than one degree Celsius throughout the sequence, and the same applies when we compare our data with current climate data. However, the precipitation is higher (between 200–252 mm) than at present. Moreover, the study of chorotypes shows some climatic changes.

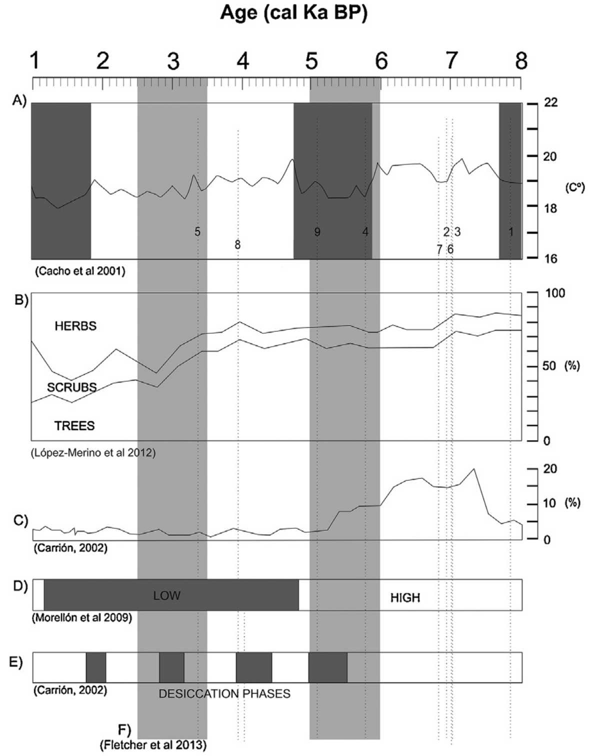


Fig. 2. Relation between the dating of each of the layers under study and other palaeoenvironmental and palaeoclimatic studies: **A)** the Alboran sea (MD95-2043) isotope curve showing cooling events (Cacho et al., 2001), **B)** percentages of trees, shrubs and herbs in the northwest (López-Merino et al., 2012), **C)** percentages of deciduous trees in the southeast (Carrión, 2002), **D)** level of water in Lake Estanya, northeast (Morellón et al., 2009), **E)** level of water in Lake Siles, southeast (Carrión, 2002), **F)** cold periods (Fletcher and Zielhofer, 2013). The abbreviations are as follows: 1: MIR24 (7880 ka BP); 2: MIR19 (6990 ka BP); 3: MIR18 (7067 ka BP); 4: MIR9 (5825 ka BP); 5: MIR4 (4026 ka BP); 6: CE13-14 (7060 ka BP); 7: CE12 (6870 ka BP); 8: EE1 (3980 ka BP); 9: VUU (5130 ka BP).

Fig. 2. Relation entre la datation de chacun des niveaux étudiés et d'autres études paléoenvironnementales et paléoclimatiques : **A)** en mer d'Alboran (MD95-2043) courbe isotopique montrant les événements de refroidissement (Cacho et al., 2001), **B)** pourcentages d'arbres, d'arbustes et d'herbes dans le Nord-Ouest (López-Merino et al., 2012), **C)** pourcentages d'arbres feuillus dans le Sud-Est (Carrión, 2002), **D)** niveau de l'eau dans le lac Estanya, au nord-est (Morellón et al., 2009), **E)** niveau de l'eau dans le lac Siles, au Sud-Est (Carrión, 2002), **F)** périodes froides (Fletcher and Zielhofer, 2013). Les abréviations sont les suivantes : 1 : MIR24 (7880 ka BP); 2 : MIR19 (6990 ka BP) ; 3 : MIR18 (7067 ka BP) ; 4 : MIR9 (5825 ka BP) ; 5 : MIR4 (4026 ka BP) ; 6 : CE13-14 (7060 ka BP) ; 7 : CE12 (6870 ka BP) ; 8 : EE1 (3980 ka BP) ; 9 : VUU (5130 ka BP).

The percentages of Euro-Siberian species are significant in the Middle-Late Neolithic and Bronze Age layers, particularly in MIR5 (64.0%), while in the Early Neolithic (MIR24, MIR19, MIR18) generalist species (CH-3) are more abundant (Fig. 4).

