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Dogs and foxes in Early-Middle Bronze Age funerary structures in the Northeast of the Iberian Peninsula: Human control of canid diet at the sites of Can Roqueta (Barcelona) and Minferri (Lleida)

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ABSTRACT

Findings of canid remains in graves at different sites in the northeast of the Iberian Peninsula are evidence of a widespread funerary practice that proliferated between the end of the 3rd and the 2nd millennium BC, in particular, in the Early-Middle Bronze Age contexts. The discovery of four foxes and a large number of dogs at the sites of Can Roqueta (Barcelona) and Minferri (Lleida) respectively, stand out among the many examples of these types of grave goods. In this work, we have made an approximation of the relationship between humans and canids through the study of their diet by analysis of stable isotopes of carbon and nitrogen in bone collagen. These analyses were complemented by archaeozoological, anthropological and archaeobotanical studies. The comparison of human and animal diets comprised a total of 37 canids, 19 domestic ungulates and 64 humans. The results indicate that the diet of the dogs was similar to that of humans, although, $\delta^{15}N$ values of dogs in Can Roqueta and Minferri are, on the average, 1.4‰ and 1.1‰, respectively, lower than those of humans. The offset between canids and the herbivorous ungulates of each site is not up to the established minimum for a trophic level, which implies an input of C3 plants and human intervention in the feeding of dogs and some of the foxes. Some particular cases in Can Roqueta suggest a specific food preparation, richer in cereals, for larger dogs (probably devoted to carrying loads), and possibly for at least one of the foxes.

Keywords

Northeast of the Iberian Peninsula; Early-Middle Bronze Age; stable isotopes; canid diet

1. INTRODUCTION

1.1. Dogs in Bronze Age burials in Catalonia

Animal offerings during burials in the Iberian Peninsula are a phenomenon that proliferated from the 5th millennium BC until the end of the Iron Age (Catagnano 2016). But burial dogs are especially important in Chalcolithic and Early-Middle Bronze Age contexts, between the end of the 3rd millennium BC and during the 2nd millennium BC (Albizuri 2011a; Albizuri et al. 2011b, Cámara Serrano et al. 2016; Conlin 2003; Daza 2011; Gómez 2003; Liesau et al. 2013; Nieto et al. 2014; Ruiz et al. 2014; Valera et al. 2010).

The first burials of canids in the Northeast of the Iberian Peninsula (mainly dogs) are recorded in funerary structures from the Middle Neolithic period onwards. Two cases were highlighted in the Northern region of the Northeast area, in Serra del Mas Bonet (Rosillo et al., 2012) and Cova de l'Avellaner (Bosch et al. 1989).Although, the most numerous examples are located within the Catalonian coastline, in the Pit Grave culture of the Middle Neolithic period (ca. 4200-3600 cal BC), as is the case of the necropolis of Bòbila Madurell (Martín Cólliga et al. 2017) or Can Tintorer, Mina 28 (Villalba 1999), the findings of one fox and one dog in Camí de Can Grau (Martí et al. 1997) and the examples of La Serreta and Ca l'Arnella sites (Albizuri et al., currently under study). At the moment, only one case has been found for the Pre-Pyrenees, in Ca l'Oliaire (Martín Cólliga et al. 2005). Yet, the rite was not generalized until the Early-Middle Bronze Age, when dogs played an important role in funerary rituals.

Although, many sites from this timeframe have been the subject of excavations, the most remarkable sites, both for their extension and the quantity of canid deposits, are the settlements of Can Roqueta (Sabadell, Barcelona), situated in the Pre-littoral Plain, and Minferri (Juneda, Lleida) in the Western Catalonian Plain (Fig. 1). In both sites, canids are interpreted as intentional deposits. Using Perri's typology (Perri 2017), canids are found in isolated structures (buried alone) and in associated structures (co-buried with humans). In most cases, they are fully or partially articulated skeletons (depositions), but we can also find distinct elements only (elemental). In some cases of full skeletons, the absence of certain anatomical parts was observed, although this is unrelated to any detectable taphonomic process. There are also exceptional cases where the right limbs were missing, as well as a unique case of a dog whose paws were removed before deposition. The absence of certain anatomical parts and the presence of some isolated remains of dogs, such as severed heads, have led to speculations as to their occasional consumption in circumstances unrelated to daily contexts. Furthermore, it is noteworthy that these bones never revealed butchery marks – only in some cases did it reveal disarticulation marks in the occipital condyles and, in a single case, disarticulation marks in the distal joints of the two radii. Foxes at both sites are represented by fully articulated skeletons and never revealed butchery marks.

Dogs are thus one element of a variety of faunal depositions essentially comprised of domestic animals (cattle, sheep, goat, pig). There are nonetheless instances of wild species, principally, carnivores and birds (Albizuri 2011a, b; Albizuri et al. 2015; Gómez 2003; Nieto et al. 2014), albeit, in a very low proportion.

Other regional Bronze Age sites (see Fig. 1) with similar burial rites include, Bòbila Madurell in Sant Quirze del Vallès Occidental (Boquer et al. 1990; Bordas et al. 1994), Can Gambús in Sabadell (Artigues et al. 2007; Roig and Coll 2016) and Pinetons in Ripollet (Balsera et al. 2011). To the south are also the sites of Pacs del Penedès, the vast settlement of Mas d'en Boixos (Bouso et al. 2004, 2005) and Cantorella, near Lleida (currently under study by A. Nieto). Yet, the findings from these sites are not included in the current study, as they remain unpublished.

insert Figure 1 around here

1.2. Dogs and people, tasks and diet

Humans and dogs share a common history from the Palaeolithic period, with putative dog ancestors dating back for more than 30,000 years BP in the Belgian cave of Goyet (Germonpré et al. 2009) or in the Altai Mountains of Siberia (Ovodov et al. 2011), and fully domesticated animals from the Magdalenian period at Late Glacial times (Horard-Herbin et al. 2014). The human–dog relationship is marked by important functional and economic factors, such as hunting, guarding, protection, herd driving, transport and loading, which can be reflected in signs of affection, such as a caring burial (Albizuri et al. 2011b; Coppinger and Schneider 1995; Morey 2010). This is relevant considering the emblematic character of dogs, which also apply to wolves, their wild counterpart. This explains their appearance in burial contexts (Guagnin et al. 2018; Losey et al. 2011; Morey 2010; Perri 2016; Russell 2012).

Among the many tasks entrusted to the dog, some are natural, such as those related to hunting or surveillance, and others require further training, such as grazing livestock or transporting either by pulling travois, carts or sleds, or carrying weights on their backs. The transport of goods by pack dogs is a subject that has not been extensively studied in Europe, although it has been recorded from historical and ethnographic accounts from Roman times to the beginning of the 20th century AD (Latham, 2016). An exception is the Peterson's doctoral thesis, which offers an explanation for the diversity of size and robustness of dog bones from the extremities of a large number of examples from Mesolithic sites in Sweden. The variability is interpreted in terms of the diversity of work and transportation tasks (Peterson, 2006). A study in Siberia has also recently identified pathologies among Palaeolithic dogs (Pitulko and Kasparov, 2017) which indicate that the task of transport was developed from the very outset of the domestication of the wolf. In the case of Can Roqueta, bent spinous processes of lumbar vertebrae found in three dogs were interpreted as sign of a constant bearing of vertical loads on their back (Albizuri et al. 2011b). This confirms the use of the dog as a pack animal in the Iberian Peninsula during the Early-Middle Bronze Age. These pathologies were also observed among dogs of the Palaeo-Indians of Alabama (Dust Cave) and Illinois (Kuehn 2014; Morey 2010; Warren 2004). Although, they were also observed in non-work related and even wild animals (Latham 2016).

