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Not so deserted...paleoecology and human subsistence in Central Iberia (Guadalajara, Spain) around the Last Glacial Maximum



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ABSTRACT

In contrast to the coastal areas of the Iberian Peninsula, the Upper Palaeolithic settlement of central Iberia, dominated by the Spanish plateau, is poorly known. Traditional models assume a total or virtual depopulation of the interior of the Iberian Peninsula during the Last Glacial. In this paper we present a detailed investigation of human–environment interactions through the first zooarchaeological, taphonomic and isotopic study of the key site of Peña Capón, a rock shelter located in the south-eastern foothills of the Central System range that contains a multi-layered deposit dated to marine isotope stage 2 (MIS 2). Analyses of the faunal assemblages of the Proto-Solutrean (3) and Middle Solutrean (2) layers show that human preferentially hunted horse, deer and Iberian ibex living in the vicinity of the rock shelter. Isotope geochemistry of the animal remains of Peña Capón provides us with the first detailed intra-tooth multi-proxy analysis for this time period in south-western Europe, providing estimates of climatic conditions, seasonal fluctuation of diet, as well as patterns of seasonal mobility. Our results indicate that human presence at Peña Capón was apparently restricted to relatively warm intervals around the LGM or reflects the presence of an ecological refuge, and provide us with evidence of recurrent human presence in the Iberian interior during the Upper Paleolithic prior to the Magdalenian.

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1. Introduction

The Iberian Peninsula, located at the southwestern edge of Europe, is generally considered to have been a glacial refugium during the Pleistocene. Together with the Italian and Balkan peninsulas, Iberia is thought to have hosted animals, plants and humans moving from the northern latitudes during periods of peak

glaciation (Straus et al., 2000; Finlayson et al., 2006; Stewart and Stringer, 2012). This would explain the relatively large number of archaeological and paleontological sites throughout the Iberian Peninsula, from the Lower Pleistocene (Carbonell et al., 2008a, 2008b; Toro et al., 2009), the Middle Pleistocene (Santonja and Villa, 1990; Arsuaga et al., 1997; Carbonell et al., 1999; Fernández-Peris, 2007) to the Late Pleistocene (Vega et al., 1999; Straus et al., 2000). A significant number of Upper Palaeolithic sites in the Iberian Peninsula are located along the Cantabrian (Straus, 1992, 2015a; Fano, 2007; Fortea et al., 2010) and Mediterranean coastlines (Davidson, 1989; Cortés-Sánchez, 1996; Bicho et al., 2007, 2010; Fullola et al., 2010; Mangado et al., 2010; Villaverde et al.,

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2010) and Atlantic regions (Bicho et al., 2007, 2010). In the interior of Iberia, which is dominated by a large upland plateau (the *Meseta*) bisected by the Central System range, Lower and Middle Palaeolithic sites are fairly common (Santonja and Pérez-González, 2000–2001; Vega et al., 1999; Panera and Rubio, 2000; Yravedra and Cobo, 2015) but the Upper Paleolithic record is poorly documented.

The paucity of sites in the center of the Peninsula could be due to a real absence of human occupation, to a lack of research effort (Cacho et al., 2010; Alcaraz-Castaño et al., 2013) or to the difficulties of locating open-air sites (Alcaraz-Castaño, 2015). In any case, this paucity has been the traditional basis for proposing a total or partial depopulation of the Spanish plateau during most of the Upper Palaeolithic until the Tardiglacial (Breuil and Obermaier, 1913; Sauvet and Sauvet, 1983; Davidson, 1986; Straus, 1991; Corchón, 1997; Straus et al., 2000; Vaquero, 2006). Causes for this purported gap in the record of human occupation that have been proposed include harsh environmental and climatic conditions of the Iberian interior, in contrast to the coastal areas of the peninsula (Finlayson, 2004; Schmidt et al., 2012; Bradtmöller et al., 2012). Although palaeoecological archives and data for MIS 2 in the Iberian interior are scarce (Ruiz-Zapata et al., 2010; Vegas et al., 2010; Martínez-Pillado et al., 2014; Alcaraz-Castaño et al., in press), recent geomorphological studies of the Central System have emphasized the harsh climatic conditions that would have prevailed during the late Pleniglacial (Palacios et al., 2012; Carrasco et al., 2013; Pedraza et al., 2013; Dominguez-Villar et al., 2015). Paleoclimate simulations also suggest that climate variability in central Iberia was relatively high, creating a high risk environment for human populations during the Last Glacial Maximum (LGM) (Burke et al., 2014).

Magdalenian occupations in the Iberian interior suggest that at least some inner territories were occupied by humans, even during cold and dry episodes of MIS 2, including the LGM, suggesting that the Upper Palaeolithic settlement of interior Iberia was not limited to the warmer phases of the Tardiglacial, as proposed by the classic models, (Davidson, 1986; Straus, 1991; Corchón, 1997; Straus et al., 2000; Vaquero, 2006). However, despite recent developments, data on the settlement of interior Iberia during MIS 2 are still scarce and too problematic to allow us to build models of human–environment interactions in the region. While technological and even symbolic information have increased significantly in recent years, chronometric, economic and ecological data are virtually absent from the record (see Alcaraz-Castaño et al., in press). This is not only because most of the sites in areas such as the Madrid basin were excavated in the first half of the 20th century (see Santonja et al., 2011), and hence lack data suitable for modern paleoecological analyses, but also because faunal remains and other biomarkers are very scarce in their assemblages.

In a recent article studying the settlement of Central Iberia around the LGM, Alcaraz-Castaño (2015) highlights recent work in this region, while pointing out the necessity of obtaining more evidence before proposing solid interpretations of human–environment interactions and population dynamics during the Late Pleniglacial in inland Iberia. Alcaraz-Castaño (2015) proposed a number of hypothetical questions that can be addressed using existing data, namely: 1) were the Solutrean occupations of Central Iberia related to relatively favorable episodes within the otherwise harsh conditions of the LGM 2) Were they favored by the existence of ecological refugia? Or 3) do they just reflect the adaptability of Upper Palaeolithic hunter-gatherers to harsh environments?

In this paper we discuss the above questions by means of zooarchaeological, taphonomic and stable isotope analyses of the faunal assemblages of the Peña Capón rock shelter (Upper Tagus basin, Spain). Peña Capón is currently the only location in Central

Iberia which has yielded faunal remains associated to lithic products during several episodes of MIS 2, and therefore is of paramount importance for studying human subsistence strategies, ecological conditions and human–environment interactions more generally for this period. This study represents the first exhaustive analysis of this faunal material, and the first detailed intra-tooth multi-proxy isotopic analysis of faunal remains for this period in southwestern Europe.

2. Peña Capón rock shelter

Peña Capón is a northwest-oriented rock shelter located in the northern part of the Spanish Southern Meseta. The rockshelter is part of a limestone formation close to the southeastern foothills of the Central System range. Situated at an altitude of 861 m above sea level, the site lies within the Upper Tagus basin (Sorbe valley, Guadalajara province) (Fig. 1). The site was discovered and excavated in 1970 by a team directed by J. Martínez Santa-Olalla, but the results were never published. It was only in the late 1990's that the archaeological assemblages, diaries and photos from the excavation were gathered and analyzed in a preliminary paper on the site by Alcolea et al. (1997a). Recently, a more detailed study of the lithic and faunal remains, including the radiocarbon dates for several bone samples, was conducted (Fig. 2); so far only data from the Proto-Solutrean layer (3) have been thoroughly published (Alcaraz-Castaño et al., 2012a, 2013).

According to existing data, the archaeological deposit of Peña Capón comprises, from top to bottom (Fig. 2), a surface level (1) containing mixed Magdalenian and Upper Solutrean materials, which includes shouldered points, a Middle Solutrean level (2) characterised by laurel leaf points, a Proto-Solutrean level (3) with Vale Comprido points, and a level containing non-diagnostic lithic products produced mostly in quartz, from which a date in the range of known dates for the Gravettian (i.e. 25.4 ± 0.3 ka cal BP) was obtained (4). Radiocarbon dates and diagnostic lithic artifacts from each layer are shown in Fig. 2 (see also Alcolea et al., 1997a; Alcaraz-Castaño et al., 2013; Alcaraz-Castaño, 2015).

The material analyzed here comes from the assemblages collected during the 1970 excavation. This excavation was stratigraphically controlled and thus the provenance of lithic and bone materials is considered secure. However, work conducted in 1970 did not include geomorphological, sedimentological or palaeoecological analyses, and hence these data are currently lacking. Furthermore, current methods of recording and screening were not used and it is very likely that small lithic and bone remains were lost in the course of excavation (Alcolea et al., 1997b; Alcaraz-Castaño et al., 2013). The rock shelter still preserves archaeological deposits, however it is currently under water (a reservoir was constructed in 1982) and is only accessible in very dry years. Thus, new archaeological excavations at the site have not been possible until very recently.

Nevertheless, Peña Capón is relevant for both the understanding of the human settlement of Central Iberia and the reconstruction of ecological and climatic conditions during MIS 2.

3. Material and methods

All available faunal remains from level 2 (Middle Solutrean) and level 3 (Proto-Solutrean) from Peña Capón have been analyzed from a zooarchaeological and taphonomic perspective, corresponding to $N = 306$ and $N = 564$ bones, respectively (Table 1). Isotopic analyses have been conducted on a total of six ungulate dental remains from layer 2 and 3, corresponding to three teeth in each layer.

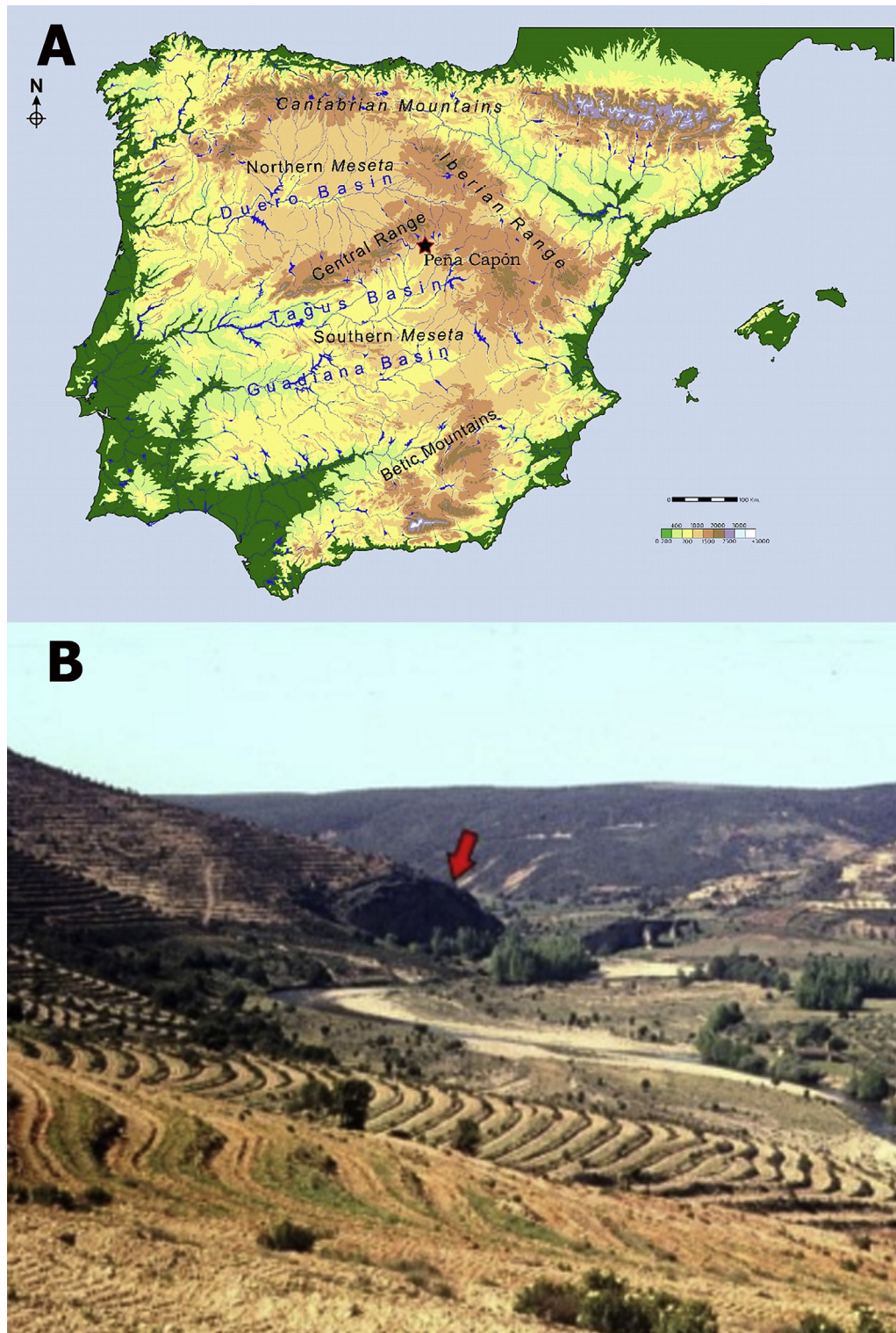


Fig. 1. A: Geographic location of the Peña Capón rock shelter in the Iberian Peninsula. B: View of the Peña Capón rock shelter in the Sorbe River Valley prior to the construction of the Beleña reservoir (in 1982).

3.1. Zooarchaeology and taphonomy

Taxonomic identification of the faunal remains is based on reference material held at the Complutense University (Madrid, Spain). In cases where the exact taxonomical determination was

not possible, epiphyses and shaft fragments were assigned to approximate animal weight or size classes following Uerpmann (1973), with 'small group' refers to Bunn (1982) size 1 and 2 size class (i.e. animals <250 kg, e.g. *Rupicapra* or *Capra*); and 'large group' referring to Bunn (1982) size 3–5 (i.e. animals of

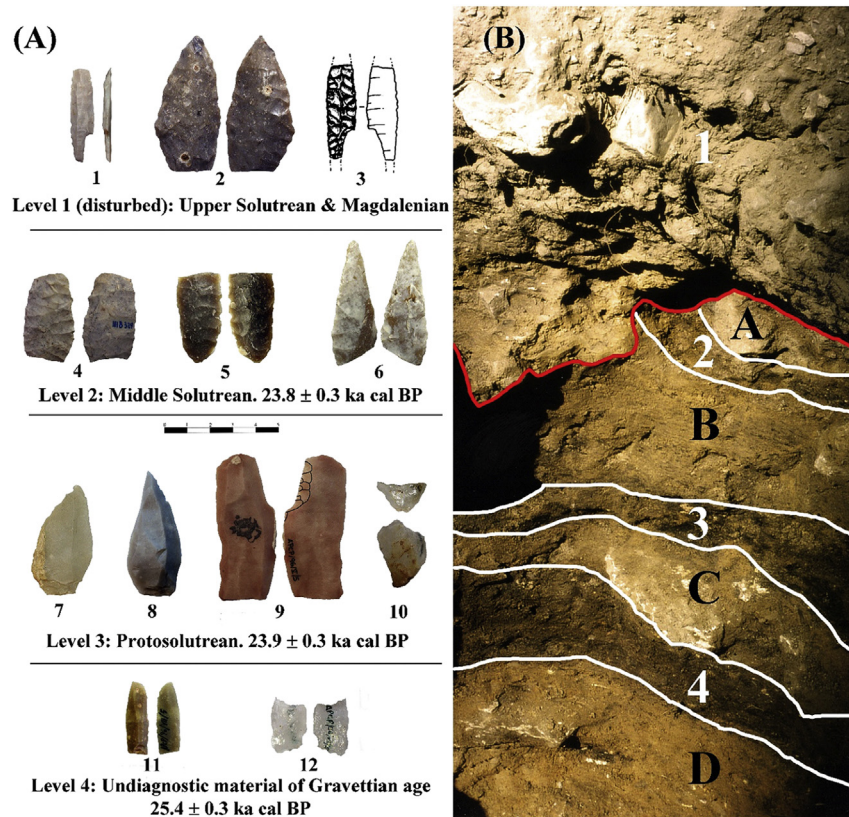


Fig. 2. (A). Lithic assemblages and dating results from the Peña Capón sequence. 1: “Mediterranean-type” shouldered point. 2: Laurel leaf point. 3: “Cantabrian-type” shouldered point. 4–6: Laurel leaf points. 7–8: Vale Comprido points. 9: Endscraper on a wide blade with inverse flat retouches. 10: Carinated bladelet core made on quartz. 11: Retouched bladelet. 12: Notch on a hyaline quartz flake. (B). Photo from the 1970 excavation of the Peña Capón stratigraphic sequence. Archaeological levels according to the 1970 excavators are highlighted in white, while the red line separates the disturbed layer 1 from the rest (after Alcaraz-Castaño, 2015: Fig. 4). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Taxonomical patterns of Peña Capón according to NISP.

