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Stable isotope analysis of human and animal remains from the Late Upper Palaeolithic site of Balma Guilanyà, southeastern Pre-Pyrenees, Spain

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ABSTRACT

Stable isotope analysis of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) was performed on collagen extracted from three human and five herbivore bone and tooth samples from the Late Upper Palaeolithic site of Balma Guilanyà (Catalonian Pre-Pyrenees, Spain). Contextual and palaeoecological data as well as radiocarbon dates indicate that the studied occupation phase took placed during the Bolling/Allerod interstadial (GI-1a event). The human remains were co-mingled without any anatomical association, corresponding to a minimum number of three individuals, and it was not possible to determine if the three analyzed samples are from one or more individuals. The mean isotope values obtained from the human remains are $\delta^{13}C = -19.8‰$ and $\delta^{15}N = 6.7‰$, while those of the large herbivores (red deer and wild goat) were $-19.8‰$ and $1.7‰$ for $\delta^{13}C$ and $\delta^{15}N$ respectively. This indicates that the main source of protein in the diet of the Balma Guilanyà human(s) came from terrestrial herbivores. There is no zooarchaeological or isotopic evidence for the consumption of freshwater or marine resources at the site, which lies 80 km from the present Mediterranean coast. The low $\delta^{15}N$ values observed in both human and animal samples correspond to a trend reported by other researchers working in northwestern Europe: a significant $\delta^{15}N$ reduction in collagen from bones datable within 20,000–10,000 BP, followed by a rise to present values in the Early Holocene. This phenomenon, generally attributed to climatic and/or pedological processes, had not been previously observed in the Mediterranean region and, until now, was thought to be restricted to northern Europe.

1. Introduction

Our knowledge about Late Glacial and Early Holocene hunter-gatherer strategies in the high altitude environments of the southeastern Pyrenees is sketchy, particularly when compared with the neighboring districts of Cantabria and the northern Pyrenees (Bahn, 1983; Straus, 1992). The human colonization of mountain ecosystems in the Late Glacial involves interesting issues. The fragmentation of mountain environments stimulates plant and animal biodiversity, which provides in turn a variety of nutritional opportunities. Although these ecosystems held relatively rich resources, they were generally available only during brief or seasonal periods. Consequently, the human occupation of these landscapes requires planning and scheduling to determine when and where to move in order to optimize resources at peak times (e.g. Gamble, 1993).

We analyzed the stable isotopes of carbon and nitrogen in collagen extracted from human and animal bone and teeth from the Late Upper Palaeolithic level of Balma Guilanyà site (Catalonia, Spain) (Fig. 1). No stable isotope studies have been carried out on other humans of this period from Spain so far, and only a limited number of studies have been undertaken in other parts of Europe (Drucker and Henry-Gambier, 2005; Francalacci, 1988; Richards et al., 2000, 2005).

Carbon and nitrogen stable isotopic values are increasingly being used to reconstruct past human and animal diets and to detect dietary changes or new subsistence adaptations, such as the broad spectrum strategies thought to be adopted by humans at the Pleistocene/Holocene transition (Stiner et al., 1999). Stable isotope analyses provide more direct information about past human diets than traditional methods of dietary reconstruction. Zooarchaeology

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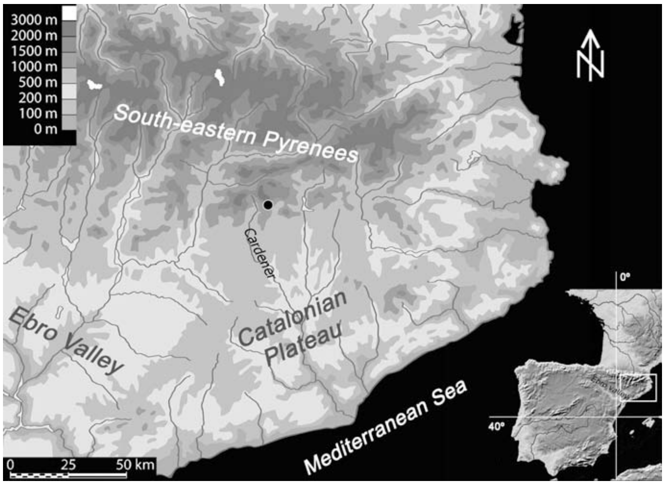

Fig. 1. Location of Balma Guilanyà at the southeastern Pyrenees.

often relies on the analysis of meal refuse faunas, which are tend to be affected by a variety of cultural, environmental and taphonomic factors (Gifford, 1991; Lyman, 1994).

The ratio of the stable isotopes of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) in bone and tooth collagen can be used to quantify the consumption of protein with different isotopic composition (DeNiro and Epstein, 1978, 1981; Schoeninger and DeNiro, 1984) and determine the trophic relationships between the various species that form an ecosystem (Fry, 1988; Minagawa and Wada, 1984). This is possible because isotopes fractionate in a predictable manner between the food consumed and body tissues, and reflect the isotopic characteristics of primary production sources ($^{13}C/^{12}C$) and the trophic position of different organisms ($^{15}N/^{14}N$).