The long journey of dogs in the company of humans is evidenced by a diet that for millennia was a proxy to that of humans, usually reflecting the same general trend in the proportion of animal and plant foodstuffs (Cannon et al. 1999; Guiry 2012; Guiry and Grimes 2013; Noe-Nygaard 1988; Pearson et al. 2015; Pechenkina et al. 2005). But this similarity depends to a great extent on other causes, such as cultural habits and environmental conditions, that can positively or negatively influence the dog's diet (Ewersen et al. 2018; Losey et al. 2013). For example, a scarce diversity of available environmental resources will imply a forced similarity between the feeding of humans and dogs. In the same vein, the consumption of human faeces will lead to new similarities between the diet of dogs and humans (Tankersley and Koster, 2009).

In recent societies, dogs that are destined to work are fed expressly and in a similar way to humans so as to ensure their effectiveness (Isik 2009; Koster and Tankersley 2012), but we have no knowledge of whether this happened in the agro-pastoral societies of the Bronze Age. The control of the dog's diet would be a determining factor in ensuring its effectiveness in the assigned task, freeing up the time spent on obtaining food and encouraging its dependence on the human group.

On the other hand, the exceptional presence in the Iberian Peninsula of four complete and articulated foxes co-buried with humans at Minferri and Can Roqueta led to other questions, especially when considering that domestic species make up 90% of the animal offerings. The presence of these wild animals creates a problem of interpretation as to their potential commensalism with humans – a hypothesis that ought to be taken into account, since they appear in the same burial contexts as dogs. The fact that they are intentionally deposited poses questions as to the symbolism of these wild animals. Although wild carnivores are generally considered to be dangerous, some studies link them as agents of protection (Peters and Schmidt 2004). Wolves and foxes at times form part of the totemic images (Brück 1999). Therefore, it cannot be ruled out that their presence in burials could be symbolic. Foxes, for example, were recorded as deposits in burials sites in Eurasia during the Neolithic period (Horwitz and Goring-Morris 2004; Maher et al. 2011; Brea et al. 2010), as well as in certain Bronze Age and Chalcolithic contexts (Morris 2011; Onar et al. 2005). This species is poorly represented in the Iberian Peninsula's archaeological sites, with the exceptions of cases in Neolithic and Chalcolithic contexts in the Province of Jaen and in Portugal (Valera and Costa 2013; Camara Serrano et al. 2016). The four foxes considered in the current study, as well as three other single cases, are exceptional to this region. The other cases in the Northeast are one animal buried with a woman at Camí de Can Grau site (Middle Neolithic) (Martí et al. 1997), one fox found in an isolated structure at Cantorella site (Late Neolithic) (under study by A. Nieto), and a third fox buried with two human skeletons in the Early Bronze Age sepulchral cave of Cervereta (Forcadell and Villalbí 1999).

1.3 Aim of the study

The dogs associated with the funerary structures as well as the non-funerary annexes of Can Roqueta and Minferri serve as the basis for this study, since they reflect a direct relationship with the deceased, and this allows a better contrast between their diets and the control that humans could have exerted over them.

The central objective of this study is to identify the level of dependence of dogs on humans and the degree of human control over them by studying their diets through the stable isotopes of carbon (C) and nitrogen (N) in bone collagen. The aim is thus to identify the socio-economic utility of dogs and the level of proximity between humans and foxes. We also want to observe if there are any morphological and feeding differences between the dogs studied in order to propose a line of study on the possible specific feeding of some specimens dedicated to hard work.

2. ARCHAEOLOGICAL CONTEXT: CAN ROQUETA AND MINFERRI

2.1. Description of the sites

The settlements of Can Roqueta and Minferri are references for the Early-Middle Bronze Age of the Northeast region of the Iberian Peninsula due to their extension and their similarities, which facilitate comparative study. Both were occupied between the end of the 3rd millennium and the first half of the 2nd millennium BC. Most of the structures of Can Roqueta that have been subject to radiocarbon dating date back to between 1900-1600 cal BC (Carlús et al., 2008). Yet, there are concrete examples that are evidence of a phase corresponding to the so-called *Bronze inicial* from the middle of the 3rd millennium to the last quarter of the 2nd millennium cal BC (Palomo et al., 2016). The dates of Minferri, in turn, place its occupation between 2100 and 1650 cal BC in the *Bronze ple* (Nieto et al. 2014; Marín et al. 2017). Both settlements are typologically analogous from the viewpoint of their material culture and their models of insertion in the territory. In spite of their similarities, they are located in distinct geographical and climatological areas: Can Roqueta is in Barcelona's humid Pre-littoral Plain, while Minferri is in the Western Catalonian Plain, which is characterised by a continental climate (see Fig. 1). Both areas are very fertile and conducive for agriculture, with easy access to natural resources (Carlús et al. 2007; Equip Minferri 1997; Alonso and López 2000).

Both sites have also been the subject of continuous archaeological work since the 1990s (Minferri: Agustí et al. 2005; Alonso 1999; Alonso and López 2000; Equip Minferri 1997; Gómez 2000a; 2000b; 2003; López 2000; 2001; Marín 2018; Marín et al. 2017; Moya et al. in press; Nieto et al. 2014; Prats 2013; 2017; Vila 2018; Can Roqueta: Albizuri 2011a; 2011b; Albizuri et al. 2011b; 2015; Boquer et al. 1990; 1992; Carlús et al. 2002; 2007; 2008; Palomo and Rodríguez 2002; Palomo et al. 2016; Rodríguez et al. 2002). Of particular interest to this study is the fact that both offer a very rich assemblage of human and animal remains, unique to the Iberian Peninsula.

The sites are of the open-air, scattered type, with residential sectors represented by dispersed, small, semi-excavated houses, roofed with wood and branches. Both sites had an economy based principally on agriculture. Features linked to production, storage and burials are dug into the geological substrate between the houses (Fig. 2 and Fig. 3). The burials containing both the deceased and grave goods take the form of simple semi-circular pits or, more rarely, complex pits with lateral niches of 2 m, and more rarely up to 3 m, in depth, with a maximum diameter spanning 1–2 m. At times, they are very close to other non-funerary pits also containing animal deposits. Some authors interpreted these structures as ritual pits linked to the burials (Albizuri 2011a; 2011b; Nieto et al. 2014).

Bioarchaeological studies of the sites reveal that their populations were dedicated to cereal farming and livestock breeding (cattle, sheep, goats, pigs). There is also evidence of bronze workshops at each settlement.

2.2. Funerary structures and animal deposits

The funerary rites are one of the most remarkable parallels between the two sites, as both comprise structures linked to inhumations with intentional animal deposits and other ritual structures containing animal deposits at less than 10 m from burial pits (Table 1). The chronological relationship between funerary and non-funerary structures can only be proven at present in one case, in which fragments of a single ceramic vessel are shared by both a burial of Can Roqueta (CRII-590) and a non-funerary structure (CRII-591) dug a few meters away. This structure also contained an important assemblage of fauna, highlighted by three dog skeletons. Although concentrated in different areas of the settlements, funerary pits are interspersed with domestic features. One of the most significant manifestations of their burial ritual, as noted previously, is the deposition of animals (especially domestic animals), in particular, dogs.

At Can Roqueta, there are more than 150 Early Bronze Age pits distributed at different sectors of the site: Can Roqueta-Torre Romeu (CRTR), Can Roqueta-Diasa, Can Roqueta II (CRII) and Can Roqueta-Can Revella (CRCRV), as seen in Figure 2. Funerary structures make up a large proportion of the pits of this chronological phase (60 structures, 220 inhumed individuals). Most were found in the CRII sector: 121 structures, of which 29 are funerary structures (40.5%), containing 180 inhumed individuals.

insert Figure 2 around here.

