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Heinrich Event 4 characterized by terrestrial proxies in southwestern Europe

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647

Abstract

Heinrich Event 4 (H4) is well documented in the North Atlantic Ocean as a cooling event that occurred between 39 000 and 40 000 yr BP. Deep-sea cores around the Iberian Peninsula coastline have been analysed to characterize the H4 event, but there are no data on the terrestrial response to this event. Here we present for the first time an analysis of terrestrial proxies for characterizing the H4 event, using the small-vertebrate assemblage (comprising small mammals, squamates and amphibians) from Terrassa Riera dels Canyars, an archaeo-palaeontological deposit located on the seaboard of the northeastern Iberian Peninsula. This assemblage shows that the H4 event is characterized in northeastern Iberia by harsher and drier terrestrial conditions than today. Our results were compared with other proxies such as pollen, charcoal, phytolith, avifauna and large-mammal data available for this site, as well as with the general H4 event fluctuations and with other sites where H4 and the previous and subsequent Heinrich events (H5 and H3) have been detected in the Mediterranean and Atlantic regions of the Iberian Peninsula. We conclude that the terrestrial proxies follow the same patterns as the climatic and environmental conditions detected by the deep-sea cores at the Iberian margins.

1 Introduction

The Heinrich events have been generally defined, according to Cayre et al. (1999), by a decrease in $\delta^{18}\text{O}$, peaks in magnetic susceptibility, an increase in the proportion of the foraminifer *Neogloboquadrina pachyderma*, as well as the appearance of IRD (Iceberg Rafted Detritus). Of these events, Heinrich Event 4 (H4), which occurred ca. 39–40 ka BP, is one of the most abrupt climate cooling episodes, well recorded in sediment cores throughout the North Atlantic Ocean and the adjacent continents (Roche et al., 2004; Sepulchre et al., 2007). Deep-sea cores around the Iberian Peninsula coastline have been analysed to characterize the Heinrich event fluctuations (Cacho et al.,

sediment was dry-screened using superimposed 5 and 0.5 mm mesh screens during fieldworks, and ~ 500 kg of the sample was water-sieved (1.5–0.5 mm) in the La Guixera Laboratory (Castelldefels City Council, Barcelona). The fossils were processed, sorted and classified at the Institut de Paleoecologia Humana y Evolució Social of the University Rovira i Virgili (Tarragona, Spain). The assemblage includes a total of 362 fragments, 182 of which were identified to genus or species level and correspond to a minimum number of 26 small vertebrates, representing at least 15 taxa (Table 1; Figs. 3, 4). The fragments were identified following the general criteria given by Furió (2007) for insectivores, Van der Meulen (1973) and Cuenca-Bescós et al. (2010) for rodents, and Bailon (1999), and Sanchiz et al. (2002), Blain (2005, 2009) and Szyndlar (1984) for the herpetofauna. The specific attribution of this material rests principally on the best diagnostic elements: humerus, ilium, scapula and sacrum for anurans; jaws and vertebrae for lizards; vertebrae for snakes; mandible, maxilla and isolated teeth for shrews; isolated teeth and humerus for Talpidae; first lower molars for Arvicolinae; and isolated teeth for *Apodemus sylvaticus* and *Eliomys quercinus*. Moreover, the fossils were grouped using the minimum-number-of-individuals (MNI) method, by means of which we determined the sample (i.e. from each level) by counting the best diagnostic elements, taking into account, whenever possible, laterality and (for amphibians) sex.

3.2 Palaeoenvironmental reconstruction

In order to reconstruct the palaeoenvironment at Canyars, we use the method of habitat weightings (see Evans et al., 1981; and Andrews, 2006), distributing each small-vertebrate taxon in the habitat(s) where it can be found at present in the Iberian Peninsula. Habitats are divided into five types (in accordance with Cuenca-Bescós et al., 2005, 2009; Blain et al., 2008; Rodríguez et al., 2011; López-García et al., 2010a, 2011a): ~~open land in which dry and wet meadows are distinguished, woodland and woodland margin areas, rocky areas and areas surrounding water.~~ These types are detailed as follows (Table 1): open dry: meadows under seasonal climate

651

change; open humid: evergreen meadows with dense pastures and suitable topsoil; woodland: mature forest including woodland margins and forest patches, with moderate ground cover; water: areas along streams, lakes and ponds; rocky: areas with a suitable rocky or stony substratum. The “Ch1&Ch2” and “Ch3” data were obtained from the percentage representation of the MNI by classifying our taxa according to chorotypes established previously by Sans Fuentes and Ventura (2000) and López-García et al. (2010b). These chorotypes are detailed as follows (Table 1): chorotype 1: Includes species with mid-European requirements, with mean summer temperatures lower than 20 °C, mean annual temperatures (MAT) between 10 °C and 12 °C and mean annual precipitation (MAP) higher than 800 mm; chorotype 2: Includes mid-European species tolerant of Mediterranean conditions, with a broader distribution in Catalonia than those of chorotype 1, with MAP higher than 600 mm; chorotype 3: Includes non-strictly Mediterranean species and strictly Mediterranean species, with a broad distribution in Catalonia and without very strict requirements.

