Spatial and temporal variation of dietary habits during the prehistory of the Balearic Islands as reflected by ^{14}C, $\delta^{15}N$ and $\delta^{13}C$ analyses on human and animal bones

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SPATIAL AND TEMPORAL VARIATION OF DIETARY HABITS DURING THE PREHISTORY OF THE BALEARIC ISLANDS AS REFLECTED BY ^{14}C, δ^{15}N AND δ^{13}C ANALYSES ON HUMAN AND ANIMAL BONES

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RESUMEN: Las islas Baleares forman un archipiélago en el Mediterráneo occidental. Las islas han estado colonizadas por humanos desde el Neolítico. El objetivo de este estudio era recabar datos sobre la importancia de la cría de animales, la agricultura y la pesca en la economía alimentaria de las sociedades baleares prehistóricas. Los datos ^{14}C, δ^{15}N y δ^{13}C del colágeno y del carbonato de animales domésticos y de humanos abarcan diferentes períodos culturales y situaciones geográficas de los asentamientos, a saber, zonas montañosas, tierras bajas y litoral. En general, los datos isotópicos no corroboran las teorías tradicionales sobre la evolución de las estrategias de subsistencia durante la prehistoria balear. Dichos datos parecen indicar de nuevo que todos los períodos se caracterizan por una dieta mixta de productos animales y vegetales, y todo da a entender que las comunidades prehistóricas baleares no aprovechaban de un modo sistemático los alimentos marinos o de agua dulce. En más de un período se podrían haber dado pequeñas diferencias regionales en la dieta.

PALABRAS CLAVE: Balear, colágeno, isótopo, animales, humanos, estrategias de subsistencia.

ABSTRACT: The Balearic Islands are an archipelago in the western Mediterranean Sea. The islands have been occupied by humans since the Neolithic. The aim of this study was to garner information on the importance of animal husbandry, agriculture and fishing within the food economy of Balearic prehistoric societies. ^{14}C, δ^{15}N and δ^{13}C data from collagen and carbonate of domestic animals and humans cover different cultural periods and a range of settlement locations, i.e., mountain, lowland and coastal sites. In general, traditional theories about the evolution of the subsistence strategies during the Balearic prehistory are not corroborated by the isotope data. It is again suggested that a mixed diet of animal and plant resources was characteristic for all periods, while it also

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becomes apparent that prehistoric Balearic communities did not systematically use marine or freshwater food items. Small regional differences in diet may have occurred in more than one period.

KEYWORDS: Balearic, collagen, isotope, animals, humans, subsistence strategies.

INTRODUCTION

The Balearic Islands form an archipelago in the western Mediterranean Sea, 80 to 300 km east of the Spanish south-eastern coast (figure 1.1). The islands have been colonised by humans, at least since the Neolithic (for detailed information on the different archaeological chronologies proposed for the Balearic Islands, see Waldren 1986, Plantalamor Massanet & Benejam 1997, Guerrero Ayuso 2001, Lull et al. 2002, Ramis et al. 2002). Since the 1960s, and still repeated in recent publications, the hypothesis has been launched that the subsistence strategy of the late Bronze Age - early Iron Age culture focused on animal husbandry, while plant cultivation remained of minor significance (see Hernandez-Gasch et al. 2002, and the references there). During the following period cereal agriculture would have gained importance (Mayoral Franco 1984). On the other hand, the Neolithic to early Bronze Age period would have been characterised by a mixed farming economy (Lewthwaite 1985). These reconstructions, however, are based upon a set of evidence that is not proof to criticism. Especially the almost ‘exclusive’ animal husbandry system of the late Bronze Age - early Iron Age period has been questioned because it is clear that the cultural archaeological data could be biased due to preservation conditions, other taphonomic factors, excavation techniques, the choice of sites (being almost always ritual places), etc. (Hernandez-Gasch et al. 2002). Moreover, the environmental archaeological record for the Balearics is still very limited (see, e.g., the overview for animal remains in Chapman & Grant 1997).

The analysis of plant and animal remains from archaeological sites can reveal which species were used for consumption and how the exploitation strategies were organised. Generally, however, it is very difficult, if not impossible, to evaluate the relative importance of animal versus plant products. Not only in sites with a hypothetical 100% survival of organic remains this would still be a methodological puzzle, in areas with less favourable preservation conditions, this is completely hopeless. The scarcity of plant remains from prehistoric Balearic sites can, for example, not be used in any interpretation about food patterns, since the phenomenon could be the result of taphonomic factors, of problems with sampling and recovery (given the state of excavation methodology in the area) or of the (ritual) nature of the sites. The preliminary archaeozoological data indicate that, at least at Son Ferrandell, the rearing of animals for meat alone was not the major aim of the site’s inhabitants, suggesting that vegetable food may have made the main contribution to the diet (Chapman & Grant 1997, 76). The same conclusion was reached by the analysis of trace elements from 24 bone samples from Càrritx (Pérez Pérez et al. 1999). To gain importance, however, these interpretations should be corroborated by an independent line of evidence. Moreover, there are other important questions, such as whether the absence of fish remains from the sites is the result of preservation conditions, of the lack of sieving during excavation, or of the subsistence strategy of the prehistoric people?

An alternative approach for dietary reconstructions consists in the analysis of the isotopic fractionation of collagen and carbonate from the bones found in human burials from the period under study. It is well known that the $\delta^{13}C$ and $\delta^{15}N$ values in the body reflect the diet of an organism, a phenomenon that is now with increasing frequency used for dietary reconstructions within archaeology (Sealy 2001). Very generally, the collagen of a bone is considered to reflect the isotope ratios of the protein fraction within the food, while the carbonate in the mineral fraction of the bone is considered to reflect the isotope ratios of the whole diet (van Klinken et al. 2000).