The human skeletal remains of Can Roqueta include all age categories, but the underrepresentation of certain age classes, such as infants less than two years as well as mature and elderly individuals, is noteworthy. In general, the animals found in both funerary and non-funerary structures at Can Roqueta are fully or partially skeletons and isolated remains of domestic animals. Birds and wild mammals are occasionally present, as seen in Figure 3. According to the minimum number of individuals (MNI) values, the most represented are the domestic animals: cattle, sheep and/or goat, pig and dog, arranged in order of importance (Albizuri 2011a, b).

insert Figure 3 around here

The Minferri funerary record is the largest in the Western Catalan plain for the first half of the Bronze Age. Funerary practices were described based on 10 individuals recovered in four structures (Equip Minferri 1997; Guerrero 1990). The number of localized structures increased significantly after the 2001 and 2006 interventions. Therefore, Minferri currently has a set of anthropological remains unearthed in 24 silo-shaped structures, corresponding to a minimum of 56 individuals (Fig. 4). Of the 182 structures, 12.3% were reused for human burials (MNI=51).

insert Figure 4 around here.

Minferri's largest concentration of burials (63%) is in Sector 2 of Zone 2, with a total of 32 individuals in the 10 structures. A second important concentration of tombs (Zone 9) is located northwest of the main excavation area (Zone 2), with six individuals placed in five different structures. The population includes all age categories. There is a significant presence of perinatal individuals and infants, as well as a low number of young people, and only a single elderly individual (Agustí et al. 2005). Grave goods and offerings are not widespread at Minferri. The few exceptions of these funerary structures contain pottery and meat offerings corresponding mainly to full or partial skeletons of cattle, sheep or goat, canids, and occasionally foxes and birds, but never pigs, as shown in Figure 5. There are also other non-funerary structures containing full or partial skeletons of animals (cattle, followed by sheep/goat, pigs and dogs).

insert Figure 5 around here

In summary, the comparison of the findings of animal offerings at Can Roqueta and Minferri suggest the presence of similarities and differences. The first similarity is the predominance of domestic species and the equal representation of dogs with respect to other domestic animals. Another noteworthy aspect is the presence of fully articulated skeletons of foxes at both sites. The dogs are numerous and appear both in tombs and in structures close to the tombs. The most pronounced differences, by contrast, are the higher representation of cattle at Minferri (at times deposited fully) and that of pig at Can Roqueta.

2.3. Food resources

The agricultural and plant data at Can Roqueta for the Early-Middle Bronze Age is scarce and comes from a single sediment sample of the Can Revella area (volume: 20 litres) and the manual collection of many acorns (1,050) during the excavation of various funerary structures. The results of the analyses illustrate the variability of crops consumed by humans and animals. Moreover, acorn offerings in certain tombs point to a symbolic and economic value of plant resources. Can Roqueta's main crop is barley (*Hordeum vulgare* s.l.), followed by the token presence of naked wheats (*Triticum aestivum/durum*) and legumes (probably pea, *Pisum sativum*). Unlike Western Catalonia, there is no evidence of flax in this territory and in this chronological framework. Yet, it was observed that oleaginous plants are often underrepresented, as their remains are only preserved by carbonisation. However, as noted, acorns abound in various features in the Can Roqueta/Revella sector, suggesting that this fruit could be ground and could have served as a diet supplement. On the other hand, it can be observed that acorns are common to silos and funerary structures elsewhere in the Bronze Age in the Iberian Peninsula (Alonso et al. 2016; Pereira and García 2002).

The plant food resources of Minferri's Middle Bronze Age sequences are, for the most part, winter cereals gleaned from the systematic sampling of 58 excavated structures, yielding a total of 4,559 litres of sediment. Although, their number is quite high (5,884 grains), their density is very low (only 0.6 finds per litre of sediment). There is a predominance of common/durum wheat (*Triticum aestivum/durum*), represented by more than 50% of the remains of cultivated plants appearing in 59% of the structures. The importance of this cereal is even more evident when compared to the next most common type of cereal, dressed barley (*Hordeum vulgare*), represented by only 16.9% of the remains and present in only 17% of the structures. Emmer (*Triticum dicoccum*), although present, is minor. Furthermore, the total absence of legumes at Minferri is remarkable. There is, nonetheless, evidence of flax cultivation (*Linum usitatissimum*) (Alonso 1999; Alonso et al. 2006). Harvested fruit comprises acorns (*Quercus* sp.), mastic (*Pistacia lentiscus*), blackthorn (*Prunus spinosa*) and blackberry (*Rubus fruticosus*) (Alonso et al. 2016).

The study of bones identified as food waste at Minferri and Can Roqueta was carried out on an assemblage comprising 484 remains from 70 silo-type structures (Gómez 2000a, b; Albizuri 2011a). The results indicate a spectrum of domestic mammals: sheep (*Ovis aries*), goat (*Capra hircus*), cattle (*Bos taurus*), pig (*Sus domesticus*), rarely dog (*Canis familiaris*) and wild mammals, such as lagomorphs (*Oryctolagus cuniculus*, *Lepus* sp.) and red deer (*Cervus elaphus*). The consumption of domestic species (excluding dog) was clearly predominant. Wild species, in turn, were only occasionally exploited for the human diet.

At Can Roqueta, such wild species also include marine mollusc (Palomo et al. 2016), although, this evidence is very limited. Sheep and goat are the most commonly represented domestic species at both sites, with pig being the third most common domestic animal ahead of cattle (Albizuri 2011a).

The evidence indicates that sheep and goats were the most frequently sacrificed as adults or sub-adults, a clear indicator of an attempt to manage the reproduction of the herd so as to profit from their milk, cheese and wool, among other by-products. Cattle, in turn, were mostly slaughtered as sub-adults, after attaining their optimal weight. Only a small number (probably needed for breeding, milk and work) surpassed the age of 36 months. Furthermore, findings of perforated vessels interpreted as strainers at both sites serve as evidence of the processing and filtering of rennet in the preparation of fermented products such as cheese and yogurt. Pigs were sacrificed for the most part around 12 months, an age corresponding to their adult weight. This is evidence of their exploitation for meat. Adults of both sexes were nonetheless retained for reproductive purposes.

3. MATERIALS AND METHODS

3.1. The sample set

In the two sites studied, canids appeared primarily in funerary and ritual structures. For this reason, we have selected 28 funerary structures containing human remains and canids for study, as seen in Table 1. The sampling was completed with samples of deposits containing dogs and other animals in 13 non-funerary structures located in the vicinity of the burials.

For the isotopic study, we selected the best-preserved remains available at the time of the study. Thus, we studied 32 dogs (21 from Can Roqueta and 11 from Minferri), one large canid, presumably a wolf, from Can Roqueta, and four foxes, three from Minferri and one from Can Roqueta (as seen in Table 2). Only one of the dogs studied was found in a structure far from the funerary zone (MIN-150). This was included in the sample to determine if there are differences between the diet of these dogs and the diets of the dogs included in the funerary structures. The only canid that can be considered to be wild is an animal that we tentatively identify as a wolf (*Canis* cf. *lupus*) because of its large size in comparison with the other dogs in the structure (Albizuri et al. 2015).

insert Table 1 about here

insert Table 2 about here

The assignment of age ranges of canids is based on the period of natural lactation as well as bone and reproductive maturity (see Table 2). They are called puppies in the first three months of life, after which they cease to breastfeed definitively. Young dogs are those in the process of replacing their teeth and they have not yet reached bone and reproductive maturity – between 4 and 10 months of age. The adult dog category begins between 10–12 months, when their skeleton reaches bone and reproductive maturity. The age range of the canids studied was determined from the degree of epiphyseal fusion of their long bones and dental eruption or wear (Horard-Herbin 2000; Piérard 1967). Sex was estimated by the presence/absence of the penile bone, only when the skeleton was whole or sufficiently represented.

Canid biometric data were obtained according to the work of Von den Driesch (1976) and Onar and colleagues (2005). Measurements were recorded with a digital calliper on the landmarks described in the literature. The robustness index and body mass were calculated following procedures stated by Onar (2005) and Onar and Belli (2005). The robustness index is based on the mid-shaft diameter (SD) and the great length (GL) of radius and tibia, analogous bones representing the fore and hind limbs, respectively. Body mass was calculated from the femur mid-shaft circumference. The estimate of height at the withers is based on the limb bones great length, according to Harcourt (1974).