Within the sequence of Mirador cave, however, various singular characteristics are seen to occur. During the Early Neolithic (MIR24, MIR19, MIR18), climatic conditions are warmer than in the rest of the sequence, generalist species occupying 43–54% of the total sample due to the high presence of *Apodemus sylvaticus* in these layers (from 40 to 50%). This warm period breaks off in MIR17, with a sharp increase (20%) in Euro-Siberian species, in this case with a high proportion (26.6%) of *M. agrestis* (Fig. 4). In the Middle Neolithic (MIR9), we registered an increase of 10% in CH-4, Mediterranean species, especially manifest in the figure of 32.1% for *Crocidura russula* (Fig. 4). These data suggest a slight thermal recovery with respect to MIR17. They could also be due to the incipient establishment of a Mediterranean climate that occurred in the Mirador area before 5000 BP (Jalut et al., 1997), but until all the layers have been analyzed, it will not be possible to say for sure. This mild climate persisted until the Bronze Age (MIR4), when there was another very slight increase (5%) in Euro-Siberian species, with the typical conditions of a continental Mediterranean climate prevailing in the northern Meseta, i.e. long, cold winters with short, warm summers (Kottek et al., 2006). However, these mild conditions were interrupted in MIR5. In this layer, another increase in the percentage of Euro-Siberian species (64.0%) is observed, corresponding to the cold period registered at this time in the Alboran sea (MD95-2043) core record (Cacho et al., 2001; Fletcher and Zielhofer, 2013) (Fig. 2).

The Habitat Weighting study shows a gradual increase in open areas to the detriment of woodland areas (Fig. 4); this is observed especially in MIR9 and MIR4, where the percentage of open dry areas reaches 20%. In MIR4 there is also a small decrease in rainfall of 52 mm with respect to MIR5. Fletcher and Zielhofer (2013) refer to an increase in dry conditions in the intervals lasting from 6000 – 5000 and 3500–2500 ka BP, as also observed in the record (SMP02-3) from the Galician continental shelf (NW Iberian Peninsula) from 4700 to 3300 ka BP (Bernárdez et al., 2008). However, this could be due to the major human impact on the environment, as indicated by archaeobotanical studies based on pollen, charcoal, seeds and phytoliths at the Mirador site (Cabanes et al., 2009; Rodríguez and Buxó, 2008). These studies have confirmed the presence of herbaceous plants related to the development of agriculture and livestock. On the other hand, García-Antón et al. (2011) have indicated that the human impact on the environment in this area of the northern Meseta was not intense in the first millennium B.C.

b) Pyrenees area

Colomera cave (Sant Esteve de la Sarga, Lleida) is located at an altitude of 670 m above sea level, on the southern face of the Pyrenees (Fig. 1) in a continental Mediterranean zone or Cfb climate (Köppen-Geiger system). Such a location is generally characterized by very cold winters and warm summers, and, unlike the northern Meseta, by very low rainfall (Kottek et al., 2006).

The chorotype study shows a predominance of chorotype 3 or generalist species (48–60%) such as *Apodemus sylvaticus*, which exceeds 40% in all layers. But despite this, there is a notable percentage of Euro-Siberian species throughout the sequence, mainly represented by *Chionomys nivalis*, which lives in strictly Euro-Siberian climatic zones, especially in CE13-14, with a substantial percentage of 28.9%. Nonetheless, Colomera also shows the greatest variety of Mediterranean species, with *C. russula*, *M. (T.) duodecimcostatus* and especially *Iberomys cabrerae*, which live in strictly Mediterranean climate zones and are not found in Euro-Siberian climates (Fig. 4). These percentages indicate abrupt changes in temperatures, because we do not find species belonging to CH-2, i.e. Euro-Siberian species that nonetheless tolerate Mediterranean conditions. Together, these climatic characteristics are typical of a continental Mediterranean climate, generally characterized by very cold winters and warm summers (Kottek et al., 2006). These typical characteristics can be seen especially in layers CE12 and EE1, because within the sequence, we see small changes in the percentages of chorotypes that indicate an improving climate from the early Neolithic (CE12), similar to during the Bronze Age (EE1). We also observe an increase of 10% in the percentage of thermo-Mediterranean taxa, which increases from 57.8% in CE12 to 68.1% in CE13-14.

The climatic characteristics deduced from the MER study, when compared with current data, indicate that the temperatures during the Holocene were 2.4 °C lower than at present and that the precipitation was higher than at present (557 mm). Temperatures are observed to be 1 °C lower for the MTC, while for the MTW they were less than 1 °C lower.