3.3 Palaeoclimatic reconstruction

Climatically, the Iberian Peninsula may be considered a minicontinent due to its large latitudinal range (between the parallels of 36° and 44° N), its geographical position between Atlantic (temperate-cold) and African-Mediterranean (temperate-warm or subtropical) influences, and its complex orography. The Iberian Peninsula is one of the most mountainous areas in Europe, and these mountains play a major role in the characterization of its climatic diversity. Climatic conditions may change abruptly over a few hundred kilometres, from the mildness of the seashore to the harshness of coastal mountain summits, resulting in a great variety of climates. As a result, taxonomic composition of the assemblage allow us to evaluate the climatic conditions. In order to assess palaeoclimatic data in Canyars, we evaluated the current distribution of all the taxa found there, permitting us to calculate the potential palaeoclimatic conditions at the site (mutual climatic range method = MCR, in accordance with Blain et al., 2009). On the basis of the distribution of the extant Iberian fauna, we simply identify the geographical

652

B. calamita. All the taxa represented as fossils in the locality, except *C. austriaca* and *Vipera*, are well represented today in the Garraf area (Montori, 1996). The scarcity of *Vipera* today may be linked with the increasing urbanization of the landscape, whereas *C. austriaca* is currently absent from the Catalan seashore following a postglacial regression (Llorente et al., 1995; Rivera et al., 2011). It is interesting to note here that *C. austriaca* is found today in Catalan mountain regions (Eurosiberian habitats or humid mountain areas; Rivera et al., 2011), where MAT is lower than 11 °C and MAP higher than 700–800 mm (Llorente et al., 1995). Although mention of the genus *Coronella* is not rare in the Catalonian Pleistocene fossil record, *C. austriaca* has only been cited in the southern part of its current distribution in the Late Pleistocene (ca. 90–30 ka) of Teixoneres cave (Moià, Barcelona; López-García et al., 2012b).

4.3 Palaeoenvironmental and Palaeoclimatic reconstruction

The resulting intersection for Canyars suggests a mean annual temperature (MAT) lower than at present (−5.2 °C) and a mean annual precipitation (MAP) slightly higher than at present (+99 mm). The mean temperature of the coldest month (MTC) is lower than the current mean (−6.1 °C), and for the warmest month (MTW) it is lower too (−4.5 °C). The mean winter precipitation (DJF) is higher (+55 mm), and the mean summer precipitation (JJA) is lower (−29 mm) than at present (Table 3). These data suggest harsher climatic conditions and slightly more humid conditions than at present for the H4 event in northeastern Iberia. Such data are well supported by the presence of taxa such as *C. austriaca* at Canyars, which, as pointed out above, currently lives in mountain areas where MAT is lower than 11 °C and MAP higher than 700–800 mm (Llorente et al., 1995).

Otherwise, the small-vertebrate assemblage for Canyars indicates an open dry environment (33%) (Fig. 6), given the presence of the species *Pelodytes punctatus*, *Bufo calamita*, *Vipera* sp., *Crocidura* sp. and *Microtus arvalis*. It further suggests a landscape alternating between dry meadowland and Mediterranean-type woodland. The species associated with “woodland” habitats represent 44% of the total association

657

(Fig. 6), mainly composed of *B.cf. bufo*, *Anguis fragilis*, *Apodemus sylvaticus* and *Eliomys quercinus*. There is also a low percentage representation of species associated with open humid meadows (13%) and water streams (4%) (Fig. 6), suggesting the existence of stable watercourses in the vicinity of the site, with riverbanks with loose soils favourable for digging species such as *A. fragilis*, *Bufo cf. bufo*, *C. cf. austriaca* and *Talpa europaea*.