NISP	Solutrean	%	Proto-Solutrean	%
Layer	2		3	
<i>Equus</i> – Horse	31	10.1	18	3.2
<i>Bos/Bison</i> – Large Bovid			2	0.4
<i>Cervus</i> – Deer	17	5.6	117	20.7
<i>Sus</i> – Wild boar	1	0.3		0.0
<i>Capra</i> – Iberian ibex	23	7.5	11	2.0
<i>Oryctolagus</i> – Rabbit	5	1.6	49	8.7
Large	64	21	126	22.4
Small	107	35.0	52	9.2
Indet	58	19.0	189	33.5
Total	306		564	

Table 2
Taxonomical patterns of Peña Capón according to MNI where A: Adult, J: Juvenile; I: infant.

Layer	Solutrean		Proto-Solutrean	
	2		3	
MNI	A/J/I	%MNI	A/J/I	%MNI
<i>Equus</i> – Horse	1	12.5	1	6.7
<i>Bos/Bison</i> – Large Bovid			1	6.7
<i>Cervus</i> – Deer	1/0/1	25	2/1/1	26.7
<i>Sus</i> – Wild boar	1	12.5		
<i>Capra</i> – Iberian ibex	2/1/0	37.5	2/0/1	20
<i>Oryctolagus</i> – Rabbit	1	12.5	3/1/2	40
Total	8		15	100

250–1000 kg, e.g. deer, horse and auroch).

The number of identified specimens (NISP) and minimum number of individuals (MNI) are used to quantify the faunal remains and to describe taxonomic representation. NISP determination follows Lyman (1994a, b), whereas MNI is based on Brain (1969) method which uses bone laterality and estimated age. Element identification of shaft fragments is based on shaft thickness, section shape, and medullar surface properties following Barba and Domínguez-Rodrigo (2005). Skeletal profiles and MNI reconstruction consider shaft thickness, section shape and medullar surface properties (Barba and Domínguez-Rodrigo, 2005). Bone elements are divided into four anatomical regions (Yravedra and Domínguez-Rodrigo, 2009): cranial (i.e. horn, cranium, mandible and teeth), axial (vertebrae, ribs, pelvis and scapula); upper appendicular limb bones (humerus, radius, ulna, femur, patella and tibia) and lower appendicular limb bones (metapodials, carpals, tarsals, phalanges and sesamoidae). Long limb bones were also divided into upper (humerus and femur), intermediate (radius and tibia), and lower (metapodials) limb bones (Domínguez-Rodrigo, 1997).

Estimates of the minimum number of elements (MNE) present in an assemblage differ substantially depending on whether shaft fragments are used for element identification or not (Pickering et al., 2003; Cleghorn and Marean, 2004). Here, we include shaft fragments in the calculation of MNE. We employed an integrative approach using the bone section division proposed by Patou-Mathis (1985), Münzel (1988), and Delpech and Villa (1993), as described in detail in Yravedra and Domínguez-Rodrigo (2009). Shafts are divided into sectors of equal size, irrespective of areas of

muscular insertion. These sectors (upper shaft, mid-shaft, lower shaft) can be easily differentiated and oriented (cranial, caudal, lateral, medial). MNE is then quantified by laying out all specimens from the same size group and documenting overlapping samples taking element size, side, age and bone sector into account.

Mortality patterns are established using the following age categories: young, young-adult and adult. Age is estimated using tooth eruption and tooth wear patterns, following Guadelli (1998) for horse, Pérez-Ripoll (1988) for Iberian ibex and Steele (2002) for red deer.

We also employed taphonomic analyses to reconstruct site formation processes, assess site integrity, and evaluate the contributions of various biogenic agents to the faunal assemblage. This was done at three levels. First of all, we examined fragmentation patterns. Bone fragments were classified into three categories: <3 cm, 3–5 cm and >5 cm. Only long bone fragments were considered and shaft circumference was also taken into account, since anthropogenic bone assemblages show greater fragmentation than carnivore assemblages, which contain a larger proportion of complete shaft circumferences (Bunn, 1982). Bunn (1982) proposes three categories for the determination of shaft circumference: (1) circumferences <25%; (2) between 25% and 75%; and (3) >75%. Thirdly, only those long bone fragments displaying green breakage were considered. This distinction is made because diagenetic (dry) breakage is relatively common in archaeological assemblages and, thus, the distribution of dry-bone breakage patterns may be quite different from the patterning in the original deposited bone accumulations.

Green bone breakage was identified using fracture planes following Villa and Mahieu (1991) guidelines. Dry breakage planes tend to be longitudinal or transverse to the long axis of the bone with a nearly 90° angle between the cortical and medullar surfaces and an uneven breakage plane surface with micro-step fractures and a rough texture. On the other hand, green breakage planes are characterised by smoother surfaces and are more likely to be oriented obliquely to the long axis of the bone.

Additionally, a systematic examination of bone surface modifications such as cut, percussion and tooth marks was carried out with 10X–20X hand lenses and different lighting angles (Blumenschine, 1988, 1995) and cut, percussion and tooth marks were recorded. The diagnostic criteria defined by Bunn (1982), Potts and Shipman (1981) and Domínguez-Rodrigo et al. (2009) guided our identification of cut marks, whereas tooth marks were recorded following Blumenschine (1988, 1995). Finally, the identification of percussion marks followed Blumenschine and Selvaggio (1988) and Blumenschine (1995). For comparative purposes, surface modifications include the evaluation of epiphysis and shafts (Blumenschine, 1988, 1995). Modifications were quantified by element type and bone section (Domínguez-Rodrigo, 1997; Domínguez-Rodrigo and Barba, 2005) based on NISP values (Bunn, 1982). The presence of tooth, percussion and cut marks was recorded for the entirety of remains, whereas estimated percentages include only well-preserved bone surfaces.

3.2. Isotopic analyses

3.2.1. Principle of analysis

The carbon, oxygen and strontium isotope analyses were performed on enamel apatite from teeth selected from the faunal assemblages from layer 2 (Middle Solutrean) and layer 3 (Proto-Solutrean) of Peña Capón. The carbon and oxygen isotope components of mammal bones and teeth mainly derive from animal diet and reflect environmental conditions and animal ecology (e.g. Luz et al., 1984; Fricke et al., 1998). Enamel is the most mineralized osseous tissue and, except in some cases of microbially-mediated

reactions (e.g. Blake et al., 1997; Lécuyer et al., 1999; Zazzo et al., 2004a), generally does not undergo diagenetic changes that could affect biogenic isotopic signals (Lee-Thorp and Sponheimer, 2003). Enamel, therefore, is usually favored for isotopic analysis.

Tooth enamel forms by accretion, from the crown to the cervix, and once formed does not undergo remodelling. Sequential sampling of crown enamel, thus, provides a continuous isotopic record from the beginning of crown formation until the completion of crown mineralization, which can cover a period of a few months to several seasons depending on the species (e.g. Luz et al., 1984; Fricke et al., 1998). However, enamel growth rate and maturation length results in different degree of dampening of the original isotopic signal between species, resulting in differences in the amplitude of the measured signals (Passey and Cerling, 2002; Kohn, 2004).

An intra-tooth incremental multi-isotopic analysis was the selected sampling strategy, including oxygen, carbon and strontium isotopic measurements, in order to obtain accurate palaeobiological, paleoecological and paleoenvironmental data. The oxygen isotope composition of the mineralized dental tissues of large mammals is mainly controlled by the isotope composition of local meteoritic water and records climatic changes at the seasonal scale (e.g. Luz et al., 1984; Fricke et al., 1998). The carbon isotope composition of osseous tissues of mammalian herbivores is largely controlled by the type of plant consumed, and allows tracking both environmental conditions and dietary habits of mammals (Cerling et al., 1997; Balasse, 2002; Tütken et al., 2006). Strontium isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) of mineralized dental tissues of terrestrial herbivores reflect the isotopic composition of substratum minerals, which formed the soils where the consumed plants grew. Therefore it can be a useful tracer of animal mobility at a regional scale that implies changes in the geology of the rocky substratum (Price et al., 2002; Tütken et al., 2006).

3.2.2. Sampling methods and analytical techniques

The sampling strategy for the isotopic analysis was designed to maximize the number of individuals sampled from each level. A total of six teeth were serially sampled. Due to the small number of teeth available from level 3, a complete row of upper molars from one horse (*Equus* sp.), including M1, M2 and M3, was sampled. In level 2, two horse maxillary teeth from two different individuals and one *Capra* upper third molar were sampled (Table 3). The crowns were mechanically cleaned to remove sediment, residual glue, cement or altered enamel. Samples of 10–20 mg of enamel powder were taken every 3 mm along the growth axis of the crown.

Carbon and oxygen isotope measurements of the carbonate fraction from apatite (henceforth $\delta^{18}\text{O}_c$ and $\delta^{13}\text{C}$) were performed on 1–1.5 mg of untreated enamel powder following standard CO_2 extraction procedures: the carbonate was reacted at 90 °C with 100% orthophosphoric acid, using a Multicarb™ preparation device online with a dual inlet IsoPrime™ mass spectrometer at GEOTOP (UQAM, Montréal). The carbonate standards used include NBS 19 (cf. Coplen, 1996) and GEOTOP in-house UQ6 carbonate standard calibrated against the Carrara Marble standard from Cambridge (cf. Hillaire-Marcel et al., 1994). The overall analytical uncertainty determined from replicate measurements of UQ6, during each run, is routinely close to 0.04‰ for both oxygen and carbon isotope measurements. All results are reported as δ -values against V-PDB (Coplen, 1996). Oxygen measurements were converted to V-SMOW following the formula: $\delta^{18}\text{O}(\text{SMOW}) = [\delta^{18}\text{O}(\text{PDB}) \times 1.03086] + 30.86$ (Bowen, 2008).

Samples with the lowest and highest $\delta^{18}\text{O}_c$ values were chosen for phosphate and strontium extraction, as described in Julien et al. (2012). For strontium, additional samples were chosen between two $\delta^{18}\text{O}_c$ choices. Treatment and analysis of the phosphates

Table 3
Carbon, oxygen and strontium isotope composition of equid and caprid tooth carbonates (c) and phosphates (p) from Peña Capón. (*) $\delta^{18}\text{O}_c$ values were converted into $\delta^{18}\text{O}_p$ -calculated values ($\delta^{18}\text{O}_p\text{-calc}$) following the combination of equations from [Iacumin et al. \(1996\)](#) and [Bryant et al. \(1996\)](#).

Layer	Species	Element	Lab#		%CO ₃	$\delta^{13}\text{C}$	$\delta^{13}\text{C}_{\text{diet}}$	$\delta^{18}\text{O}_c$	$\delta^{18}\text{O}_c$	$\delta^{18}\text{O}_p\text{-calc}^*$	$\delta^{18}\text{O}_p$	$^{87}\text{Sr}/^{86}\text{Sr}$
						VPDB	VPDB	VPDB	VSMOW	VSMOW	VSMOW	
2/solutrean	Equus	UP2 L	PC1	N	14	14	14	14	14	14	2	2
				Mean	4.8	-10.1	-24.2	-7.1	23.6	14.8	15.7	0.70932
				Min	4.5	-10.6	-24.7	-8.0	22.7	13.9	15.2	0.70923
				Max	5.5	-9.8	-23.9	-6.2	24.5	15.8	16.3	0.70940
				Range	1.0	0.8	0.8	1.8	1.9	1.8	1.1	0.00018
2/solutrean	Equus	UP/M R	PC2	N	18	18	18	18	18	18	2	2
				Mean	4.6	-10.5	-24.6	-6.4	24.3	15.5	17.1	0.70915
				Min	3.4	-11.3	-25.4	-8.1	22.6	13.9	16.6	0.70912
				Max	5.4	-9.2	-23.3	-5.6	25.2	16.4	17.5	0.70918
				Range	2.0	2.1	2.1	2.5	2.6	2.5	1.0	0.00007
2/solutrean	Capra	UM3 L	PC3	N	8	8	8	8	8	8	—	1
				Mean	4.4	-10.7	-24.8	-5.9	24.8	16.0	—	—
				Min	4.0	-11.0	-25.1	-7.1	23.5	14.8	—	—
				Max	4.6	-10.5	-24.6	-4.4	26.4	17.5	—	0.71003
				Range	0.6	0.5	0.5	2.7	2.8	2.8	—	—
3/Protosolutrean	Equus	UM1 L	PC4A	N	10	10	10	10	10	10	1	3
				Mean	4.9	-10.0	-24.1	-6.4	24.3	15.5	—	0.71025
				Min	4.3	-10.1	-24.2	-7.3	23.4	14.6	16.6	0.71014
				Max	5.4	-9.7	-23.8	-5.6	25.1	16.3	—	0.71038
				Range	1.1	0.4	0.4	1.7	1.7	1.7	—	0.00024
3/Protosolutrean	Equus	UM2 L	PC4B	N	11	11	11	11	11	11	2	2
				Mean	4.8	-10.5	-24.6	-6.2	24.5	15.7	17.7	0.71021
				Min	4.1	-10.8	-24.9	-7.1	23.6	14.8	16.9	0.71003
				Max	5.3	-10.2	-24.3	-5.3	25.4	16.6	18.4	0.71040
				Range	1.2	0.6	0.6	1.8	1.9	1.8	1.5	0.00037
3/Protosolutrean	Equus	UM3 L	PC4C	N	12	12	12	12	12	12	3	3
				Mean	4.9	-10.7	-24.8	-6.2	24.5	15.7	17.0	0.71007
				Min	4.5	-11.1	-25.2	-7.4	23.3	14.5	15.9	0.70993
				Max	5.5	-9.9	-24.0	-5.3	25.4	16.6	17.6	0.71028
				Range	1.0	1.2	1.2	2.1	2.1	2.1	1.6	0.00036

followed the method described in [Lécuyer et al. \(1993\)](#) and [Fourrel et al. \(2011\)](#) and were performed at the Laboratoire de Géologie de Lyon (UCB Lyon 1). Oxygen isotope measurements were obtained with a EuroVector EA3028-HT™ system connected to an

IsoPrime isotope ratio mass spectrometer in continuous-flow mode. Extraction and measurement of the strontium isotope ratios were performed at GEOTOP (UQAM, Montréal), following current procedures (e.g. [Horwitz et al., 1992](#)). The sample aliquot

