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Multi-isotopic diet analysis of south-eastern Iberian megalithic populations: the cemeteries of El Barranquete and Panoría

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Abstract

The southern Iberian megalithic cemeteries of Panoría and El Barranquete offer an excellent opportunity to explore ancient dietary patterns. Due to the special nature of these funerary contexts as palimpsests, a multi-proxy approach including multi-isotopic determination and a high-resolution dating framework was carried out. As a result, 52 samples were isotopically measured, of which 48 were also radiocarbon dated. With this new isotopic series as a basis, three main conclusions can be drawn: (i) the diet was based on C_3 plants and terrestrial animals with no evidence of marine protein consumption; (ii) there is a general tendency for carbon isotope values to increase during the Bronze Age, which is consistent with the intensification of crop farming taking place at the time; and (iii) nitrogen isotope variability is especially remarkable when comparing collective to individual tombs. People buried individually show the highest and the most variable nitrogen ratios in contrast with those buried in collective tombs that show similar nitrogen values over time. These differences support the hypothesis of a conservative megalithic population resisting cultural innovations during the Argaric Bronze Age.

Keywords Bioarchaeology · Megalithism · Stable isotope analysis · Dietary patterns · Radiocarbon chronology · Iberian Peninsula

Introduction

Biochemical analysis of human remains has been gaining traction over recent years and has now achieved a key position in current archaeological agendas. In addition to the obvious advantages of the traditional estimation of sex, age at death and health conditions, recent developments in ancient DNA and stable isotope analyses have changed our understanding of critical aspects of past populations, including their diet, mobility and genetic affinities. The potential of bioarchaeology to make significant contributions is generating the greatest expectations in long-term archaeological debates on subjects such as the origin of complex societies, migration movements and the appearance of the Neolithic lifestyle. Research on the Iberian Peninsula has recently joined this general trend. Different studies have focused on dietary and mobility patterns from the Neolithic to the Bronze Age[1] (Díaz-Zorita Bonilla et al. 2012; Díaz-Zorita Bonilla 2017; Fernández Crespo and Schulting 2017; Waterman et al. 2014, 2016, 2017; Horwath et al. 2014; Fontanals-Coll et al. 2015a, b, 2016; Díaz-del-Río et al. 2017; Salazar-García and Silva-Pinto 2017; Sarasketa-Gartzia et al. 2017; Alt et al. 2016) and, to a lesser extent, on genetic affinities and differences (Haak et al. 2010; Szécsényi-Nagy et al. 2017; Esparza et al. 2017; Alt et al. 2016; Gamba et al. 2011; Martiniano et al. 2017).

Our research is aimed at exploring the dietary patterns of the megalithic societies in southern Iberia. Stable isotope

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[1] The general chronological framework of Late Prehistory of the south-eastern Iberia can be summarised as follows: Neolithic (5500–3000 cal BC) (Camalich Massieu and Martín Socas 2013; Martín Socas et al. 2017), Chalcolithic (3000–2200 cal BC) (Molina et al. 2004; Lull et al. 2015; Aranda Jiménez et al. 2017) and Bronze Age (2200–850 cal BC) (Lull et al. 2013; Aranda Jiménez et al. 2015).

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analysis of carbon and nitrogen offers a key line of evidence that provides new insights into inter-individual and inter-group diet variability. These data can be used to answer important questions about the megalithic societies of south-eastern Iberia. For instance, how important was the consumption of terrestrial and marine resources in megalithic societies, especially in those populations that lived near the Mediterranean Sea? As the megalithic cemeteries studied are characterised by long periods of use, did the diet change over time? Was there any intra-tomb or inter-tomb diet variability? How do the isotopic values of megalithic societies fit in with the southern Chalcolithic and Bronze Age populations? There was any difference in consumption between individuals buried in collective or individual tombs? And if this were the case, what do these differences mean in social and economic terms?

To answer these questions, we focused our attention on the cemeteries of El Barranquete (Níjar, Almería) and Panoría (Darro, Granada), both of which offer an excellent opportunity for achieving these goals, as they are among the best known megalithic sites in southern Iberia (Fig. 1). The analysis of these mortuary contexts is a complex matter because they normally have the appearance of intricate palimpsests. The frequent use of these funerary spaces, in many cases over long periods, produces a mass of stratified, mixed human bones found piled on top of each other and overlapping in many cases. Primary depositions were typically disturbed by later activities, mainly subsequent interments, but also by horizontal and vertical displacements as a result of factors such as gravity and voids created by soft tissue decomposition (Aranda Jiménez et al. 2018a, b; Lozano Medina and Aranda Jiménez 2018).

Approaching the study of these archaeological contexts mainly revolves around trying to understand the different practices that involved the accumulation and transformation of successive and partially preserved ritual activities. As Lucas (2005, p. 37) pointed out, palimpsests "refer to the traces of multiple, overlapping activities over variable periods of time and the variable erasing of earlier traces". Palimpsests, therefore, imply different episodes of deposition that are found superimposed on one another and re-worked in such a way that it becomes difficult, and at times impossible, to separate them into well-defined events. The preserved material traces of these events normally appear so mixed up that they blur the original individual episodes of deposition (Bailey 2007).

A multi-proxy analysis emerges as an excellent choice for achieving a better understanding of the dietary patterns of such archaeological contexts. A biogeochemical study should take into account aspects such as the stratigraphic sequence of depositions, the taphonomy of the human remains and the time sequence of the events in order to provide fine-grained cultural assessments. With these considerations in mind, we have studied the El Barranquete and Panoría human bone collections through two main proxies that include a multi-isotopic diet determination such as δ^{13}C, δ^{15}N and δ^{34}S and a high-resolution dating framework that incorporates a large series of radiocarbon dates. The general background of these cemeteries will first be outlined, then the new multi-isotopic