The human sample comprises a total of 64 individuals. From Minferri, we have 8 adult males, 14 adult females and 15 sex-indeterminate remains (9 infants, 2 young adults and 2 adults). From Can Roqueta, we have 5 adult males, 8 adult females and 16 sex-indeterminate remains (6 infants, 7 young adults and 3 adults). The low number of males studied is probably the result of a demographic bias in recovered human remains and the difficulty of sex assignment in poorly preserved skeletons. The biological study of the human samples includes the estimation of sex and age at death. Identification of the sex of adult humans was based on the morphological observation of the coxal bone (Bruzek 2002). In absence of the hip bone, sex was also determined according to robustness and morphological characteristics of the skull (Buikstra and Ubelaker 1994; Ferembach et al. 1979). The age estimation of the sub-adult humans was based essentially on dental criteria, evaluating the stages of maturation and eruption of the deciduous and permanent teeth (AlQahtani 2009; Moorrees et al. 1963a, b). The degree of cranial and postcranial bone maturation was also taken into consideration (Scheuer and Black 2000). Infants were identified by the length of their long bones (Fazekas and Kosa 1978; Kosa 1989).

Since the determination of the age of death of adult individuals is very broad and precision is therefore difficult to attain, other criteria had to be considered, including traces of degenerative diseases, the degree of occlusal wear, the stage of pubic symphysis (Todd 1921, in Garvin et al. 2012) and the stages of formation of the auricular surface of the ilium (Lovejoy 1985, from Garvin et al. 2012).

For the isotopic study, the standard age groups were condensed into three groups based on their presumed type of nutrition and, in the case of adults, on their reproductive potential: 1) individuals under 4 years (including perinatal) who could yield isotopic signatures indicative of breastfeeding; 2) young adults from 5 to 14 years of age who no longer consume maternal milk, but have not yet attained physical maturity and possibly had access to a different diet from that of adults; and 3) adults surpassing 15 years of age. In these cases, when possible, the sexes are considered separately.

Other animal species for establishing an isotopic baseline comprise 19 domestic ungulates: 11 cattle (*Bos taurus*), 6 ovicaprines (*Capra hircus*/*Ovis aries*) and two pigs (*Sus domesticus*) (see Table 1).

3.2. Methodology of the isotope analysis

Measuring the isotopic composition of collagen from the most compact parts of the bones of adults results in values that offer data about the average diet over a period of time, estimated between five and ten years (Schwarcz and Schoeninger 2012) before the death of an individual. Collagen from non-compact (trabecular) areas of the bones of human adults is representative of the average diet over a period of about four years. The bone collagen turnover rate in dogs, in turn, is much higher than that of humans. Thus, the rate among young adult dogs is reported to be between six months and three years (Fischer et al. 2007).

The standard treatment of bone collagen extraction begins with at least ten ultrasonic bath wash cycles lasting about five minutes, alternating with acetone and distilled water baths until no turbidity is observed. The samples are then dried for 48 to 72 hours at room temperature. About 1 g of each bone is then ground in an agate mortar until reduced to particles measuring <0.3 mm.

Between 250 to 350 mg of bone powder was used for the extraction of bone collagen following the procedure advanced by Bocherens and colleagues (1997). The pulverised sample was subject to successive digestions in HCl 1M (20') and NaOH 0.125N (20 h) at room temperature to remove both the bone mineral fraction and potential contaminating organic materials. Each digestion was followed by microfiltration with 5 µm filters to remove the residue. Microfiltration allows separating the dissolved inorganic matter, as well as both soluble organic acids and bone organic components (including degraded collagen) from the well preserved collagen. Finally, the collagen was diluted by incubation in HCl 0.01M at 90º C for 17 hours, and was subsequently lyophilised and then subjected to combustion analysis in an isotopic ratio mass spectrometer (IRMS), Finnigan Mat Delta Plus coupled to an elemental analyser Carlo-Erba 1108, with an analytical reproducibility greater than 0.2‰ for carbon and greater than 0.2 ‰ for nitrogen. The IRMS analyses were carried out in the Unit of Instrumental Techniques of Analysis of the Services of Support to Research (SAI) of the University of A Coruña. The internal standard was acetanilide, and quantifications were duplicated. The results are presented under the delta (δ) notation, which reflects the proportion between both isotopes in the sample in relation to the proportion in an international standard, in this case, the Vienna PeeDee Belemnite (VPDB) and atmospheric air (AIR) for carbon and nitrogen respectively, as shown in the equation:

$$\delta X (‰)=(Rsample/Rstandard)-1 * 1000$$

where X is the heavier isotope and R is the $^{15}N/^{14}N$ or $^{13}C/^{12}C$ ratio.

All samples had well preserved collagen according to the usual quality criteria: percentage of carbon in collagen was higher than 13%, percentage of nitrogen in collagen was higher than 5% (Ambrose 1990) and C/N atomic ratio in collagen was between 2.9 and 3.6 (DeNiro 1985).

3.3. Statistical methods

Statistical tests were carried out using the Paleontological Statistics (PAST) software package (Hammer et al. 2001), version 3.20. The statistics include linear correlation analysis, Cluster Analysis (Ward's minimum variance method; Ward 1963) as an exploratory method to observe affinity in isotopic values between individuals and a hypothesis contrast to compare distributions of isotopic values between groups. To compare isotopic values between groups, due to the small number of individuals in some of the groups, we chose to perform a nonparametric test: a two-tailed Mann-Whitney *U* test (Mann and Whitney, 1947) with Bonferroni corrected *p* values and a significance level set at 0.05.

4. RESULTS

4.1. Age and physical traits of dogs in burials

The age at death of the dogs in both sites reveal fairly similar trends. Among the 21 dogs of Can Roqueta, 16 are adults ranging from about one year of age up to three to four years of age. Of the remaining individuals, two fall into the category of old adults, three are puppies between one and three months of age and two are young dogs around six months of age. In Minferri, out of a total of 11 dogs, four were adults. Of these, only one is over four years old, and the rest are between 2.5 and 3.5 years old. Four individuals are sub-adults (6 to 10 months old), and two dogs were too poorly preserved to determine their age. In summary, dogs in burials seem to have been preferably between 2.5 and 3.5 years of age; that is; they were individuals in transition towards adulthood or in its early stages.

Certain biometric traits yielded an approach to the morphology of the canid populations in both sites, as seen in Figures 6A and 6B. All of them are medium-sized animals on the basis of their height at withers (see Tables 2 and 4). The data obtained from the fore and hind limbs of the animals with complete epiphyseal fusion showed average height at withers values of 48.6 cm at Can Roqueta and 44.5 cm at Minferri (Fig. 6A).

The robustness index was calculated from a small number of animals (Table 3). The results again reflect a greater span in terms of size of the dogs of Can Roqueta (Fig. 6B). The difference in average height between the dogs of the two sites is repeated in the robustness index, with notable differences – especially in the tibia robustness index, in which the dogs of Can Roqueta clearly surpassed those of Minferri.

insert Figure 6A about here

insert Figure 6B about here

On the other hand, body weight estimations yielded greater values at Can Roqueta (between 14 and 19.4 kg) than at Minferri (between 8.4 and 14.5 kg), as seen in Table 3.