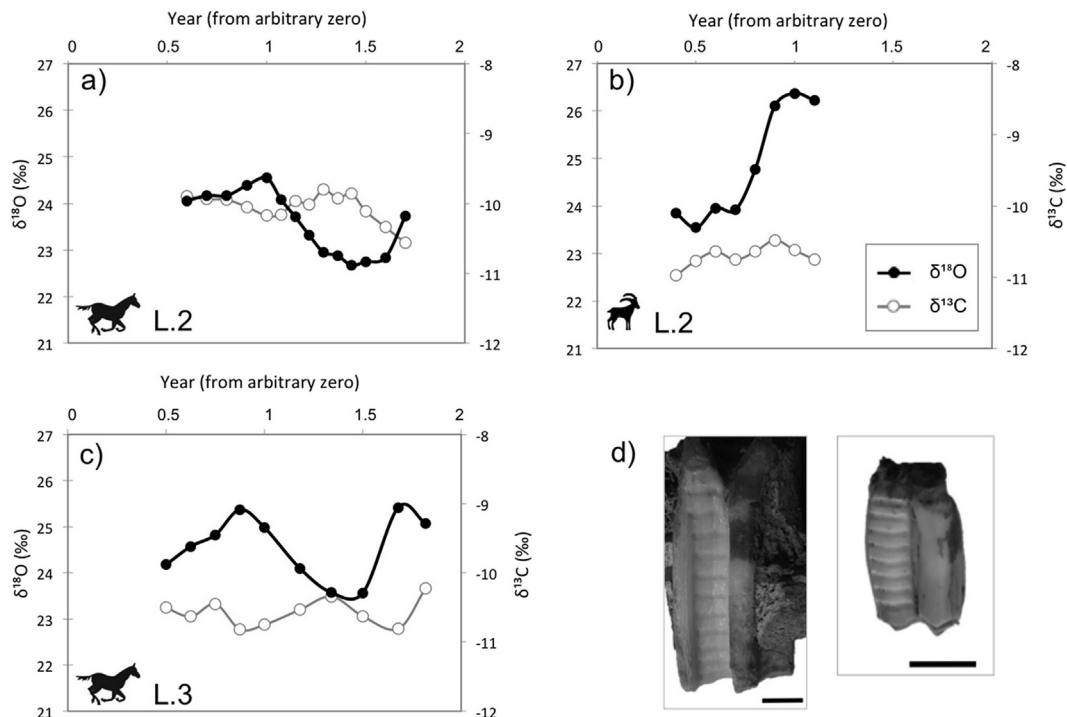


Fig. 3. Examples of $\delta^{18}\text{O}_c$ (black dots) and $\delta^{13}\text{C}$ (white dots) intra-tooth variations of enamel samples from Peña Capón (a and b: PC1 horse and PC3 ibex from layer 2; c: PC4B horse from layer 3), and examples of serially sampled tooth (left: PC4B horse UM2 from layer 3, right: PC3 ibex UM3 from layer 2). Scales bars = 1 cm.

used for Sr isotopes (0.1 g) was dissolved in a Teflon™ beaker using a mixture of concentrated hydrofluoric and nitric acids. Details about Sr chemistry protocol can be found in Maccali et al. (2013). Sr isotope ratios were measured with a GV Sector-54™ mass spectrometer in dynamic collection mode. The Sr fraction was loaded onto a single Re filament with a Ta oxide activator. Repeated analysis of the NBS 987 Sr standard yielded a value of $^{87}\text{Sr}/^{86}\text{Sr} = 0.710263 \pm 17$ (2σ , $n = 7$). Blanks for Sr were typically <150 pg.

3.2.3. Inferring past air temperatures and vegetation consumed

Enamel $\delta^{18}\text{O}_c$ and $\delta^{18}\text{O}_p$ values were used to estimate past temperatures. $\delta^{18}\text{O}_c$ values were converted into $\delta^{18}\text{O}_p$ -calculated following the combination of equations from Iacumin et al. (1996) and Bryant et al. (1996), which do not significantly differ from the one determined by Zazzo et al. (2004b). $\delta^{18}\text{O}_p$ -measured and $\delta^{18}\text{O}_p$ -calculated were converted into drinking water $\delta^{18}\text{O}$ values ($\delta^{18}\text{O}_{mw}$) with the formulas available for caprid and equid, provided by Delgado-Huertas et al. (1995) and Rey et al. (2013) after Bryant et al. (1994). Air temperature was then estimated using the following equation: T ($^{\circ}\text{C}$) = $1.978(\pm 0.008) \delta^{18}\text{O}_{mw} + 26.414(\pm 0.595)$ provided by Rey et al. (2013).

The carbon isotope fractionation between plants and herbivore bioapatite of -14.1% (Cerling and Harris, 1999) was used to calculate the $\delta^{13}\text{C}$ values of the plants consumed ($\delta^{13}\text{C}_{\text{diet}}$).

4. Results

4.1. Faunal representation, mortality patterns and paleoenvironmental implications

The taxa identified in Peña Capón are *Bos/Bison*, *Cervus elaphus*, *Sus scrofa*, *Capra pyrenaica* and *Oryctolagus cuniculus*. Taxonomic profiles of the two levels analyzed here are as follows:

Level 3 (Proto-Solutrean) with a total of 564 remains (Table 1), and a minimal number of individuals (MNI) of 15 (Table 2), contains the largest faunal assemblage. In terms of MNI, with the exception of *Oryctolagus* (MNI = 5), red deer dominates the macrovertebrate assemblage (with 4 individuals), followed by ibex, horse and the large bovid (with 3, 1 and 1 individuals respectively). Red deer remains also dominate in terms of NISP, followed by horse and ibex. Mortality patterns indicate that adults dominate, though juvenile red deer and ibex are well represented.

Level 2 (Middle Solutrean) is the second largest assemblage with a total of 306 remains (Table 1) and a MNI of 8 (Table 2). The main taxon is the Iberian ibex, with a MNI of three individuals, followed by red deer (with 2 individuals) and a single equid. Horse is the most important taxon according to NISP, with 31 bone fragments (slightly more than 10% of total NISP), suggesting that this taxon suffered relatively higher fragmentation than other prey species. Mortality patterns indicate an emphasis on adults, though a juvenile ibex and an infant deer are also present.

4.2. Isotopic data

4.2.1. Preservation of the isotopic signal

The carbonate contents of all sampled teeth were similar to the carbonate content of modern enamel (Table 3) (Sydney-Zax et al., 1991). The $\delta^{13}\text{C}$ values fall within the range of published values for Pleistocene European large herbivores (e.g. Feranec et al., 2010; Iacumin et al., 2010; Julien et al., 2012; Ecker et al., 2013; Domingo et al., 2015). The intra-tooth $\delta^{18}\text{O}_c$ variations depict the expected sinusoidal pattern and reflect seasonal fluctuations of $\delta^{18}\text{O}$ in environmental surface waters (Fig. 3), although this pattern is attenuated for one specimen (PC2). $\delta^{18}\text{O}_c$ and $\delta^{18}\text{O}_p$ values globally

show the same pattern within each tooth, with $\delta^{18}\text{O}_c$ values fluctuating according to $\delta^{18}\text{O}_p$. Moreover, the mean difference of 7.3‰ between $\delta^{18}\text{O}_c$ and $\delta^{18}\text{O}_p$ values (min. 5.7‰, max. 9.5‰) matches the differences reported for other mammals (Fox and Fisher, 2001).

The $\delta^{18}\text{O}$ variations of the sampled teeth recorded about 8 months of growth for the Caprid tooth and 1–1.5 years of enamel growth for the horse teeth based on modern observations (Kohn, 2004). The ranges of $\delta^{18}\text{O}_c$ intra-tooth variations are globally similar for the equids from level 2 and the individual horse from level 3. Specimen PC2 has a larger range of variation of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}_c$ values that result from a single (likely anomalous) value located at the base of the crown, which could be due to the thinness of the enamel in this area of the crown. This means that it could have recorded a shorter period of time resulting in a less dampened isotopic signal. Alternatively, it could reflect diagenetic alteration. The ibex shows a greater range of $\delta^{18}\text{O}_c$ intra-tooth variation in comparison to the horses (Table 3, Fig. 3), which corresponds to the differential attenuation of environmental isotopic signals between small bovid dental enamel in comparison to horse enamel (i.e. average damping of 10% for caprids vs 40–50% for equids – Kohn, 2004).

These results lead us to conclude that the biogeochemical signals recorded in the enamel samples from Peña Capón have not been significantly altered or modified since the death of the animals and allow palaeobiological, paleoecological and paleoclimatic reconstructions.

4.2.2. Palaeobiological and palaeoenvironmental interpretations

Intra-tooth $\delta^{13}\text{C}$ variation spans a narrow range of -11.3 to -9.2% (mean = -10.4%). All sampled horse teeth from Peña Capón show a similar pattern of intra-tooth variation whereby $\delta^{13}\text{C}$ values tend to be slightly higher when $\delta^{18}\text{O}$ values are high and conversely (this tendency is less clear for *Capra*) (Fig. 3). With the exception of a single specimen (PC2), which was discussed previously, all carbon isotope ratios fall within a narrow range of values ($\leq 1\%$). This could indicate limited variation in diet during the time of crown formation or alternatively, globally similar mean isotopic values of the different plants ingested (cf. Julien et al., 2015; Rivals et al., 2015).

Mean $\delta^{18}\text{O}$ values of biogenic minerals (apatite carbonates) vs those of meteoric waters ($\delta^{18}\text{O}_{mw}$), as well as mean $\delta^{13}\text{C}_{\text{diet}}$ values have been calculated for each cycle when at least two $\delta^{18}\text{O}_c$ peak values were available. Mean annual $\delta^{18}\text{O}_{mw}$ and $\delta^{13}\text{C}_{\text{diet}}$ values are similar within the same individual (e.g. PC4, a horse partial tooth-throw from layer 3), as well as between individuals of the same layer (Fig. 4). Specimens from layer 2 and 3 also have very similar $\delta^{13}\text{C}$ diet values (Fig. 4). This could indicate ecological stability within and between the two layers, and/or similar diets for the different horses.

The carbon isotopic values indicate the exclusive consumption of C_3 plants, with no intake of C_4 plants, as expected for a Pleistocene Eurasian context (Tieszen, 1991). The sampled herbivores were feeding on plants from open environments, likely grassland or steppe. However, the herbivore species we sampled might have been feeding selectively, and one cannot exclude the possibility that other types of vegetation were available but were not exploited by the specimens studied here.

Strontium isotope ratios are globally similar within the same tooth (Table 3), which indicates that the sampled individuals were probably not moving over a large geographical area during the formation time of their teeth, and were primarily sedentary. However, the strontium signatures of horses in level 2 (with relatively low $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.70932 ± 0.00018 and 0.70915 ± 0.00007) are clearly distinct from that of the ibex from this level ($^{87}\text{Sr}/^{86}\text{Sr} = 0.71003 \pm 0.00007$), as well as the horse in layer 3

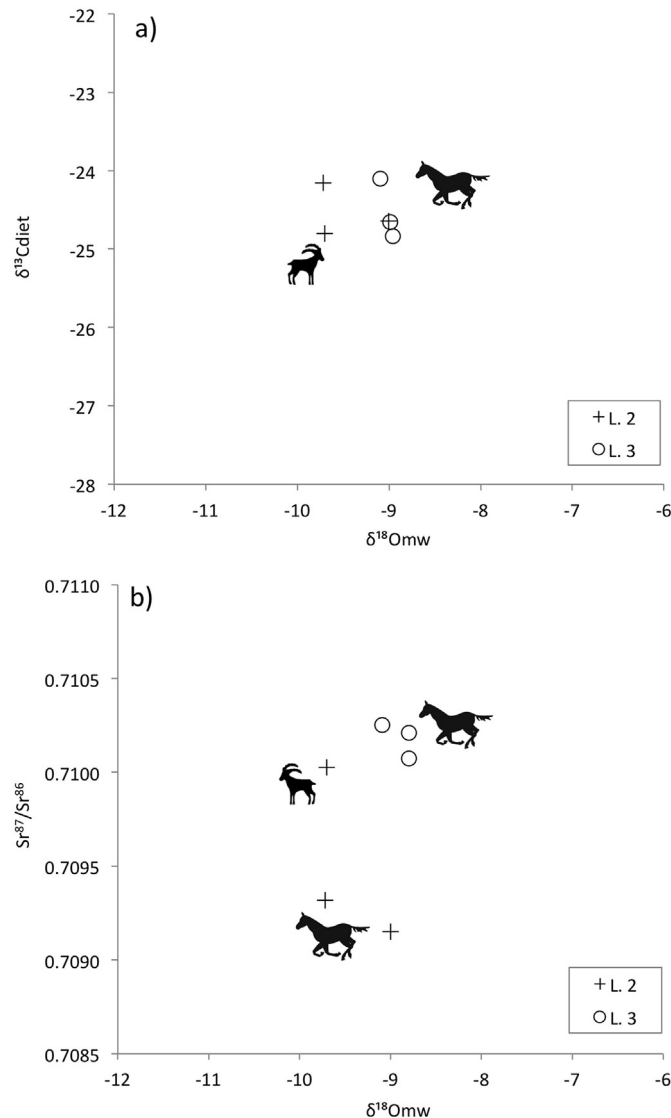


Fig. 4. Calculated annual mean $\delta^{18}\text{O}$ meteoric water values ($\delta^{18}\text{Omw}$), a) compared to the $\delta^{13}\text{C}$ of the plants inferred from the animal diet ($\delta^{13}\text{C}_{\text{diet}}$) and b) compared to the mean strontium isotope ratios of tooth enamel samples from Peña Capón (L.2 = layer 2; L.3 = layer 3).

(mean $^{87}\text{Sr}/^{86}\text{Sr} = 0.71019 \pm 0.00047$) (Fig. 4b). Ibex tends to feed on dry slopes or on upland plateaux. The horse from layer 3 presents a similar, more radiogenic $^{87}\text{Sr}/^{86}\text{Sr}$ signal to the ibex, which indicates that it might also have lived in a more upland environment, whereas the level 2 Sr isotope ratios for horse are more likely to be associated with the local limestone-dominated lowland environment.

The past mean annual air temperature estimated from mean enamel $\delta^{18}\text{O}$ values average 8.5 and 8.8 ± 3 °C for layer 2 and 3 respectively. Temperature estimates from measured $\delta^{18}\text{O}$ values, with mean annual values of 16.4‰ for layer 2 and 17.2‰ for layer 3, indicate mean air temperatures of 10.3 and 11.9 ± 3 °C. These values indicate relatively colder temperatures than the present-day conditions for the region - with a mean of 12.4 °C in the locality of Muriel, 3 km away from Peña Capón. These estimates are higher however, than temperatures predicted from climate simulations of the Last Glacial Maximum centered on 21,000 cal. BP (Fig. 5) which provide an estimate of 6.5 ± 2.9 °C for the mean annual temperature in the area of the site (cf. Burke et al., 2014).

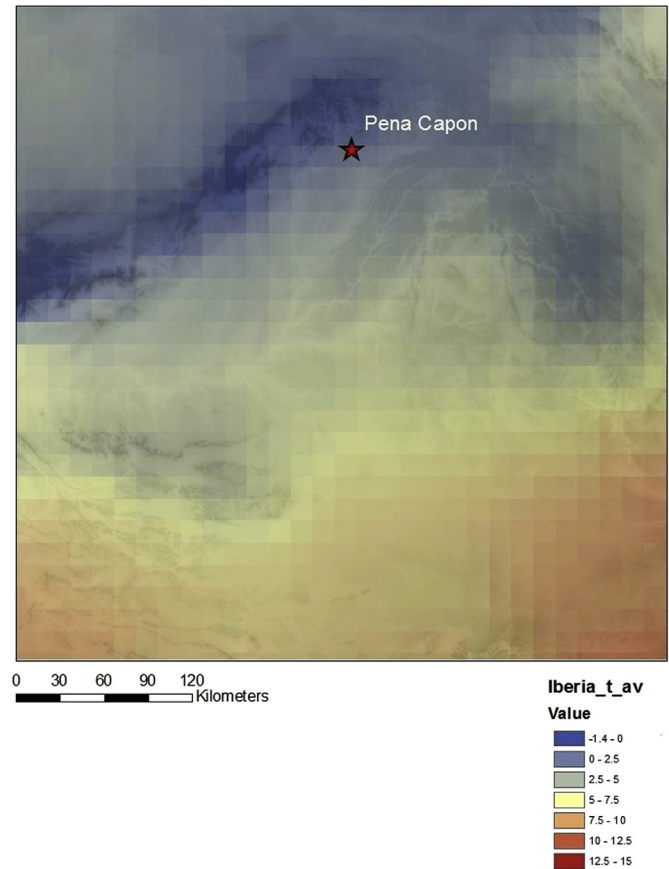


Fig. 5. Paleoclimatic simulations centered on 21,000 cal. BP for the region of Peña Capón used as comparison for the temperature expected during the LGM.