This study presents data recorded from human bones from prehistoric sites from Mallorca, Menorca and Formentera. The aim is to see whether information about the subsistence strategy of these people could be extracted from the isotopic signatures, and whether diachronic trends were observable from the material. Isotope measurements on animal bones, often from the same sites from which human bone was studied, were taken as reference for the human data. The present report builds further upon a previous one (Van Strydonck et al. 2002a) but includes an important number of new data, and an new analysis method (isotope measurements from bone carbonate). Isotope data from archaeological material from the Balearic Islands have also been gathered by others (e.g., Davis 2002) but, for methodological reasons, only the dataset compiled by our own research will be used here. A large number of the radiocarbon dates presented here have already been listed by Van Strydonck et al. (1998, 2001, 2002b, 2004).

MATERIAL AND METHODS

The $\delta^{13}C$ and $\delta^{15}N$ data in this paper are a by-product of the radiocarbon analyses on animal and human bone from different sites at the Balearic Islands, performed, since 1986, at the Royal Institute of Cultural Heritage (Brussels, Belgium). This has both advantages and disadvantages: sample selection is relatively unbiased because all sites are potentially studied, but, on the other hand, not all samples dated in the past 18 years could be incorporated in the present study. For instance, in the beginning, stable isotope measurements were not taken, while the evaluation of the $\Delta\delta^{13}C_{coll\text{-}carb}$ is certainly an analysis that was only performed during the later part of our investigation.

^{14}C activity was measured using routine LSC (Forest and Van Strydonck 1995) or AMS (Van Strydonck and van der Borg 1991) procedures. The results are expressed as ages BP (Stuiver and Pollach, 1977). The pre-treatment of the bones followed Longin (1971). The protein content was checked by means of the C/N ratio by a Carlo Erba NA1500 analyser. All bone samples used in this study have a $C/N \leq 3$, except IRPA-1179, IRPA-1066, UtC-9018, KIA-15220, KIA-20208, KIA-20461 with C/N values between 3.1 and 5.3. None of these samples, however, produced aberrant isotope data. Stable isotope measurements were performed on a Finnigin Mat Delta E mass spectrometer with a reproducibility of 0.1‰ for $\delta^{13}C$ and 0.3‰ for $\delta^{15}N$.

For certain animal bones, a species identification was not available, because the specimens had been subjected to radiocarbon dating before they were studied by an archaeozoologist. When identification was made, we were always dealing with domestic mammals, i.e. sheep, goat, cattle or pig. As traditional in archaeozoology, the remains of sheep and goat could not always be separated. Based on the local cultural entities (see the references above), the human samples can be subdivided in four chronological groups. These time periods coincide roughly with the Neolitic – Early Bronze Age period (phase 1: before 1600 BC), the Bronze Age (phase 2: 1600 – 1050 BC), the Iron Age (phase 3: 1050-500 BC), and a protohistoric to Early Roman period (phase 4: after 500 BC).

RESULTS

Table 1 and figure 1.2 give all data recorded from the sample set. The results will be discussed separately for the animal and the human sub-samples.

Animal bones

Figure 1.2 shows the clear difference between the scatter of animal samples and that of the human material. All together, the data for the animals show a large variation, a trend that must, at least partly, be explained by inter-species differences. Where species identifications of the animal samples were available, it became clear that most of the material sampled comes from true herbivores, i.e., cattle, sheep or goat, except for the single skeletal element of pig, and one of a dog (see further). Most of the unidentified animal samples will thus most probably also come from herbivores. Moreover, as far as we know, pigs were relatively rare in Balearic prehistory (Chapman & Grant 1997, 82, Figure 7.6). In general, the variation of the isotope fractionation within the group of herbivores will have been influenced by differences in the plants they consumed. Not only different plant species can have different isotope characteristics (see the references in van Klinken et al. 2000, 43), but also the spot where they grow can be highly influential. Altitude, salinity, local humidity and amount of sunlight (canopy effect) can have an influence on the $\delta^{13}C$ of plants (see the references in Bocherens 2000, 73) and therefore also on the $\delta^{13}C$ of the collagen of the herbivores. There are also differences in isotopic fractionation between different parts of the same plants (e.g., roots, leaves). The $\delta^{13}C$ of the bone collagen of an animal will thus also be significantly determined by its foraging habits (Heaton 1999). Finally, it should be stressed that isotopic fractionation is largely different between two groups of plant species, having a different physiology, i.e., C3 and C4 plants. The latter group, however, was not present on the Balearic Islands in prehistory. In general, the different selection of plants, consumed by sheep, goat and cattle, will have caused the wide scatter of data points within the (mostly herbivorous) animal group. Furthermore, this pattern could explain the larger scatter of the goat-sheep datapoints compared to the cattle datapoints (two species versus one).

That the sample of pig, an animal often described as omnivorous, falls within the variation of the true herbivores, is not really surprising since primitive herds of pigs, that are kept in natural environments, eat mostly plant material (in contrast to pigs that live in human habitations and are fed on consumption refuse) (Ervynck et al. 2003). Finally, a dog bone from Sa Cala (KIA-2015) showed stable isotope values that are comparable to those of the human bones, a pattern that can be explained by the omnivorous diet of a dog, comparable to that of many human populations, but different of that of real herbivores such as sheep, goat or cattle.

Three distinct outliers are present within the animal dataset, one with an extremely negative ^{13}C ratio, coming from the site of Ses Païsses (KIA-11890), whilst another, with an extremely high ^{13}C ratio, comes from Son Gallard (KIA-23435). A third animal outlier falls into the variation of the human samples: a goat jaw from Son Fornés (UtC-9327), of which the aberrant value is probably caused because a mixture of bone and tooth collagen was measured (see Bocherens 2000), The averages for the domestic mammals not taking into account the three aberrant samples and the data for the dog ($\delta^{13}C = -20.41 \pm 0.75‰$ and

$\delta^{15}N$ = 5.44±1.77‰) coincide well with those listed in the literature for herbivorous mammals ($\delta^{13}C$= -21‰, $\delta^{15}N$= +5‰: Lanting and van der Plicht 1996).

Finally, it has been investigated whether there is a diachronic trend in the measurements for the animal bone samples. However, no trend could be observed: regression analyses between the uncalibrated radiocarbon dates and $\delta^{13}C$ or $\delta^{15}N$ values proved that there were no relations between these variables (regression data not depicted here).