Carbon isotopes indicate the proportion of proteins from marine and terrestrial origin (Chisholm et al., 1982) and/or from C_3- and C_4-type plants (Schoeninger et al., 1983) in diets. The $\delta^{13}C$ values in bone collagen from herbivores may vary between −20‰ and −8‰ depending on whether they have 100% C_3-plant or 100% C_4-plant diets. However, since there were no edible C_4 plants in Pleistocene Europe (Sage and Monson, 1999), here carbon isotope analyses can be used to estimate the consumption of marine proteins, which also have enriched $\delta^{13}C$ values relative to terrestrial proteins. For example, in an ecosystem devoid of C_4 plants, a $\delta^{13}C$ value around of −12‰ would indicate that about 100% of the ingested protein was of marine origin (Ambrose, 1993; DeNiro, 1987; Katzenberg, 1992; Keegan, 1989).

Nitrogen stable isotope ratios provide information about the trophic level of the organism in question. The $\delta^{15}N$ values of the consumer are 3–5‰ higher than the mean $\delta^{15}N$ of the consumed protein (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984).

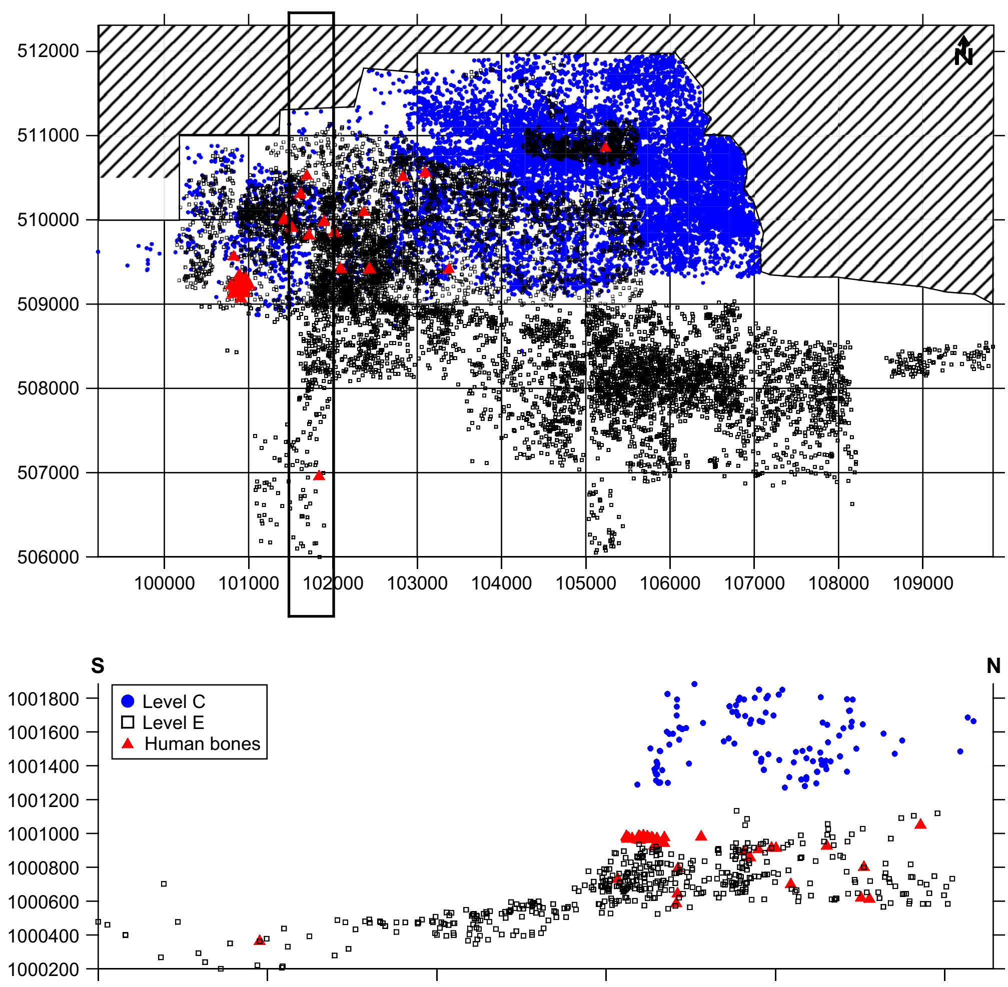

Fig. 2. Upper: horizontal plot of the archaeological units of Balma Guilanyà. Lower: vertical N–S plot between $X = 101{,}500$–$102{,}000$ with the stratigraphic position of levels C and E, and the location of human remains (▲) on level E (all measures are in mm).

Table 1
Radiocarbon data from Balma Guilanyà. Chronometric frame based on the SFCP calibration model with 2σ (Shackleton et al., 2004; Weninger et al., 2007) and the NGRIP GICC05 chronometric model (Andersen et al., 2006).

Level	Reference	BP	Method	$\delta^{13}C$	Sample	cal BP (95%)	Chronoclimatic period	Cultural affiliation
EJ	Beta-185066	12,180 ± 50	AMS	−24.5	Charcoal	14,550–13,870	GI-1e	Azilian
E	UBAR-367	11,460 ± 230	CONV	−25.7	Charcoal	13,790–12,910	GI-1c/GI-1a	
E	Ua-34297	11,095 ± 195	AMS	−19.6	Human tooth	13,380–12,660	GI-1a	
E	Beta-210729	10,940 ± 50	AMS	−26.4	Hazelnut	12,990–12,710	GI-1a	
E	Ua-34298	10,195 ± 255	AMS	−19.9	Human bone	12,830–10,990	GI-1a/Preboreal	
C1	Beta-210728	9840 ± 50	AMS	−25.5	Hazelnut	11,340–11,180	Preboreal	Mesolithic
C	Beta-186168	9410 ± 60	AMS	−21.4	Charcoal	10,790–10,510	Preboreal	
C	UBAR-368	8970 ± 430	CONV	−24.8	Charcoal	11,250–9050	Preboreal/Boreal	
C	Beta-185064	8680 ± 50	AMS	−26.2	Charcoal	9790–9510	Boreal	
C	Beta-210730	8640 ± 50	AMS	−24.3	Hazelnut	9730–9490	Boreal	