4.3. Skeletal profiles and taphonomic evidence

All anatomical elements are represented in level 2. Upper appendicular bones dominate the large and small mammal assemblages, followed by the lower appendicular bones of large mammals (Table 4). Level 3 shows a similar pattern, with the upper appendicular bones being the best represented elements for all size classes (Table 4). Axial bones are better represented in level 3 than in level 2, especially for large mammals. The scapula and pelvis of small mammals are poorly represented, lower limbs are more frequent. These skeletal profiles, despite the small size of the sample, suggest that whole carcasses were transported to the site in levels 2 and 3.

The taphonomic study of the Peña Capón faunal assemblages reveals that the bones are well-preserved. With moderate degrees of breakage. More than 68% and 55% of the bone fragments in levels 2 and 3 are larger than 3 cm (Table 5). There is little evidence of weathering or hydrological alterations. In level 3, 8% of the bones bear trampling marks while alterations produced by carnivores (tooth marks) affect 4% of the sample (Table 5). Carnivore modifications (tooth marks) affect 16.7% of the ibex bones and 15.4% of the horse remains (Table 6).

Anthropogenic alterations are well-represented in the faunal assemblages from both levels, with more than 12% of the bones presenting cut marks (Table 5). Percussion marks have been also recorded in 5% of the bones in layer 2 and 7% in layer 3. According to these data, we can conclude that both humans and carnivores played a role in the transformation of the faunal assemblages of Peña Capón, and hence it is very likely that carnivores caused the observed bias against long bone epiphyses (above).

Table 4
Skeletal profiles of Peña Capón levels 2 and 3 with respect to MNE, MAU and % MAU. Teeth are excluded of MAU and % MAU.

	Layer 2 Solutrean						Layer 3 Proto-Solutrean					
	MNE Large	MAU	%MAU	MNE Small	MAU	%MAU	MNE Large	MAU	%MAU	MNE small	MAU	%MAU
Horn							1	1	18.2			
Skull	1	1	40.0	1	1	66.7	1	1	18.2	1	1	100.0
Maxilla							1	0.5	9.1			
Mandible	2	1	40.0	2	1	66.7	2	1	18.2	1	0.5	50.0
Teeth	15			8			6			5		
Vertebrae	1	0.04	1.5	1	0.04	2.6	3	0.12	2.1	1	0.04	3.8
Ribs	1	0.04	1.5	3	0.12	7.7	7	0.27	4.9	4	0.15	15.4
Scapulae	1	0.5	20.0	2	1	66.7	2	1	18.2			
Humerus	5	2.5	100.0	1	0.5	33.3	9	4.5	81.8	1	0.5	50.0
Radius				1	0.5	33.3	3	1.5	27.3			
Ulna				1	0.5	33.3	1	0.5	9.1	1	0.5	50.0
Metacarpal	1	0.5	20.0				1	0.5	9.1			
Pelvis				1	0.5	33.3	4	2	36.4			
Femur	2	1	40.0	2	1	66.7	11	5.5	100.0	2	1	100.0
Tibia	4	2	80.0	3	1.5	100.0	8	4	72.7	2	1	100.0
Metapodial	2	1	40.0	1	0.5	33.3	4	2	36.4	1	0.5	50.0
Metatarsal	1	0.5	20.0	1	0.5	33.3	2	1	18.2	1	0.5	50.0
Tallus												
Phalanges	4	0.17	6.7				2	0.08	1.5	1	0.04	4.2
Sesamoid	1	0.17	6.7							1	0.17	16.7
Total	41			28			68			22		

Table 5
Main bone alterations documented in Peña Capón faunal assemblages. For frequencies of cut, percussion and tooth marks, teeth have been excluded from the total of NISP.

Layer	2	3
NISP	306	564
%Bones >3 cm	68%	55%
% Bones weathering 0–1	100%	100%
% Bones with water alteration	2%	4%
% Bones bad preservation	<2%	<2%
% Large bones with green fracture	100%	93%
% Bones with trampling marks	<1%	8%
% Bones with % cut marks	12%	13%
% bones with % percussion marks	5%	7%
% bones with tooth marks	1%	4%

In order to assess the relative roles played by humans and carnivores in the faunal assemblages, we have analyzed the frequencies of cut and tooth marks, comparing them with the frames of reference proposed by different authors (see section 3.1.). We have also analyzed the skeletal distribution of cut marks and the dimensions of the tooth marks. Results show that there are no instances of tooth marks overlying cut marks. The skeletal distribution of cut marks in levels 2 and 3 (Figs. 6–9) shows that for large group-sized animals, bones associated with large muscle packages yield relatively high frequencies of cut marks (Figs. 6–9) related to tasks such as defleshing and disarticulating.

As for small group size carcasses, in level 2 there is not enough available evidence to allow a solid interpretation concerning

Table 6
Tooth Marks (TM), Cut Marks (CM) and Percussion Marks (PM) of taxa documented in levels 2 and 3 of Peña Capón. Teeth are excluded from NISP.

Layer 2	Layer 2			Layer 3	Layer 3		
	Bones with TM	NISP	%TM		Bones with TM	NISP	%TM
<i>Sus</i>		1	0	<i>Bos</i>	0	2	0
<i>Capra</i>		15	0.0	<i>Capra</i>	1	6	16.7
<i>Cervus</i>		16	0.0	<i>Cervus</i>	3	111	2.7
<i>Equus</i>		17	0.0	<i>Equus</i>	2	13	15.4
<i>Oryctolagus</i>		5	0.0	<i>Oryctolagus</i>	6	49	12.2
Large	1	64	1.6	Large	6	126	4.8
Small	2	107	1.9	Small	2	52	3.8
Indet		58	0.0	Indet	2	189	1.1
Layer 2	Layer 2			Layer 3	Layer 3		
Bones with CM	NISP	%CM	Bones with CM		NISP	%CM	
<i>Sus</i>	1	1	100.0	<i>Bos</i>	0	2	0
<i>Capra</i>	1	15	6.7	<i>Capra</i>	2	6	33.3
<i>Cervus</i>	5	16	31.3	<i>Cervus</i>	29	111	26.1
<i>Equus</i>	4	17	23.5	<i>Equus</i>	8	13	61.5
<i>Oryctolagus</i>		5	0.0	<i>Oryctolagus</i>	4	49	8.2
Large	13	64	20.3	Large	19	126	15.1
Small	8	107	7.5	Small	9	52	17.3
Indet	2	58	3.4	Indet	1	189	0.5
Layer 2	Layer 2			Layer 3	Layer 3		
Bones with PM	NISP	%PM	Bones with PM		NISP	%PM	
<i>Sus</i>	0	1	0	<i>Bos</i>	0	2	0
<i>Capra</i>	0	15	0.0	<i>Capra</i>	1	6	16.7
<i>Cervus</i>	2	16	12.5	<i>Cervus</i>	18	111	16.2
<i>Equus</i>	2	17	11.8	<i>Equus</i>	3	13	23.1
<i>Oryctolagus</i>	0	5	0.0	<i>Oryctolagus</i>	0	49	0
Large	5	64	7.8	Large	11	126	8.7
Small	5	107	4.7	Small	3	52	5.8
Indet	1	58	1.7	Indet	2	189	1.1

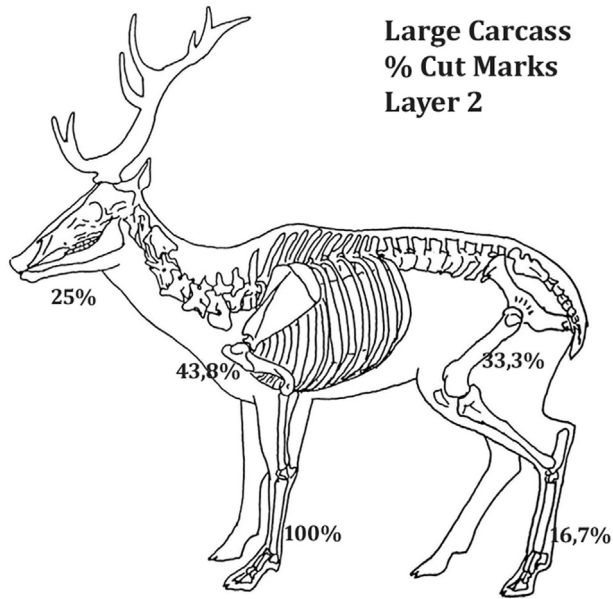


Fig. 6. Anatomical distribution of cut marks recorded in large-sized animals (Large bovid + Equus + Cervus + Large indeterminate bones) from layer 2.

human behaviour. However, 9% of the ribs yielded cut marks (Fig. 8). Which suggests that humans probably had primary access to the carcasses. Data on small carcasses of level 3 is slightly more informative, since the high frequencies of cut marks in posterior limbs, as well as a total of 13% of ribs yielding cut marks (Fig. 9), point to exploitation of the main muscle packages of these animals and probably indicates they were hunted by humans.

Comparing frequencies of cut marks recorded in appendicular bones of both large and small sized animals of Peña Capón with different referential frameworks (see the caption of Fig. 10), we observe that they are best adjusted to patterns in which humans

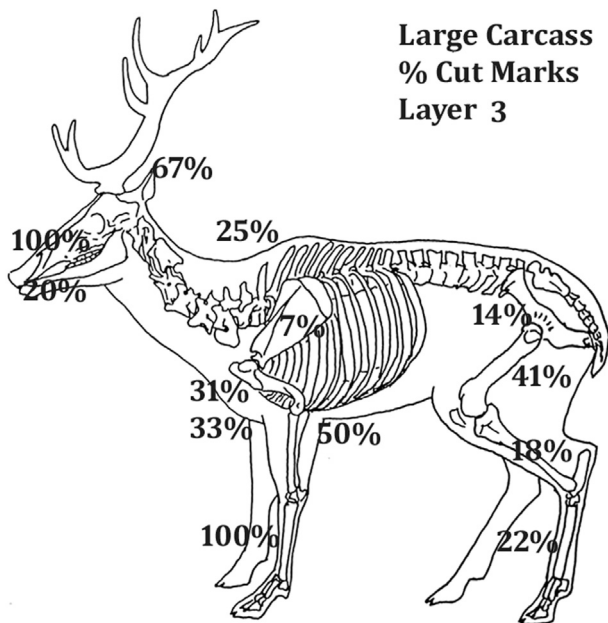


Fig. 7. Anatomical distribution of cut marks recorded in large-sized animals (Large bovid + Equus + Cervus + Large indeterminate bones) from layer 3.

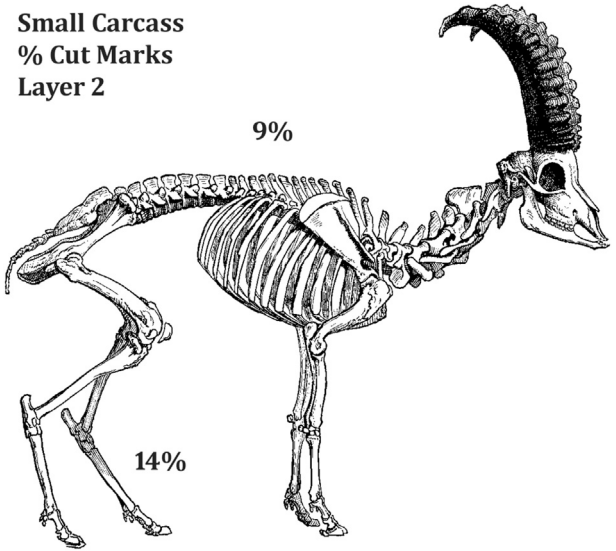


Fig. 8. Anatomical distribution of cut marks recorded in small-sized animals (Capra + Small indeterminate bones) from layer 2.

had primary access to meat resources, while they differ significantly from those in which humans acted as secondary agents (Fig. 10). Similarly, frequencies of tooth marks do not fit experimental patterns in which carnivores acted as primary agents (Fig. 11), suggesting that carnivores were not the primary agents of bone accumulation and transformation at Peña Capón. Below it can be observed some cut marks of Peña Capón (Fig. 12).

However, besides acting as secondary agents after human activities, the impact of carnivores on the bone assemblages is high. In Table 7 we show how large mammals epiphyses are totally absent in both layers 2 and 3, and the ratio of epiphyses to diaphyses is relatively low for small mammals. This pattern is consistent with a high, although secondary, access of carnivores to the carcasses previously accumulated and transformed by humans. The small size of the tooth marks, in all cases <2 mm along their greatest length, suggest that these carnivores were probably also of small size (Andrés et al., 2012).

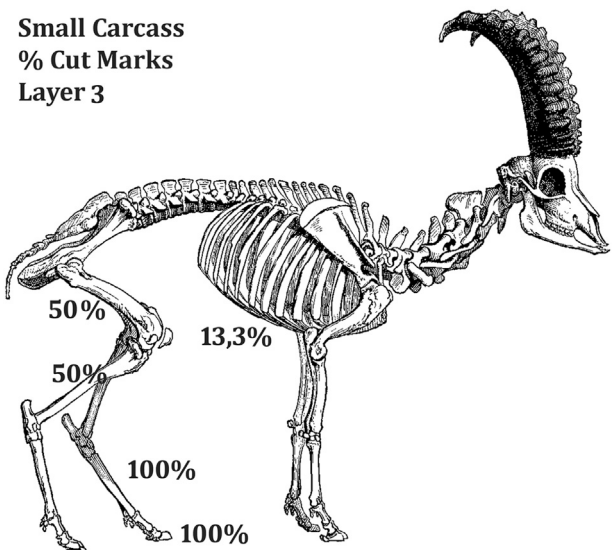


Fig. 9. Anatomical distribution of cut marks recorded in small-sized animals (Capra + Small indeterminate bones) from layer 3.