Human bones

When the total set of measurements for the human bones is compared with the animal samples, a general interpretation can be made about the former human diet. It is known that a predator has a less negative value of $\delta^{13}C$ and a more positive value of $\delta^{15}N$ compared to its prey. Theoretical studies suggest that the differences, describing the shift or a trophic level within the food chain, ideally should be +5‰ for $\delta^{13}C$ (Ambrose 1993, but see further) and +2 to +4‰ for $\delta^{15}N$ (Ambrose 1991), meaning that, when the human diet would have consisted solely of the meat of herbivores, these differences should describe the variation between the mean values for the isotope fractionations of humans and herbivores. Indeed, Lanting and van der Plicht (1996) give $\delta^{13}C$= -18‰ and $\delta^{15}N$= +8‰ for carnivores. When freshwater animals would have been added to the diet, more negative $\delta^{13}C$ measurements would be obtained and more positive $\delta^{15}N$ values. When marine food products would have been consumed, a less negative $\delta^{13}C$ and a more positive $\delta^{15}N$ would be recorded. When a human population would have survived solely on plant products, their isotope fractionation values must have been identical to those of herbivore mammals. In general, the isotope ratios of the human samples do not differ enough from that of the domestic animals to suggest a predominantly carnivorous diet (they certainly also do not attain the values listed by Lanting and van der Plicht 1996). A mixed diet of plant and animal material is thus much more likely. Generally, it must also be stressed that both N and C isotope fractionation values clearly indicate that the diet in Balearic prehistory was not predominantly based upon marine resources (implying that people living on an island were hardly fishing) and that people were also not concentrating upon the exploitation of freshwater animals (which can be explained by the islands' biogeography). Would one of these strategies have been incorporated within the subsistence system, clearly different $\delta^{13}C$ and $\delta^{15}N$ values would have been obtained.

Since the isotope data for the human material show a large variation, both for the $\delta^{13}C$ and the $\delta^{15}N$ ratios, it must now be established whether there are no significant differences between groups within the human sample population. Most likely, diachronic trends could be expected and therefore the data were split up taking into account the different phases defined earlier (figs 3 to 6). Figure 4.7 summarises the average isotope values for the animal and the four human datasets. The differences in $\delta^{13}C$ values show no unidirectional diachronic trend and vary between 0.9 and 1.2‰. The differences between the average $\delta^{15}N$ values of the animals and the human subgroups vary between 3.6 and 4.6‰. Disregarding the possible differences between individual sites (see further), the slightly higher $\delta^{15}N$ value in the youngest phase could generally be explained by a change in diet compared to the earlier phases. This change, however, must have been rather limited because the differences of the $\delta^{13}C$ and $\delta^{15}N$ values observed between the four phases are certainly not dramatic.

The inter-site differences seem much more important than the diachronic differences. This possibly suggests differences in diet between human populations on the islands or could be linked with the diverse ecology and geography of the islands, often showing marked differences between biotopes located within short distances. Moreover, most of the sites studied show specific structures, or characteristic burial rituals, thus suggesting different cultural (sub-)groups, a pattern that also makes acceptable that variation in subsistence strategy existed. These data also suggest that there is no important food trade between the different communities on the islands because this trade should mask the geographical differences. The data from the oldest human bones (phase 1: Figure 2.3) can be roughly divided in two groups: a larger group containing the samples from Alcaïdus, Biniai Nou, S'Aigua Dolça, Càrritx and Son Bauló and a second group containing the samples from Ca Na Costa and the cliff sites Cova Gregoria B, Son Moleta and Son Gallard. The two samples from Can Martorellet fall between the two groups. The isotope values of the second group can perhaps indicate a terrestrial subsistence strategy that was more carnivorous than that of the first group, or, in the case of sample KIA-14330 from Ca Na Costa, a diet that included a (limited) consumption of marine resources. The fact that there is no comparative material from Formentera, however, limits the interpretation possibilities. The samples representing phase 2 (Figure 2.4) show roughly the same picture. Once again the inter-site differences can be noted, although, in this phase, the differences between δ^{15}N values are less outspoken. The human bone samples from phase 3 (Figure 3.5) show once again the same picture. Remarkable is the very tight group from Cova Gregoria A, except for one sample. This aberrant result can perhaps indicate that this particular individual was an immigrant from another community (Van Strydonck et al. in prep), or that weare dealing with a person that had a different diet because of his status, gender or even personal taste. Note that the same type of outliers, although less obvious, are also present in other sites and periods. The fact that the one sample from Cova Gregoria B is situated in the same part of the graph as those from cave A, indicates that the diachronic shift is much less important than the site depending variations. In phase 4 (Figure 3.6), however, one sample from Illa Des Porros shows a rather low δ^{15}N value. Together with the sample from Biniai Nou, these specimens accentuate the larger variation in phase 4 compared to the preceding phases 2 and 3.

Figure 4.8 summarises an additional approach within the analysis of the former dietary patterns on the Balearic Islands, i.e., the evaluation of the 'spacing' between the δ^{13}C values of the collagen and the carbonate fractions of the animal and human bones, in function of their date. It has been proven that this measurement yields considerably higher values for herbivores compared to carnivores. For the animal samples, this parameter varies around +10.5‰, a value considerably higher than listed for herbivores in the literature (+8 to +9‰: Bocherens 2000). How this difference must be explained, is not clear, but more important is that most of the values for the human samples do not really differ from those of the herbivorous domestic animals. In any case, the conclusion must be that a clear carnivorous diet cannot be established for a period within the pre-and protohistory of the Balearic Islands, but that differences between sites seem to exist.