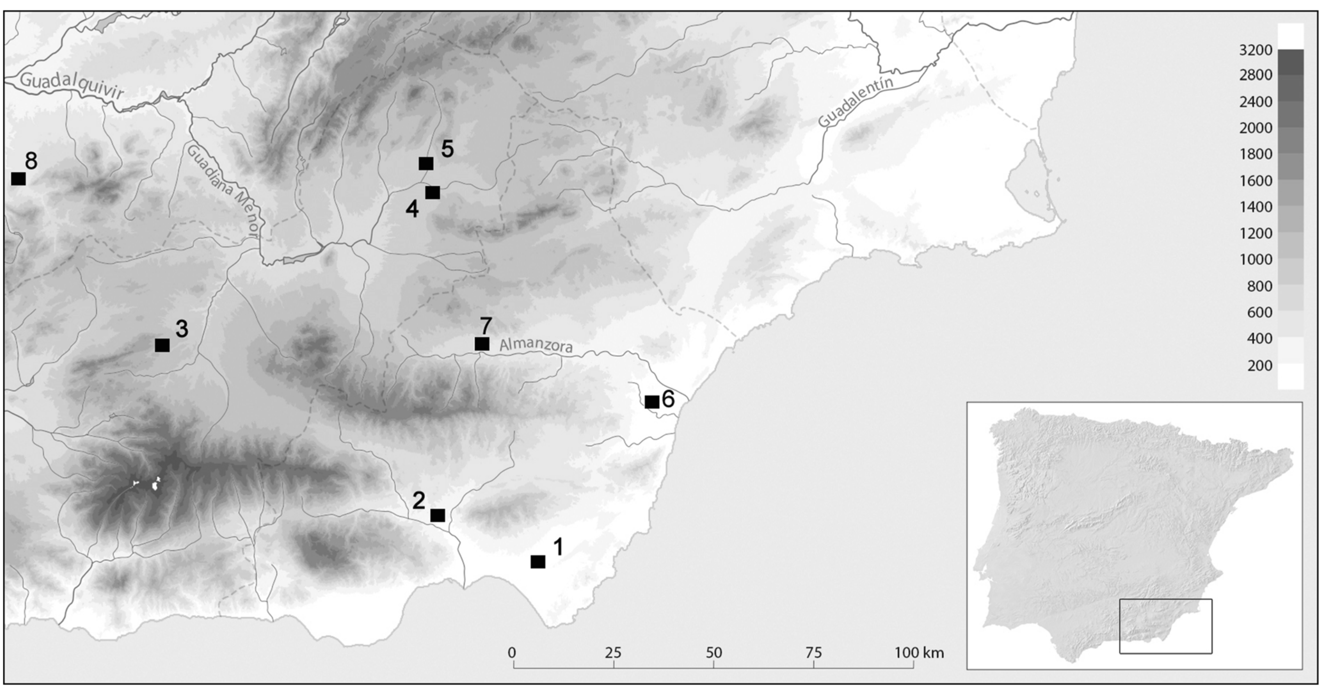


Fig. 1 Map showing the location of the archaeological sites mentioned in the text: (1) El Barranquete; (2) Los Millares; (3) Panoría; (4) Cerro de la Virgen; (5) La Carada; (6) El Garcel; (7) Las Churuletas and (8) Marroquíes

diet and chronological measurements will be considered and, finally, their social implications will be discussed in the context of the southern Iberian megalithic societies.

Archaeological background: the cemeteries of El Barranquete and Panoría

The megalithic cemetery of El Barranquete lies on a plain to the west of a seasonal river, the Rambla de Morales, near the Mediterranean coast in the present-day province of Almería. Discovered in 1968, it was excavated during different fieldwork seasons between 1968 and 1971 and later published in a full report (Almagro Gorbea 1973). The investigations revealed at least 17 megalithic tombs, of which 11 were excavated. All the monuments conform to the megalithic classification of *tholoi* or tombs with chambers covered by false vaults. The funerary chambers were entered through passages that were normally divided into equal segments by perforated slabs. Small side-chambers in both the passages and the main chambers were also a common feature. These tombs were covered by mounds built of concentric stone walls filled with earth and small stones.

Human remains were found in chambers, passages, side-chambers and, more unusually, in the mounds (Fig. 2). Mortuary deposits consisted of a mass of mixed skeletal remains found in a complex stratigraphy that was excavated in different layers. Two specific ritual behaviours were identified inside the funerary chambers. Firstly, skulls and long bones were found, in many cases, carefully deposited and individualised by different stones placed around them. It seems likely that these “bone packages” were collected and placed in this way once the bodies had lost their ligaments and soft tissue. Secondly, some of the bones had been partially burnt, which is also evidenced by ash and burn marks on the chamber floors (Aranda Jiménez and Lozano Medina 2014; Díaz-Zorita Bonilla et al. 2016; Aranda Jiménez et al. 2018a).

The megalithic cemetery of Panoría is located in the foothills of the mountain of the same name, at the easternmost end of the Sierra Harana mountains in the present-day province of Granada. Discovered in 2012, it is the latest addition to the known megalithic cemeteries spread across the Guadix Basin. Thanks to intensive surveys, 19 dolmens have been found. Most of them consist of small tombs with polygonal, rectangular or trapezoidal chambers—normally between 160 and 110 cm in length—and short passages. Four of these megalithic tombs plus a stone cist were excavated between February and June 2015 (Benavides López et al. 2016; Aranda Jiménez et al. 2018b, c; Díaz-Zorita Bonilla et al. 2017).

Of the 5 excavated tombs, 4 were at least partially disturbed by human activities of uncertain origin. In these cases, only small, fragmented human bones, mixed with the sedimentary deposits that filled the funerary chambers, were documented. In two cases, Tombs 7 and 18, a few anthropological remains—mainly large bones—were found in primary position. The most remarkable case was Tomb 10, in which the anthropological deposit was found in an excellent state of preservation (Fig. 3). The mortuary remains found in the chamber and passage consisted of a mass of mixed human bones that were found piled on top of each other. Although most of the skeletal remains were scattered, in a few cases, complete individuals or specific anatomical parts were found in an articulated or semi-articulated position (Aranda Jiménez et al. 2018b, c).

Materials and methods

We analysed the human bones from three tombs (nos. 8, 9, 10) at El Barranquete and five tombs (nos. 6, 7, 8, 10, 18) at Panoría. Both collections had been studied previously from an anthropological and zooarchaeological point of view (Díaz-Zorita Bonilla et al. 2016, 2017). According to these studies, the minimum number of individuals (MNI) identified for the El Barranquete cemetery was 38 in the case of human skeletons and six in the case of domestic animals (cattle and ovicaprines), plus a dog, a lagomorph and seashells. In the case of Panoría, the MNI for humans was 37. In both cemeteries, all anatomical parts were represented and the skeletal remains belonged to men, women and children of all ages, although most of them were in the adult range. Sex or age differences did not appear to have been a determining factor in these funerary practices. The distribution of the MNI by cemetery, tombs and specific areas inside tombs can be seen in Table 1.

Due to the nature of these tombs as palimpsests, the criterion used to select the samples was the MNI, as this is the best way of ensuring that no individual is analysed twice. Then, in the case of El Barranquete, all the bone elements corresponding to the MNI were selected, except for two individuals from Tomb 8, which had insufficient bone for multi-isotopic measurements. Additionally, three more samples of faunal remains were also considered. For Panoría, most individuals were found in tomb 10 (MNI = 28). In this case, the MNI was calculated on the basis of the teeth; nevertheless, the samples to be isotopically analysed were selected according to a more specific criterion. A new MNI based on bones and not teeth was established to include the articulated individuals. This kind of sample is especially suitable for dating, as it is a primary context; hence, the contemporaneity between the date obtained and the act of deposition can be guaranteed. As result, the new MNI was 12. In Tomb 8, although the MNI identified was four, only three samples were selected for multi-isotopic studies, as one of them did not have preserved

Fig. 2 Plan of Tomb 8 including the human remains (after Almagro Gorbea 1973)

Fig. 3 Anthropological remains from Tomb 10 of the Panoría cemetery

Table 1 Distribution of the minimum number of individuals by cemetery, tombs and specific areas inside tombs

Tomb	Sector	MNI	^{14}C	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$
El Barranquete						
Tomb 8	Passage 2nd section	3	1	1	1	–
	Chamber layer I	4	3	4	4	1
	Chamber layer II	10	8	8	8	2
	Total	17	12	13	13	3
Tomb 9	Mound	1	1	1	1	1
	Passage	2	1	2	2	–
	Chamber layer II	4	4	4	4	2
	Chamber layer III	3	3	3	3	1
	Side-chamber	7	5	5	5	–
	Total	17	14	15	15	4
Tomb 10	Passage	2	1	2	2	1
	Chamber	2	2	2	2	2
	Total	4	3	4	4	3
Unknown tomb	–	–	–	1	1	–
Total El Barranquete		38	29	33	33	10
Panoría						
Tomb 6	Chamber	1	1	1	1	
Tomb 7	Chamber	3	3	3	3	
Tomb 8	Chamber phase I	2	2	2	2	
	Chamber phase II	2	–	–	–	–
Tomb 10	Passage 1st section Passage 2nd section	6 4	12	12	12	
	Chamber	18				
Tomb 18	Chamber	1	1	1	1	
Total Panoría		37	19	19	19	
Total		75	48	52	52	

collagen. Therefore, for the Panoría cemetery, the number of samples considered was 20 instead of 37.