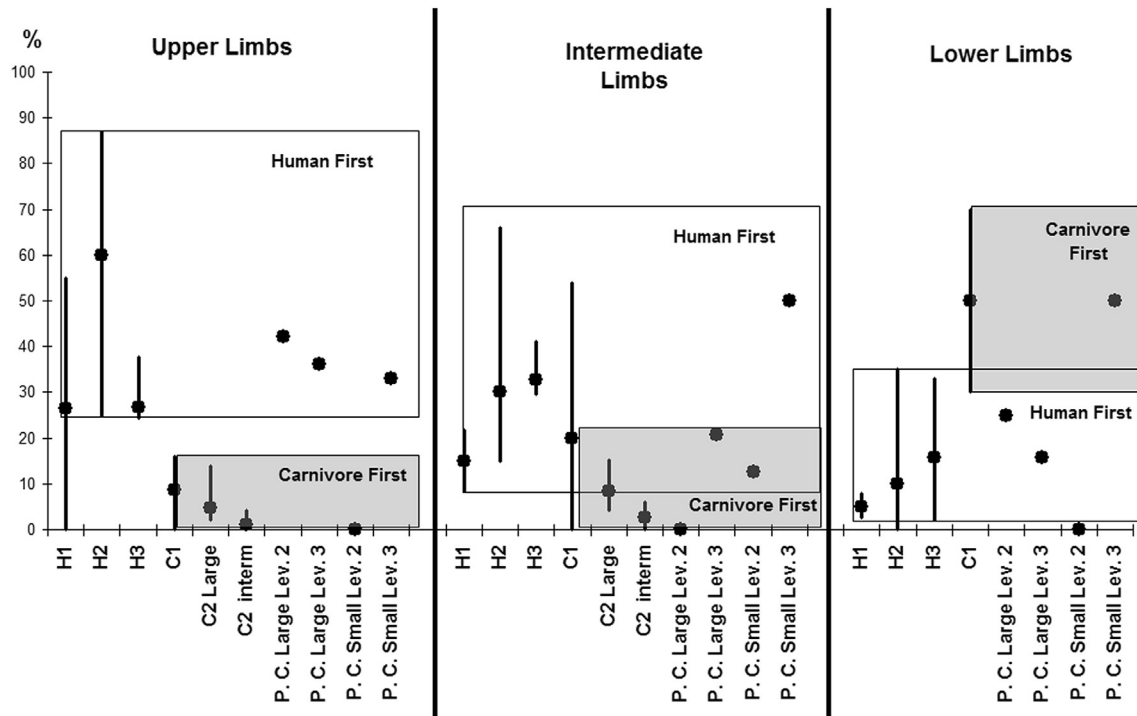


Fig. 10. Cut mark frequencies on appendicular bones of large-sized and small-sized animals in Peña Capón 2 and 3 compared to the models for frame referential work, where early human access to the small-sized carcasses (H1) (Barba and Domínguez-Rodrigo, 2005), early human access to large-sized carcasses (H2) (Domínguez-Rodrigo, 1997), early human access to large-sized carcasses of Hadza (H3) (Lupo and O’Connell, 2002), early carnivore access (C1) (Domínguez-Rodrigo, 1997) and early carnivore access from large carcass (C2 Large) and intermediate taxon (C2 intermed.) (Gidna et al., 2014). Dark boxes represent the range of values for early carnivore access (C).

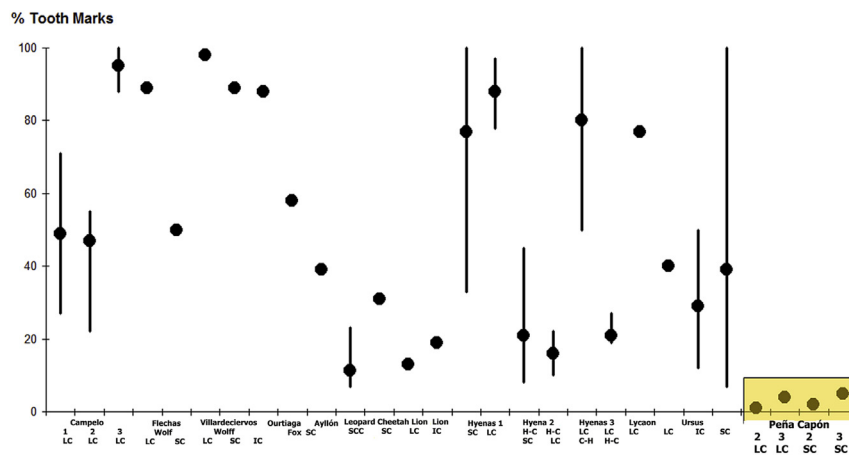


Fig. 11. Tooth mark frequencies on large-sized (LC) and small (SC) carcasses in Peña Capón site compared to the patterns generated by wild wolves according to Campelo carcasses of Yravedra et al. (2011) and Flechas and Villardeciervos. Foxes in Ourtiaga and Ayllón (Yravedra et al., 2014a), leopards and cheetah (Domínguez-Rodrigo et al., 2009); Lions (Gidna et al. (2014); hyenas 1 (Bunn, 1982), hyenas 2 (Blumenschine, 1995), hyenas 3 (Capaldo, 1997), where C–H (experimental data with primary access of hyena and second of human); H–C (contrary); Lyccon (Yravedra et al., 2014b); Ursus arctos (Arilla t al., 2014) and Peña Capón data from large and small size classes of levels 2 and 3.

In addition to carnivore action, other processes may affect the relative representation of bone epiphyses. For example, bones were used as fuel in some archaeological sites (Morin, 2010; Yravedra et al., 2016) and experimental research shows that this results in the loss of epiphyses (Thery-Parisot and Costamagno, 2005; Costamagno et al., 2005; Yravedra and Uzquiano, 2013). However, the very small number of burned bones at Peña Capón does not support this hypothesis. Alternatively, bone grease production may be invoked (Binford, 1978; Munro and Bar Oz, 2005) but this does not seem likely either. Percussion marks indicate some marrow extraction (below) but the fragmentation rates are far less than one

would expect if bone grease were systematically being sought, not are there any fragments of spongy tissue.

Small sample sizes make further statistical testing difficult. Nonetheless, we tested whether differential element representation was attributable to bone density using density data for sheep (Lyman, 1994b) for the small mammal size class and reindeer for large mammals (Lam et al., 1999). A positive correlation between bone density and bone preservation was observable for small mammals in level 3 (Fig. 13b).

One possible explanation for the absence of epiphyses and the under-representation of axial elements in the assemblages is that



Fig. 12. Shaft of radius with cut marks.

Table 7

Number of epiphyses and diaphyses with respect to MNE where: PEph is Proximal Epiphysis, and DEph is Distal Epiphysis.

MNE	Large			Small		
	PEph	Shaft	DEph	PEph	Shaft	DEph
Layer 2. Solutrean						
Humerus		5	1		1	1
Femur		2			2	
Radius				1		
Tibia		4			3	
Metacarpal		1				
Metatarsal		1			1	
Layer 3 Proto-Solutrean						
Humerus		9		1		
Femur		11		1	2	
Radius		3				
Tibia		8			2	1
Metacarpal		1				
Metatarsal		2			1	

the total excavated area of the site is still too small to capture all of the variability. Alternatively, we suggest that carnivore activity at the site may have produced the patterns described here. Although there are not many carnivore remains, tooth scoring indicates that small carnivores such as fox were present at the site and these canids are known to scatter bone and modify epiphyses (Yravedra et al., 2014b; Krajcarz and Krajcarz, 2012).

Another important feature recorded in the two studied levels are percussion marks. They have been documented on long bones of deer, horses, ibex and some unidentified bones corresponding to both large and small mammals (Table 6). These alterations show that human activity was not limited to the exploitation of meat, but also involved obtaining marrow. Furthermore, in level 3 there is at least one diaphysis showing percussion marks related to knapping activities, as well as some osseous artifacts and engraved bones showing linear motifs (Alcaraz-Castaño et al., 2013; Fig. 8).

Finally, while there are few rabbit remains in level 2, in level 3 they represent up to 9% of NISP and 40% of MNI (Tables 1 and 2). The age-profiles for rabbit in level 3 show 3 adults, 2 infants and 1 juvenile individuals (Table 2) and the skeletal profiles are biased against epiphyses (Table 9). The total observed MNE is only 3% of the expected MNE for a MNI of six individuals (Table 8). 8% of rabbit remains in level 3 are cut-marked (Table 6), including one femur, one scapula, one radius and one mandible, all of them related to defleshing activities. Carnivore action is also represented by tooth marks on five mandibles and one ulna.

Human predation of lagomorphs is well attested in the archaeological record of Iberia during the Upper Palaeolithic, including Portugal (Brugal, 2006; Bicho et al., 2006; Hockett and Haws, 2002), Mediterranean Spain (Aura et al., 2002; Pérez Ripoll, 2005) and the interior (Yravedra, 2007b; Yravedra and Andrés, 2014). According to the evidence presented above, we can

conclude that at least some lagomorphs were introduced to the site by humans, however, carnivores were probably also responsible for introducing rabbits into the site. Besides tooth marks, carnivore action is suggested by the osteological bias affecting rabbit skeletons (above). Furthermore, at least 50% of individuals were infants or juveniles. While some studies suggest that human activity may produce assemblages with young age classes (Cochard et al., 2012). The pattern typically produced by human accumulations is adult-dominated (Yravedra, 2008). Finally, breakage patterns also point to the action of carnivores. Besides the fact that 50% of the rabbit bones are cylinders, 58% of them present an intense degree of breakage (Table 8 and 9). Rabbit assemblages produced by humans have relatively high frequencies of shaft cylinders (Hockett, 1991; Cochard et al., 2012; Brugal, 2006) but they are not as intensively fragmented as in carnivore assemblages (Yravedra, 2008).

Overall, the taphonomic and zooarchaeological study of faunal assemblages recovered in levels 2 and 3 of Peña Capón suggests that, during Proto-Solutrean and Solutrean times, animal resources introduced to the rock shelter were transported and processed by humans and later scavenged by carnivores with the possible exception of rabbits. Cut marks show the existence of different activities related to defleshing and disarticulating activities, and the presence of bones corresponding to all anatomical portions suggests that whole animals were transported to the rockshelter.

5. Discussion and conclusions

The main objective of this study was to perform a detailed exploration of human-environment interactions for Proto-Solutrean and Solutrean occupations of Central Iberia, through a combined zooarchaeological, taphonomic and isotopic investigation of the faunal assemblages of Peña Capón levels 2 and 3. Our results allow us to explore this issue, and to move forward in the discussion of the pattern of human settlement in the interior of the Iberian Peninsula during MIS 2.

The taphonomical and zooarchaeological analysis points to the exploitation of deer, horse, iberian ibex and rabbits by humans. Whole carcasses seem to have been introduced to the site and processed there. Carnivores acted as secondary agents which suggests that human occupations of the site could have been of short duration, thus allowing carnivores to scavenge the animal remains previously exploited by Upper Palaeolithic hunters and abandoned at the rock shelter. This is in consonance with the high number of lithic projectile points abandoned at the site both in level 2 and 3 (Alcolea et al., 1997b; Alcaraz-Castaño et al., 2013), and thus allows us to suggest that the rock shelter could have functioned as a hunting camp where preys were processed after their capture in the environs of the site. However, the presence of a relatively large number of domestic tools, such as burins and especially end-scrapers (which sum up to 20.8% of retouched tools in level 3) (Alcaraz-Castaño et al., 2013; Table 5) suggests that the rock shelter may also have functioned as a residential site (either seasonal or permanent), with a more prolonged duration of occupation (Alcaraz-Castaño, 2015). Clearly, additional analyses based on new excavations, including technological, lithological, spatial, environmental and sedimentological data, are needed in order to assess the duration and function of the site.

The taxonomic profiles for levels 2 and 3 at Peña Capón suggest that different habitats were exploited during Proto-Solutrean and Solutrean times. While Pleistocene horses have a flexible behaviour but are generally adapted to open grasslands, cervids prefer more closed habitats and ibex typically live in steep, rocky habitats. Their presence at the site, therefore, fits the geographic location of the Peña Capón rock shelter in an open region in proximity to a variety of different ecological niches. While the site itself is located in a

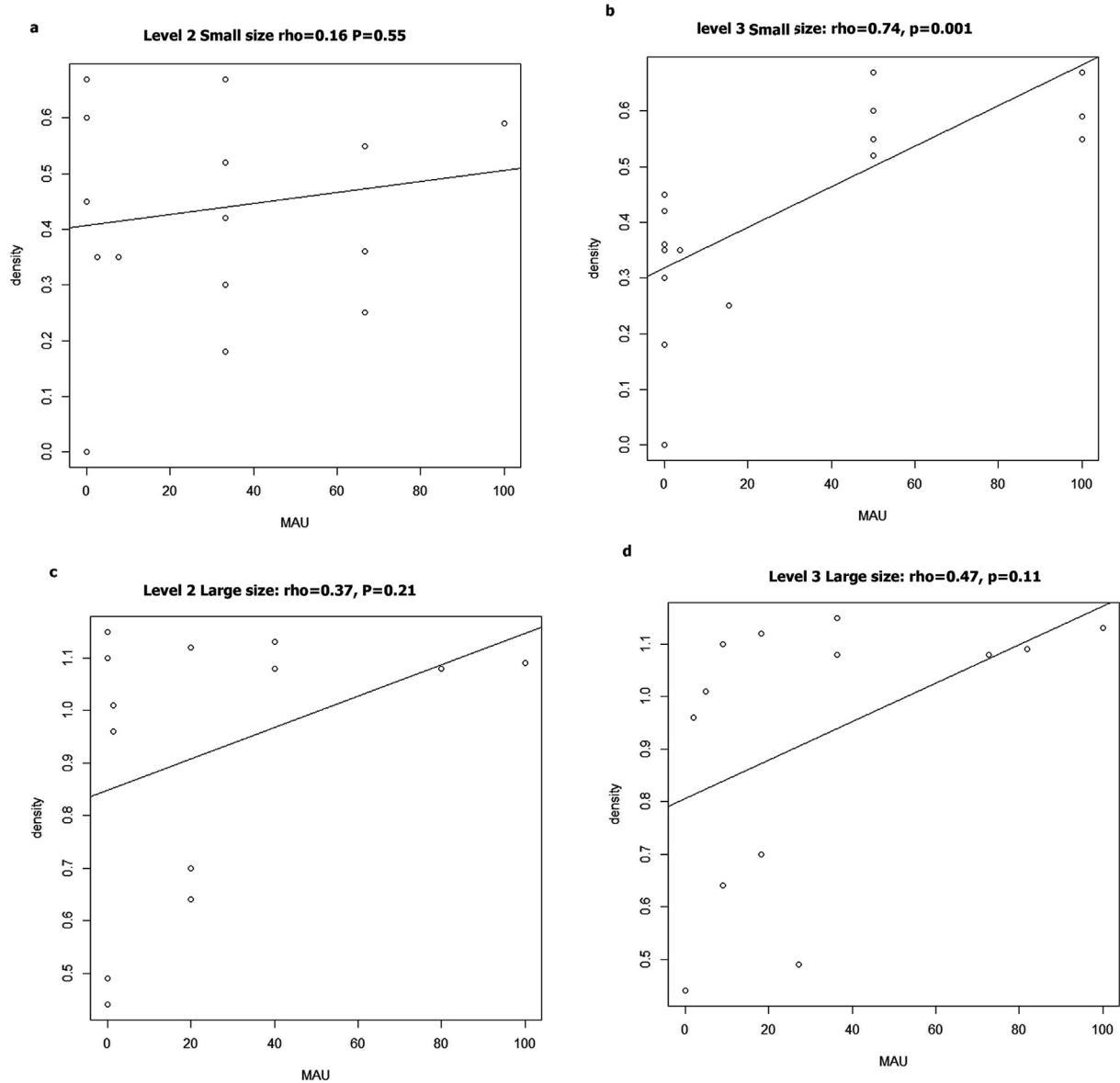


Fig. 13. Bivariate Spearman's tests for the layers 2 and 3 for large and small size animal according Lyman (1994a,b) density data for small size and Lam et al. (1999) for large size.

Table 8

Skeletal profiles of lagomorphs and percentage of observed MNE with respect to expected MNE for six individuals and MAU with %MAU. Peña Capón level 3.

Layer 3. <i>Oryctolagus cuniculus</i>						
	NISP	MNE	Expected MNE for 6 MNI	Observed MNE (%) with respect to expected MNE	MAU	%MAU
Skull			6	0		
Maxilla	1	1	12	8	0.5	10
Mandible	14	10	12	83	5	100
Vertebrae			312	0		
Ribs	1	1	180	1	0.04	0.8
Scapulae	3	3	12	25	1.5	30
Humerus	2	1	12	8	0.5	10
Radius	5	3	12	25	1.5	30
Ulna	2	2	12	17	1	20
Mettacarpal			60	0		
Pelvis	4	3	12	25	1.5	30
Femur	5	3	12	25	1.5	30
Tibia	7	7	12	58	3.5	70
Metatarsal	5	5	60	8	0.5	10
Tarsal-carpal			180	0		
Phalanges			360	0		
Total	49	39	1266	3		

Table 9
Circumference degree and length of fragments measured against the total surface of the original bone. Peña Capón level 3.