CONCLUSION

The foregoing analysis represents a further attempt to use stable isotope analysis in order to make inferences about the diet of the pre- and protohistoric people inhabiting the

Balearic Islands. It has of course been impossible to exactly evaluate the relative importance of animal versus plant products within the diet, but the hypothesis of a mixed diet, relying on the exploitation of both resources, remains the most likely. Both isotope ($\delta^{13}C$ and $\delta^{15}N$) values and spacing data between carbonate and collagen certainly yield no conclusive evidence for an exclusively carnivorous diet during a certain cultural period. Nevertheless, there are dietary differences between sites, but these are not systematically diachronic. During the oldest phase, for example, the difference between the data from the main islands and the small island of Formentera remains remarkable. During the youngest phase, slight differences in diet may have been present between sites, suggesting an increasing variation within diets. Finally, it is generally clear that marine or freshwater resources were hardly used by the prehistoric communities.

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N°	Site	Species	Lab nr.	^{14}C age (BP)	$^{13}C_{col}$ ‰	^{15}N ‰	$^{13}C_{carb}$ ‰
1	Alcaïdus						
	(Alaior, Menorca)	human	KIA-13988	3340±30	-19.64	+10.50	
		human	KIA-13989	3360±30	-19.82	+7.95	
		human	KIA-13990	3110±30	-19.90	+8.03	
		human	KIA-13991	3075±35	-19.75	+8.44	
		human	KIA-13992	3220±35	-19.79	+8.64	
2	Baduia						
	(Valldemosa, Mallorca)	animal	UtC-7110	2960±35	-20.68	+8.77	
		animal	UtC-9019	2960±40	-20.01	+5.06	
		animal	UtC-9020	2900±45	-21.62	+5.24	
3	Biniai Nou						
	(Maó, Menorca)	human	UtC-7846	2270±35	-19.48	+10.66	
		human	UtC-8949	3745±35	-19.92	+11.39	
		human	UtC-9043	3290±40	-19.50	+8.63	
		human	UtC-8950	3635±35	-19.74	+8.49	
		human	UtC-8951	3200±35	-19.67	+8.42	
		human	KIA-11901	3605±30	-19.62	+9.83	
		human	KIA-11902	3660±25	-19.39	+9.00	
4	Binipati Nou						
	(Ciutadella, Menorca)	human	IRPA-1176/1186	2803±35	-19.50	+11.83	-9.66
5	Biniparratx Petit						
	(Maó, Menorca)	animal	KIA-15219	2685±30	-19.97	+6.65	
		animal	KIA-15220	2735±25	-20.23	+5.66	
		animal	KIA-15222	2775±40	-21.56	+5.55	
		animal	KIA-15221	2825±25	-20.14	+4.52	
		animal	KIA-15245	2475±30	-20.22	+6.34	
		animal	KIA-15218	2370±30	-22.06	+4.55	
6	Cala Morell						
	(Ciutadella, Menorca)	human	UtC-10074	2875±45	-19.57	+9.33	
7	Cales Coves						
	(Alaior, Menorca)	human	KIA-12681	2475±25	-19.89	+9.08	
		human	KIA-12680	2470±35	-19.71	+10.79	
		human	KIA-12682	2595±30	-19.88	+10.83	
		human	KIA-12679	2480±25	-20.31	+10.71	-13.99
		human	KIA-12678	2415±30	-19.82	+10.71	-12.86
		human	IRPA-1185	2525±35	-19.50	+10.23	
8	Ca Na Costa						
	(Formentera)	human	KIA-14329	3595±35	-18.69	+9.06	
		human	KIA-14330	3535±40	-18.79	+12.74	
9	Can Martorellet						
	(Pollencia, Mallorca)	human	KIA-15714	3555±30	-19.05	+8.47	
		human	KIA-15721	3450±30	-19.26	+7.96	
10	Cap de Forma Murada						
	(Maó, Menorca)	animal	UtC-10075	2755±30	-21.28	+6.05	
		animal	UtC-10076	2930±35	-19.76	+4.51	
		animal	UtC-10077	2815±45	-20.79	+3.47	
		animal	KIA-21224	2915±30	-21.59	+5.55	-10.20
		human	KIA-21228	2245±30	-19.06	+9.91	-9.43

Table 1. Provenance, species identification, laboratory code, uncalibrated radiocarbon date, and δ^{13}C and δ^{15}N measurements for all samples studied.

11	Càrritx						
	(Barranc d'Algendar, Menorca)	human	UtC-7858	3325±40	-19.40	+9.62	
12	Closos de Can Gaià						
	(Felanitx, Mallorca)	animal	KIA-11239	2650±25	-20.43	+4.84	
		animal	KIA-11229	2740±30	-21.08	+6.46	
		animal	KIA-11232	2790±40	-21.11	+5.37	
		animal	KIA-11241	3040±25	-19.63	+3.48	
		animal	KIA-11233	3065±35	-20.02	+4.95	
		animal	KIA-11242	2890±35	-19.32	+3.02	
		animal	KIA-11231	2960±25	-20.20	+4.70	
13	Cova Gregoria A						
	(Valldemossa, Mallorca)	human	KIA-23133	2520±30	-18.76	+9.91	-9.28
		human	KIA-23134	2585±30	-18.75	+9.72	-10.57
		human	KIA-23135	2510±30	-18.77	+9.29	
		human	KIA-23136	2460±30	-18.79	+10.14	-11.23
		human	KIA-23137	2620±35	-18.79	+10.17	-10.82
14	Cova Gregoria B						
	(Valldemossa, Mallorca)	human	KIA-23406	3155±30	-18.83	+9.12	-9.43
15	Coval Simó						
	(Escorca, Mallorca)	animal	KIA-14323	3670±30	-21.61	+5.30	
16	Es Tudons						
	(Ciutadella, Menorca)	human	IRPA-1179	2820±40	-19.46	+9.08	-9.43
17	Illa des Porros						
	(Santa Margalida, Mallorca)	human	KIA-13567	2170±55	-19.63	+11.73	
		human	KIA-13537	2185±30	-19.21	+10.91	
		goat	KIA-11243	2975±25	-21.27	+3.70	-7.76
		goat	KIA-11244	2765±30	-19.68	+2.41	-8.03
		cattle	KIA-11246	3040±30	-20.23	+8.08	-7.91
		human (foetus or newborn)	KIA-11245	2410±25	-19.00	+10.11	
		human	KIA-13532	1905±25	-19.73	+9.68	
		human	KIA-13531	2005±25	-19.33	+11.07	
		human	KIA-13533	2165±35	-19.62	+12.43	
		human	KIA-13535	2275±25	-19.80	+11.04	
		human	KIA-11869	2375±25	-19.46	+9.92	-7.92
		human	KIA-11870	2285±25	-19.13	+6.84	-7.39
		cattle	KIA-11868	3100±35	-20.22	+3.88	-7.56
		human (child)	KIA-11240	2395±25	-19.90	+12.04	
18	Puig d'en Pau						
	(Costix, Mallorca)	animal	KIA-14882	2545±30	-20.45	+2.35	
		animal	KIA-14823	2735±40	-21.19	+7.86	
		animal	KIA-14821	2770±30	-20.91	+1.77	
		animal	KIA-14820	2590±35	-20.40	+4.12	
19	Rafal Rubí						
	(Alaior, Menorca)	human	IRPA-1170	2765±40	-19.56	+7.56	
		human	KIA-15730	2870±30	-19.83	+7.80	
		human	KIA-16269	3085±25	-20.20	+8.87	
		human	KIA-16270	3090±30	-19.76	+8.24	
		human	KIA-16271	3035±30	-20.35	+8.46	
		human	KIA-16272	3050±30	-19.88	+8.59	
20	Sa Cala						
	(Formentera)	animal (dog)	KIA-20215	2565±25	-18.90	+10.43	