In order to provide a background isotopic signature, the available $\delta^{13}C$ and $\delta^{15}N$ isotopic data on faunal remains have been considered, which means 23 isotopic determinations belonging to three different south-eastern sites contemporaneous to the megalithic populations studied (Table 2). Eighteen isotopic values come from the Chalcolithic site of Marroquíes (Beck et al. 2018), four from the Neolithic site of El Garcel and one from the megalithic tomb of Las Churuletas 1. This last sample has also been radiocarbon dated (Beta-439073, 4200 ± 30, 2900–2670 cal BC at 95% probability) (Aranda Jiménez et al. 2017).

Isotope analyses of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$

The combined analysis of $\delta^{13}C$ and $\delta^{15}N$ is now rather commonly performed when investigating past diets. It has been widely applied to investigating of the proportion of plant and animal proteins. While $\delta^{13}C$ is used to discriminate between C_3 and C_4 plants (e.g. Schoeninger et al. 1983; Schoeninger and DeNiro 1984; Ambrose 1993; Froehle et al. 2012), this isotopic tracker is also used to estimate the consumption of terrestrial vs marine proteins (Calvin and Benson 1948; Randson and Thomas 1960; Whelan et al. 1970; Schoeninger and DeNiro 1984). Carbon has an enrichment of 1‰ between trophic levels (DeNiro and Epstein 1978), between the consumer and the consumed plants. Nitrogen isotopes reflect the consumption of animal and plant proteins with an increase of about 3–5‰ between the $\delta^{15}N$ values of the collagen of the food consumed and that of their consumer (e.g. Minagawa and Wada 1984; Bocherens and Drucker 2003). The endpoints for $\delta^{13}C$ are ca. −21 to −20‰ for a C_3 terrestrial protein consumption and ca. −12‰ for pure marine resources (Schoeninger et al. 1983; Richards and Hedges 1999) are not region-specific and therefore we have additionally measured $\delta^{34}S$ to get accurate insights on the palaeodiet. Both isotopic pairs in combination are rather useful to determine the proportions of different sources of protein in the diet. In addition to these analyses, sulphur is also a valuable palaeodietary proxy for analysing the consumption of aquatic resources (Nehlich 2015). For sulphur isotopes, the

Table 2 $\delta^{13}C$ and $\delta^{15}N$ isotopic data on faunal remains from the archaeological sites of Marroquíes, El Garcel and Las Churuletas

Site	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C:N	%C	%N	Reference
Marroquíes	Bovid	− 18.2	7.7	3.3	39.7	13.9	Beck et al. 2018
Marroquíes	Ovicaprid	− 19	5.9	3.3	43.7	15.4	Beck et al. 2018
Marroquíes	Bovid	− 19.6	7.2	3.3	33.9	11.9	Beck et al. 2018
Marroquíes	Ovicaprid	− 20	6.3	3.3	37.8	13.4	Beck et al. 2018
Marroquíes	Suid	− 20.3	10.6	3.3	38.8	13.7	Beck et al. 2018
Marroquíes	Suid	− 19.4	7.4	3.3	41.9	14.7	Beck et al. 2018
Marroquíes	Bovid	− 20.5	7	3.4	39.0	13.5	Beck et al. 2018
Marroquíes	Bovid	− 17.9	8.8	3.3	31.6	11.0	Beck et al. 2018
Marroquíes	Bovid	− 19	6.9	3.4	31.4	10.8	Beck et al. 2018
Marroquíes	Cervid	− 19.3	6.9	4.1	11.3	3.2	Beck et al. 2018
Marroquíes	Canis	− 20.1	7	3.3	37.8	13.4	Beck et al. 2018
Marroquíes	Capreolus	− 19.1	6.2	3.3	32.4	11.5	Beck et al. 2018
Marroquíes	Bovid	− 20.3	5.8	3.3	33.1	11.8	Beck et al. 2018
Marroquíes	Ovicaprid	− 20.4	3.4	3.3	29.2	10.3	Beck et al. 2018
Marroquíes	Suid	− 20.1	7.8	3.3	27.7	9.7	Beck et al. 2018
Marroquíes	Bovid	− 21.6	5	4.0	9.9	2.9	Beck et al. 2018
Las Churuletas	Ovicaprid	− 20	5.8	3.4	42.7	14.6	Aranda Jiménez et al. 2017
El Garcel	Deer	− 18.8	5.4	3.5	42.9	14.2	Unpublished
El Garcel	Ovicaprid	− 19.7	7.8	3.4	35.2	12.2	Unpublished
El Garcel	Large mammal	− 19.8	9.2	3.3	43.0	14.9	Unpublished
El Garcel	Ovicaprid	− 19.8	9.6	3.5	41.2	13.8	Unpublished

trophic fractionation is not well known; however, with the data available (Nehlich 2015), it would seem that $\delta^{34}S$ values show a slight enrichment of + 0.5‰ on average in consumers, compared to their diet.

About 500 mg of bone material was used for collagen extraction at the Department of Geosciences of the University of Tübingen. Prior to collagen extraction, elemental analyses (%C, %N and %S) were performed on whole bone powder in order to understand the carbon and nitrogen content as an indicator of good collagen preservation. Then, we proceeded with the collagen extraction following standard methods (DeNiro and Epstein 1981; Bocherens et al. 1997) and the chemical and stable isotopic analyses ($\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$) of the extracted collagen. Stable isotopes were measured using a NC2500 CHN elemental analyser coupled to a Thermo Quest Delta + XL mass spectrometer. Values of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ are reported according to the international V-PDB standards, atmospheric air (AIR) and CDT respectively. The reproducibility for elemental composition of carbon, nitrogen and sulphur was 0.1%, 0.03% and 0.05%, respectively. The reproducibility for $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ measurements was ± 0.1‰, ± 0.2‰ and ± 0.4‰ respectively. In-house tests with modern camel and elk collagen standards, as well as Sigma-Aldrich Collagen, showed that elemental contents of carbon, nitrogen and sulphur were reproducible to 0.2%, 0.2% and 0.01%, respectively. All statistical analyses were performed with Past software, version 3.10 (Hammer et al. 2001). As a result, the isotopic diet determination was successfully performed for 52 samples, 33 from El Barranquete and 19 from Panoría (Table 3).

Radiocarbon measurements

O the 52 samples with $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ analyses, 48 have also been radiocarbon dated (Table 3). All samples were measured using accelerator mass spectrometry (AMS) in three different laboratories: Beta Analytic Ltd. (Beta) (USA), the National Accelerators Centre (CNA) (Spain) and the Swiss Federal Institute of Technology (ETH) (Switzerland).[2] Radiocarbon dates were calibrated using the internationally agreed atmospheric curve, *IntCal13* (Reimer et al. 2013), and the *OxCal v4.2* computer program (Bronk Ramsey 2001, 2009). The new radiocarbon series have already been discussed in depth elsewhere (Aranda Jiménez and Lozano Medina 2014; Aranda Jiménez et al. 2018a, b; Lozano Medina and Aranda Jiménez 2018).

[2] Radiocarbon measurements were performed at different labs in order to assess if the results were consistent between them and therefore their reliability.