Layer 3 Shaft	Circumference degree			Total	% >75%
	>75%	25–75%	<25%		
Femur	3	1	1	5	60%
Humerus		1	1	2	
Radius	4	1		5	80%
Tibia	3	1	3	7	43%
Total	10	4	5	19	53%

Shaft	Length against the total surface of the bone			Total	% >25%
	>75%	25–75%	< 25%		
Femur		2	3	5	60%
Humerus		1	1	2	50%
Radius		2	3	5	60%
Tibia	1	2	4	7	57%
Total	1	7	11	19	58%

rocky area suitable for ibex, upland meadows where horses could have grazed are also found nearby. The isotopic results indicate that different ranges were exploited by horses in layer 2 and layer 3, with likely a shift from lowland to upland pastures, despite similar feeding behaviour deduced from the analyses performed. The behavioural flexibility of Pleistocene horses has been pointed out in other studies (e. g. Ecker et al., 2013; Julien et al., 2015; Rivals et al., 2015) and reflects the flexibility reported for modern equid populations (Waring, 2003). This has direct repercussions for our understanding of the hunting tactics and subsistence practices of Peña Capón's hunter-gatherers, who depended on the availability of game in their territory. Moreover, the Sorbe River valley also likely hosted shrub lands and more closed environments that red deers and wild boars could have used. However, the animals identified in both assemblages are generalists, capable of adapting to a range of climatic conditions and are not typical of either cold or temperate environments. For this reason, isotopic date are valuable as they provided not only a direct record of animal palaeobiology but also estimates of air temperature.

Temperature estimates derived from the oxygen isotope analysis of vertebrate apatite indicate, for the two levels, a climate slightly colder than present day climate conditions in the region, but warmer than simulated condition for the LGM, indicating that the site was not occupied during the coldest phase of the last Glacial. Between HE 2 and the onset of the LGM there is a brief warm interval recorded in the Greenland ice-core record (GI-2) at 23.3 ± 0.3 ka BP (Wolff et al., 2010; Yokoyama et al., 2000). The proposed age of level 2 (Fig. 2) is 19.9 ± 0.1 ka ^{14}C BP (23.8 ± 0.3 ka cal BP), which falls within GI-2, a warm interval at the end of the Heinrich 2 event (HE 2), although the proposed dates for this event vary. It may be that the Solutrean occupation of Peña Capón took place during this interval, therefore. However, level 3 is also dated to 19.9 ± 0.1 ka ^{14}C BP (or 23.9 ± 0.3 ka cal BP), and it may be hard to make the same argument for two levels (see Fig. 2). The isotope estimates for level 3 are warmer than expected based on the climate simulation results for the LGM.

The results obtained from both the faunal and isotopic analyses show consistent and complementary signatures, allowing a refined understanding of the Peña Capón sequence. Data on past temperatures and environmental reconstruction during MIS 2 obtained from isotopic analyses of faunal remains in South-Western Europe are still scarce but congruent (see Royer et al., 2014; Domingo et al., 2015). The mean annual air temperature estimates and palaeoecological reconstruction presented here enable us to present some initial thoughts about the nature of human occupations of Central Iberia during MIS 2. Our results suggest that both Proto-Solutrean

and Middle Solutrean occupations of Peña Capón did not take place during harsh environmental conditions, but rather occurred during relatively warm events. This provides support for hypotheses 1 and 2 outlined above, namely that the Late Pleniglacial human occupations of Peña Capón were either produced during warm events within or around the LGM (perhaps the GI-2), or that more favorable conditions (micro-refugia) existed within the Iberian plateau - perhaps defined by the valleys of the south-eastern foothills of the Central System range.

Our analysis indicates that the Sorbe Valley functioned as an ecosystem rich enough to sustain a diversified animal community including deer, horse, ibex and rabbits which were hunted by Upper Palaeolithic humans during MIS 2. This picture contrasts with the classic idea of a virtually depopulated Iberian plateau, lacking in biotic resources during most of the Upper Palaeolithic (Breuil and Obermaier, 1913; Sauvet and Sauvet 1983; Davidson 1986; Straus 1991; Corchón 1997; Straus et al., 2000; Vaquero 2006; but see Straus 2015b for a very recent interpretation that takes into account the new data on Peña Capón and other sites in the Madrid basin as evidence of the human settlement of Central Iberia, possibly related to relatively temperate episodes within the LGM). The cultural sequence of Peña Capón, together with the cluster of Solutrean sites in the Manzanares valley (Baena and Carrión, 2002; Alcaraz-Castaño et al., 2012b; in press; Tapias et al., 2012) and the increasing number of Magdalenian sites located both North and South of the Central System Range (Adán and Jordá, 1989; Vega et al., 2010; Cacho et al., 2010, 2012; Cacho, 2013), the Ebro valley (Utrilla et al., 2010, 2012) and the northern Meseta (Corchón, 2002), suggest that Central Iberia was inhabited during a large part of the Upper Palaeolithic, starting at least in the Proto-Solutrean, and including different cold and dry events both during MIS 2 and 1. Furthermore, a number of Palaeolithic rock art sites are known in interior Iberia, yielding both Magdalenian and pre-Magdalenian depictions, some of them showing cold-adapted fauna (Corchón, 1997; Ripoll and Municio, 1999; Alcolea et al., 1997b; Alcolea and Balbín, 2003a, 2003b, 2013). Most of these sites indicate human exploitation of animal resources in the surroundings (Sesé and Soto, 2002; Yravedra, 2007a, 2007b; Yravedra and Andrés, 2014), thus suggesting that the Iberian interior was rich in game and served as nutritional support for Upper Paleolithic humans living in the area, where carnivores such as fox or lynx, rabbits and diverse herbivores shown large evidences of human exploitation (Yravedra, 2005; Yravedra and Andrés, 2014).

In conclusion, Peña Capón rock shelter has revealed itself to be an important archive for investigating human-environment interactions in Central Iberia during MIS 2. There are very few other sources of economic, biological and ecological data currently available for the Iberian plateau during pre-Magdalenian times, and hence Peña Capón is of great importance for our understanding of the complexities of the human-environment interactions at this key period of human prehistory. Additional fieldwork will be necessary to fully understand human occupation of central Iberia in the Upper Paleolithic, and it is now of paramount importance to open up new avenues of research aimed at gaining more data on the settlement of Central Iberia during MIS 2 and to keep testing these and other hypotheses.

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References

- Adán, G., Jordá Pardo, J., 1989. Industrias óseas del Paleolítico y postpaleolítico pirenaico en relación con los nuevos hallazgos de Jarama II (Guadalajara). *Espacio Tiempo y Forma Serie I Prehistoria y Arqueología* 2, 109–130.
- Alcaraz-Castaño, M., 2015. Central Iberia around the last glacial maximum: hopes and prospects. *J. Anthropol. Res.* 71 (4), 565–578.
- Alcaraz-Castaño, M., Alcolea, J., Balbín, R. de, GarcíaValero, M.A., Yravedra, J., Baena, J., 2012a. Entre el Gravetiense y el Solutrense: el nivel 3 de Peña Capón (valle del Sorbe, Guadalajara). In: De las heras, C., Lasheras, J.A., Arrizabalaga, A., De la Rasilla, M. (Eds.), *Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico*, Monografías del Museo Nacional y Centro de Investigación de Altamira, 23, pp. 126–142.
- Alcaraz-Castaño, M., López Recio, M., Roca, M., Tapias, F., Rus, I., Baena, J., Morín, J., Pérez-González, A., Santonja, M., 2012b. Nuevos datos sobre el yacimiento solutrense de Las Delicias (Madrid, España). *Espacio Tiempo y Forma Serie I Nueva época Prehistoria y Arqueología* 5, 427–446.
- Alcaraz-Castaño, M., Alcolea, J., Balbín, R. de, García Valero, M.A., Yravedra, J., Baena, J., 2013. Los orígenes del Solutrense y la ocupación pleniglacial del interior de la Península Ibérica: implicaciones del nivel 3 de Peña Capón (Valle del Sorbe, Guadalajara). *Trabajos de Prehistoria* 70, 28–53.
- Alcaraz-Castaño, M., López-Recio, M., Tapias, F., Cuartero, F., Baena, J., Ruiz-Zapata, B., Morín, J., Pérez-González, A., Santonja, M., 2015. The human settlement of central Iberia during MIS 2: new technological, chronological and environmental data from the Solutrean workshop of las Delicias (Manzanares River Valley, Spain). *Quat. Int.* <http://dx.doi.org/10.1016/j.quaint.2015.06.069> (in press).
- Alcolea, J.J., de Balbín, R., 2003a. Témoins du froid. La faune dans l'art rupestre paléolithique de l'intérieur péninsulaire". *L'Anthropologie* 107, 471–500.
- Alcolea, J.J., de Balbín, R., 2003b. El Arte Rupestre Paleolítico del interior peninsular. Elementos para el estudio de su variabilidad regional. In: de Balbín, R., Bueno, P. (Eds.), *El Arte Prehistórico desde los inicios del siglo XXI*, Primer Symposium Internacional de Arte Prehistórico de Ribadesella (Ribadesella 2001), pp. 223–253.
- Alcolea, J.J., de Balbín, R., 2013. El Arte rupestre Paleolítico del interior peninsular. In: *Arte sin artistas, una mirada al Paleolítico*. Museo Arqueológico Regional, Comunidad de Madrid, Madrid, pp. 187–207.
- Alcolea, J.J., Balbín, R. de, García Valero, M.A., Jiménez, P.J., Aldecoa, A., Casado, A.B., Andrés, B. de, Ruiz Pedraza, S., Sainz Rubio, P., Suárez Rueda, N., 1997a. Avance al estudio del poblamiento paleolítico del Alto Valle del Sorbe (Muriel, Guadalajara). In: de Balbín, R., Bueno, P. (Eds.), *II Congreso de Arqueología Peninsular (Zamora 1996) I, Paleolítico y Epipaleolítico*. Fundación Rei Alfonso Henriques, Zamora, pp. 201–218.
- Alcolea, J.J., Balbín, R. de, García, M.A., Jiménez, P.J., 1997b. Nouvelles découvertes d'Art Pariétal Paléolithique á la Meseta: La grotte del Reno (Valdesotos, Guadalajara). *L'Anthropologie* 101, 144–163.
- Andrés, M., Gidna, A., Yravedra, J., Domínguez-Rodrigo, M., 2012. A study of dimensional differences of tooth marks (pits and scores) on bones modified by small and large carnivores. *Archaeol. Anthropol. Sci.* 4, 209–219.
- Arilla, M., Rosell, J., Blasco, R., Domínguez-Rodrigo, M., Pickering, T.R., 2014. The "Bear" essentials: actualistic research on *Ursus arctos* arctos in the Spanish pyrenees and its implications for paleontology and archaeology. *PLoS ONE* 9 (7), e102457. <http://dx.doi.org/10.1371/journal.pone.0102457>.
- Arsuaga, J.L., Martínez, I., García, A., Carretero, J.M., 1997. Sima de los Huesos (Sierra de Atapuerca, Spain). The site. *J. Hum. Evol.* 33, 109–127.
- Aura, J.E., Villaverde, V., Pérez Ripoll, M., Martínez Valle, R., Guillem, P., 2002. Big game and small prey: paleolithic and epipaleolithic economy from Valencia (Spain). *J. Archaeol. Method Theory* 9, 215–268.
- Baena, J., Carrión, E., 2002. Los materiales solutrenses. In: *Blasco Bosqued, C. (Ed.), La Colección Benta del Museu d'Arqueologia de Catalunya*. Una nueva mirada a la prehistoria de Madrid. Museu d'Arqueologia de Catalunya, Barcelona, pp. 79–130.
- Balasse, M., 2002. Reconstructing dietary and environmental history from enamel isotopic analysis: time resolution of intra-tooth sequential sampling. *Int. J. Osteoarchaeol.* 12, 155–165.
- Barba, R., Domínguez-Rodrigo, M., 2005. The taphonomic relevance of the analysis of bovid long limb bone shaft features and their application to element identification. Study of bone thickness and morphology of the medullar cavity. *J. Taphon.* 3, 29–42.
- Bicho, N.F., Haws, J., Hockett, B., 2006. Two sides of the same coin-rocks, bones and site function of Picareiro Cave, central Portugal. *J. Anthropol. Archaeol.* 25, 485–499.
- Bicho, N., Carvalho, A., González-Sainz, C., Sanchidrián, J., Villaverde, V., Straus, L.G., 2007. The upper paleolithic rock art of Iberia. *J. Archaeol. Method Theory* 14, 81–151.
- Bicho, N., Manne, T., Cascabeira, J., Marreiros, J., Mendonça, C., Évora, M., Gibaja, J., Pereira, T., 2010. O Paleolítico superior do sudoeste da Península Ibérica: o caso do Algarve. In: Mangado, X. (Ed.), *El Paleolítico Superior Peninsular, Novedades del Siglo XXI*. SERP, Barcelona, pp. 219–238.
- Binford, L.R., 1978. *Nunamiut Ethnoarchaeology*. Academic Press, New York, p. 509.
- Blake, R.E., O'Neil, J.R., Garcia, G.A., 1997. Oxygen isotope systematics of biologically mediated reactions of phosphate: I. Microbial degradation of organophosphorus compounds. *Geochim. Cosmochim. Acta* 61 (20), 4411–4422.
- Blumenschine, R., 1988. An experimental model of the timing of hominid and carnivore influence on archaeological bone assemblages. *J. Archaeol. Sci.* 15, 483–502.
- Blumenschine, R., 1995. Percussion marks, tooth marks and the experimental determinations of the timing of hominid and carnivore access to long bones at FLK Zinjanthropus, Olduvai Gorge, Tanzania. *J. Hum. Evol.* 29, 21–51.
- Blumenschine, R., Selvaggio, M.M., 1988. Percussion marks on bone surfaces as a new diagnostic of hominid behaviour. *Nature* 333, 763–765.
- Bowen, G.J., 2008. Spatial analysis of the intra-annual variation of precipitation isotope ratios and its climatological corollaries. *J. Geophys. Res.* 113, D05113.
- Bradtmöller, M., Pastoors, A., Weninger, B., Weniger, G.-C., 2012. The repeated replacement model – rapid climate change and population dynamics in upper Pleistocene Europe. *Quat. Int.* 247, 38–49.
- Brain, C.K., 1969. The contribution of Namib Desert Hottentot to understanding of australopithecus bone accumulations. *Sci. Pap. Namib. Desert Res. Stn.* 32, 1–11.
- Breuil, H., Obermaier, H., 1913. *Travaux exécutés en 1912. L'Anthropologie XXIV*. Institut de Paléontologie Humaine, pp. 1–16.
- Brugal, J.P., 2006. Petit gibier et fonction de sites au Paléolithique supérieur: Les ensembles fauniques de la grotte d'Ancrerial (Porto de Mos, Estrémadura, Portugal). *Paléo* 18, 45–68.
- Bryant, J.D., Luz, B., Froelich, P.N., 1994. Oxygen isotopic composition of fossil horse tooth phosphate as a record of continental paleoclimate. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 107, 303–316.
- Bryant, J.D., Koch, P.L., Froelich, P.N., Showers, W.J., Genna, B.J., 1996. Oxygen isotope partitioning between phosphate and carbonate in mammalian apatite. *Geochim. Cosmochim. Acta* 60, 5145–5148.
- Bunn, H.T., 1982. *Meat-eating and Human Evolution: Studies on the Diet and Subsistence Patterns of Plio-pleistocene Hominins in East Africa*. Ph. Dissertation. University of California, Berkeley.
- Burke, A., Levavasseur, G., James, P.M.A., Guiducci, D., Arturo Izquierdo, M., Bourgeon, L., Kageyama, M., Ramstein, G., Vrac, M., 2014. Exploring the impact of climate variability during the Last Glacial Maximum on the pattern of human occupation of Iberia. *J. Hum. Evol.* 73, 35–46.
- Cacho, C., 2013. Ocupaciones magdalenenses en el interior de la Península Ibérica. In: *La Peña de Estebanvela (Ayllón, Segovia)*. Junta de Castilla y León.
- Cacho, C., Martos, J.A., Jordá Pardo, J., Yravedra, J., Avezuela, B., Valdivia, J., Martín, I., 2010. El Paleolítico superior en el interior de la Península Ibérica. Reflexión crítica y perspectivas de futuro. In: Mangado, X. (Ed.), *El Paleolítico superior peninsular. Novedades del siglo XXI*, Barcelona 2010. Monografies del Seminari d'Estudis i Recerques Prehistòriques, 8, pp. 75–96.
- Cacho, C., Martos, J.A., Jordá Pardo, J., Yravedra, J., Sesé, C., Zapata, L., Avezuela, B., Valdivia, J., Ruiz, M., Marquer, L., Martín, I., Tejero, J.M., 2012. Human landscapes of the Late Glacial Period in the interior of the Iberian Peninsula: La Peña de Estebanvela (Segovia, Spain). *Quat. Int.* 272–273, 42–54.
- Capaldo, S.D., 1997. Experimental determinations of carcass proceeding by Plio-Pleistocene hominids and carnivores at FLK 22 (Zinjanthropus), Olduvai Gorge, Tanzania. *J. Hum. Evol.* 33, 555–598.
- Carbonel, E., Mosquera, M., Rodríguez, X.P., Bermudez de Castro, J. M^o, Rosell, J., Sala, R., Vallverdú, J., 2008a. Eurasian Gares. The earliest human dispersals. *J. Anthropol. Res.* 64, 195–228.
- Carbonel, E., Bermúdez de Castro, J.M., Parés, J.M., Pérez-González, A., Cuenca-Bescós, G., 2008b. The first hominin of Europe. *Nature* 452, 465–470.
- Carbonell, E., Rosas, A., Díez, J.C., 1999. Atapuerca: Ocupaciones Humanas y Paleología del Yacimiento de Galería. *Arqueología en Castilla y León* 7.
- Carrasco, R.M., Pedraza, J., Domínguez-Villar, D., Villa, J., Willenbring, J.K., 2013. The Plateau glacier in the Sierra de Béjar (Iberian Central System) during its maximum extent. Reconstructing and chronology. *Geomorphology* 196, 83–93.
- Cerling, T.E., Harris, J.M., 1999. Carbon isotope fractionation between diet and bioapatite in ungulate mammals and implications for ecological and paleoecological studies. *Oecologia* 120, 347–363.
- Cerling, T.E., Harris, J.M., MacFadden, B.J., Leakey, M.G., Quade, J., Eisenmann, V., Ehleringer, J.R., 1997. Global vegetation change through the Miocene/Pliocene boundary. *Nature* 389, 153–158.
- Cleghorn, N., Marean, C.W., 2004. Distinguishing selective transport and in situ attrition: a critical review of analytical approaches. *J. Taphon.* 2, 43–67.
- Cochard, D., Brugal, J.-Ph., Morin, E., Meignen, L., 2012. Evidence of small fast game exploitation in the Middle Paleolithic of Les Canalettes (Aveyron, France). *Quat. Int.* 264, 32–51.
- Coplen, T.B., 1996. New guidelines for the reporting of stable hydrogen, carbon, and