21	Sa Creu des Ramis						
	(Maó, Menorca)	animal	KIA-20080	2960±25	-19.93	+5.63	
		animal	KIA-20069	2890±25	-21.75	+7.69	
22	S'Aigua Dolça						
	(Colonia de Sant Pere, Mallorca)	human	KIA-15223	3485±40	-19.60	+9.4	
		human	KIA-15224	3420±30	-19.40	+8.1	
23	Sant Tomás						
	(Sant Tomás, Menorca)	animal	KIA-15732	2185±30	-21.18	+6.21	
24	Ses Arenes						
	(Ciutadella, Menorca)	human	KIA-23402	3290±25	-18.43	+8.96	
		human	KIA-23403	3025±25	-18.44	+8.47	
		human	KIA-23404	3085±25	-18.60	+9.30	
		human	KIA-23405	3185±25	-18.88	+8.57	
		human	KIA-23149	3225±35	-18.13	+8.94	
		human	KIA-23150	3390±35	-18.64	+8.51	
25	Ses Aritges						
	(Ciutadella, Menorca)	human	UtC-7852	2875±35	-19.27	+9.68	
		human	UtC-7853	3060±35	-19.69	+9.20	
		human	UtC-7854	3090±35	-19.26	+8.82	
		human	UtC-7855	2905±35	-19.24	+10.21	
		human	UtC-7857	2970±60	-19.47	+8.21	
26	Ses Païses						
	(Artà, Mallorca)	probably sheep	KIA-11890	2475±25	-24.24	+8.30	
		sheep or goat	KIA-11867	2525±25	-20.04	+2.82	
27	Ses Roques Llises						
	(Alaior, Menorca)	human	KIA-18761	3395±35	-19.21	+10.70	-9.04
		human	KIA-18767	2955±30	-19.59	+9.63	-9.14
		human	KIA-20204	3135±35	-19.33	+9.02	
		human	KIA-18762	3030±40	-20.18	+10.36	-8.72
		human	KIA-21225	2890±25	-19.84	+8.36	-7.15
28	S'Hospitalet						
	(Manacor, Mallorca)	animal	KIA-23769	2205±30	-19.97	+5.61	
29	So na Caçana						
	(Alaior, Menorca)	animal	IRPA-1128	2410±40	-21.05	+9.57	
30	Son Bauló						
	(Santa Margalida, Mallorca)	human	KIA-13224	3480±30	-19.57	+9.58	
		human	KIA-13225	3365±30	-19.76	+9.03	
31	Son Blanc						
	(Ciutadella, Menorca)	human	KIA-20084	2730±30	-19.07	+12.10	
32	Son Ferrandell-Oleza						
	(Valldemosa, Mallorca)	sheep or goat	UtC-10079	3605±35	-20.73	+3.58	
		cattle			-20.50	+5.83	-9.16
		pig	KIA-10559	3440±35	-21.13	+5.66	
		sheep or goat			-20.04	+6.80	
		sheep or goat	KIA-10560	3550±30	-20.22	+4.79	
		cattle			-19.69	+6.16	-7.3
		cattle	KIA-11228	3565±35	-20.45	+5.55	
		sheep or goat			-19.56	+6.89	
		sheep or goat	KIA-10557	3540±30	-20.42	+3.28	-8.52
		cattle			-20.83	+5.56	
		sheep or goat	KIA-10583	3625±30	-20.37	+3.38	-9.82
		cattle			-20.26	+5.20	