2. The Balma Guilanyà site

Balma Guilanyà is a rock shelter located in a small mountain valley (1157 m a.s.l.) of the Serra de Busa in the southeastern Pre-Pyrenees, near the city of Solsona, Catalonia, Spain ($X = 385{,}087$, $Y = 4{,}660{,}546$, UTM H31N ED50) (Fig. 1). This valley links the high western sierras of the southeastern Pyrenees with the Ebro basin and the Central Catalonian plateau (Parcerisas et al., 2003). The 15×5 m rock shelter was formed in Eocene conglomerates and contains a 2 m stratigraphic succession of clays, cobbles and limestone weathered from the rock wall and Quaternary deposits with lithic and faunal assemblages attributable to the Pleistocene/Holocene boundary.

The excavation of a 25 m^2 surface revealed stratified deposits with two different sedimentary units that can be correlated with two chrono-cultural periods. Archaeological evidence and radiocarbon dates place the upper unit (levels C1 and C) within the Mesolithic. The lower unit contains at least three archaeological levels assigned to the Late Palaeolithic (Azilian). These two units are separated by a wall collapse that sealed the Pleistocene sequence, and impeded downward migration and the mixing of Postglacial and Late Glacial elements.

The vertical dispersion of artifacts from the first Late Glacial level, level E, is a palimpsest produced by repeated visits to the rock shelter over a period of a few hundred years (Fig. 2). The artifacts recovered are primarily bladelets and curved-backed micro-points associated with circular micro-endscrapers and domestic tools on flake such as scrapers, denticulates and scaled pieces (or *pièces esquilles*), representing altogether *ca.* 80% of the retouched assemblage (Martínez-Moreno et al., 2006, 2007). Their sizes suggest a clear microlithization process that does not exclusively involve points and bladelets (i.e. hunting toolkit), but all retouched elements (specifically endscrapers). These typological characteristics can be tentatively attributed to the early-Azilian (Guilaine and Martzluff, 2007; Straus et al., 2002), but such diagnostic elements as flat "Azilian" harpoons or painted pebbles are lacking. The occurrence of perforated marine shells (*Nassarius incrassatus*, *Dentalium* sp. and *Columbella rustica*) at this inland site suggests that the people utilizing the Balma Guilanyà shelter formed part of a long distance social/trade network, an activity that took place throughout the Upper Palaeolithic and was widespread in the Pyrenees during the Late Glacial and Mesolithic (Bahn, 1983; Martínez-Moreno et al., 2008).

Approximately one hundred charcoal samples were identified as mountain pine (*Pinus sylvestris*) (Parcerisas et al., 2003), but some hazelnut shells (*Corylus avellana*) were found in the cultural layers as well. The associated fauna consists mainly of wild goat (*Capra pyrenaica*), red deer (*Cervus elaphus*), wild boar (*Sus scropha*) and