Dogs at Can Roqueta are therefore generally larger and more robust than those at Minferri. They also revealed pathologies in three cases (CRII-481-1, CRII-591-1 and CRII-505-1) in the lumbar neural apophyses that showed bent spinous processes (Albizuri et al. 2011b). These pathologies have been related to the use of the dog as a work animal, especially in sled dogs (Warren 2004), particularly in specimens from North America and Artic Siberia (Latham 2016). However, these pathological alterations could be related to the age-associated degenerative disease *spondylosis deformans*, which affects even wild specimens (Latham 2016), although, veterinary studies on these pathologies have determined a broader casuistry (Lawler et al. 2016).

insert Table 3 about here

Characterising foxes is much more complex, especially considering their small number. The old fox in funerary structure CRII 481 at Can Roqueta, represented by 130 bones, is almost complete (lacking the sacrum, the metatarsals and most of the phalanges). It was unearthed in anatomical connection (Albizuri et al. 2015). The absence of a penile bone indicates that the animal is probably female (Albizuri et al. 2015). This finding is also in line with osteometric data of foxes from current Anatolia (Onar 2005). It is noteworthy that this animal presents several fully healed fractures that occurred before its death. Towards the end of its life, this animal suffered a fracture of the right hind limb that affected the distal middle end of the fourth metatarsal, as evidenced by adhesion of the bone with the metatarsals to each side and the fusion of the distal fibula with the tibia, as seen in Figure 7. Both fractures occurred at the same moment. The vascularization observed in the callus of the fourth metatarsal indicates that the healing process was still active. The null angulation of both halves of the diaphysis of MT4 is compatible with the immobilization of this area, presumably by humans.

insert Figure 7 about here

The three foxes from Minferri correspond to adults deposited whole and in anatomical connection. A female and a male between 2 and 4 years of age were placed next to a woman in burial MIN-88. A third, in structure MIN-355, is identified as an 18-month-old male placed next to the isolated femurs of a woman.

4.2. Results of the isotopic analysis

A total of 120 samples yielded collagen in line with the requested standards of quality, that is, yield values greater than 3.5%, atomic C/N ratios between 2.9 and 3.6 (DeNiro 1985) and percentages of carbon and nitrogen greater than 13 and 5%, respectively. The detailed data, together with the values obtained from $\delta^{13}C$ and $\delta^{15}N$, are listed in Table 4 (domestic ungulates), Table 5 (canids) and Table 6 (humans) and represented in Figure 8.

insert Table 4 about here
insert Table 5 about here
insert Table 6 about here
insert Figure 8 about here

The domestic ungulates from both sites (Table 4) serve to establish an isotopic baseline and lead to a better interpretation of canid and human diets. Cattle (*Bos taurus*) from Minferri (n=6) show fairly homogeneous values of $\delta^{13}C$ = -19.8±0.5‰, from -19.0 to -20.3‰. Yet, the values of nitrogen are more dispersed ($\delta^{15}N$ = 6.4±1.4‰, from 4.5 to 7.6‰). The five *Bos* from Can Roqueta offer $\delta^{13}C$ values analogous to those of Minferri (average $\delta^{13}C$ = -19.4±0.6‰, from -18.9 to -20.1‰), and $\delta^{15}N$ average values and dispersion slightly lower than that of Minferri (average $\delta^{15}N$ = 5.8±0.7‰, from 4.8 to 6.2‰). Sheep and/or goat (*Ovis/Capra*) $\delta^{13}C$ values are fairly similar at both sites, in spite of those at Can Roqueta (n=2; -19.2±0.4‰) being slightly higher than those at Minferri (n= 4; -19.7±0.6‰). The average $\delta^{15}N$ values of sheep and goat at Minferri reveal higher values (7.5±1.7‰) than those at Can Roqueta (5.1±1.2‰). Both sites offer widely dispersed $\delta^{15}N$ values for sheep and goats: a dispersion that is not related, in principle, to the species. This dispersion probably stems from the fact that these animals were fed in different environments. Finally, the data for the pigs of Minferri (n=2) revealed more negative $\delta^{13}C$ values (-20.2±0.1‰) and higher $\delta^{15}N$ values (8.6±0.9‰) than other ungulates.

The isotopic values of the dogs (*Canis familiaris*), foxes (*Vulpes vulpes*) and one large canid, a wolf (*Canis* cf. *lupus*), are listed in Table 5. The wolf from Can Roqueta shows relatively high values for both isotopes ($\delta^{13}C$=-18.8‰; $\delta^{15}N$=9.4‰), greater than the rest of the dogs from the same site and even greater than that of the dogs at Minferri, which generally have higher values than those at Can Roqueta. Adult Minferri dogs (n=7) yielded $\delta^{15}N$ values (average 8.7±0.4‰, from 8.5 to 9.1‰) that were greater than those of Can Roqueta (n=16; average $\delta^{15}N$ = 7.7±0.6‰, from 6.5 to 8.6‰), while $\delta^{13}C$ values are also slightly more positive (average -19.0±0.3‰, from -19.3 to -18.5 at Minferri and -19.3±0.3‰, from -20.1 to -18.8‰ at Can Roqueta). The values of the young dogs at Minferri (n=4) hardly differ from those of adults (δ^{13}C=-18.7±0.3‰, δ^{15}N=9.0±0.3‰). At Can Roqueta, the two young dogs revealed very different values for both isotopes – practically at both ends of the adults' distribution. The δ^{15}N average value of the three puppies is similar to that of adults (7.8±0.9‰), but offers slightly higher δ^{13}C mean values (δ^{13}C=-18.7±0.3‰). However, one of the three puppies at Can Roqueta shows clear δ^{15}N enrichment, as expected of an animal at the age of lactation.

The four foxes (3 from Minferri and 1 from Can Roqueta) revealed different values. At Minferri, the average δ^{13}C values are slightly more negative than those of adult dogs (-19.4±0.3‰), and the δ^{15}N values are slightly higher than the adult dogs (9.3±0.6‰). The old fox from Can Roqueta shows an isotopic signature far from the adult dogs at the site, and much farther from the foxes at Minferri. Its combination of high δ^{13}C values (-18.0‰) and a relatively low δ^{15}N (7.8‰) only finds some similarity with some puppies and one sub-adult from the site, yet it still differs from them in its less negative δ^{13}C.

As for humans, adults at both sites (Table 6) showed quite similar distribution in isotopic values, with averages slightly higher at Minferri (n=24; average δ^{13}C=-19.1±0.5‰, average δ^{15}N=9.8±0.7‰) than those at Can Roqueta (n=15; average δ^{13}C=-19.5±0.3‰, average δ^{15}N=9.1±0.7‰). The apparent similarity disappears when males and females were analysed separately. In Can Roqueta, there is a clear distinction between sexes in δ^{15}N, with the female (n=8) mean value of 8.7±0.2‰ being lower than that of the site's males (n=5; δ^{15}N=10.0±0.7‰) and lower than the mean of individuals of both sexes at Minferri. Females at Minferri, in turn, showed a greater dispersion of both isotope values (n=14; δ^{13}C=-19.3±0.6‰, δ^{15}N =9.6±0.8‰) than the males (n=8; δ^{13}C=-18.9±0.2‰, δ^{15}N=10.1±0.3‰). Young humans (between 5 and 15 years of age) are isotopically indistinguishable from adults. At Can Roqueta specifically, their average values are equal to those of females. Both sites clearly share high δ^{15}N values in most children (less than four years of age). However, there are exceptions: the isotopic signatures of one child from each site are indistinguishable from those of young and adult humans, and at Can Roqueta, the case of a perinatal individual attains much higher δ^{15}N values than those expected when compared to the adults. This is reflected in the great dispersion of the values of the children at Can Roqueta, as opposed to those at Minferri (see Fig. 8).