Table 3 Multi-isotopic measurements and radiocarbon dating from El Barranquete and Panoría cemeteries

Sample	Type of material	δ^{13}Ccoll (‰)	δ^{15}Ncoll (‰)	δ^{34}Scoll (‰)	%C	%N	%S	C/N	Lab code	Radiocarbon age (BP)	Calibrated date (95% confidence) Cal BC
8.1	Mandible from an adult probably male	− 19.7	9.9	–	36.1	12.5	–	3.4	CNA-3231	4190 ± 40	2900–2630
8.2	Mandible from an adult probably male	− 18.9	10.9	13.2	25.7	8.9	0.11	3.4	CNA-3230	4159 ± 42	2890–2620
8.3	Mandible from an adult probably male	− 18.8	10.9	13.6	36.5	12.8	0.14	3.3	CNA-3234	4132 ± 35	2880–2580
8.4	Mandible from an adult	− 19.1	10.3	–	23.4	7.9	–	3.4	Beta-436481	4040 ± 30	2840–2470
8.5	Left humerus from an adult	− 18.9	11.6	–	39.6	14.0	–	3.4	Beta-440653	4030 ± 30	2630–2470
8.6	Left femur from an infantile	− 18.7	9.8	–	42.2	15.2	–	3.2	Beta-440654	3990 ± 30	2580–2460
8.7	Sacrum from an infantile	− 19.0	10.1	–	35.4	12.4	–	3.3	CNA-3233	3939 ± 36	2570–2300
8.8	Mandible from an adult probably male	− 19.5	9.0	–	32.6	11.3	–	3.4	ETH-66525	3888 ± 25	2470–2290
8.9	Mandible from an adult probably male	− 19.1	10.4	–	28.6	9.8	–	3.4	Beta-436480	3850 ± 30	2460–2200
8.10	Right tibia from an adult	− 19.0	8.7	–	36.7	12.9	–	3.3	CNA-3239	3724 ± 35	2280–2020
8.11	Right femur from an adult	− 19.1	9.5	–	41.99	15.0	–	3.3	Beta-440651	3140 ± 30	1500–1300
8.12	Right tibia from an adult	− 19.2	9.4	–	32.8	11.4	–	3.4	CNA-3237	3083 ± 32	1430–1260
8.13	Right tibia from an adult	− 18.9	10.6	10.0	28.3	9.9	0.16	3.3	–	–	–
9.1	Right femur from an adult	− 19.2	9.4	–	37.7	13.1	–	3.3	ETH-66528	3905 ± 25	2470–2300
9.2	Skull (right temporal) from an adult	− 19.3	10.0	–	32.7	11.5	–	3.3	CNA-3250	3768 ± 35	2300–2040
9.3	Iliac crest from a juvenile	− 20.0	9.6	–	41.8	14.3	–	3.4	Beta-440650	3720 ± 30	2210–2030
9.4	Skull fragment from an adult	− 18.7	10.8	–	41.8	14.8	–	3.3	CNA-3252	3670 ± 35	2190–1940
9.5	Right femur from an adult	− 18.7	10.7	–	35.9	12.6	–	3.3	ETH-66527	3618 ± 25	2040–1890
9.6	Skull fragment from an adult	− 19.2	10.4	–	31.5	11.2	–	3.2	ETH-66529	3615 ± 25	2040–1890
9.7	Right humerus from an adult	− 18.6	10.6	10.8	35.3	12.4	0.14	3.3	ETH-66526	3606 ± 25	2030–1890
9.8	Left pelvis from a juvenile	− 19.0	10.1	–	41.87	14.7	–	3.3	Beta-440649	3600 ± 30	2040–1880
9.9	Right femur from a juvenile	− 18.9	10.1	–	28.9	9.8	–	3.4	ETH-68006	3564 ± 22	2010–1780
9.10	Skull (right temporal) from an adult	− 18.9	11.2	11.5	30.9	10.8	0.21	3.3	Beta-436482	3550 ± 30	2010–1770
9.11	Mandible from a young adult	− 18.6	10.3	–	39.69	13.7	–	3.4	Beta-440652	3540 ± 30	1960–1760
9.12	Left pelvis from an adult	− 18.8	11.0	–	40.99	14.4	–	3.3	Beta-440648	3480 ± 30	1890–1690
9.13	Skull (occipital) from an infantile	− 18.9	11.1	9.0	33.5	12.1	0.16	3.2	CNA-3247	3426 ± 35	1880–1630
9.14	Skull (right temporal) from an adult	− 19.0	11.2	8.8	46.7	16.1	0.17	3.4	CNA-3248	3335 ± 36	1740–1520
9.15	Right scapula	− 19.3	10.9	–	27.1	9.1	–	3.5	–	–	–
10.1	Mandible from an adult probably male	− 18.5	11.0	12.4	29.1	10.0	0.13	3.4	Beta-436483	4330 ± 30	3020–2890
10.2	Left humerus from a infantile	− 18.5	10.3	–	37.7	13.3	–	3.4	CNA-3256	3037 ± 31	1410–1210
10.3	Right femur from a juvenile	− 18.6	10.6	12.1	35.3	12.0	0.17	3.4	Beta-436484	3020 ± 30	1400–1130
10.4	Left mandible from an adult	− 18.7	11.6	12.3	34.1	12.0	0.16	3.3	–	–	–
–	Skull from canine	− 17.1	9.2	–	30.7	10.9	–	3.3	–	–	–
6.1	Femur from an adult	− 19.5	9.7		32.9	11.3		3.4	ETH-69960	4353 ± 25	3030–2900

Table 3 (continued)

Sample	Type of material	δ^{13}Ccoll (‰)	δ^{15}Ncoll (‰)	δ^{34}Scoll (‰)	%C	%N	%S	C/N	Lab code	Radiocarbon age (BP)	Calibrated date (95% confidence) Cal BC
7.1	Right humerus from an adult	− 19.2	9.3		35.3	12.3		3.4	ETH-69961	4608 ± 25	3500–3340
7.2	Left radius from an adult	− 19.3	10.2		39.72	13.8		3.4	Beta-448208	4550 ± 30	3370–3100
7.3	Left radius from an adult	− 19.8	9.9		39.18	12.5		3.7	Beta-448209	3910 ± 30	2480–2290
8.1	Left femur from an adult	− 20.0	9.7		23.3	7.5		3.6	ETH-71513	3959 ± 26	2570–2340
8.2	Right femur from an adult	− 19.7	9.4		19.8	6.5		3.3	SUERC-72323	4365 ± 30	3090–2900
10.1	Left femur from an adult	− 19.3	8.5		40.5	14.4		3.3	ETH-69962	3945 ± 24	2565–2345
10.2	Left femur from an adult	− 19.4	8.2		40.7	14.5		3.3	ETH-69963	3993 ± 24	2575–2465
10.3	Left femur from an adult	− 19.5	8.8		37.6	13.3		3.3	ETH-69964	3899 ± 24	2470–2300
10.4	Left femur from an adult	− 19.8	9.2		36.8	12.7		3.4	ETH-69965	3718 ± 17	2200–2035
10.5	Left femur from an adult	− 19.7	8.0		31.6	11.1		3.3	ETH-69966	3942 ± 24	2565–2345
10.6	Left femur from an adult	− 19.6	9.0		36.3	12.9		3.3	ETH-71515	3886 ± 23	2465–2295
10.7	Left femur from an adult	− 19.4	8.3		40.7	14.3		3.3	ETH-69967	3941 ± 24	2565–2345
10.8	Left femur from an adult	− 19.3	9.0		40.2	14.3		3.3	ETH-69968	3980 ± 24	2570–2460
10.9	Left femur from an adult	− 19.7	9.0		38.1	13.6		3.3	ETH-69969	3959 ± 24	2570–2345
10.10	Left femur from an adult	− 19.4	8.4		40.0	14.2		3.3	ETH-69970	3954 ± 24	2570–2345
10.11	Fibula from a juvenile	− 19.4	9.3		40.94	14.3		3.3	Beta-448207	3700 ± 30	2200–1980
10.12	Left femur from an adult	− 20.1	8.0		33.8	11.9		3.3	SUERC-72324	3898 ± 30	2470–2290
18.1	Right humerus from an adult	− 19.6	9.1		33.8	11.5		3.4	ETH-71514	4123 ± 23	2865–2580