		cattle	KIA-10582	3625±30	-19.55	+3.93	
		sheep or goat			-20.26	+4.85	
		cattle	KIA-10558	3445±30	-19.90	+6.23	
		sheep or goat			-19.89	+3.70	
		animal	UtC-9021	3460±45	-20.31	+4.73	
		animal	UtC-9022	3620±50	-20.22	+8.15	
		animal	UtC-8952	3585±35	-19.88	+4.71	
		animal	KIA-20208	2705±30	-20.44	+8.99	-9.99
		animal	KIA-20484	3480±25	-19.30	+4.16	-8.81
33	Son Gallard (Deià, Mallorca)	human	KIA-21214	2135±30	-19.00	+11.09	-10.88
		human	KIA-21215	3295±30	-18.90	+10.51	-10.46
		animal	KIA-23732	2725±30	-19.55	+3.65	
		animal	KIA-23434	3745±25	-18.99	+4.32	-9.51
		sheep or goat	KIA-23734	3595±30	-19.97	+7.71	
		animal	KIA-23441	3485±30	-19.51	+5.82	-10.02
		cattle (?)	KIA-23435	3660±25	-15.27	+4.81	-8.07
		sheep or goat	KIA-23436	3570±33	-18.40	+5.83	-9.67
34	Son Fornés (Montuïri, Mallorca)	animal	KIA-11888	2270±25	-20.54	+9.05	-7.36
		animal	KIA-11997	2460±25	-21.13	+3.38	
		animal	KIA-11889	2405±25	-21.31	+3.01	-9.56
		animal	KIA-11886	2210±25	-21.25	+4.78	-8.97
		human	UtC-2286	2100±40	-19.40	+12.18	
		human	UtC-2287	2150±40	-19.30	+13.39	
		animal	KIA-20461	2450±25	-19.74	+7.13	-10.67
		animal	KIA-20473	2425±25	-19.49	+10.23	-10.20
		Goat	UtC-9327	2490±50	-19.51	+8.91	
		human	KIA-23128	2095±30	-18.42	+11.68	
		human	KIA-23147	2645±35	-18.73	+11.96	
		human	KIA-23120	2265±30	-18.68	+11.87	
35	Son Mas (Valldemosa, Mallorca)	animal	IRPA-1066	2430±40	-21.37	+7.02	-9.39
		animal	UtC-9018	2200±40	-21.99	+6.72	
		human	UtC-4675	2655±30	-19.85	+9.63	
		animal	UtC-9017	2940±45	-20.39	+9.01	
		animal	KIA-20199	2910±25	-20.19	+5.56	-11.24
		animal	KIA-20203	2980±30	-20.15	+4.83	-12.42
		animal	KIA-20487	2845±25	-20.12	+5.21	
36	Son Moleta (Sóller, Mallorca)	human	KIA-20213	3850±25	-18.86	+9.45	-11.54
37	Talati de Dalt (Maó, Menorca)	animal	KIA-11230	2140±40	-21.47	+5.16	-10.98
		animal	KIA-11220	2775±30	-21.54	+4.81	
		animal	KIA-19500	3605±30	-19.71	+5.60	-9.35
		animal	KIA-19499	3550±30	-19.51	+5.80	-9.50
38	Torrent d’en Barragot (Ses Salines, Mallorca)	human	KIA-22648	2515±25	-19.31	+10.17	

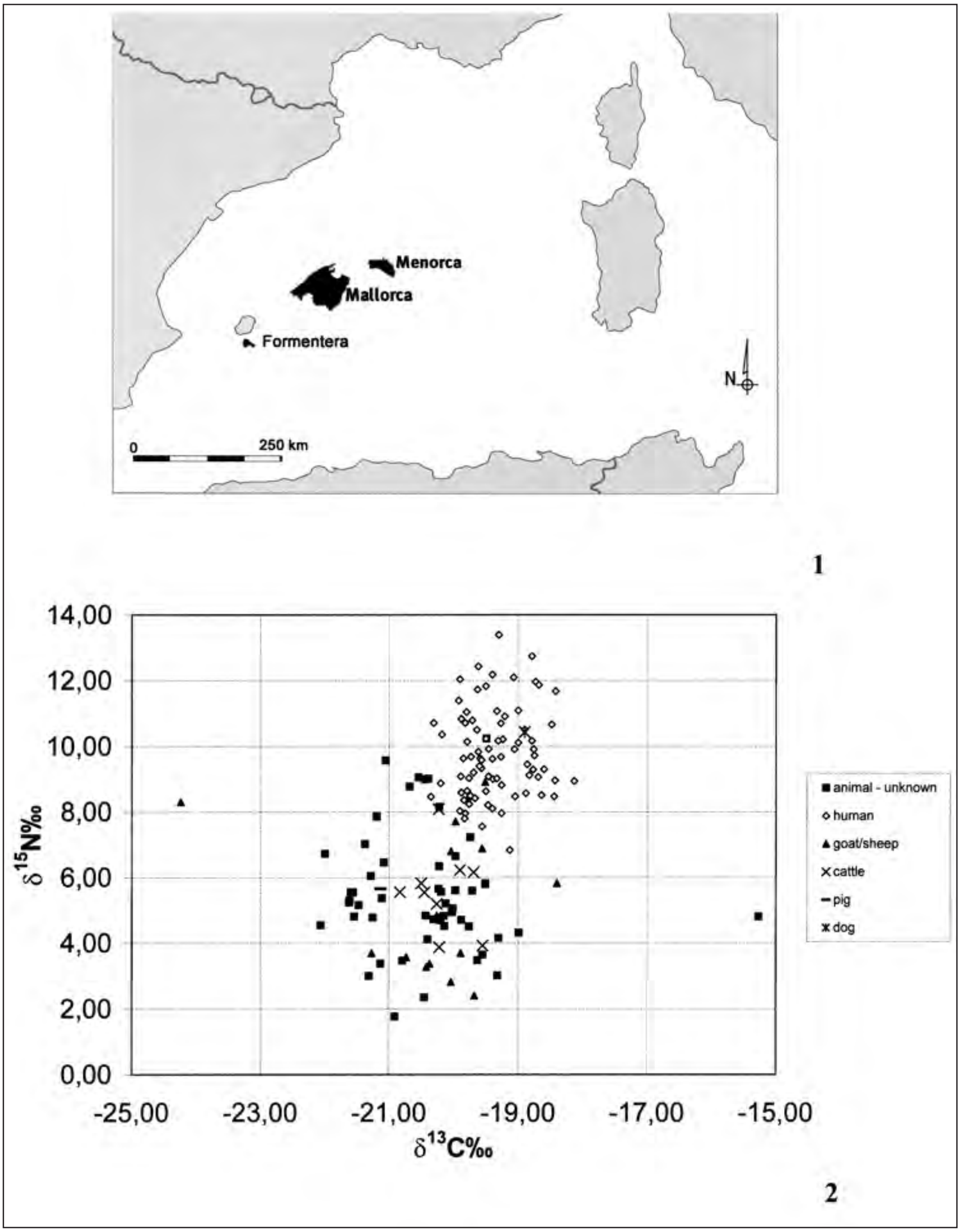


Fig. 1. (**1**) The Balearic Islands Mallorca, Menorca and Formentera. No samples from Ibiza were analysed. (**2**) $\delta^{13}C$ and $\delta^{15}N$ (‰) from all samples studied.