5. DISCUSSION

5.1. Isotope baseline, environment and inter-site comparison

Today, there are climatic differences between the sites at Can Roqueta and Minferri. Although, both share Mediterranean conditions with a tendency towards a continental climate, and although, Can Roqueta is closer to the coast than Minferri, the littoral mountains act as a barrier. The average annual rainfall at Can Roqueta ranges between 550 and 700 mm. Minferri's continental climate, in turn, is more pronounced, with greater aridity and an average annual rainfall of about 400 mm. The two sites presently also share similar average temperatures, although, those of Minferri are slightly higher (Bolós 1979). Carbon isotopic discrimination studies of *Pinus halepensis* coals from Minferri (Ferrio et al. 2006) indicate a higher average annual rainfall in the past, between 464±50 and 576 mm. Unfortunately, this type of data is not available for Can Roqueta. Yet, its lower aridity during the period of study appears to correspond to a regional trend (Ferrio et al. 2006). If this were the case, the climatic difference could account for the higher general δ^{15}N values at Minferri, since aridity yields an increase in δ^{15}N values in soils and plants (Heaton 1987). The climate also affects the δ^{13}C baseline, as aridity and insolation are positively correlated to δ^{13}C values in plants, while rainfall is negatively correlated (Szpak et al. 2013; Goude and Fontugne 2016). It is therefore possible that the difference in isotopic values between the fauna and humans of both sites is a result of slightly different isotopic baselines.

For δ^{15}N, the average difference between both sites is +0.6‰ in *Bos*, but rises to +2.4‰ between *Ovis/Capra*. Thus, δ^{15}N values at Minferri among all the herbivore domestic ungulates are +1.2‰ higher than those of Can Roqueta, while ungulates showed lower values (-0.3‰). However, the dispersion of the ovicaprine values seems to indicate that not all of them were fed in the same environment. As a whole, strict herbivores from both sites do not differ significantly in their isotope values (Mann-Whitney *U* test, U=18.5, p=0.1102 for δ^{13}C and U=15.5, ^{p}=0.058 for δ^{15}N).

We only have data from two Minferri pigs, of which there is a clear isotopic difference between them. Clearly, one of the pigs is more omnivorous than the other, and probably received leftover human food in its diet.

Adult dogs also showed more positive mean values at Minferri than at Can Roqueta, with a significant difference of +1.0‰ for $\delta^{15}N$ (*U*=2.5, *p*>0.0001) and +0.3‰ for $\delta^{13}C$ (*U*=29, *p*=0.055). Lastly, Minferri adult humans are enriched with +0.7‰ for $\delta^{15}N$ and +0.4‰ for $\delta^{13}C$ over those at Can Roqueta. Both sites have slightly different medians for adult human isotopic values (Mann-Whitney *U* test, *U*=82.5, *p*=0.0022 for $\delta^{13}C$, *U*=106, *p*=0.0172 for $\delta^{15}N$).

Thus, it is not possible to compare the $\delta^{15}N$ or $\delta^{13}C$ values of the two settlements directly, given the variation of the mean differences in each group (ungulates, canids, humans). Therefore, we are going to consider both sites independently.

5.2. Canid diet

When defining the trophic level of an organism by studying stable isotopes, it is common to compare the isotopic signals of the individual in question with the baseline values obtained from individuals with an unequivocally herbivorous diet. In our case, we could use as baseline the $\delta^{15}N$ values of cattle and even of sheep or goat of each deposit. Thus, the adult dogs at Can Roqueta showed an offset of +1.9‰ on the cattle (+2.1‰ with respect to all herbivorous ungulates), lower than the minimum of +3‰ expected for a trophic level (Bocherens and Drucker 2003). In Minferri, the offset is +2.3‰ in relation to the cattle (but only +1.9‰ if all herbivorous ungulates are included). We can therefore say that the diet of the dogs from both sites was not particularly rich in animal protein, as would be expected in a wild carnivore. In fact, the wolf at Can Roqueta does reach a characteristic carnivore offset (+3.8‰), while the fox at this site resembles dogs in its $\delta^{15}N$ value. In the Minferri foxes, the $\delta^{15}N$ offset is +2.9‰ over the cattle.

However, in defining the trophic level of dogs with respect to herbivorous ungulates, we cannot resort to a simple calculation of the offset of the mean values of $\delta^{15}N$. In the case of Can Roqueta, adult dogs have a high dispersion in their values of $\delta^{15}N$ for a mean value to be representative of the group. In the case of Minferri, the herbivorous ungulates present extended values of $\delta^{15}N$. In addition, we cannot lose sight of the differences in $\delta^{13}C$ that could respond to the introduction of foods with particular signatures, such as marine protein or C4 plants (Chisholm et al. 2006; Schwarcz and Schoeninger 1991, 2012). Therefore, we use a cluster analysis to group individuals together according to their similarities in the values of both isotopes.

The cluster analysis of all the adult animals from each site, as shown in Figure 9, yielded relevant data. All the dogs at Minferri (Fig. 9A), including the specimen in structure MIN-150, outside of the main assemblage, as well as the foxes, align with the values of one pig and two *Ovis/Capra*. The pig probably had an omnivorous diet, perhaps including leftover food. Ovicaprines, however, must have come from other environments, given their high δ^{15}N signal compared to other herbivores, which are plainly separated in another cluster. The dogs at Can Roqueta (Fig. 9B), on the other hand, split into two clusters: a set of eight dogs is grouped together with the fox and the wolf, while the remaining eight dogs cluster with some herbivorous ungulates. A statistical analysis (Mann-Whitney's non-parametric *U* test) indicates that at both sites, the groups obtained are strongly determined by differences in δ^{15}N rather than δ^{13}C, and that the difference in δ^{15}N median of each cluster is highly significant, and carbon signature is only of relative importance in a secondary sense.

insert Figure 9 around here

If the different values observed in δ^{15}N are related to a greater or lesser consumption of animal protein, it is interesting to compare these values with osteometric data to see if the greater intake of animal protein is reflected in the size or robustness of dogs. Figure 10 shows the results of comparing both parameters. Unexpectedly, neither height at withers (Fig. 10A), robustness index (Fig. 10B) nor estimated body mass (Fig. 10C) showed a positive correlation with δ^{15}N values in adult dogs. In fact, the correlation is negative at the height at withers and strongly negative for body mass. The parameters defining the robustness of the correlation (correlation coefficient r, standard error of the correlation coefficient SEr and probability *p*) indicate an unexpected strong relationship between the lower intake of animal protein and the increase in body size and especially in body mass (see Figure 9). In summary, dogs with a greater body mass have lower isotopic values, indicating lower consumption of animal protein and, accordingly, a higher input of vegetal food. Interestingly, some of these also show spine pathologies. It could be argued that the scarcity of proteins from animal origin could have caused such pathology in these dogs. However, a veterinary study and diagnosis was made using microcomputed tomography (Philips, Brillance CT 16 Slice®) (Albizuri et al. 2011a, b). The diagnosis was due to lateral deformation from weight borne from an early age. The specimens analysed were complete, with no associated infectious, degenerative or traumatic pathologies in any other part of their skeleton, which would be expected in the case of common aging processes (Latham 2016), not forgetting that the affected individuals are relatively young (between 1 and 2.5 years). Deformations due to taphonomic causes have also been discarded. The vertebral bodies were normal, but different spinous processes presented a lateral curving in different directions (right, left). This fact rules out a deformation by infectious causes, since in such a case, all the spinous processes would be deflected in the same direction (Lawler et al. 2016). In addition, the radiological study showed that the spinous processes show a thickening of the cortical bone only in the affected section of vertebrae, which is a response to the continuous weight of vertical loads on the lumbar region, possibly being felt from an age when their bones were still in the process of ossification (Albizuri et al. 2011a, b).

insert Figure 10 around here

5.3 Human versus canid diet

Interpreting the diet of the canids at the sites of Can Roqueta and Minferri from the isotopic data requires comparisons with the values of other domestic animals, particularly, with humans. This study has therefore included data from the humans most closely linked to canids, that is, those either sharing burial structures with these animals or those in burials near non-funerary structures containing canids. Hence, when considering the isotopic values of the adult humans of Minferri and Can Roqueta and the values of the respective assemblages of domestic ungulates (see Fig. 8), the ^{15}N enrichment (+3.5‰ in Can Roqueta, +3.0‰ in Minferri) is in the lower limit for one trophic level (O'Connell et al. 2012), suggesting that the overall diet at both settlements was not especially rich in animal protein. The average $\delta^{13}C$ offset between humans and herbivores was also reduced (-0.2‰ in Can Roqueta, +0.7‰ in Minferri), suggesting that most of the protein came from local terrestrial environment, and no marine or freshwater resources were consumed routinely (Chisholm et al. 2006). In Minferri, the variety of human isotopic values is greater than in Can Roqueta, which points to a greater variety in feeding practices.