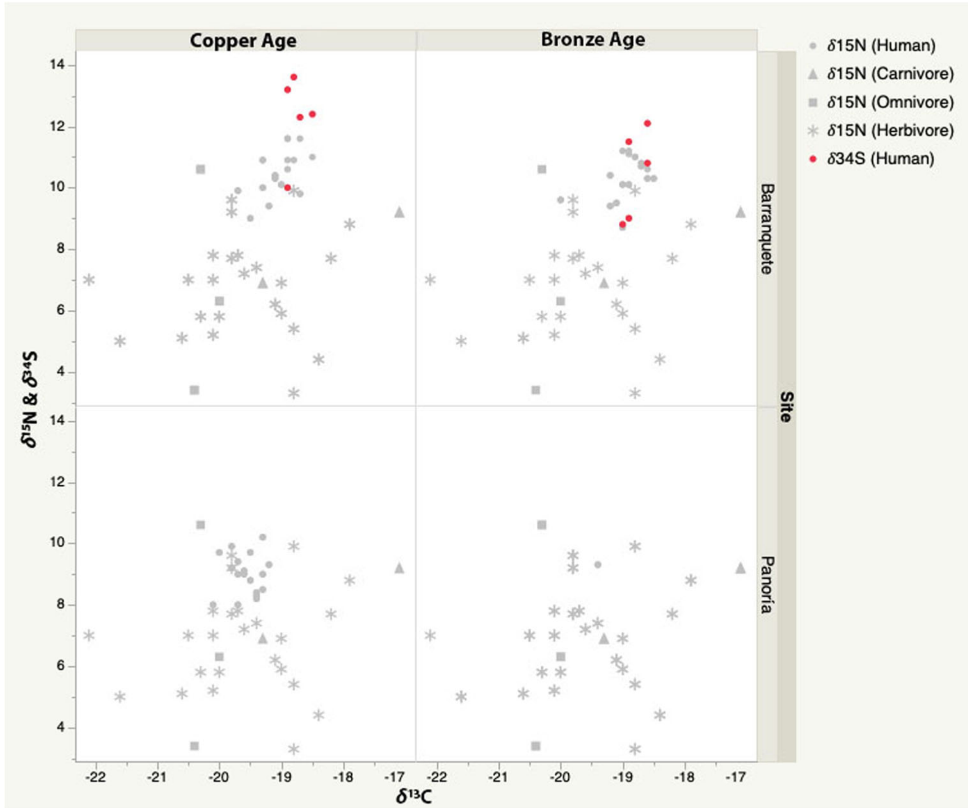


Fig. 4 δ^{13}C, δ^{15}N and δ^{34}S results by chronological periods from El Barranquete and Panoría

Results of δ^{13}C, δ^{15}N and δ^{34}S

The results of elemental analyses in whole bone showed differential preservation. We used these analyses to begin the screening of bones with poor collagen preservation. Thus, samples with elemental analysis results of $\%N < 0.40$ were discarded. The carbon and nitrogen elemental composition in whole bone of the samples of %N ranged from 0.40 to 3.02 and for %C from 3.16 to 10.37 for El Barranquete and for Panoría from 0.49 to 2.00 (%N) and from 4.23 to 8.52 (%C).

Collagen yields for the carbon, nitrogen and sulphur elemental composition ranged at El Barranquete from 23.4 to 46.7%, 7.9 to 16.1% and 0.13 to 0.21%, respectively, and at Panoría for carbon and nitrogen from 19.8 to 40.9% and 6.5 to 14.5%, respectively (Table 3). The atomic C/N ratio ranged from 3.2 to 3.5 with a mean of 3.3 for El Barranquete and from 3.3 to 3.6 with a mean of 3.3 for Panoría (Table 3). Therefore, all the samples, except for one from Panoría (sample 7.3), were within the acceptable C/N ratio recommended by van Klinken (1999) (see Aranda Jiménez et al. 2018b for further discussion). For the δ^{34}S values of samples, we took into account those results whose C/S and N/S atomic ratios ranged between 300–900 and 100–300 respectively (Nehlich and Richards 2009).

For El Barranquete, the δ^{13}C values for the human group ranged from − 20 to − 18.5‰ and the mean was − 18.9‰ ± 0.3 (1σ). The δ^{15}N values ranged from + 8.7 to + 11.6‰ and the mean was + 10.3‰ ± 0.7 (1σ). There were only two faunal remains, a dog (*Canis*) showing a δ^{13}C of − 17.1‰ and δ^{15}N of + 9.2‰ and a lagomorph showing a δ^{13}C of − 20.6‰ and δ^{15}N of + 5.1‰ (Fig. 4). Those individuals exhibiting > 10‰ of δ^{15}N, δ^{34}S were also measured to ascertain the differences between terrestrial and aquatic-based diets. The range of δ^{34}S values ($n = 10$) was from + 8.8 to + 13.6‰ and the mean was + 11.3‰ ± 1.6 (1σ) (Fig. 4). For Panoría, the δ^{13}C values for the human group ranged from − 20 to − 19.2‰ and the mean was − 19.6‰ ± 0.2 (1σ). The δ^{15}N ratios ranged from + 8 to + 10.1‰ and the mean was + 8.9‰ ± 0.6 (1σ).

Considering the contemporaneous comparative fauna (Table 2) from Marroquíes ($n = 18$), Las Churuletas ($n = 1$) and El Garcel ($n = 4$), the results show a mean for δ^{13}C of − 19.9‰ ± 1.1 (1σ), − 20‰ and − 19.5‰ ± 0.4 (1σ), respectively. While for δ^{15}N, the results for Marroquíes show + 6.9‰ ± 1.5 (1σ), for Las Churuletas + 5.8‰ and for El Garcel + 8‰ ± 1.8 (1σ).

From a chronological point of view, isotopic measurements can be separated into two main groups: one of 31 individuals belonging to the Late Neolithic and Chalcolithic,[3] and another consisting of 17 Bronze Age people. As a result, we can

[3] We created only one Late Neolithic and Copper Age group as of the 31 dated individuals, only two fell within the Late Neolithic (ETH-69961, 4608 ± 25, 3500–3340 cal BC at 95% probability and Beta-448208, 4550 ± 30, 3370–3100 cal BC at 95% probability). Both cases belong to the Tomb 7 at the cemetery of Panoría (Table 3).

observe that at El Barranquete, the samples from the Chalcolithic period showed a δ^{13}C of − 19.7‰ ± 0.3 (1σ) and δ^{15}N of + 10.3‰ ± 0.7 (1σ), while for the Bronze Age, the δ^{13}C is − 18.9‰ ± 0.35 (1σ) and δ^{15}N of + 10.3‰ ± 0.7 (1σ). For the cemetery of Panoría, most of the samples were dated to the Chalcolithic and the mean δ^{13}C is − 19.5‰ ± 0.2 (1σ) and δ^{15}N of + 8.9‰ ± 0.65 (1σ) and the only sample dated to the Bronze Age showed a δ^{13}C of − 19.4‰ and δ^{15}N of + 9.3‰.