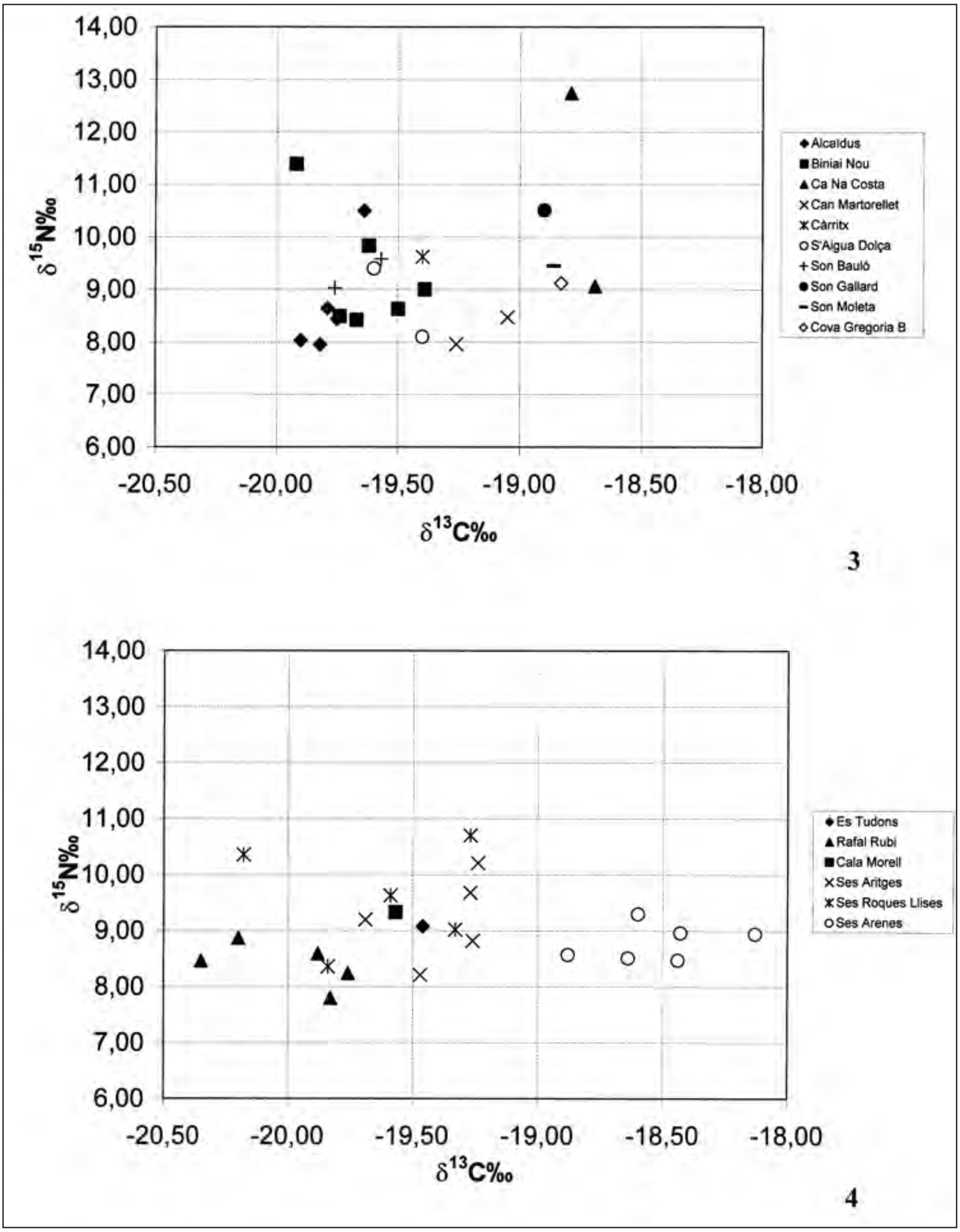
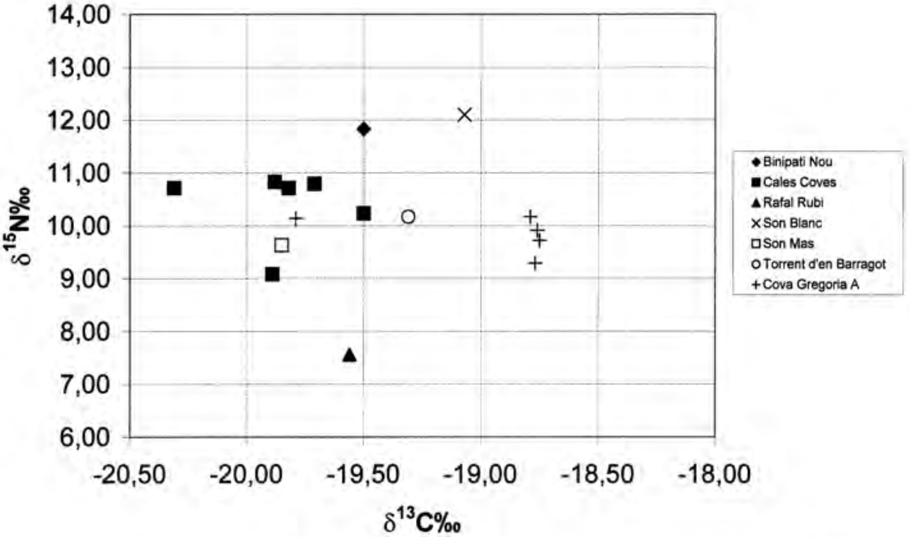


Fig. 2. (**3**) δ^{13}C and δ^{15}N (‰) from all human bone samples belonging to phase 1 (before1600 BC). (**4**) δ^{13}C and δ^{15}N (‰) from all human bone samples belonging to phase 2 (1600-1050 BC).