Regarding potential differences in animal protein consumption between sexes, females of Can Roqueta showed lower values of $\delta^{15}N$ than the males, most of which clearly reflect a higher intake of animal protein than the rest of the individuals, including the canine identified as a wolf. On the contrary, in Minferri, some females reach values of $\delta^{15}N$ that are equal to those of the males or even surpass them.

High $\delta^{15}N$ values in children younger than four years of age are related to breastfeeding, since maternal milk in humans increases $\delta^{15}N$ values between 2 and 3‰ with respect to maternal isotopic values (Fogel et al. 1989; Fuller et al. 2006). Children at both Minferri and Can Roqueta show to a greater or lesser degree signs of their stage of lactation, thus, barring the two aforementioned exceptions.

The cluster analysis applied to all dogs and humans revealed different patterns at each site. In Can Roqueta, as shown in Figure 11, most children form a group that is clearly distinct from all other humans. Most males are grouped together with the wolf. Dogs fall into two groups: 1) dogs with higher input of vegetables (now including the fox); and 2) dogs that cluster with a group of humans, including several young humans, as well as a male and a female. Mann-Whitney *U* tests show that differences in average $\delta^{15}N$ between clusters are highly significant.

At Minferri, as shown in Figure 12, all dogs appear in a group, including young humans and some females, that is marked with lower $\delta^{15}N$ values. Two male foxes form part of this group, which is in line with a diet marked by a lower animal protein intake. A third fox, in turn, a female, is associated with another group of female humans with values closer to males, which also indicate a greater consumption of animal protein.

*insert Figure 11 about here**insert Figure 12 about here*

Isotopic signatures indicate that dogs at both sites did not consume the same food, nor in the same proportion as humans, but there is an overall similarity, especially with females and young people. The dog isotopic values at both sites indicate an intake of C3 plants, evidencing their mixed diet. By contrast, the only canid classified by its osteometric data as a wolf (*Canis* cf. *lupus*) reveals higher values, indicating that it consumed more meat than the other canids, although, this is below the level of human males who have more animal protein in their diet. Therefore, the isotopic data does not confirm the classification based on the archaeozoological analysis and raises questions about whether this canid was a larger dog, even a hybrid that fed differently.

The overall isotopic data of humans and dogs shows great correspondence with the palaeoeconomic data gleaned from agriculture and livestock research, which points to the development of cereal crops and legumes, as well as the exploitation of wild plants and products yielded by the domestic animals (meat and milk). Thus, the values of dogs could mirror the human diet – a line of thinking advanced by most isotopic studies that include dogs and humans (Cannon et al. 1999; Guiry 2012; Guiry and Grimes 2013; Noe-Nygaard 1988; Pearson et al. 2015; Pechenkina et al. 2005). Previously reported $\delta^{15}N$ differences between archaeological humans and dogs were, on the average, 2 to 3‰ lower in dogs, although, in some cases, both groups showed indistinguishable nitrogen signatures (for a summary, see Guiry, 2012). Adult humans from Can Roqueta and Minferri showed $\delta^{15}N$ values that are +1.4 and +1.1‰ higher, respectively, than adult dogs: a slim difference that indicates their overall similar trophic level. However, except in the case of the robust dogs of Can Roqueta, who have a high proportion of cereals in their diet, the results of the isotopic analysis do not allow us to affirm that the humans fed their dogs specifically. Dogs have an opportunistic eating behaviour, so they could have accessed food waste or human faeces, although, in the case of coprophagy, the values of $\delta^{15}N$ would increase, since in humans the faeces are enriched with ^{15}N in the diet (Kunhle et al. 2013).

5.4 The ethnographic parallelisms

In Minferri, dogs cluster clearly within certain human groups (females and youth), at times, from the same structures. Moreover, a similar trend is also discernible at Can Roqueta between a group of dogs and young humans. This correspondence at both sites could indicate that females and young people dedicated greater care to dogs. This type of relationship was observed in the 18th century AD among the Hidatsa of North Dakota, whose women were responsible for the training and feeding of these animals (soup of corn and meat scraps), as they were a precious asset, serving as pack dogs, especially for collecting wood (Wilson 1924). The male diet at Can Roqueta and Minferri, in turn, differs from the female diet and that of most of the dogs. Even if the sample of males is smaller than that of females and young people, this distance could potentially indicate a division of labour.

The dogs at both sites share a morphological homogeneity that could point to a certain control over their reproduction. Dogs in most of the funerary structures are young animals (2.5–3.5 years), showing complete epiphyseal fusion with weights corresponding to that of adults. This homogeneity, combined with the data on their diet, leads to speculation as to a selection based on certain traits. Nonetheless, there are differences in height and body volume that indicate a greater corpulence among the Can Roqueta assemblage. Can Roqueta also has a group of dogs with very low $\delta^{15}N$ signatures and a greater body mass, that had a singular diet rich in cereals. Certain animals from this group show vertebral pathologies that suggest they served as pack animals. Thus, some dogs of Can Roqueta, that appear to have been assigned to specific tasks requiring a great amount of energy, could had been fed a diet rich in carbohydrates. Cereals are not a foreign food for dogs, because – parallel to the development of agriculture – dogs, like humans, were developing ways of improving digestion of starch through the multiplication of copies of the amylase gene (Ollivier et al. 2016). Ancient written sources confirm this type of food in the canine diet: Columela, Hispano-Roman scholar of the first century AD, recommended for the feeding of dogs "barley flour mixed with whey" or "spelt or wheat bread, mixed with cooked bean broth" (Columela, 7.12.10, Álvarez de Sotomayor 1824).

The diet of the dogs at Minferri, by contrast, appears to be more uniform, although, they must have also carried out assigned tasks. Work dogs, in order to ensure their performance must not go hungry. In some cases, their food is equivalent to that consumed by humans (Koster and Tankersley 2012). In current cases, this control is visible: the food offered to dogs in the Siberian region of Lake Baikal, for example, is cooked separately, and although it is very similar to human nutrition, it includes less pleasing items, such as tendons, hoofs, periostea, intestines and blood (Bocherens et al. 2015). Moreover, food preparation is at times given special care, such as when dogs must travel long distances in the company of their herds, as is currently the case of the Kangal race in Turkey, which are ancestrally nourished with a mixture of barley flour, oats and wheat with milk whey or milk and yogurt, called *yal*. Only on very rare occasions are they offered leftovers of lamb bone. Meat is normally available to dogs only in the form of what they can catch, usually rodents in the desert or around the village, or an odd bird or hare (Isik 2009). Ethnographic research on the preparation of food for dogs in Haut-Diois, France (Chevallier 1987) describes the two types of diets. The first, called *soupe*, is more common and is given to dogs once a day (in the morning). It is in fact a meal of varied content, most often consisting of the leftover soup previously eaten by humans. The second type of food for dogs – especially conceived for working dogs, *chien de berger* (sheepdogs) – does not contain any animal content. Denis Chevallier further stated that the dog's daily diet is mainly vegetarian and is only occasionally supplemented by animal castoffs, such as sheep fetuses, varieties of viscera, bones, etc (Chevallier 1987).