- oxygen isotope ratio data. *Geochim. Cosmochim. Acta* 60, 3359.
- Corchón, M.S. (Ed.), 1997. La cueva de la Griega de Pedraza. *Arqueología en Castilla y León, Memorias* 3, Zamora.
- Corchón, M.S., 2002. El Tardiglaciario y la transición al Postglaciario en la Meseta Norte española: una visión de síntesis (reflexiones acerca de las investigaciones realizadas en los últimos 10 años en el territorio de Castilla-León). *Zephyrus* 55, 85–142.
- Cortés Sánchez, M., Muñoz Vivas, V.E., Sanchidrián Torti, J.L., Simón Vallejo, M.D., 1996. El Paleolítico en Andalucía. La dinámica de los grupos predadores en la Prehistoria andaluza. *Ensayo de Síntesis*. Repertorio bibliográfico de 225 años de investigación. Córdoba.
- Costamagno, S., Théry-Parisot, I., Brugal, J.P., Guibert, R., 2005. Taphonomic consequences of use of bones as fuel. Experimental data and archaeological application. In: O'Connor, T. (Ed.), *Biosphere to Lithosphere, Proceedings of the 9th Conference of the International Council of Archaeozoology*. Oxbow books, Oxford, pp. 51–62.
- Davidson, I., 1986. The geographical study of Late Palaeolithic stages in Eastern Spain. In: Bailey, G.N., Callow, P. (Eds.), *Stone Age Prehistory*. Cambridge University Press, Cambridge, pp. 95–118.
- Davidson, I., 1989. La economía del final del Paleolítico de la España Oriental (Memorias del SIP Valencia).
- Delgado Huertas, A., Iacumin, P., Stenni, B., Sanchez Chillon, B., Longinelli, A., 1995. Oxygen isotope variations of phosphate in mammalian bone and tooth enamel. *Geochim. Cosmochim. Acta* 59, 4299–4305.
- Delpéch, E.P., Villa, P., 1993. Activités de chasse et boucherie dans la grotte des Eglises. In: Desse, J., Audouin-Rouzeau, F. (Eds.), *Exploitation des animaux sauvages a travers de temps, Colloque International de l'Homme et l'Animal*, IV. Editions APDCA, pp. 79–102.
- Domingo, L., Pérez-Dios, P., Hernández Fernández, M., Martín-Chivelet, J., Ortiz, J.E., Torres, T., 2015. Late quaternary climatic and environmental conditions of northern Spain: an isotopic approach based on the mammalian record from La Paloma cave. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 440, 417–430.
- Domínguez-Rodrigo, M., 1997. Meat eating by early homids at FLK Zinj 22 Site, Olduvay Gorge Tanzania: an experimental approach using cut-mark data. *J. Hum. Evol.* 33, 669–690.
- Domínguez-Rodrigo, M., De Juana, S., Galán, A.B., Rodríguez, M., 2009. A new protocol to differentiate trampling marks from butchery cut marks. *J. Archaeol. Sci.* 36, 2643–2654.
- Domínguez-Rodrigo, M., Barba, R., 2005. A study of cut marks on small-sized carcasses and its application to the study of cut marked bones from small mammals at the FLK Zinj site. *J. Taphon.* 3, 121–134.
- Dominguez-Villar, D., Carrasco, R.M., Pedraza, J., Cheng, H., Edwards, R.L., Willenbring, J.K., 2015. Moist and cold climate between Heinrich events H2 and H3 caused the maximum extent of glaciers in the central and western Mediterranean prior to the Last Glacial Maximum. In: *Oral Presentation at XIX INQUA Congress. Quaternary Perspectives on Climate Change, Natural Hazards and Civilization*. Nagoya, Japan, 26 July – 2 August 2015.
- Ecker, M., Bocherens, H., Julien, M.A., Rivals, F., Raynal, J.P., Moncel, M.-H., 2013. Middle Pleistocene ecology and Neanderthal subsistence: insights from stable isotope analyses in payre (Ardèche, southeastern France). *J. Hum. Evol.* 65, 363–373.
- Fano, M.A., 2007. Las Sociedades del Paleolítico en la Región Cantábrica. *Kobie, Anejo* 8, Diputación Foral de Bizkaia, Bilbao.
- Feranec, R.S., García, N., Díez, J.C., Arsuaga, J.L., 2010. Understanding the ecology of mammalian carnivores and herbivores from Valdegoba cave (Burgos, northern Spain) through stable isotope analysis. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 297, 263–272.
- Fernández Peris, J., 2007. La Cova del Bolomor (Tavernes de la Valldigna, Valencia). Las industrias líticas del Pleistoceno medio en el ámbito del Mediterráneo peninsular. *Trabajos Varios del SIP*, 108, Valencia.
- Finlayson, C., 2004. Neanderthals and Modern Humans. In: *An Ecological and Evolutionary Perspective*. Cambridge University Press, Cambridge.
- Finlayson, C., et al., 2006. Late survival of Neanderthals at the southernmost extreme of Europe. *Nature* 443, 850–854. <http://dx.doi.org/10.1038/nature05195>.
- Fortea, J., Rasilla, M.de la, Santamaría, D., Martínez, L., Duarte, E., Fernández de la Vega, J., 2010. El Paleolítico superior en Asturias en los albores del siglo XXI. In: Mangado, X. (Ed.), *El Paleolítico Superior Peninsular, Novedades del Siglo XXI*. Universidad de Barcelona, Barcelona, pp. 271–289.
- Fourel, F., Martineau, F., Lecuyer, C., Kupka, H.J., Lange, L., Ojeimi, C., Seed, M., 2011. $^{18}\text{O}/^{16}\text{O}$ ratio measurements of inorganic and organic materials by elemental analysis-pyrolysis-isotope ratio mass spectrometry continuous-flow techniques. *Rapid Commun. Mass Spectrom.* 25, 2691–2696.
- Fox, D.L., Fisher, D.C., 2001. Stable isotope ecology of a late Miocene population of Gomphotherium productus (Mammalia, Proboscidea) from port of entry pit, Oklahoma, USA. *Palaos* 16, 279–293.
- Fricke, H.C., Clyde, W.C., O'Neil, J.R., 1998. Intra-tooth variations in $\delta^{18}\text{O}$ (PO_4) of mammalian tooth enamel as a record of seasonal variations in continental climate variables. *Geochim. Cosmochim. Acta* 62, 1839–1850.
- Fullola, J.M., Roman, D., Soler, N., Villaverde, V., 2010. Le Gravettien de la côte Méditerranéenne Ibérique. *Paleo* 19, 73–88.
- Gidna, A., Kisui, B., Mabulla, A., Musiba, C., Domínguez-Rodrigo, M., 2014. An ecological neo-taphonomic study of carcass consumption by lions in Tarangire National Park (Tanzania) and its relevance for human evolutionary biology. *Quat. Int.* 322–323, 167–180.
- Guadelli, J.L., 1998. Détermination de l'âge des caveaux fossiles et établissement des chasses d'âge. *Paléo* 10, 87–93.
- Hillaire-Marcel, C., de Vernal, A., Bilodeau, G., Wu, G., 1994. Isotope Stratigraphy, sedimentation rates and paleoceanographic changes in the Labrador Sea. *Can. J. Earth Sci.* 31, 63–89.
- Horwitz, E.P., Chiarizia, R., Dietz, M.L., 1992. A novel strontium-selective extraction chromatographic resin. *Solvent Extr. Ion Exch.* 10, 313–336.
- Hockett, B.S., 1991. Toward distinguishing human and raptor patterning on leporid bones. *Am. Antiq.* 56, 667–679.
- Hockett, B., Haws, J.A., 2002. Taphonomic and methodological perspectives of leporid hunting during the upper paleolithic of the Western Mediterranean Basin. *J. Archaeol. Method Theory* 9, 269–302.
- Iacumin, P., Bocherens, H., Mariotti, A., Longinelli, A., 1996. Oxygen isotope analyses of co-existing carbonate and phosphate in biogenic apatite: a way to monitor diagenetic alteration of bone phosphate? *Earth Planet. Sci. Lett.* 142, 1–6.
- Iacumin, P., Di Matteo, A., Nikolaev, V., Kuznetsova, T.V., 2010. Climate information from C, N and O stable isotope analyses of mammoth bones from northern Siberia. *Quat. Int.* 212, 206–212.
- Julien, M.-A., Bocherens, H., Burke, A., Drucker, D.G., Patou-Mathis, M., Krotova, O., Péan, S., 2012. Were European steppe bison migratory? ^{18}O , ^{13}C and Sr intra-tooth isotopic variations applied to a palaeoethological reconstruction. *Quat. Int.* 271, 106–119.
- Julien, M.A., Rivals, F., Serangeli, J., Bocherens, H., Conard, N.J., 2015. A new approach for deciphering between single and multiple accumulation events using intra-tooth isotopic variations: application to the Middle Pleistocene bone bed of Schoningh 13 II-4. *J. Hum. Evol.* 89, 114–128.
- Kohn, M.J., 2004. Comment: tooth enamel mineralization in ungulates: implications for recovering a primary isotopic time-series, by B. H. Passey and T. E. Cerling (2002). *Geochim. Cosmochim. Acta* 68, 403–405.
- Krajcarz, M., Krajcarz, M.T., 2012. The red fox (*Vulpes vulpes*) as an accumulator of bones in cave-like environments. *Int. J. Osteoarchaeol.* 24, 459–475.
- Lam, Y.M., Chen, M.X., Pearson, O.M., 1999. Intertaxonomic variability in patterns on bone density and the differential representation of bovid, cervid, and equid elements in the archaeological record. *Am. Antiq.* 64, 343–362.
- Lécuyer, C., Grandjean, P., O'Neil, J.R., Capetta, H., Martineau, F., 1993. Thermal excursions in the ocean at the cretaceous-tertiary boundary (northern Morocco): $\delta^{18}\text{O}$ record of phosphatic fish debris. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 105, 235–243.
- Lécuyer, C., Grandjean, P., Sheppard, S.M.F., 1999. Oxygen isotope exchange between dissolved phosphate and water at temperatures ≤ 135 °C: inorganic versus biological fractionations. *Geochim. Cosmochim. Acta* 63 (6), 855–862.
- Lee-Thorp, J., Sponheimer, M., 2003. Three case studies used to reassess the reliability of fossil bone and enamel isotope signals for paleodietary studies. *J. Anthropol. Archaeol.* 22, 208–216.
- Luz, B., Kolodny, Y., Horowitz, M., 1984. Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. *Geochim. Cosmochim. Acta* 48, 1689–1693.
- Lupo, K.D., O'Connell, J.F., 2002. Cut and tooth mark distributions on large animal bones: ethnoarchaeological data from the Hadza and their implications for current ideas about early human carnivore. *J. Archaeol. Sci.* 29, 85–109.
- Lyman, R.L., 1994a. Relative abundance of skeletal specimens and taphonomic analysis of vertebrate remains. *Palaos* 9, 288–298.
- Lyman, R.L., 1994b. *Vertebrate Taphonomy*. Cambridge University Press, Cambridge, p. 552.
- Maccali, J., Hillaire-Marcel, C., Carignan, J., Reisberg, L.C., 2013. Geochemical signatures of sediments documenting Arctic sea ice and water mass export through Fram Strait since the Last Glacial Maximum. *Quat. Sci. Rev.* 64, 136–151.
- Mangado, X., Tejero, J.M., Fullola, J.M., Petit, M.A., García-Argüelles, P., García, M., Soler, N., Vaquero, M., 2010. Nuevos territorios, nuevos grafismos: una visión del Paleolítico Superior en Cataluña a inicios del siglo XXI. In: Mangado, X. (Ed.), *El Paleolítico Superior Peninsular, Novedades del siglo XXI*. SERP, Barcelona, pp. 61–81. *Monografies* n.8.
- Martínez-Pillado, V., Aranburu, A., Arsuaga, J.L., Ruiz-Zapata, B., Gil-García, M.J., Stoll, H., Yusta, I., Iriarte, E., Carretero, J.M., Edwards, R.L., Cheng, H., 2014. Upper Pleistocene and Holocene palaeoenvironmental records in Cueva Mayor karst (Atapuerca, Spain) from different proxies: speleothem crystal fabrics, palynology, and archaeology. *Int. J. Speleol.* 43, 1–14.
- Münzel, S.C., 1988. Quantitative analysis and archaeological site Interpretation. *Archaeozoologia* 2, 93–110.
- Morin, E., 2010. Taphonomic implications of the use of bone as fuel in: The taphonomy of burned organic residues and combustion features in archaeological contexts, Théry-Parisot I. In: Chabal, L., Costamagno, S. (Eds.), *Proceedings of the Round Table, Valbonne, May 27–29 2008*, pp. 209–217. *P@lethnologie* 2.
- Munro, N.D., Bar-Oz, G., 2005. Gazelle bone fat processing in the Levantine Epipalaeolithic. *J. Archaeol. Sci.* 32, 223–239.
- Passey, B.H., Cerling, T.E., 2002. Tooth enamel mineralization in ungulates: implications for recovering a primary isotopic time-series. *Geochim. Cosmochim. Acta* 66, 3225–3234.
- Palacios, D., De Andrés, N., De Marcos, J., Vázquez-Selem, L., 2012. Glacial landforms and their paleoclimatic significance in the Sierra de Guadarrama, Central Iberian Peninsula. *Geomorphology* 139–140, 67–78. <http://dx.doi.org/10.1016/j.geomorph.2011.10.003>.
- Panera, J., Rubio, S., 2000. Bifaces y Elefantes, Zona Arqueológica 1.
- Patou-Mathis, M.E., 1985. La fracturation des os longs de grands mammifères:

- élaboration d'un lexique et d'une fiche type. Outillage peu élaboré en os et en bois de cervidés. *Artefacts* 1, 11–22.
- Pedraza, J., Carrasco, R.M., Domínguez-Villar, D., Villa, J., 2013. Late pleistocen glacial evolutionary stages in the Gredos Mountains (Iberian central Sistem). *Quat. Int.* 302, 88–100.
- Pérez Ripoll, M., 1988. Estudio de la secuencia del desgaste de los molares de Capra pyrenaica de los yacimientos prehistóricos. *Archivo de Prehistoria Levantina* 18, 83–128.
- Pérez Ripoll, M., 2005. Caracterización de las fracturas antrópicas y sus tipologías en huesos de conejo procedentes de los niveles gravetienses de la Cova de les Cendres (Alicante). *Munibe* 57, 239.
- Pickering, T.R., Marean, C., Domínguez-Rodrigo, M., 2003. Importance of limb bone shaft fragments in zooarchaeology: a response to "On in situ attrition and vertebrate body part profiles" (2002), by M.C. Stiner. *J. Archaeol. Sci.* 30, 1469–1482.
- Potts, R., Shipman, P., 1981. Cutmarks made by stone tools from Olduvai Gorge, Tanzania. *Nature* 291, 577–580.
- Price, T.D., Burton, J.H., Bentley, R.A., 2002. The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. *Archaeometry* 44, 117–135.
- Rey, K., Amiot, R., Lécuyer, C., Koufos, G.D., Martineau, F., Fourel, F., Kostopoulos, D.S., Merceron, G., 2013. Late Miocene climatic and environmental variations in northern Greece inferred from stable isotope compositions ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$) of equid teeth apatite. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 388, 48–57.
- Ripoll, López, S., Municio, González, L.J., 1999. Domingo García. Arte Rupestre Paleolítico al aire libre en la meseta castellana, Memorias. *Arqueología en Castilla y León*, 8. Junta de Castilla y León.
- Rivals, F., Julien, M.A., Kuitens, M., van Kolfschoten, T., Serangeli, J., Drucker, D.G., Bocherens, H., Conard, N.J., 2015. Investigation of equid paleodiet from Schöningen 13 II-4 through dental wear and isotopic analyses: archaeological implications. *J. Hum. Evol.* 89, 129–137.
- Royer, A., Lécuyer, C., Montuire, S., Primault, J., Fourel, F., Jeannet, M., 2014. Summer air temperature, reconstructions from the last glacial stage based on rodents from the site Taillies-des-Coteaux (Vienne), Western France. *Quat. Res.* 82 (2), 420–429.
- Ruiz-Zapata, B., Gil-García, M.J., Bustamante, I., 2010. Paleoenvironmental reconstruction of Las Tablas de Daimiel and its evolution during the quaternary period. In: Sánchez-Carrillo, S., Angelier, D.G. (Eds.), *Long-Term Research in Las Tablas de Daimiel*. Springer, pp. 23–43.
- Santonja, M., Pérez-González, A., 2000–2001. El Paleolítico Inferior en el interior de la Península Ibérica. Un punto de vista desde la Geoarqueología. *Zephyrus* 53–54, 27–77.
- Santonja, M., Pérez-González, A., Vega, L.G., Uribelarra, D., 2011. La evolución de las ideas sobre el paleolítico en Madrid. In: Santonja, M. (Ed.), *Actas de las quintas jornadas de Patrimonio Arqueológico en la Comunidad de Madrid*. Comunidad de Madrid, Madrid, pp. 27–60.
- Santonja, M., Villa, P., 1990. The lower paleolithic of Spain and Portugal. *J. World Prehistory* 4 (1), 45–94.
- Sauvet, G., Sauvet, S., 1983. Los grabados rupestres prehistóricos de la Cueva de la Griega (Pedraza, Segovia). *Corpus Artis Rupestris* 1, *Palaeolithica Ars* 2. Salamanca.
- Schmidt, I., Bradtmöller, M., Kehl, M., Paastors, A., Tafelmaier, Y., Weninger, B., Weniger, G.-C., 2012. Rapid climate change and variability of settlement patterns in Iberia during the Late Pleistocene. *Quat. Int.* 274, 179–204.
- Sesé, C., Soto, E., 2002. Catálogo de los yacimientos de Vertebrados del Pleistoceno en las terrazas de los ríos Jarama y Manzanares. In: Panera, J., Rubio, S. (Eds.), *Bifaces y Elefantes*. Zona Arqueológica 1.
- Steele, M.T., 2002. Red Deer: Their Ecology and How They Were Hunted by Late Pleistocene Hominids in Western Europe (Department of Anthropological sciences and the committee on graduate studies of Stanford University in partial fulfilment of the requirements for the degree of Doctor of Philosophy).
- Stewart, J.R., Stringer, C.B., 2012. Change human evolution out of Africa: the role of refugia and climate. *Science* 335, 1317–1321. <http://dx.doi.org/10.1126/science.1215627>.
- Straus, L.G., 1991. Human geography of the late upper paleolithic in Western Europe: present state of the question. *J. Anthropol. Res.* 46 (2), 259–278.
- Straus, L.G., 1992. *Iberia before the Iberians*. University of New Mexico Press, Albuquerque.
- Straus, L.G., 2015a. Recent developments in the study of the upper paleolithic of Vasco-Cantabrian Spain. *Quat. Int.* <http://dx.doi.org/10.1016/j.quaint.2014.05.008>.
- Straus, L.G., 2015b. The human occupation of southwestern Europe during the last glacial maximum. *Solutrean cultural adaptations in France and Iberia*. *J. Anthropol. Res.* 71 (4), 465–492.
- Straus, L.G., Bicho, N., Winegardner, A.C., 2000. The Upper Palaeolithic settlement of Iberia: first-generation maps. *Antiquity* 74, 553–566.
- Sydney-Zax, M., Mayer, I., Deutsch, D., 1991. Carbonate content in developing human and bovine enamel. *J. Dent. Res.* 70, 913–916.
- Tapias, F., López-Recio, M., Manzano, I., Alcaraz-Castaño, M., Morín, J., Sesé, C., Dapena, L., Alarcón, A., Yravedra, J., Arteaga, C., 2012. Geoarqueología y Paleontología de los depósitos del Pleistoceno Superior del antiguo arroyo Abroñigal (Cuenca del Manzanares, Madrid): el yacimiento del Puente de los Tres Ojos. *Cuaternario y Geomorfología* 26 (1–2), 105–132.
- Théry-Parisot, I., Costamagno, S., 2005. Propriétés combustibles des ossements. Données expérimentales et réflexions archéologiques sur leur emploi dans les sites paléolithiques. *Gallia Préhistoire* 47, 235–254.
- Tieszen, L.L., 1991. Natural variations in the carbon isotope values of plants: implications for archaeology, ecology, and paleoecology. *J. Archaeol. Sci.* 18, 227–248.
- Toro, I., Lumley, H., Fajardo, B., Barsky, D., Cauche, D., Celiberti, V., Grégoire, S., Martínez-Navarro, B., Patrocínio, M., Ros-Montayo, S., 2009. L'industrie lithique des gisements du Pléistocène inférieur de Barranco León et Fuente Nueva 3 à Orce, Grenade, Espagne. *L'Anthropologie* 113, 111–124.
- Tütken, T., Vennemann, T.W., Janz, H., Heizmann, E.P.J., 2006. Palaeoenvironment and palaeoclimate of the Middle Miocene lake in the Steinheim basin, SW Germany: a reconstruction from C, O, and Sr isotopes of fossil remains. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 241, 457–491.
- Uerpmann, H.P., 1973. Animal bone finds and economic archaeology: a critical study of "Osteoarchaeological" method. *World Archaeol.* 4, 307–322.
- Utrilla, P., Montes, L., Mazo, C., Alday, A., Rodanés, J.M., Blasco, M.F., Domingo, R., Bea, M., 2010. El Paleolítico Superior en la cuenca del Ebro a principios del siglo XXI. Revisión y novedades. In: Mangado, X. (Ed.), *El Paleolítico superior peninsular. Novedades del siglo XXI*. Barcelona 2010, *Monografies del Seminari d'Estudis i Recerques Prehistòriques*, 8, pp. 23–61.
- Utrilla, P., Domingo, R., Montes, L., Mazo, C., Rodanés, J.M., Blasco, F., Alday, A., 2012. The Ebro Basin in NE Spain: a crossroads during the Magdalenian. *Quat. Int.* 272–273, 88–104.
- Vaquero, M., 2006. El tránsito Paleolítico Medio/Superior en la Península Ibérica y la Frontera del Ebro. *Comentario a Zilhão*. *PIRENAE* 37, 107–129.
- Vega, G., Raposo, L., Santonja, M., 1999. Environments and settlement in the Middle palaeolithic of the Iberian Peninsula. In: Roebroeks, W., Gamble, C. (Eds.), *The Middle Palaeolithic Occupation of Europe*. University of Leiden, pp. 23–48.
- Vega, L.G., Sevilla, P., Colino, F., Gutiérrez, F., Peña, P., Rodríguez, R., Barez, S., 2010. Nuevas investigaciones sobre los yacimientos paleolíticos en la Sierra Norte de la Comunidad de Madrid. Resúmenes. *V Jornadas de Patrimonio arqueológico en la Comunidad de Madrid*. In: Los primeros pobladores: arqueología del Pleistoceno, pp. 21–22. Museo Arqueológico Regional. Alcalá de Henares.
- Vegas, J., Ruiz-Zapata, B., Ortiz, J.E., Galan, L., Torres, T., García-Cortes, A., Gil-García, M.J., Pérez-González, A., Gallardo-Millán, J.L., 2010. Identification of arid phases during the last 50 kyr Cal BP from the Fuentillejo maar lacustrine record (Campo de Calatrava Volcanic Field, Spain). *J. Quat. Sci.* 25, 1051–1062.
- Villa, P., Mahieu, E., 1991. Breakage patterns of human long bones. *J. Hum. Evol.* 20, 1–22.
- Villaverde, V., Roman, D., Martínez, R., Badal, E., Bergadà, M.M., Guillén, P., Pérez, M., Torrado, C., 2010. El Paleolítico superior en el País Valenciano. Novedades y perspectivas. In: Mangado, X. (Ed.), *El paleolítico superior peninsular. Novedades del siglo XXI*. *Monografies n.8. SERP*, Barcelona, pp. 85–113.
- Waring, G.H., 2003. *Horse Behavior*. Noyes Publications, Norwich, N.Y.
- Wolff, E.W., Chappellaz, J., Blunier, T., Rasmussen, S.O., Svensson, A., 2010. Millennial-scale variability during the last glacial: the ice core record. *Quat. Sci. Rev.* 29, 2828–2838.
- Yokoyama, Y., Esat, T., Lambeck, K., Fifield, L., 2000. Last Ice Age millennial scale climate changes recorded in Huon Peninsula corals. *Radiocarbon* 42 (3), 383–401.
- Yravedra, J., 2005. Aprovechamiento Cárnico de lince (*Lynx pardina*) durante el Pleistoceno Superior en el interior de la Península Ibérica. *Munibe* 57/1, 303–311.
- Yravedra, J., 2007a. Aproximación tafonómica a los cazadores de la segunda mitad del Pleistoceno Superior de la mitad norte del interior de la Península Ibérica. *Arqueoweb* 9.1.
- Yravedra, J., 2007b. Zooarqueología y tafonomía de los macromamíferos y lagomorfos de La Peña de Estebanvela (Segovia). In: Cacho, C., Ripoll, S., Muñoz, J.F. (Eds.), *La Peña de Estebanvela (Estebanvela-Ayllón, Segovia)*, pp. 167–216. Grupos magdalenenses en el sur del Duero. Memorias de Arqueología de Castilla y León 17. Junta de Castilla y León, Valladolid.
- Yravedra, J., 2008. Los lagomorfos como recurso alimenticio en Cueva de Ambrosio (Almería, España). *Zephyrus* 61, 63–80.
- Yravedra, J., Andrés, M., 2014. Estrategias de subsistencia entre los grupos magdalenenses de la Peña de Estebanvela (Ayllón, Segovia). In: Cacho, C. (Ed.), *Ocupaciones magdalenenses en el interior de la Península Ibérica. La Peña de Estebanvela (Ayllón, Segovia)*. Junta de Castilla y León, pp. 211–241.
- Yravedra, J., Cobo-Sánchez, L., 2015. Neanderthal exploitation of ibex and chamois in southwestern Europe. *J. Hum. Evol.* <http://dx.doi.org/10.1016/j.jhevol.2014.10.002>.
- Yravedra, J., Domínguez-Rodrigo, M., 2009. The shaft-based methodological approach to the quantification of long limb bones and its relevance to understanding hominid subsistence in the Pleistocene: application to four Palaeolithic sites. *J. Quat. Sci.* 24, 85–96.
- Yravedra, J., Lagos, L., Bárcena, F., 2011. A Taphonomic study of wild wolf (*Canis Lupus*). Modification of horse bones in Northwestern Spain. *J. Taphon.* 9, 37–65.
- Yravedra, J., Fosse, P., Andrés, M., Besson, J.P., 2014a. Taphonomic analysis of small ungulates modified by fox (*Vulpes vulpes*) in Southwestern Europe. *J. Taphon.*
- Yravedra, J., Andrés, M., Domínguez Rodrigo, M., 2014b. A taphonomic study of the African wild dog (*Lycaon pictus*). *Archaeol. Anthropol. Sci.* <http://dx.doi.org/10.1007/s12520-013-0164-1>.
- Yravedra, J., Uzquiano, P., 2013. Burnt bone assemblages from El Esquilero cave (Cantabria, Northern Spain): deliberate use for fuel or systematic disposal of organic waste? *Quat. Sci. Rev.* 68175–68190.
- Yravedra, J., Álvarez-Alonso, D., Estaca, V., López Cisneros, P., Arrizabalaga, A., Elorza, M., Iriarte, M.ª, Jordá, J.F., Sesé, C., Uzquiano, P., 2016. New evidence of

- bones used as fuel in the Gravettian level at Coïmbre cave, northern Iberian Peninsula. *Archaeol. Anthropol. Sci.* <http://dx.doi.org/10.1007/s12520-016-0317-0>.
- Zazzo, A., Lécuyer, C., Mariotti, A., 2004a. Experimentally-controlled carbon and oxygen isotope exchange between bioapatites and water under inorganic and microbially-mediated conditions. *Geochim. Cosmochim. Acta* 68 (1), 1–12.
- Zazzo, A., Lécuyer, C., Sheppard, S.M.F., Grandjean, P., Mariotti, A., 2004b. Diagenesis and the reconstruction of paleoenvironments: a method to restore original $\delta^{18}\text{O}$ values of carbonate and phosphate from fossil tooth enamel. *Geochim. Cosmochim. Acta* 68, 2245–2258.