Discussion

In general, considering all measurements as a whole—human and animal data including the contemporaneous sites—, the isotopic values are consistent with a terrestrial C_3 ecosystem (van der Merwe 1982; Schwarcz and Schoeninger 1991). Regarding the δ^{13}C or δ^{15}N results from El Barranquete, despite the proximity of the cemetery to the sea (*c.* 7 km), there is no evidence that marine proteins were dietary staples. Nevertheless, additional δ^{34}S isotopic were carried out to test the possible hidden marine input that could explain the slight correlation between high δ^{13}C and δ^{15}N values. The δ^{34}S values show a range wider than 5‰. However, there is no correlation between δ^{34}S values and both δ^{13}C or δ^{15}N ratios, and the δ^{34}S values are lower than the possible marine influence (around 20‰ according to Nehlich 2015). A possible enrichment of δ^{34}S values due to the sea-spray effect has also been discarded (Leach et al. 1996; Richards et al. 2001).

Unfortunately, there is no δ^{34}S comparative data for Spanish Late Prehistory, except for the Balearic Islands in the case of the megalithic structure of Ca Na Costa (Nehlich et al. 2012). In this instance, the δ^{34}S ($n = 8$) showed a mean of 16.5‰ ± 1.4 (1σ). The authors' conclusion, based on human and animal data, was that there was no indication of marine protein consumption, even considering the ^{13}C-depleted and ^{15}N-enriched values. According to the δ^{13}C, δ^{15}N and δ^{34}S ratios, the consumption of marine resources by the El Barranquete population could be definitively ruled out. This case is even more evident in Panoría with δ^{13}C (average − 19.6‰ ± 0.2) and δ^{15}N (average + 8.9‰ ± 0.6) values, closer to those of a diet exclusively reliant on terrestrial sources. In Panoría, only one sample (7.2) showed a δ^{15}N value > 10‰.

Intra- and inter-cemetery comparison

An intra-site comparison is especially suitable in the case of El Barranquete, because of its substantial period of use (1780–2405 years at 68% probability). Funerary activity began at the end of the fourth millennium (3260–2925 cal BC at 68% probability) and ended in the last centuries of the second millennium (1245–875 cal BC at 68% probability), thus spanning the Chalcolithic and Bronze Age (Aranda Jiménez et al. 2018a). The comparison between the isotopic ratios of people belonging to each cultural period shows the same δ^{15}N values, which probably means that meat consumption did not change significantly over time. The main differences appeared in the δ^{13}C ratios, with an enrichment of ~ 1‰ during the Bronze Age (Welch's *t*-test* $t = 0.97815$, $df = 29.94$, p value = 0.3358). This change is consistent with the innovations in subsistence practices, which implied an intensification of crop farming. Archaeological evidence, including archaeobotanical studies, correlations between the size and location of settlements and the analysis of the stone tools used in crop production during the Early Bronze Age of south-eastern Iberia (best known as the Argaric Culture), indicate that farming, mainly of cereals, became a key subsistence activity (Aranda Jiménez et al. 2015). The isotopic ratios of the population buried at El Barranquete during the Bronze Age seem to support these changes in food production and consumption.

The inter-cemetery comparison can be established only for the Chalcolithic, as in the Panoría cemetery, only one individual showed a radiocarbon date that fell, at least partially, within the Bronze Age (sample 10.11). As a general rule, the range of carbon and nitrogen isotopic values at El Barranquete is broader than that of Panoría, which shows less variability (Fig. 4). Nevertheless, it is in the δ^{15}N where significant differences appear, as nitrogen ratios are ~ 2‰ higher in Barranquete (average 10.3‰ ± 0.7) than in Panoría (average + 8.9‰ ± 0.65) (Welch's *t*-test* $t = 7.0905$, $df = 41.307$, p value = 1.18e − 08). According to the results previously discussed, the isotopic ratios show no signs of aquatic protein consumption. Therefore, this variation may reflect differences in the ecological settings, as well as possible environmental changes, such as the increase in aridity from the Late Neolithic onwards (Lillios et al. 2016; Ramos-Roman et al. 2018).

The final comparison explored the isotopic differences and similarities between tombs. Only three tombs, Barranquete 8 and 9 and Panoría 10, were considered, as they show the largest series of measurements (Table 4). The results confirm

Table 4 δ^{13}C and δ^{15}N values by tombs and periods at El Barranquete and Panoría

Site	Tomb	*N*	Period	δ^{13}C	1σ	δ^{15}N	1σ
El Barranquete	8	8	Chalcolithic	− 19.1	0.3	10.2	0.6
El Barranquete	8	3	Bronze Age	− 19.1	0.1	9.2	0.4
El Barranquete	9	3	Chalcolithic	− 19.2	0.05	10.1	0.7
El Barranquete	9	12	Bronze Age	− 18.9	0.3	10.5	0.5
Panoría	10	11	Chalcolithic	− 19.5	0.2	8.5	0.4
Panoría	10	1	Bronze Age	− 19.4	–	9.3	–

Table 5 Results of $\delta^{13}C$ and $\delta^{15}N$ from different cemeteries located in southern Iberia

Archaeological context	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Los Millares					
Tomb 55	–	Adult	− 19.6	9.5	Waterman et al. 2017
Tomb 55	–	Adult	− 18.9	10.5	Waterman et al. 2017
Tomb 55	–	Adolescent	− 20.2	8.9	Waterman et al. 2017
Tomb 55	–	Infantile	− 20.0	8.8	Waterman et al. 2017
Tomb 57	–	Adult	− 19.8	9.7	Waterman et al. 2017
Tomb 57	–	Adult	− 19.2	10.4	Waterman et al. 2017
Tomb 57	–	Infantile	− 19.6	9.5	Waterman et al. 2017
Tomb 74	–	Young Adult	− 19.6	10.1	Waterman et al. 2017
Tomb 74	–	Adult	− 19.5	10.4	Waterman et al. 2017
Tomb 63	–	Adult	− 18.9	9.7	Waterman et al. 2017
Cerro de la Virgen					
Tomb 1	–	Infantile II	− 19.5	11.7	Molina González et al. 2016
Tomb 4	–	Infantile II	− 19.3	11.2	Molina González et al. 2016
Tomb 4	–	fetus	− 18.4	12.8	Molina González et al. 2016
Tomb 5	Female	Adult	− 18.7	10.6	Molina González et al. 2016
Tomb 6	Male	Adult	− 18.1	11.4	Molina González et al. 2016
Tomb 6	Female	Senile	− 19.2	10.4	Molina González et al. 2016
Tomb 8	–	Adult	− 19.3	8.	Molina González et al. 2016
Tomb 11	Male	Adult	− 19.4	11.7	Molina González et al. 2016
Tomb 12	–	Juvenile	− 18.4	11.9	Molina González et al. 2016
Tomb 14	Female	Senile	− 19.2	10.1	Molina González et al. 2016
Tomb 16	–	Infantile I	− 19.6	11.7	Molina González et al. 2016
Tomb 19	Female	Senile	− 19.3	12.2	Molina González et al. 2016
Tomb 20	Male	Adult	− 19.1	12.2	Molina González et al. 2016
Tomb 21	Male	Senile	− 18.5	13.3	Molina González et al. 2016
Tomb 21	Female	Senile	− 19.1	11.4	Molina González et al. 2016
Tomb 22	–	Juvenile	− 18.8	10.7	Molina González et al. 2016
Tomb 22	–	Juvenile	− 18.8	10.5	Molina González et al. 2016
Tomb 24	–	Infantile I	− 18.8	11.4	Molina González et al. 2016
Tomb 26	Male	Adult	− 19.2	11.5	Molina González et al. 2016
Tomb 27	–	Infantile I	− 18.8	10.2	Molina González et al. 2016
Tomb 29	–	Infantile I	− 18.7	10.9	Molina González et al. 2016
Tomb 29	Female	Juvenile	− 19.1	12.0	Molina González et al. 2016
Tomb 30A	Male	Adult	− 18.9	10.1	Molina González et al. 2016
Tomb 30B	Female	Adult	− 19.0	9.6	Molina González et al. 2016
Tomb 30C	–	Infantile I	− 19.2	7.3	Molina González et al. 2016
Tomb 31	–	Infantile I	− 18.3	9.1	Molina González et al. 2016
Tomb 32	–	Infantile II	− 18.7	8.3	Molina González et al. 2016
Tomb 34	Male	Adult	− 18.7	11.4	Molina González et al. 2016
La Carada					
Tomb 1	Male	Adult	− 18.9	10.7	Molina González et al. 2016
Tomb 1	Male	Adult	− 18.8	11.1	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.3	10.7	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.1	10.2	Molina González et al. 2016