Our study of the habitat reveals a minor increase in open dry areas to the detriment of open humid areas, and the level of precipitation is shown to be the same in all the layers. The zooarchaeological data also attest a scarce presence of ovicaprids, which would indicate the presence of pastures, suggesting that herds might have been stabled inside the cavity (fumier). From archaeobotanical data, agricultural practices are evidenced by the significant presence of cereals and legumes, but this presence is likewise scarce (Oms et al., 2008, 2009).

This low pressure on the environment is reflected in the predominance of woodland in all layers of Colomera cave, increasing towards more recent layers. This could be due to the type of cave occupation. The human communities that frequented Colomera cave were probably nomadic, since the narrow circumstances of the cave (in the middle of a gorge) do not seem appropriate for the establishment of a camp of shepherds or an agricultural holding around the cave (Oms et al., 2008, 2009). This was common in mountain areas at the time, where occupations have been found to occur later than in the plains (Tarroso et al., 2014).

c) Northwest area

Valdavara-1 cave is located in the Iberian Massif at an altitude of 600 m above sea level (Becerreá, Lugo) (Fig. 1). This site represents a continental Mediterranean climate, with influences from an Atlantic climate or Csb climate (Köppen-Geiger system). The summers are dry, as in the previous case, but precipitation is more abundant and occurs mainly in winter, with the arrival of fronts from the Atlantic (influence of the temperate zone), and in the winter the temperatures are mild (Font Tullot, 2000).

The MER analysis of the small-mammal assemblages in the Bronze Age (VUU) of Valdavara-1 cave indicates mild temperatures (Fig. 3): i.e. the MTC is 5 °C, the highest of the sites studied in this paper, and the MTW is 17.20 °C, the lowest of the sites studied in this paper (Table 3). These low temperatures in the warmer months (MTW) could be related to a cold climate period in the Iberian Peninsula, as observed in the temperature curve of the Alboran sea (MD95-2043) core record (Cacho et al., 2001; Fletcher and Zielhofer, 2013) (Fig. 2). At the same time, the precipitation for this layer is very high (1690 mm), the highest in our study.

These features are also observed in the study of the chorotypes from Valdavara-1 cave (Becerreá, Lugo). Similar percentages of Mediterranean and Euro-Siberian species tolerant to Mediterranean conditions are seen, while the percentage of Euro-Siberian species *sensu stricto* is negligible (Fig. 4).

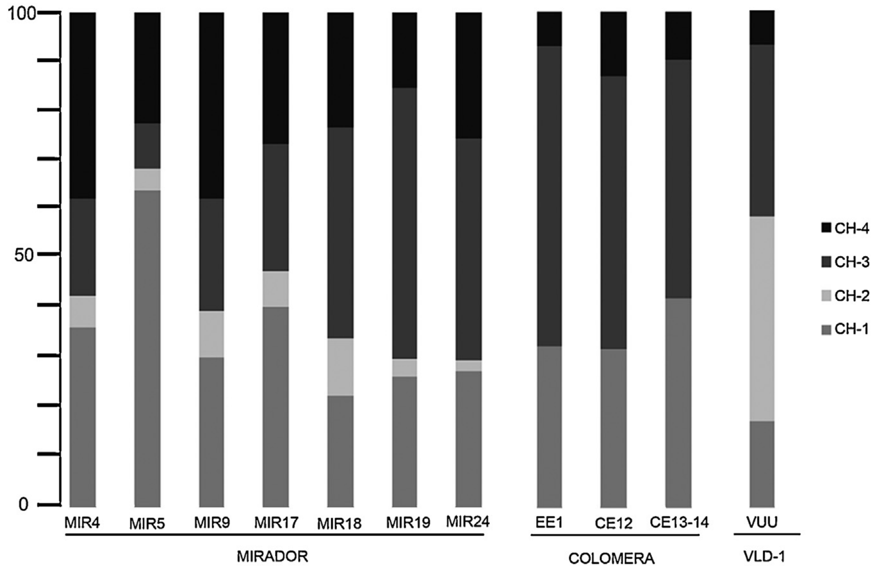


Fig. 3. Percentage of chorotypes at each of the sites under study.
Fig. 3. Pourcentage de chorotypes dans chacun des sites étudiés.