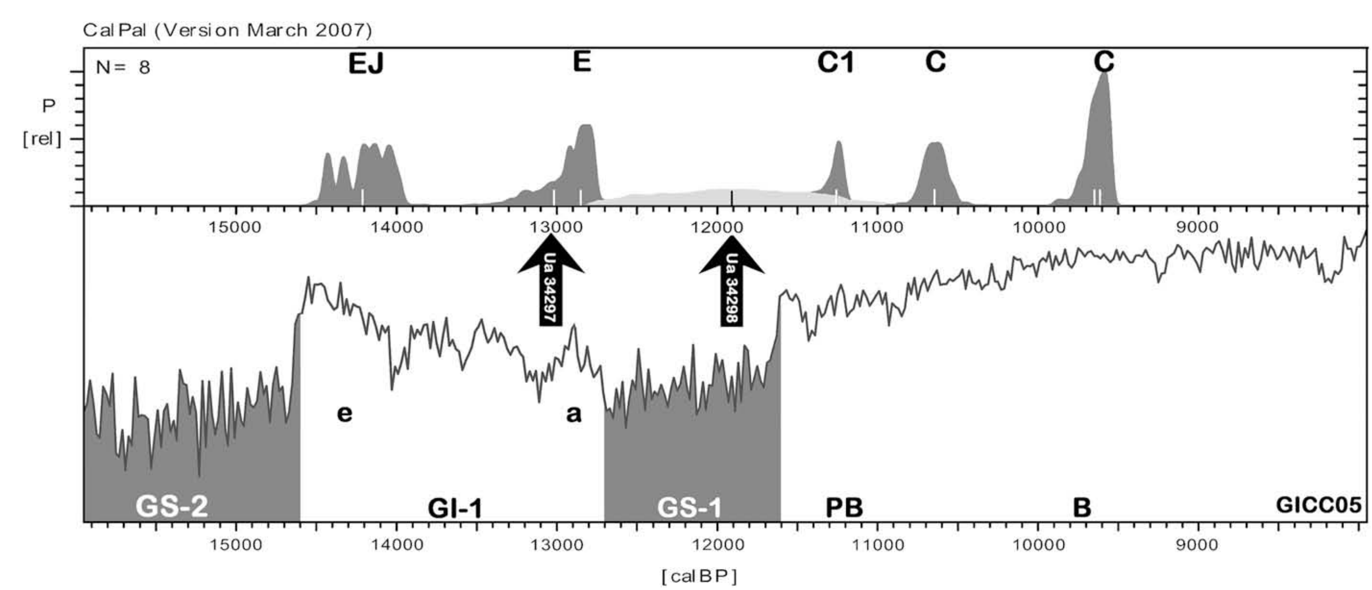

Fig. 3. Gaussian distribution of the AMS radiocarbon data series from Balma Guilanyà in years cal BP with 2σ compared with the $\delta^{18/16}O$ of the NGRIP GICC05 chronometric model (Andersen et al., 2006) and CalPal 2005 SFCP calibration model (Weninger et al., 2007). The dates from human tooth (Ua-34297) and bone (Ua-34298) from level E are indicated by arrows. The wide range of Ua-34298 is represented in light grey to distinguish it from those of other samples. Conventional dates UBAR-367 and UBAR-368 have not been included.

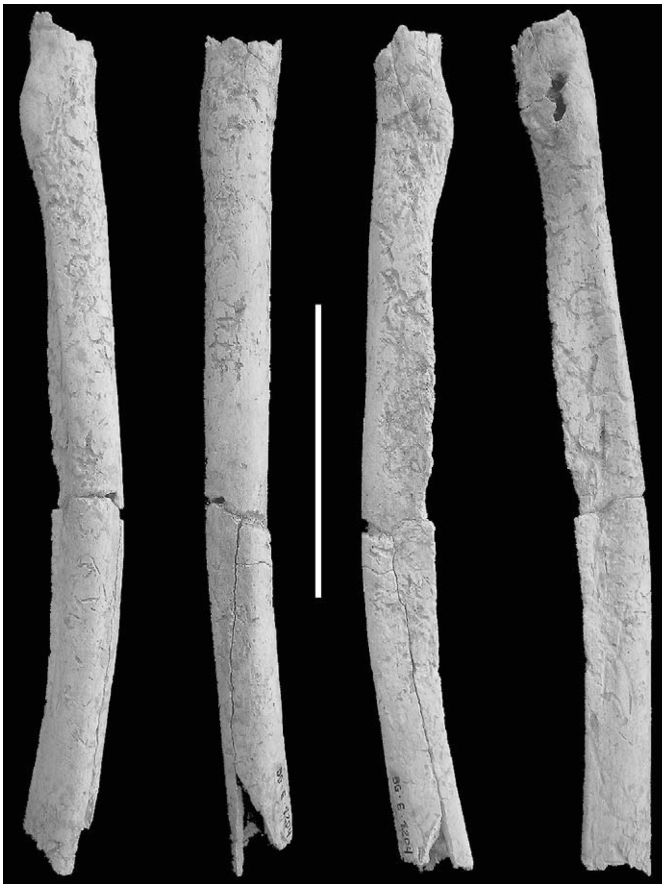

Fig. 4. Human radius from Balma Guilanyà level E sampled for stable isotope analysis (scale 5 cm).

rabbit (*Oryctolagus cuniculus*). This does not quite agree with the category of "mountain kill-site" suggested for some Cantabrian sites with similar chronologies (Straus, 1992). The presence of immature wild goat and boar remains implies seasonal occupation, at least during summer or early autumn. The location of the site in a small mid-altitude valley directly connected with the Ebro basin and the Catalonian plateau (Fig. 1) suggests short and repeated stays during the warm season.

The ten radiocarbon ages obtained from the site were calibrated according to the SFCP calibration model (Shackleton et al., 2004) and the chronometric range has been compared with oxygen isotope variations ($\delta^{18}O$) over the GICC05 time scale (Andersen et al., 2006) provided by the CalPal software (Weninger et al., 2007) (Table 1 and Fig. 3). This procedure allows correlations with a palaeoclimatic scale based on continuous and high resolution proxies. The radiocarbon results suggest that the lower sequence (levels E and EJ) belongs to the Bolling/Allerod interstadial (GI-1), while the upper sequence (levels C1 and C) corresponds to the Preboreal and Boreal periods. Level E yielded two different dates. One is a conventional date from charcoal (UBAR-367) with a calibrated range of 13,790–12,910 cal BP, which places the assemblage in the Bolling/Allerod interstadial. The other one is an AMS determination to 12,990–12,710 cal BP from a burnt hazel endocarp (Beta-210729), which agrees with the previous date and also supports the placing of the depositional event in the late Bolling/Allerod interstadial. These dates place the occupation of level E at the GI-1a event or the Allerod interstadial (Martínez-Moreno et al. 2007). The presence of hazelnuts at this level suggests the existence of local forest refugia not detected by anthracologic analysis. The date of 14,550–13,870 cal BP obtained on charcoal from level EJ (Beta-185066) suggests that the occupation of the site began during the GI-1e event or the Bolling interstadial.

The dates of 13,380–12,660 (Ua-34297) and 12,830–10,990 (Ua-34298) cal BP yielded by the human remains confirm that these are not an intrusive burial feature. Diagenetic factors and/or variation of atmospheric ^{14}C content may be responsible for the wide differences in the central tendencies between the AMS dates obtained from human tooth (Ua-34297) and bone (Ua-34298) samples (Bondevik et al., 2006). Even if the range of Ua-34298 stretches well into the Younger Dryas phase, the more precise dates from human bone (Ua-34297) and burnt hazelnuts (Beta-210729) are probably more representative of the true age of the human bone assemblage from level E.