Table 5 (continued)

Archaeological context	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Tomb 1	Male	Adult	− 19.3	9.7	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.6	9.9	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.6	8.3	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.3	10.5	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.2	10.4	Molina González et al. 2016
Tomb 1	Male	Adult	− 20.5	4.7	Molina González et al. 2016
Tomb 1	Male	Adult	− 19.6	9.7	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.5	9.8	Molina González et al. 2016
Tomb 1	Female	Adult	− 21.3	8.0	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.2	10.4	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.5	10.1	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.6	9.6	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.6	9.8	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.3	9.4	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.6	11.2	Molina González et al. 2016
Tomb 1	Female	Adult	− 19.1	9.2	Molina González et al. 2016
Valencina-Castilleja					
La Alcazaba	Female	Middle age adult	− 19.0	9.0	Díaz-Zorita Bonilla 2017
La Alcazaba	Undetermined	Adult	− 18.8	8.7	Díaz-Zorita Bonilla 2017
La Cima	Female	Young adult	− 19.8	6.5	Díaz-Zorita Bonilla 2017
El Algarrobillo	Female	Middle age adult	− 18.8	8.7	Díaz-Zorita Bonilla 2017
Cerro de la Cabeza	Female	Young adult	− 18.9	7.5	Díaz-Zorita Bonilla 2017
PP4-Montelirio	Male	Young adult	− 19.1	9.9	Díaz-Zorita Bonilla 2017
Montelirio UE 101	Female	20–30 years old	− 18.3	8.7	Fontanals-Coll et al. 2015a
Montelirio UE 102	Female	25–30 years old	− 19.1	9.0	Fontanals-Coll et al. 2015a
Montelirio UE 103	Female	25–34	− 19.1	8.9	Fontanals-Coll et al. 2015a
Montelirio UE 114	Female	20–30 years old	− 19.9	9.1	Fontanals-Coll et al. 2015a
Montelirio UE 112	Female	18–30 years old	− 19.4	10.0	Fontanals-Coll et al. 2015a
Montelirio UE 370	Undetermined	30–35 years old	− 20.3	8.9	Fontanals-Coll et al. 2015a
Montelirio UE 107	Female	Adult	− 19.5	9.5	Fontanals-Coll et al. 2015a
Montelirio UE 346	Female?	30–39 years old	− 20	8.9	Fontanals-Coll et al. 2015a
Montelirio UE 343	Female	20–30 years old	− 19.3	8.9	Fontanals-Coll et al. 2015a
Montelirio UE 360	Female	18–30 years old	− 19.3	9.0	Fontanals-Coll et al. 2015a
Montelirio UE 111		20–30 years old	− 20.4	9.2	Fontanals-Coll et al. 2015a

that the general trends previously highlighted were also to be found on this analytical scale. The $\delta^{13}C$ values increased slightly during the Bronze Age at El Barranquete, mainly in Tomb 9, where almost all the buried individuals belonged to this period. The nitrogen ratios also showed low values at Panoría, in contrast to El Barranquete, with most of the measurements > 10. It seems, therefore, that intra- and inter-cemetery isotopic differences are linked to cultural and chronological variations, rather than to social asymmetries in food consumption.

The Panoría and El Barranquete cemeteries in the context of southern Chalcolithic and Bronze Age populations

The new isotopic series has also been analysed from a more general comparative perspective, which would allow us to explore how they fit into the subsistence patterns of southern Iberian societies. For this purpose, all mortuary contexts with available isotopic measurements were compiled (Table 5). The dataset analysed came from Late Neolithic and

Table 6 Averaged values of $\delta^{13}C$ and $\delta^{15}N$ by sites and periods in southern Iberia

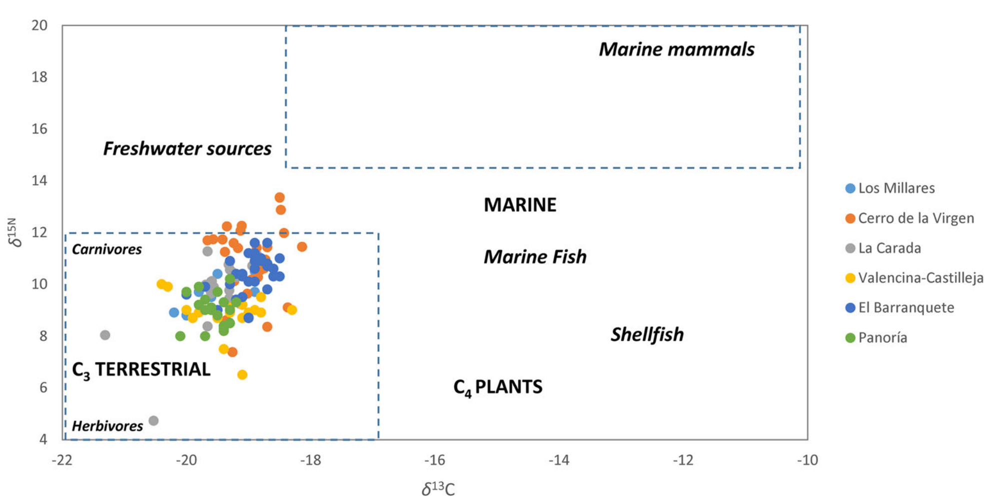
Site	N	$\delta^{13}C$	1σ	$\delta^{15}N$	1σ	Reference
Copper Age						
Barranquete	14	− 19.7	0.3	10.3	0.7	In this paper
Panoría	19	− 19.6	0.2	8.9	0.6	In this paper
Los Millares	10	− 19.5	0.4	9.8	0.6	Waterman et al. 2017
Valencina-Castilleja	17	− 19.4	0.6	8.8	0.8	Fontanals-Coll et al. 2015a; Díaz-Zorita Bonilla 2017
La Carada	20	− 19.5	0.5	9.7	1.4	Molina González et al. 2016
Bronze Age						
Barranquete	17	− 18.9	0.3	10.3	0.7	In this paper
Cerro de la Virgen	28	− 19.0	0.4	10.9	1.4	Molina González et al. 2016

Chalcolithic tombs known as La Carada (Molina González et al. 2016), two Chalcolithic sites, Los Millares (Waterman et al. 2017) and Valencina-Castilleja (Fontanals-Coll et al. 2015a; Díaz-Zorita Bonilla 2017), and one cemetery belonging to the Argaric culture, Cerro de la Virgen (Molina González et al. 2016). With the exception of the last site, which consists of individual tombs located inside settlements, all the others, including Panoría and Barranquete, can be classed as collective tombs.