Finally, the small-vertebrate assemblage of the Canyars site is dominated by taxa related with mid-European requirements (chorotype 1 and 2, 67%), but with a high percentage representation of taxa related with Mediterranean requirements (chorotype 3, 4v.7%) (Fig. 6). According to Sommer and Nadachowski (2006), the co-occurrence of temperate and cold-adapted species is the normal dynamic detected in south European peninsulas such as the Iberian Peninsula, which functioned as refuges for species in cold periods, in this case during the H4 event. However, in Cova del Gegant (López-García et al., 2008, 2012c), another Late Pleistocene locality of the Garraf Massif, chronologically placed between 49–60 ka (i.e., before HE4), Mediterranean taxa are dominant (chorotype 3, 89%) showing a different climatic signal in small vertebrates assemblage. Moreover the proximity of the Canyars to the coastline meant that in cold periods, when the sea level decrease, there was a coastal plain with probably drier conditions in front of the site and behind a forested areas with more humid conditions offering rocky and woodland habitats.

5 Comparison and discussion

5.1 Comparison with other terrestrial proxies

Other terrestrial proxies such as charcoal, pollen, phytoliths, avifauna and large mammals from the Canyars site have also been analysed (Daura et al., 2013). The pollen, avifauna and large-mammal results indicate the presence of a steppe-dominant landscape (cf. *Mammuthus* sp., *Coelodonta antiquitatis*, *Equus ferus*, *Pyrhocorax graculus*,

658

Artemisia) surrounding the Canyars site. Together with woodland environment taxa such as *Pinus sylvestris*, temperate forest taxa such as *Sus scrofa*, *Lynx pardinus* and *Ursus arctos* also coexist. The charcoal results indicate a dominance of forest (*Pinus sylvestris*) formations, while the phytoliths indicate a dominance of grasslands, representing arid conditions (Daura et al., 2013).

What is indicated by all these studies is the same as with the small-vertebrate analysis: “woodland taxa” such as *Anguis fragilis*, *Apodemus sylvaticus* and *Eliomys quercinus* are dominant, but they alternate with abundant “open dry taxa”, such as *Microtus arvalis* and *Bufo bufo*. Accordingly, the small-vertebrate assemblage from the Canyars site contains species that currently live at high latitudes in Catalonia (chorotype 1 and 2), such as *Anguis fragilis*, *Coronella austriaca*, *Talpa europaea*, *Microtus arvalis* and *Microtus agrestis*, which represent 60 % of the association and indicate colder conditions than nowadays in the area. These species coexist at Canyars with Mediterranean taxa, such as *Crocidura* sp., *Microtus (Terricola) duodecimcostatus* and *Microtus (Iberomys) cabrerac*, which represent 40 % of the association.

As pointed out above, this sort of association is typical of cold periods in southern European peninsulas such as the Iberian Peninsula, which functioned as refuges for species during unfavourable climatic periods (Sommer and Nadachowski, 2006). In this respect, Cova del Gegant (above mentioned) is absolutely dominated by temperate taxa in 89 % of the association showing a reduction of chorotype 3 and woodland conditions from layer V to III while Canyars is formed mainly by Ch1&2.

On the other hand, the presence of a “patchy landscape” signal at Canyars is normal, given the location of the site near the sea and the relief of Garraf Massif behind, nevertheless the environment is dominated by arid conditions. In cold periods the sea level was lower than today (López-García et al., 2008), and the area around the site would have consisted of a large plain in front of it, with probably drier conditions, together with a temperate forest in riparian woodland and behind it, with probably more humid conditions with pines (*Pinus sylvestris*) woodland, as is the case with other nearby sites, such as Cova del Gegant (López-García et al., 2008, 2012c).

659

5. Comparison with other sites associated with the H4 event

Few are the sites with small-vertebrate studies in Iberia where the H4 event has been detected, and Canyars is the only known site located on the Mediterranean and below 41° N latitude. Apart from Canyars, two sites are documented with small-vertebrate assemblages from the H4 event: El Portalón level P16 (Sierra de Atapuerca, Burgos), with a chronology of ca. 38 ka BP for this event; and the Cueva del Conde level N20b (Santo Adriano, Asturias), with a chronology ca. 39 ka BP for this event (Fig. 1) (López-García et al., 2010a, 2011b). All the sites associated with the H4 event are characterized by a landscape dominated by open forest formations, lower mean annual temperatures (MAT) and mean temperatures of the coldest month (MTC), and relatively high levels of mean annual precipitation (MAP) (Fig. 7). However, direct comparison of these three sites shows differences between them in terms of open dry and open humid meadowland and MAP. While in El Portalón (P16) and Cueva del Conde (N20b) the environment is dominated by open humid meadowland reaching values higher than 25 %, in Canyars the landscape is dominated by open dry meadowland with values above 30 % (Fig. 7). Similarly, the MAP, although higher than at present in all three cases, is proportionally higher at El Portalón (P16) and Cueva del Conde (N20b), where it reaches values higher than 1000 mm, while in Canyars the values are lower than 800 mm (Fig. 7). The differences in the H4 event at these three sites can be explained by their geographical position within the Iberian Peninsula: while El Portalón and Cueva del Conde are located in the Atlantic climatic influence, Canyars is located in the Mediterranean climatic influence. According to Sánchez-Goñi et al. (2002) and Sepulchre et al. (2007), the Atlantic sea core (MD95-2042) shows a MAP about 300 mm higher than the Mediterranean sea core (MD95-2043) during the H4 event, providing the Iberian Atlantic region with more humid environmental conditions than in the Mediterranean region today, as is also shown by the results obtained from the small-vertebrate studies.