Table 3
Relation of temperature and precipitation, obtained by the MER (Mutual Ecogeographic Range) analysis of the small mammals at each of the sites studied: MAT (mean annual temperature); MTW (mean temperature of the warmest month); MTC (mean temperature of the coldest month) and MAP (mean annual precipitation). SD (standard deviation): Max (maximum); Min (minimum); Δ (difference in relation to the current means at the meteorological stations).
Tableau 3
Relation entre température et précipitations, obtenue en utilisant la méthode MER (domaine écogéographique commun) à partir des micromammifères pour chacun des sites étudiés : MAT (température moyenne annuelle) ; MTW (température moyenne du mois le plus chaud) ; MTC (température moyenne du mois le plus froid) et le MAP (précipitations moyennes annuelles). SD (écart-type) : Max (maximum) ; Min (minimum) ; Δ (différence par rapport à la moyenne actuelle des stations météorologiques).

Sites	Layers	MAT			MTW			MTC			MAP		
		Mean	SD	Δ	Mean	SD	Δ	Mean	SD	Δ	Mean	SD	Δ
Mirador	MIR4	9.9	1.5	−0.2	18.5	1.4	−0.2	2.5	1.2	0.0	794	221	200
	MIR5	10.0	1.6	−0.1	18.6	1.4	−0.1	2.6	1.2	0.1	846	284	252
	MIR9	9.9	1.5	−0.2	18.5	1.4	−0.2	2.5	1.2	0.0	794	221	200
	MIR17	9.9	1.5	−0.2	18.5	1.4	−0.2	2.5	1.2	0.0	794	221	200
	MIR18	9.9	1.5	−0.2	18.5	1.4	−0.2	2.5	1.2	0.0	794	221	200
	MIR19	9.9	1.5	−0.2	18.5	1.4	−0.2	2.5	1.2	0.0	794	221	200
	MIR24	10.0	1.6	−0.1	18.6	1.4	−0.1	2.6	1.2	0.1	846	284	252
Colomera	EE1	8.0	1.0	−2.4	18.6	1.9	−0.6	1.5	1.3	−1.0	971	349	88
	CE12	8.0	1.0	−2.4	18.6	1.9	−0.6	1.5	1.3	−1.0	971	349	88
	CE13–14	8.0	1.0	−2.4	18.6	1.9	−0.6	1.5	1.3	−1.0	971	349	88
Valdavara-1	VUU	11.4	1.2	−0.2	17.2	1.3	−1.9	5.0	1.7	−0.2	1690	575	749

Mild temperatures are thus indicated by the MER and the chorotypes, and the temperatures are a little higher nowadays than in the Holocene, above all the MTW, with temperatures 1.9 °C higher (Table 3). The same results are shown by the record (SMP02-3) from the Galician continental shelf (NW Iberian Peninsula). This record indicates a warm and dry period characterized by low nutrient levels and productivity, as also revealed by planktonic foraminifera (Bernárdez et al., 2008).

The palaeoenvironmental reconstruction has revealed a high percentage of woodland (67.9%) (Fig. 5). Some authors have confirmed the persistence of pine forest in NW Iberia until the Late Holocene (Morales-Molino et al., 2011). However, a considerable percentage of open areas (26%) can also be observed. These results coincide with other palaeobotanical analyses, which have confirmed that shrubland expansion was significant by around ca. 5500 BP in the Iberian Peninsula in general (Carrión, 2002; Carrión et al., 2010b), but particularly in the Northwest, where the study by López-Merino et al. (2012) recorded an increase in shrubs to the detriment of trees (Fig. 3).

In summary, it has been observed that in all the studied sites, despite the regional variations resulting from their different geographic locations, the climatic evolution