As is the case in El Barranquete and Panoría, isotopic determinations ($\delta^{13}C$ and $\delta^{15}N$) for these four sites suggested a diet based on C_3 plants and terrestrial animals (Table 6). The input of aquatic resources was not detected, despite the proximity of Los Millares and El Barranquete to the Mediterranean Sea and that of Valencina-Castilleja to an ancient marsh. Carbon isotopic values ($\delta^{13}C \sim 19‰$) show very similar ratios for the Chalcolithic population. Again, the main differences occur with those of the Bronze Age. The addition of the Early Bronze Age cemetery of Cerro de la Virgen confirms the trend of an increase in $\delta^{13}C$ values at this time (Fig. 5). Nitrogen isotopes, however, show a very different picture. In the Chalcolithic sites, there are two main groups, one with lower values ~ 9‰, Panoría and Valencina, and another group with higher ratios ~ 10‰, made up of Los Millares, El Barranquete and La Carada. With the current state of affairs, it is difficult to explain those differences. The large variability in the ecological settings and environmental changes may be one explanation; however, social differences in meat consumption cannot be ruled out.

$\delta^{15}N$ isotopic differences can also be found between the Chalcolithic and the Bronze Age funerary contexts. The population buried during the Bronze Age at El Barranquete shows a similar ratio to the highest values found among the previous Chalcolithic sites. However, it is in Cerro de la Virgen that the highest $\delta^{15}N$ values (averages 10.9‰) were reached, together with the highest standard deviation (1.4) (Fig. 6). It seems that in this case, the variability in meat protein intake could explain those values. This scenario is consistent with the differences found in meat consumption across Argaric funerary rituals. According to the available evidence, the consumption of cattle, sheep or goat meat in Argaric funerary feastings followed an accurate social pattern. Bovine meat was consumed only as part of the ritual feasting of the ruling elites. In contrast, sheep/goats would have been a component of the lower social strata

Fig. 5 $\delta^{13}C$ and $\delta^{15}N$ human values by sites in southern Iberia



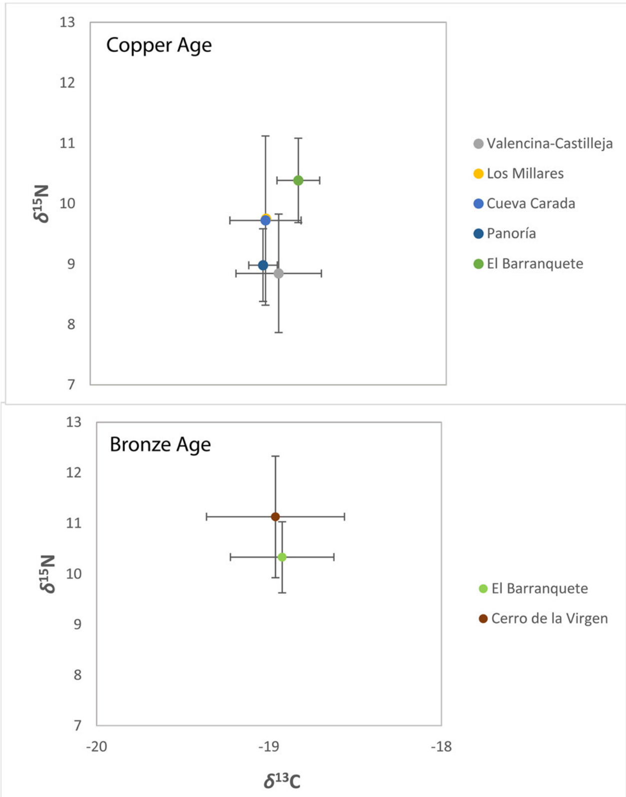


Fig. 6 δ^{13}C and δ^{15}N results from different cemeteries located in southern Iberia

mortuary rituals and of the tombs of children aged under 12 (Aranda Jiménez and Esquivel Guerrero 2007; Sánchez Romero et al. 2007; Aranda Jiménez and Montón-Subias 2011; Aranda Jiménez 2016).

Conclusions

The multi-proxy approach applied to the study of megalithic societies has proved to be a very useful framework for exploring the dietary patterns of megalithic societies. The combination of radiocarbon dating and stable isotope analysis enables fine-grained assessments of archaeological contexts characterised by long periods of use and multiple depositional events. Although the isotopic series obtained for the El Barranquete and Panoría cemeteries can be considered an improvement, we are still far from fully understanding the dietary patterns of these populations. Therefore, the following conclusions must be considered as preliminary.

The isotopic values for all the populations previously analysed suggest a diet based on C_3 plants and terrestrial animals, with no evidence of any relevant consumption of marine resources. To further explore these results, additional sulphur stable isotopes were carried out to test for possible hidden marine input. The δ^{34}S isotopic ratios also confirmed the absence of marine or freshwater resource consumption. The population buried at El Barranquete and Panoría seem to have followed, as did their southern Iberian counterparts, a subsistence strategy relying principally on terrestrial sources. Nevertheless, this does not mean that these populations lived with their backs to the sea. On the contrary, the appearance of seashells mixed with human remains inside the megalithic tombs suggests that the sea was important in the worldview of these societies. In fact, different types of seashell are frequently found not only in cemeteries near the coast, but also in those, such as Panoría, which were located far inland (Benavides López et al. 2016; Díaz-Zorita Bonilla et al. 2017).

The inter- and intra-comparison between both El Barranquete and Panoría, and between them and the aforementioned cemeteries, allows us to reach several conclusions. Firstly, during the Chalcolithic period, stable isotope analysis shows homogeneous values, which suggest a rather uniform pattern of consumption. The slight isotopic differences may be associated with variations in soil productivity, environmental setting and climate from region to region. Secondly, the most important differences in isotopic ratios appear when comparing Chalcolithic and Bronze Age populations. There is a general trend for $\delta^{13}C$ values to increase during the Bronze Age, which is consistent with the intensification of crop farming by the Argaric societies.

However, the main change can be found in nitrogen isotopes. Their variability, which reached ~2‰, is especially noticeable when comparing collective and individual tombs. The appearance during the Early Bronze Age of a new funerary ritual based on individual inhumations inside settlements features in association with the highest δ^{15}N and the greatest internal variability. Social asymmetries traditionally linked to these funerary innovations are supported by these values that suggest variations in meat consumption. As has been previously noted, the Argaric funerary feasts provide further confirmation of the differences in meat consumption. It is also remarkable that contemporary Bronze Age inhumations in collective tombs, such as those found in Barranquete, do not show these isotopic differences. On the contrary, they show the same δ^{15}N values as the previous Chalcolithic interments. The differences in isotopic variability between collective and individual tombs were found not only throughout time, but also between contemporary people who incorporated a new way of life known as the Argaric culture, and those that, through the continuity and reuse of old megalithic monuments, exhibited their resistance to these cultural changes.

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