660

5.3 Discussion

In general, the studies of the sea cores (MD95-2042, MD95-2043 and MD99-2343) from the Iberian margins show the Heinrich Events, including the H4 event, to have been characterized by low sea surface temperatures (SST), with values of -7°C to -10°C , and a climate on land drier than today, with lower levels of Mediterranean forest and higher levels of steppe vegetation (Cacho et al., 1999; Sánchez-Goñi et al., 2002; Sánchez-Goñi and d'Errico, 2005; Sierro et al., 2005; Sepulchre et al., 2007). Despite these general data, there are differences between the Heinrich Events and within them. The H4 event and the previous (H5) and subsequent events (H3) are characterized by a fluctuation in woodland taxa and in the extrapolated mean temperatures of the coldest month (MTC) and mean annual precipitation (MAP) (Sánchez-Goñi et al., 2002; Naughton et al., 2009) (Fig. 8). According to these data, the H4 event is considered the most abrupt event compared with the H3 and H5 events, with the MTC between -6 and -10°C compared to nowadays and the MAP 700 mm lower than at present in the Iberian Mediterranean region and 200 mm lower than currently in the Iberian Atlantic region (Sánchez-Goñi et al., 2002; Naughton et al., 2009). According to Cacho et al. (1999) and Sierro et al. (2005), the H3 event is the least cold in comparison to the H4 and H5 events. The data obtained with small-vertebrate studies for the H4 event and the H3 and H5 events (López-García et al., 2010a, 2011b, 2012a, c; López-García and Cuenca-Bescós, 2010) seem to follow the same patterns previously established by the sea-core studies at the Iberian margins (Fig. 8). The small-vertebrate studies show that fluctuations in the percentage values for woodland taxa follow the same pattern as the woody taxa established for the sea core MD95-2043, reaching minimum values (25%) in H5 event layer E from the Abric Romani (López-García and Cuenca-Bescós, 2010; Burjachs et al., 2012) (Table 4). As with the woodland percentage representations, the MTC and the MAP established by means of small-vertebrate studies for the H5 to H3 events follow the same pattern as the curves extrapolated from the sea core MD95-2043 (Sánchez-Goñi et al., 2002) (Fig. 8), reaching minimum values in H5

661

event layer E from the Abric Romani (MTC = -6.41°C ; MAP = $+90$ mm, in relation to the present) (López-García and Cuenca-Bescós, 2010) and in the H4 event from Canyars (MTC = -6.08°C ; MAP = $+99$ mm, in relation to the present) (Table 4). Moreover, direct comparison between level III of Cova del Gegant and the Canyars site reveals less rigorous conditions for the H5 event at the former, where there is no representation of the mid-European species *M. agrestis*, *T. europaea*, *A. fragilis* and *C. austriaca*, which do appear at Canyars (López-García et al., 2012c). As has previously been pointed out by Cacho et al. (1999) and Sierro et al. (2005), however, small-vertebrate studies show the H3 event to be the least harsh of these Heinrich Events, with values for MAP = $+378$ mm and MTC = -0.1°C with respect to the present for layer P11 of El Portalón (López-García et al., 2010a) (Table 4).

6 Conclusions

The data derived from the studied small vertebrates recovered from Canyars add further to our knowledge of the H4 event in the Iberian Peninsula. The small-vertebrate assemblage reveals that the H4 event was characterized in northeastern Iberia by cold climatic conditions, with a landscape alternating between dry meadowland and Mediterranean-type woodland. This assemblage is dominated by mid-European taxa together with a high percentage representation of Mediterranean taxa, a co-occurrence that is the normal dynamic detected in south European peninsulas, which functioned as refuges for species in cold periods. The location of Canyars may have also provided a coastal plain in front of the site with drier conditions and a Mediterranean forest behind with more humid conditions than today.

Secondly, a direct comparison of the data obtained from the small-vertebrate association from Canyars with other terrestrial proxies that have been studied, such as charcoal, pollen, phytoliths, birds and large mammals, corroborates our data, showing that the climate during the H4 event was harsher and drier than today in the northeastern Iberian Peninsula.