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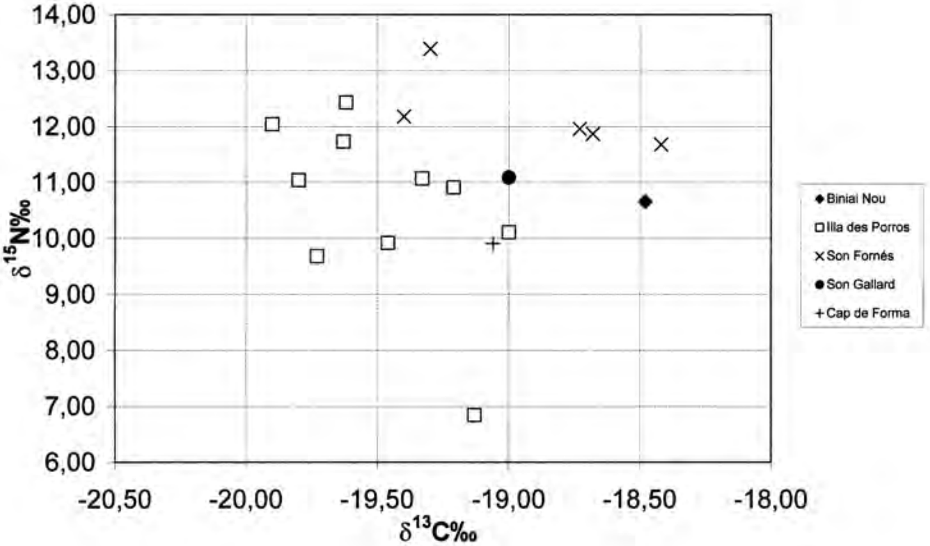

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Fig. 3. (**5**) δ^{13}C and δ^{15}N (‰) from all human bone samples belonging to phase 3 (1050-500 BC). (**6**) δ^{13}C and δ^{15}N (‰) from all human bone samples belonging to phase 4 (after 500 BC).

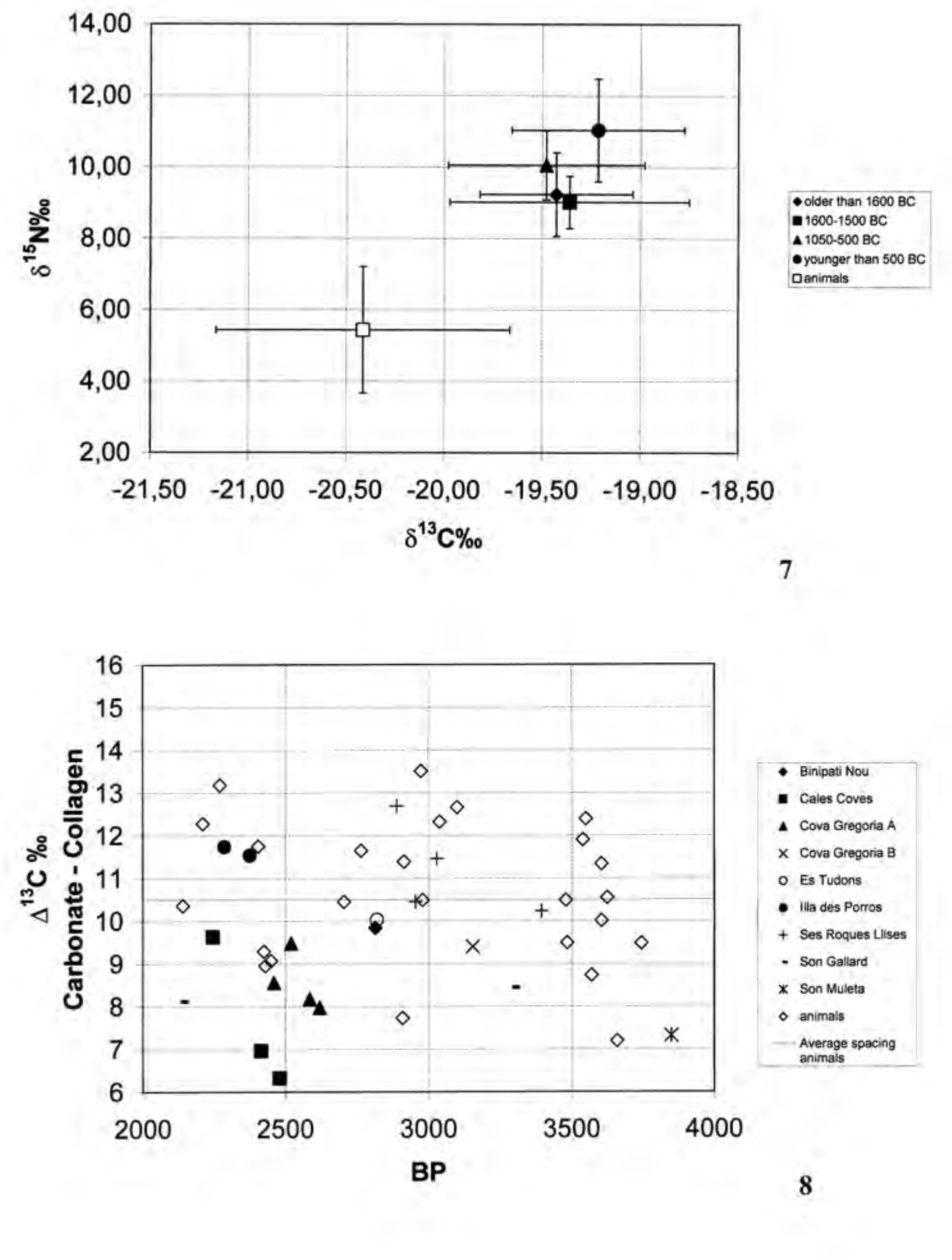

Fig. 4. (**7**) Average $\delta^{13}C$ and $\delta^{15}N$ values (‰) ± 1σ for animal and human samples from phase 1, 2, 3 and 4. (**8**) $\Delta\delta^{13}C_{collagen\text{-}carbonate}$ (‰) from animal and human bone samples. The horizontal line represents the average value of the animal bones.