The radiocarbon ages of 11,340–11,180 cal BP (Beta-210728) and 10,790–10,510 cal BP (Beta-186168) from levels C1 and C, which may represent two different occupation horizons, confirm the utilization of the site in the Preboreal period. The shelter was subsequently reoccupied during the Boreal period, some time in the first half of the 10th millennium cal BP, as indicated by two AMS dates ranging within 9,800–9,500 cal BP (Beta-185064 and Beta-210730). The abundance of hazelnut at level C may reflect the onset of mild and warm climatic conditions associated with the Holocene reforestation and the formation of deciduous forests.

The radiocarbon series points to a possible occupation hiatus during the Younger Dryas period. The absence of human occupation at Balma Guilanyà during this event would suggest that climatic fluctuations could have influenced the human occupation of Pyrenean ecosystems, but this does not seem to be the case at the neighboring site of Balma Margineda (Guilaine and Martzluff, 1995).

The human remains from level E comprise fourteen teeth, a small number of very fragmentary skull bones, and five postcranial bones consisting of three phalanges, one scaphoid and a left radius fragment (Fig. 4). They represent a minimum of three individuals on the basis of duplications, ontogenic aspects and tooth abrasion (Ruiz et al., 2006). One of the individuals is a child of around five years old and the other two are adults. The postcranial remains may correspond to a single individual (possibly a young woman), but they are too few for a reliable anthropological interpretation. A number of fragments from a shattered adult cranium were found concentrated in a small area of 20 cm^2.

All the human remains were scattered within a surface of about 0.5 m^2 (Fig. 2) and it has not been possible to observe any signs of a burial structure so far. Although the contextual meaning of this concentration of human bones is unclear, we hope that future fieldwork may shed some light on this matter.

Table 2
Isotope results from Balma Guilanyà.

Code	Sample	Species	C:N (%)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)
E1204	Radius	*Homo sapiens sapiens* (Human)	3.5	6.5	−20.0
E3998	Tooth	*Homo sapiens sapiens* (Human)	3.5	6.7	−19.6
E NC	Skull	*Homo sapiens sapiens* (Human)	3.4	6.8	−19.9
E1427	Diaphysis frag.	*Cervus elaphus* (Red deer)	3.4	2.0	−20.0
E1396	Radius	*Cervus elaphus* (Red deer)	3.4	1.9	−20.0
E3741	Rib	*Cervus elaphus* (Red deer)	3.4	1.6	−19.7
E1451	Radius-ulna	*Capra pyrenaica* (Wild goat)	3.4	1.5	−19.6
E3398	Talus	*Oryctolagus cuniculus* (Wild rabbit)	3.3	1.8	−21.2

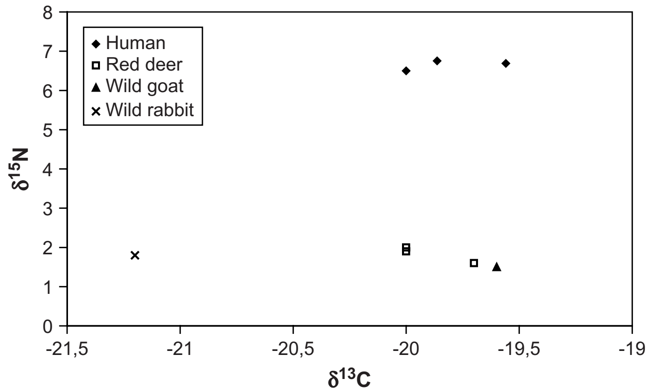

Fig. 5. δ^{15}N and δ^{13}C values (‰) of human and animal remains from Balma Guilanyà.

Despite their limited number, the human remains recovered from Balma Guilanyà are of great importance because they represent the only known human assemblage from this period in Catalonia.

3. Materials and methods

3.1. Samples for stable isotopes analysis

Three human samples were selected for stable isotope analysis, a radius, skull fragment and an upper right second molar, all from adult individual(s). Unfortunately, it was not possible to determine whether these three samples represent three different individuals, and indeed could represent a single individual.

In general, the animal bones from Balma Guilanyà were poorly preserved and fragmentary, likely due to both taphonomic processes as well as human modification as indicated by cut marks, bone breakage and signs of fire exposure. Most of the faunal remains are long bone diaphyses and, consequently, only approximately 25% of them could be identified to species. Nevertheless, samples of five herbivores (1 wild rabbit, 1 wild goat and 3 red deer) from the same level as the human remains (level E) were analyzed in order to understand the isotope processes in the ecosystem they shared with humans and to reconstruct the trophic relationships within it. On the basis of their size, all the bones chosen for stable isotopes analysis belong to adult individuals.

Details of the samples chosen for stable isotope analyses are given in Table 2.

3.2. Stable isotope analytical procedures

Stable isotope determinations were performed in two different laboratories. The human radius (E1204) and the five herbivores were analyzed at the Department of Archaeological Sciences at the University of Bradford, UK (Garcia-Guixé et al., 2006a), and the human tooth (E3998) and skull fragment (E NC) were prepared and analyzed at the Archaeological Research Laboratory at Stockholm University, Sweden.

Collagen extraction for all samples was carried out according to the procedure described by Brown et al. (1988), which is a modified Longin (1971) method with the addition of an ultrafiltration step. The analyses of the stable isotope ratios of carbon (^{13}C/^{12}C) and nitrogen (^{15}N/^{14}N) in the extracted lyophilized collagen were made using a C:N Elemental Analyser (Roboprep) connected to a Europa Scientific Geo 20/20 mass spectrometer (IRMS) (University of Bradford) and Carlo Erba NC2500 analyser connected to a Finnigan MAT Delta+ mass spectrometer (Stockholm University).