662

Furthermore, a comparison with the other small-vertebrate studies in the Iberian Peninsula where the H4 event has been detected, such as El Portalón layer P16 or Cueva del Conde layer N20b, shows this event to be characterized by a landscape dominated by open forest formations, with lower mean annual temperatures (MAT) and mean temperatures of the coldest month (MTC), and relatively high levels of mean annual precipitation (MAP). However, the H4 event provides the Iberian Atlantic region (El Portalón and Cueva del Conde) with more humid environmental conditions than the Mediterranean region (Canyars), as is also shown by the previous results obtained by sea core samples from the Iberian margins.

Finally, a comparison of our data obtained from the small-vertebrate assemblage with the general dynamic of the Heinrich events reveals that the small-vertebrate studies for the H3 to H5 events in the Iberian Peninsula follow the same pattern as the previous studies undertaken for the Iberian margin sea cores, showing that the H4 event is the most abrupt event compared with the H3 and H5 events and that H3 is the least cold of the three.

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669

Table 1. Representation of the Number of Identified Specimens (NISP), the Minimum Number of Individuals (MNI) and the percentage of the MNI (%) for the small vertebrates from Canyars, and the small-vertebrate distribution by habitat and by chorotype. OD = open dry; OH = open humid; Wo = woodland/woodland-edge; Ro = rocky; Wa = water; Ch1 = chorotype 1; Ch2 = chorotype 2; Ch3 = chorotype 3; (g) = generalist; (m) = Mediterranean requirements. x represents the relationship between chorotypes and taxa.

	NISP	MNI	%	OD	OH	Wo	Ro	Wa	Ch1	Ch2	Ch3
<i>Pelodytes punctatus</i>	24	4	15.38	0.5		0.2	0.1	0.2			x(g)
<i>Bufo cf. bufo</i>	3	1	3.85	0.1	0.3	0.4		0.2			x(g)
<i>Bufo calamita</i>	97	5	19.23	0.75		0.25					x(g)
Lacertidae indet.	6	2	7.69								
<i>Anguis fragilis</i>	5	1	3.85		0.25	0.75				x	
<i>Coronella cf. austriaca</i>	6	1	3.85	0.25	0.25	0.25	0.25			x	
<i>Vipera</i> sp.	8	1	3.85	0.25	0.25	0.25	0.25				x(m)
Ophidia indet.	12	–									
<i>Talpa europaea</i>	1	1	3.85		0.5	0.5				x	
<i>Crocidura</i> sp.	1	1	3.85	0.5		0.5					x(m)
<i>Microtus arvalis</i>	3	2	7.69	0.5		0.5			x		
<i>Microtus agrestis</i>	2	1	3.85		0.5	0.5				x	
<i>M. (Terricola) duodecimcostatus</i>	2	1	3.85		0.5	0.5					x(m)
<i>M. (Iberomys) cabreræ</i>	1	1	3.85		0.5	0.5					x(m)
<i>Apodemus sylvaticus</i>	9	3	11.54			1					x(g)
<i>Eliomys quercinus</i>	2	1	3.85			0.5	0.5				x(g)
Total	182	26	100								

670

Table 2. Percentage representations of alterations caused by post-depositional agents in Canyars microvertebrates.

Alterations caused by post-depositional agents	
Manganese oxide	54
Root grooves	10.3
Abrasion	5.3
Chemical corrosion	4
Fissures	2.5
Concretions	0.7
Calcium carbonate	0.7
Weathering	0.3

671

Table 3. Relation of temperature and precipitation for Canyars. MAT = mean annual temperatures; MTC = mean temperature of coldest month; MTW = mean temperature of warmest month; MAP = mean annual precipitation; DJF = mean winter precipitation; JJA = mean summer precipitation; n = number of intersection points; Max = maximum of values obtained; Min = minimum of values obtained; Mean = mean of values obtained; SD = standard deviation of values obtained.

	n	mean	Max	Min	SD
MAT	46	10.11	13.00	6.00	1.75
MTC	46	2.72	9.00	0.00	1.59
MTW	46	18.50	22.00	16.00	1.35
MAP	46	757.6	1200	450	177
DJF	46	175.2	256	95	40
JJA	46	96.96	197	71	37

672

Table 4. Relation between woodland percentage, mean annual precipitation (MAP) and mean temperature of coldest month (MTC) for the different sites where the H3 to H5 events have been detected.