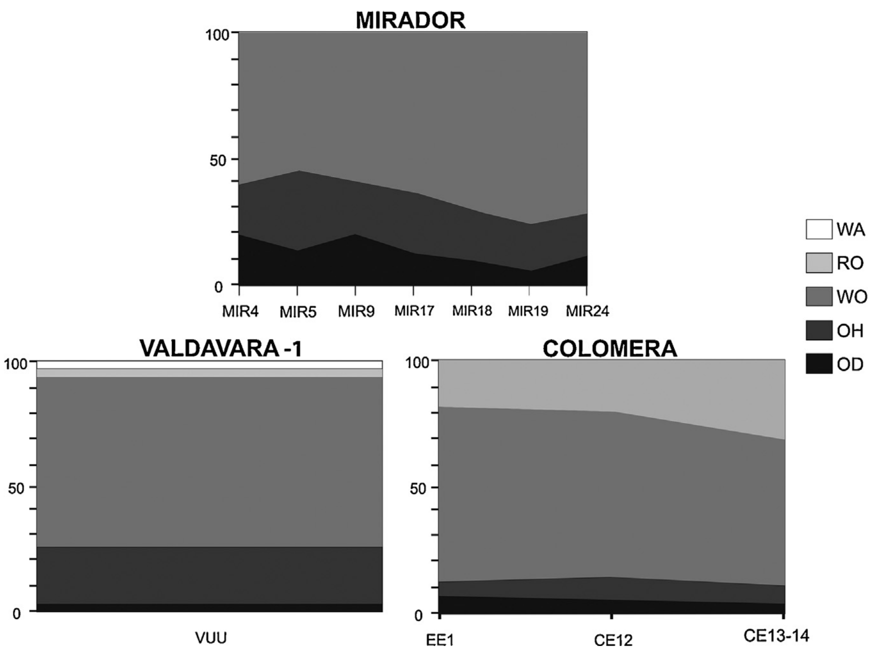


Fig. 4. Percentage of the habitats represented at each site. The abbreviations are as follows: R, Rocky; WA, Water; OD, Open Dry; OH, Open Humid; WO, Woodland.

Fig. 4. Pourcentage des habitats représentés dans chaque site. Les abréviations sont les suivantes : R, milieux rocheux ; WA, milieux aquatiques ; OD, milieux ouverts et secs ; OH, milieux ouverts et humides et WO, milieux forestiers.

followed the same pattern. From the Early Neolithic to the Bronze Age, the temperature and rainfall were maintained stable at Colomera and Mirador caves. The study of the palaeoenvironment showed slight variation between the studied sequences which are not related to the palaeoclimatic data. For this reason, we think that some landscape variations are related to the human impact, though this impact is slight. We recovered synanthropic species (taxa adapted to the conditions created or modified by human activities) such as *M.* (*Terricola*) *duodecimcostatus*, *M.* (*Terricola*) *lusitanicus*, *M. arvalis*, *E. quercinus* and *C. russula* (Mistrot, 2000). However, we did not find commensal species (e.g., *Mus musculus domesticus*) in any of the sites studied. Such species would have indicated a strong human impact. The pattern of expansion of these species through the Mediterranean basin suggests that they did not colonise the Iberian Peninsula until the first millennium BC (Cucchi et al., 2005).

4. Conclusions

From the Early Neolithic to the Bronze Age (ca. 7000–3000 BP) of the Iberian Peninsula, the evolution of the palaeoenvironment was conditioned not only by palaeoclimatic conditions, but was also linked to human activity.

In general, the climatic conditions in this period were more or less stable. The MER analysis shows winters that were colder than nowadays, above all in the Mediterranean area (Colomera), while in the northern Meseta (Mirador), we observe lower temperatures in the warmer months, and in the northwest (Valdavara-1) the temperatures were similar to today. As regards precipitation during the Holocene, in the northwestern site of Valdavara-1 this was lower than at present, whereas in the other studied sites it was higher.

The chorotype study shows that the dominant species in most of the studied layers were generalist species, but despite this we have detected a small weather pulse that occurred at different times in each study area. These changes could be related to the establishment of the Mediterranean climate in each area from ca. 7000 BP.

The landscape is dominated by woodland, with a gradual increase in open dry meadows in the major part of the studied sites during the Bronze Age. In some cases, this increase in open dry areas is linked to rising temperatures and declining rainfall, as is the case for Valdavara-1, while in Colomera and above all Mirador one notices a change in the landscape that follows a different dynamic, possibly caused by human activity. While the reduction in arboreal cover has been linked to the start of anthropogenic activity after ca. 4500 BP, in Mirador cave and Valdavara-1 cave, we see a decrease in woodland, but in Colomera cave there was an increase in woodland. Although some synanthropic species are represented in the studied sites, a strong human impact cannot be ascertained, because there is no evidence of the presence of commensal species.

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