The percentages of carbon and nitrogen in the collagen extract were determined to calculate the C:N ratio and check the biochemical quality of the collagen (DeNiro, 1985; van Klinken, 1999). The results are given in parts per thousand (‰) in terms of δ^{13}C and δ^{15}N notation relative to the standards vPDB (*PeeDee Belemnite* – Vienna standard) and atmospheric N_2 (AIR – *Ambient Inhalable Reservoir* standard) respectively.

All samples were run twice and standards were analyzed in the same manner as the controls (one standard per 10 sample determinations). The analytical error (1σ) for both δ^{13}C and δ^{15}N fell within ±0.2‰.

4. Results and discussion

The results of the stable isotope analyses are listed in Table 2 and presented in graphic form in Fig. 5. All the analyzed samples have a C:N ratio within 3.0–3.5, which is the accepted range for well-preserved collagen (DeNiro, 1985).

The wild rabbit sample (E3398) has a δ^{13}C value of −21.2‰ and a δ^{15}N value of 1.8‰. Rabbits and other small mammals are seldom analyzed for stable isotopes. They are rare in prehistoric sites due to the small size and fragile nature of their remains, which makes them easily affected by post-depositional taphonomic processes

Table 3
δ^{15}N and δ^{13}C values of humans from European Late Pleistocene sites. Nd: no data.

Site and reference	Samples	^{14}C BP	cal BP (95%)	C:N	δ^{15}N	δ^{13}C
Saint-Germain-la-Rivière (Drucker and Henry-Gambier, 2005)	Rib	15,780 ± 200	19,040 ± 440	3.4	10.2	−19.2
Gough's Cave (Richards et al., 2000)	Nd	11,820 ± 120	13,730 ± 260	3.3	7.1	−18.9
	Nd	11,700 ± 100	13,590 ± 240	3.2	5.4	−19.1
	Nd	12,300 ± 100	14,340 ± 440	3.3	6.5	−18.6
	Nd	12,380 ± 110	14,550 ± 560	3.4	7.1	−18.5
Sun Hole 2 Cave (Richards et al., 2000)	Nd	12,210 ± 160	14,270 ± 540	3.4	7.2	−19.8
Kendrick's Cave (Richards et al., 2005)	Humerus	11,880 ± 90	13,770 ± 240	3.4	13.8	−17.9
	Femur	11,930 ± 90	13,820 ± 240	3.4	13.4	−18.0
	Femur	12,090 ± 90	14,090 ± 400	3.4	13.9	−17.7
	Femur	11,760 ± 90	13,660 ± 180	3.3	13.7	−18.1
Arene Candide (Francalacci, 1988; Bietti, 1987)	Nd	10,910 ± 90	12,850 ± 140	3.2	8.9	−20.0
	Nd			3.4	9.1	−18.9
Balma Guilanyà	Radius	Nd	Nd	3.5	6.5	−20.0
	Tooth	11,095 ± 195	13,020 ± 360	3.5	6.7	−19.6
	Skull	10,195 ± 255	11,910 ± 920	3.4	6.8	−19.9

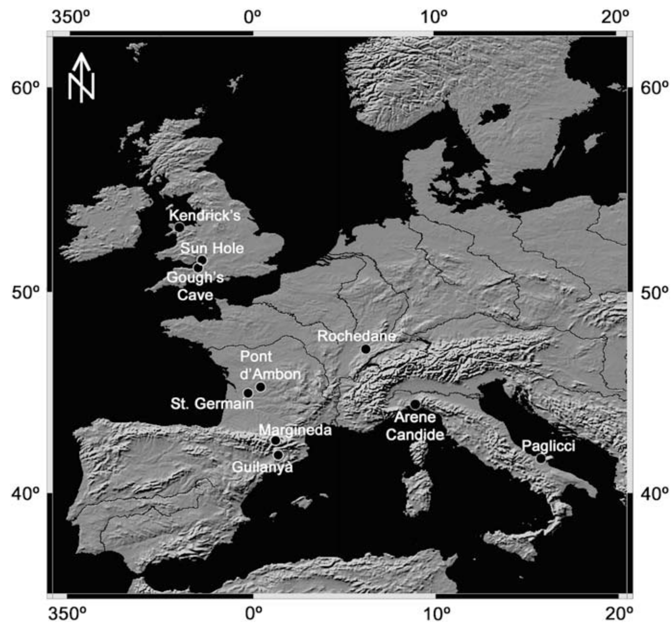

Fig. 6. Location of Balma Guilanyà and other Late Glacial sites discussed in the text.

that may affect the collagen. Furthermore, since small mammals, especially rabbits, may burrow into archaeological layers, there is always the possibility of their bones being intrusive. Nevertheless, there is ample evidence for small mammal hunting in the Late Upper Palaeolithic of southwest France (Simek and Snyder, 1988) and the Iberian Peninsula (Aura et al., 2002a,b; Hockett and Bicho, 2000). At any rate, the limited occurrence of rabbit bones at Balma Guilanyà suggests that they did not have a significant role in the local human diet.