HE	Ka BP	Sites	Woodland (%)	MAP (mm)	MTC (°C)
3	ca. 30	Portalón (P11)	34	378	-0.1
4	ca. 38	Portalón (P16)	32	841	-0.6
	ca. 38–39	Canyars	44	98.6	-6.08
	ca. 39–40	Conde (N20b)	40	127	-5
5	ca. 46	A. Romani (E)	25	90	-6.41
	ca. 45–48	Xaragalls (C4)	66	266	-6.05
	ca. 49	Gegant (III)	48	191	-6.2

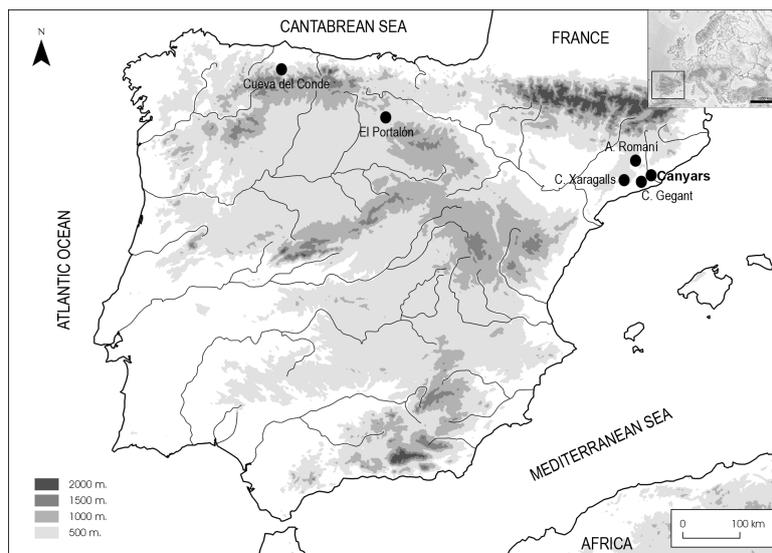


Fig. 1. Location of the sites mentioned in text in the Iberian Peninsula, including Canyars (Terrasses de la Riera dels Canyars).

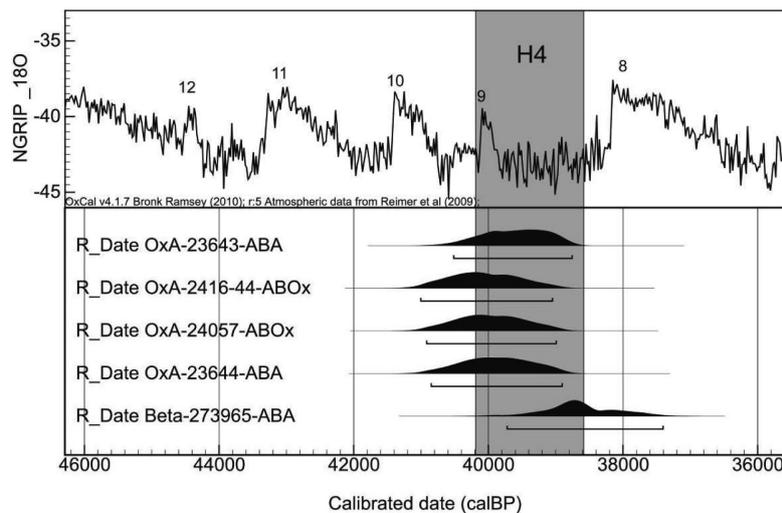


Fig. 2. Plot of the Canyars ^{14}C dates, calibrated with the Intcal09 curve (Reimer et al., 2009) and compared with the North Greenland Ice Core Project NGRIP $\delta^{18}\text{O}$ ice-core record of Svensson et al. (2006) and Andersen et al. (2005), showing GI interstadials and Heinrich Event 4 according to Svensson et al. (2008) (Prepared using OxCal v. 4.1.7; Bronk Ramsey, 2009).

675

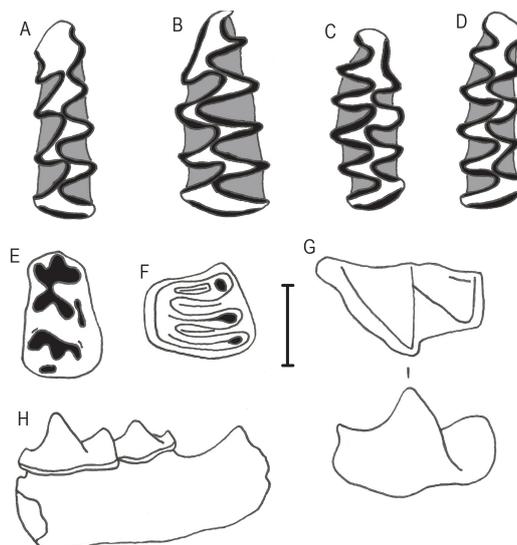


Fig. 3. Some small mammals from Canyars. A: first left lower molar (m1) *Microtus (Terricola) duodecimcostatus* (occlusal view); B: m1 left *Microtus (Iberomys) cabreræ* (occlusal view); C: m1 right *Microtus agrestis* (occlusal view); D: m1 right *Microtus arvalis* (occlusal view); E: m1 right *Apodemus sylvaticus* (occlusal view); F: m1 right *Eliomys quercinus* (occlusal view); G: third left lower molar (m3) *Talpa europæa* (occlusal and labial views); H: left mandible (m2–m3) *Crocidura* sp. Scale 1 mm.