Due to the lack of comparative stable isotope data on small mammals from this period, we compared our results with published data on modern rabbits. Bocherens and Mariotti (1992) measured δ^{13}C values of −21.4 and −23.8‰ in two modern French rabbits (*Oryctolagus cuniculus*). Another study by Bocherens et al. (2003) on 12 modern rabbit samples from 5 different locations on Tenerife (Canary Islands, Spain) yielded ranges between −23.1 and −15.5‰ for δ^{13}C and between 3.5 and 9.0‰ for δ^{15}N. They attribute the wide δ^{13}C variation to the consumption of plants with different photosynthetic pathways (C_3 and CAM or C_4) and the broad range in δ^{15}N values to the influence of marine brine (sea-spray) and/or agricultural practices on terrestrial plants. The carbon isotope value from the Balma Guilanyà rabbit agrees with those found in the literature, and suggests a typical C_3-plant based diet. The nitrogen value is considerably lower than modern results, but it is consistent with the low nitrogen levels of other herbivores from the site. This feature is probably linked to the low δ^{15}N values often associated with the last glacial stadial and, on this basis, we feel that the rabbit is not intrusive. In any event, the rabbit results will not be discussed further because they diverge somewhat from the values of the other analyzed herbivores, possibly due to the particular physiology of lagomorphs (Pehrsson, 1983a,b).

The mean isotope values of the four analyzed ungulates from Balma Guilanyà are -19.8 ± 0.2‰ for δ^{13}C and 1.7 ± 0.2‰ for δ^{15}N. The three red deer values are very similar. The wild goat results lie close to those of red deer, but show the lowest δ^{15}N and highest δ^{13}C values (Table 2 and Fig. 5). The results are in good agreement with those obtained by other authors from European sites of the same period (Richards et al., 2000, 2005; Richards and Hedges, 2003). For example, the mean herbivore values of -19.7 ± 0.3‰ for δ^{13}C and 1.7 ± 1.2‰ for δ^{15}N obtained from the British Late Upper Palaeolithic by Richards et al. (2000) are almost identical to ours.

The mean isotope values of the Balma Guilanyà human remains are $\delta^{13}C = -19.8 \pm 0.2$‰ and $\delta^{15}N = 6.7 \pm 0.1$‰. If one takes the mean δ^{13}C value of −19.8‰ obtained for the contemporaneous fauna as the theoretical end point for a 100% terrestrial diet, the human values would then indicate that all the consumed proteins were of terrestrial origin.

Without the isotopic values of hervibores from the same site as reference, we would probably have erroneously concluded that the human diet consisted primarily of plant food based on a comparison of the δ^{15}N values of Holocene faunas (e.g. Garcia-Guixé et al., 2006b). However, by comparing the human values with those of herbivores at the site, we come to the conclusion that the individual(s) in question consumed primarily animal protein. The mean human δ^{15}N value of 6.7 ± 0.1‰ is much higher than the mean δ^{15}N of the associated herbivores (1.7 ± 0.2‰). The 5‰ difference corresponds to the 3–5‰ trophic level enrichment observed for the δ^{15}N values of consumers compared to diet (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984). There is little evidence for freshwater fish consumption at Balma Guilanyà site, neither from stable isotope data nor from zooarchaeological analysis. A significant consumption of freshwater resources by humans would have been indicated by higher δ^{15}N values. Furthermore, neither fish remains nor fishing implements have been found at the site despite its situation a few kilometres away from the Cardener River (Fig. 1). This contrast with the Late Glacial levels of the Balma Margineda site, which lies next to Valira River and have evidence of *Salmo*

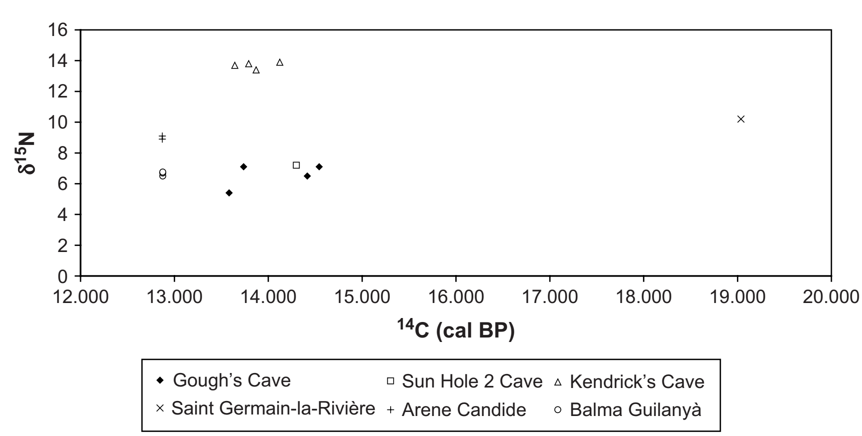

Fig. 7. δ^{15}N values (‰) and radiocarbon dates (cal BP) from Balma Guilanyà and other contemporaneous sites in Europe. For references see Table 3.

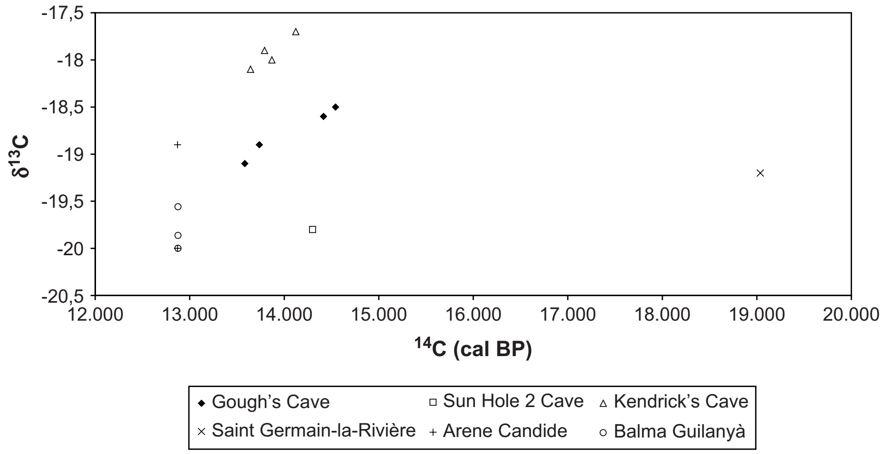

Fig. 8. δ^{13}C values (‰) and radiocarbon dates (cal BP) from Balma Guilanyà and other contemporaneous sites in Europe. For references see Table 3.

trutta fishing with a strong late summer mortality pattern (Guilaine and Martzluff, 2007).