676

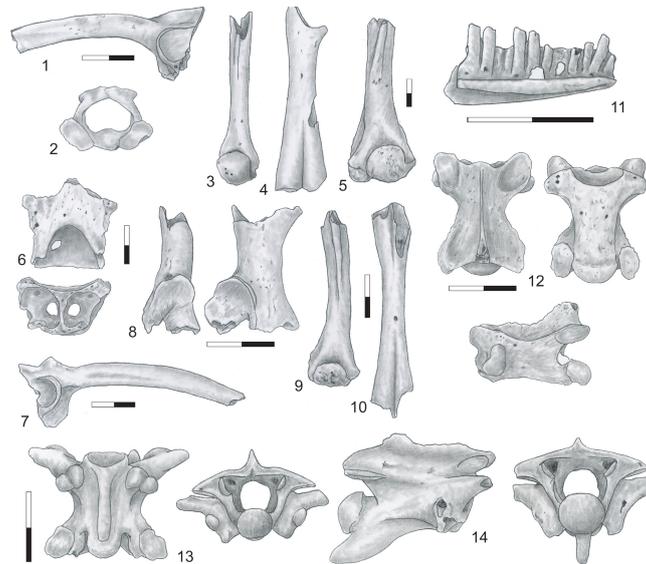


Fig. 4. Some amphibians and squamates from Canyars. 1–4, *Pelodytes punctatus*. 1: left ilium, lateral view; 2: atlas, anterior view; 3: right humerus of female, ventral view; 4: radioulna, lateral view; 5, *Bubo* cf. *bufo*, left humerus of female, ventral view; 6–10, *Bufo calamita*. 6: sphenethmoid, dorsal and anterior views; 7: right ilium, lateral view; 8: right scapula, posterior and dorsal views; 9: right humerus of female, ventral view; 10: tibiofibula, dorsal view; 11, Lacertidae indet., left dentary, medial view; 12, *Anguis fragilis*, trunk vertebra, dorsal, ventral and left lateral views; 13, *Coronella* cf. *austriaca*, trunk vertebra, ventral and posterior views; 14, *Vipera* sp., trunk vertebra, right lateral and posterior views. All scales equal 2 mm.

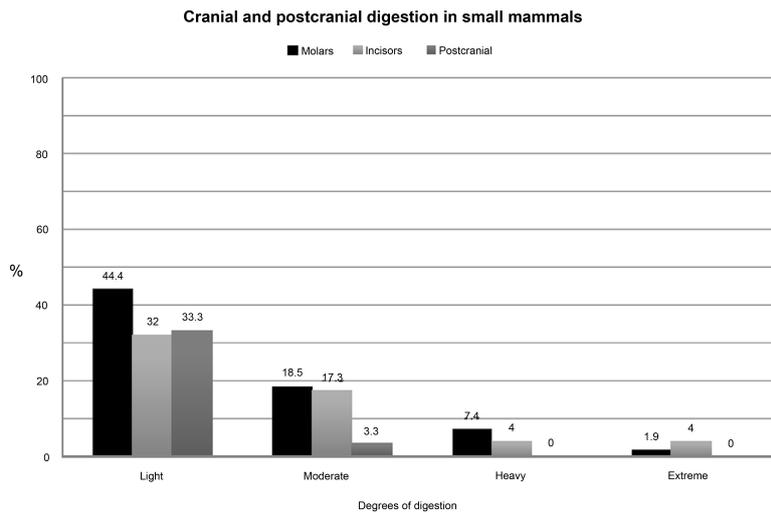


Fig. 5. Percentages of small-mammal elements from Canyars showing different degrees of digestion. We identify 4 degrees of digestion, from light to extreme, following the method of Andrews (1990) for incisors and molars, and the method of Fernández-Jalvo (1992) for postcranial elements. ~~The pictures in 2 incisors and 12 postcranial elements have prevented us from classifying these remains according to a specific degree of digestion.~~

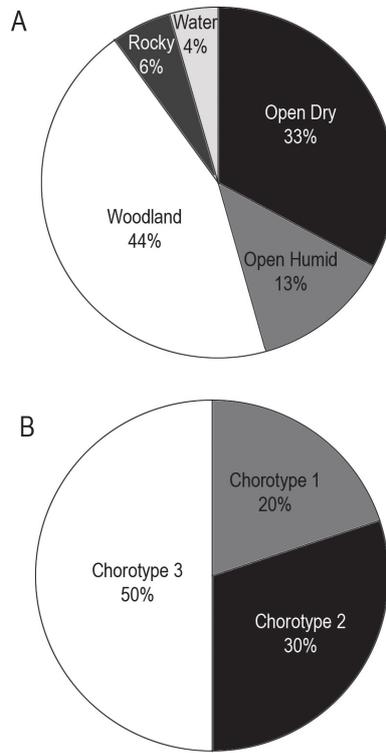


Fig. 6. (A) Small-vertebrate association by habitat. **(B)** Small-vertebrate association by chorotype. Data have been taken from the percentage of the Minimum Number of Individuals.

679

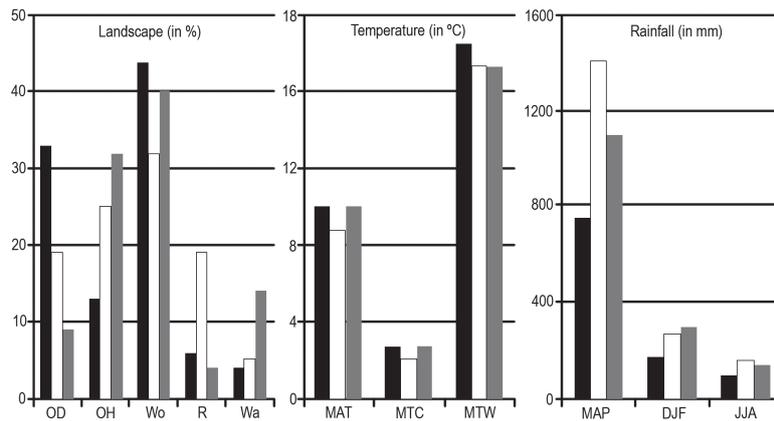


Fig. 7. Environmental and climatic comparisons between Canyars (black bar), El Portalón (white bar) and Cueva del Conde (grey bar). Data for El Portalón are from López-García et al. (2010a) and for Cueva del Conde are from López-García et al. (2011b). Abbreviations: OD, open-dry; OH, open-humid; Wo, woodland; R, rocky; Wa, water edge; MAT, mean annual temperature; MTC, mean temperature of the coldest month (January); MTW, mean temperature of the warmest month (July); MAP, mean annual precipitation; DJF, mean winter precipitation; and JJA, mean summer precipitation.

680

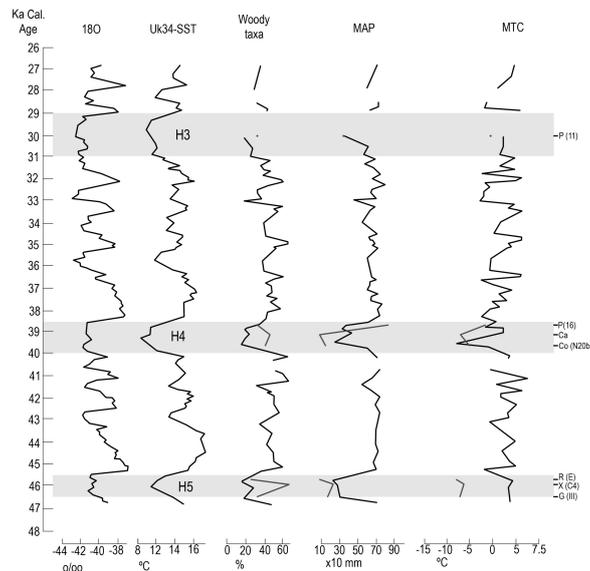


Fig. 8. Proposed correlation of the NorthGRIP2 Isotope (^{18}O) curve, the quantitative variation in the annual sea surface temperature (Uk37-SST), the synthetic pollen diagram from the last glacial section (47 000–27 000 cal yr BP) of core MD95-2043, and the values estimated for annual precipitation (MAP) and mean temperature of the coldest month (MTC) in southeastern Iberia (modified from Sánchez-Goñi et al., 2002) with the various layers with smallvertebrate studies where H3 to H5 events have been detected. P (11 and 16): El Portalón layer P11 and P16; Ca: Terrassa Riera dels Canyars (Canyars); Co (N20b): Cueva del Conde layer N20b; R (E): Abric Romani layer E and G (III): Cova del Gegant layer III (grey lines indicate the data obtained with these studies).