The reason for the low δ^{15}N values often obtained for European mammals from this time period is not fully understood, but it could be related to reduced δ^{15}N values in plants due to climatic and/or pedological processes. In their study of northwest European faunas, Richards and Hedges (2003) observed a significant drop in δ^{15}N values from herbivore collagen during the period of 20,000–10,000 BP (uncal), followed by a rise in values in the Holocene. They attribute this phenomenon to climate-induced edaphic factors at the end of the last stadial, which, although correct, is a cautious broad statement that denotes our lack of knowledge of the complex processes involved. Interestingly, this phenomenon was thought to be restricted to northern Europe (Richards and Hedges, 2003) and it had not been observed in the Mediterranean region until now. No δ^{15}N drop was found in bone collagen from contemporaneous sites like Arene Candide (Francalacci, 1988), or the Paglicci cave in southeastern Italy (Iacumin et al., 1997). On the other hand, a clear drop in δ^{15}N values was reported from red deer bones at Rochedane, near the French-Swiss border, but not at Pont d'Ambon or at Saint-Germain-la-Rivière, near the French Atlantic coast (Drucker et al., 2003; Drucker and Henry-Gambier, 2005). On this basis, it is possible that the higher altitude and/or proximity to alpine glaciers at Balma Guilanyà and Rochedane may have been responsible for processes similar to those of northern Europe. In any event, further research is needed to understand these processes and to confirm the existence of this trend at Balma Guilanyà and the Iberian Peninsula.

Other isotopic studies from Late Upper Palaeolithic individuals in Europe support the idea of a diet based mainly on hunting terrestrial herbivore species (Table 3 and Figs. 6–8). The isotope values of the individual(s) from Balma Guilanyà agree well with those reported by Richards et al. (2000), who obtained a mean δ^{13}C of -19.0 ± 0.5‰ and δ^{15}N of 6.7 ± 0.8‰ for five Late Upper Palaeolithic individuals in the UK. Evidence for a significant marine input on upper Palaeolithic human diets has been found at only one site, Kendrick's Cave in Wales, UK (Richards et al., 2005). However, since this is a coastal site, it is perhaps not surprising that up to 30% of the protein consumed by its occupants would have been of marine origin.

The fact that most of the consumed proteins have an animal source does not necessarily exclude the possibility of vegetable resources forming part of the diet for the human(s) from Balma Guilanyà. The isotopic signal would be somewhat masked since plants provide much less protein than meat per dry weight. It is nevertheless interesting to point out that there are indications of the utilization of nuts and cyperaceae during the Late Glacial. Burnt hazelnut shells found at level E suggest that incipient nut processing, an activity well documented in the Mesolithic of the southwestern Pyrenees, may have originated in the Bolling/Allerod interstadial (Martínez-Moreno et al., 2006, 2007). However, since hazelnuts have as 4–10 times more protein than most other plant foods, an important consumption of them would have resulted in a significant contribution of vegetal protein, which was not the case. Therefore, these nuts, and plants in general, were a minor source of dietary protein. The cypereacea residues found at this level may have been used in basketry.

5. Concluding remarks

Based on the stable isotope analysis reported here we conclude that the human(s) from the Balma Guilanyà site derived the majority of their dietary protein from the consumption of terrestrial herbivores such as red deer and wild goat, and secondarily, wild rabbits. Neither the zooarchaeological data nor the stable isotope results provide any evidence for the consumption of marine of freshwater resources. This is not surprising, since the site lies currently about 80 km from the present coast, which would have been even further during the Late Pleistocene. As the dietary data do not indicate that a significant part of their time was spent at the coast consuming marine foods, it is most likely that marine shells found at the site are ornamental objects that can be connected to a long-distance exchange system (Martínez-Moreno et al., 2008).

Based on the isotope results, we also conclude that plant resources were only a minor source of dietary protein. The burnt hazelnuts found at the site were likely a seasonal resource and were not a significant dietary component.

The stable isotope analyses of animal remains from the site were critical for the interpretation of the human results, as they, like sites in northern Europe, exhibited unusually low δ^{15}N values, compared to Holocene faunas. This stresses the importance of analyzing the associated archaeological fauna, especially in this time period, for a more accurate interpretation of the diets of all of the mammals in the ecosystem of interest.

As stable isotope analysis of bone is a destructive technique and requires well-preserved samples, there are relatively few studies of Palaeolithic humans. This is especially true for Southern Europe where the collagen preservation for Pleistocene humans and fauna is often very poor. Therefore, this study presents important new data for a region where there is relatively little data. The results show that like most of the studies in northern Europe, humans were mainly subsisting on terrestrial herbivores, almost certainly obtained through hunting. Further isotopic studies, especially in regions poor in data, will further add to the emerging picture of diet and subsistence strategies amongst Middle and Late Palaeolithic humans in Europe.

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