In Can Roqueta, a high proportion of cereals were also observed in some puppies, leading to the hypothesis that in certain cases (absence of the mother, selection of specimens for work require differential feeding patterns), these animals were raised with a higher intake of carbohydrates. Only one puppy at Can Roqueta (CRII-591-2), who was between two and three months old, showed a high δ^{15}N signature that can be attributed to the trophic effect of ingesting maternal milk (Fogel et al. 1989). The other two puppies (between one and four months of age) combine isotopic signatures characterised by the absence of maternal milk and a diet rich in cereal. It is noteworthy that ethnoarchaeological studies carried out in Tunisia (Alonso et al. 2014) indicate that women mix part of the cereal grinding by-products with water to feed puppies, as shown in Figure 13.

insert Figure 13 about here

5.5. Diet of foxes

According to their isotopic signatures, the foxes of Minferri consumed various types of food. They cannot, in fact, be linked to any specific diet. One of these foxes, a female, exhibited signs of consumption of a more carnivorous diet. In all three cases, however, they cluster together with human females (with their different types of food) and dogs. On the contrary, the old fox at Can Roqueta revealed a diet with important input of vegetal protein, similar to that of the dogs and closer to two puppies and a young dog (see Fig. 10), albeit with more positive δ^{13}C values. This deviation could be interpreted as resulting in a diet rich in marine molluscs (Chisholm et al. 2006). Yet this is unlikely, due to Can Roqueta's relative distance from the sea. In addition, the fractures of this animal's metatarsus and fibula were fused at a late period in its life, probably preventing it from traveling long distances for several weeks. This fracture must have caused a limp that could leave the animal more vulnerable and could mean that it would be hunted more easily. But its particular isotopic signature, which differs significantly from the Minferri foxes, raises the possibility that this fox could have been fed by humans for a period before its death at old age. Although, there is no archaeological evidence to back up this hypothesis, the old fox from Can Roqueta could have received food with cereals, including an appreciable input of the C4 group, such as foxtail millet (*Setaria viridis/italica*), since there are no wild plants in the archaeological record that can offer these results (Vila 2018). Yet, this interpretation must be taken with caution, as very little is presently known about this type of millet in the Northwest of the Iberian Peninsula and is only recorded at the cave of Punta Farisa in a Middle Bronze Age context (Alonso and Buxó 1993). Although, the presence of foxtail millet at Can Roqueta increases over time in structures of the Late Bronze Age to the Early Iron Age (Antolín, Mensua, Piqué, personal communication, unpublished 2008), evidence on the Early-Middle Bronze Age phases, the subject of the present study, are still lacking.

6. CONCLUSIONS

In this work, we present an isotopic analysis of canids and humans in two Bronze Age sites in the Northeast region of the Iberian Peninsula, Can Roqueta and Minferri, respectively, with the peculiarity that these animals were found deposited during human burials or in nearby ritual structures. This led us to contemplate their possible relationship in life with the humans, which could in fact transcend that of the realms of ceremony and symbolism. Furthermore, the isotopic study of the dogs and foxes also yields information about their diet and their role in the economic and social environment of each settlement.

The dogs at both sites presented a morphological homogeneity that may indicate a certain control over their reproduction. In addition, the inclusion of cereals in their diet, evidenced by their isotopic signatures, leads to the interpretation that animals were subject to human control and possibly some sort of selection based on specific characteristics. The inclusion of cereals in the diet of dogs cannot occur naturally. This indicates that humans may have deliberately prepared the food consumed by the animals at both sites, and that the food probably included the same plants, notably, cereals of group C3, as those consumed by humans. Proteins identified in the animal diet probably came from bones and leftovers of meat, muscles and tendons, or even from dairy products, but these could also be the result of the dogs' behaviour as opportunistic feeders.

The humans probably fed the dogs to ensure that they fulfilled their assigned tasks, be it the task of guarding or protecting grazing herds. The relationship observed at both sites between the diet of dogs and that of female and young humans appears to suggest a greater dedication by this human group to the nurture and care of dogs.

However, there are differences that point to a diet richer in cereal, detectable in the most robust specimens that also show load pathologies. This coincidence opens up an interesting line of research into the possibility of a differential feeding of dogs intended for work in ancient societies. Isotopic data from some of the foxes indicate a similarity with the feeding patterns of the humans that they accompanied at death and with dogs, raising the possibility of a high level of interaction between these wild canids and societies of the past for reasons that still cannot be identified.

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Table captions

Table 1. Analyzed structures of Can Roqueta and Minferri. In each structure: identification of the site and area, chronological identification (E-MBA: Early-Middle Bronze Age), functional interpretation (FS: funerary structure; NFS: no funerary structure), and minimum number of individuals (MNI) of humans and fauna. In brackets, those that were sampled for isotopic analysis.

Table 2. Data on canid samples: structure, species and identification number, age category assigned, age in months (m) or years (y) and sex when it is possible to determine it. Height at withers average (SH) is expressed in cm and estimated according to Harcourt (1974) from the long bone great length (GL). Those data with an asterisk were obtained from a single bone measurement.

Table 3. Osteometric data of dogs: long bone measurements (GL, great length; SD, mid-shaft diameter) are expressed in mm. Estimation of height at withers (SH) is expressed in cm according to Harcourt (1974). Body weight estimation (BW) is expressed in kg and is calculated from femur circumference (Onar and Belli 2005). Robustness index according to Onar and Belli (2005).

Table 4. Isotopic analysis values of the bone collagen of domestic ungulates: funerary structure and sample number, species, sex (F, female; M, male), quality parameters (collagen yield in %, bone %C and %N, atomic C/N) and isotopic ratio for C and N (nd = not determined).

Table 5. Isotopic analysis values of bone collagen of the canids: structure and sample number, species, quality parameters (collagen yield in %, bone %C and %N, atomic C/N) and isotopic ratio for C and N (nd = not determined).

Table 6. Isotopic analysis values of human bone collagen: unit and individual number, age group for isotopic analysis, sex in adults (F, female; M, male; I , indeterminate), quality parameters (collagen yield in %, bone %C and %N, atomic C/N) and isotopic ratio for C and N (nd = not determined).

Figure captions

Figure 1. Situation map of Can Roqueta and Minferri and other sites cited in the text: 1) Bòbila Madurell, 2) Can Gambús, 3) Pinetons, 4) Mas d'en Boixos, and 5) Cantorella

Figure 2. Plan of the archaeological sectors of Can Roqueta highlighting the structures dating to the Early-Middle Bronze Age. Detail of Can Roqueta II: funerary structures (triangle) non-funerary structures (circle)

Figure 3. Animal deposits at Can Roqueta. a) CRII-736: piglet skeleton, b) CRII-583: cow skull, c) CRTR-162: dog skeleton, d) CRII-481: fox skeleton, and e) CRII-481: sheep skeleton

Figure 4. Plan with the position of the Early-Middle Bronze Age Minferri animal deposits. Detail of archaeological sectors: a) Area 2 and b) Area 9

Figure 5. Animal deposits at Minferri: a) MIN-355: female burial with a complete fox skeleton, b) MIN-88: female burial with two complete fox skeletons, c) MIN - 405: skeletons of two cows and two dogs, d) MIN-405: skeletons of one cow and one dog, e) MIN-361: dog skeleton, f) MIN-354: dog skull, f) MIN-354: dog skeleton, h) MIN-367: dog skull, i) MIN-367: dog skeleton, and j) MIN-367: dog skull

Figure 6. Osteometric data of dogs. A, Comparison of dog shoulder height by site. B. Comparison of radius and tibia dimensions by site.

Figure 7. CRII-481 right hindlimb of a fox with fused fractures on the distal fibula and the fourth metatarsal*:* a) palmar view of the five metatarsals. The arrows highlight the scars on the shaft, on the distal tibiofibular area and on the fourth metatarsal, b) dorsal view of the metatarsal and the healing in the fourth metatarsal that affected the other metatarsals, c) plantar view of the metatarsals and the healing area in the fourth metatarsal that affects the other metatarsals.

Figure 8: Bivariate diagrams of the isotopic signatures of C and N at Can Roqueta and Minferri. A and B, all individuals. C and D, mean values with error bars equivalent to 2 SD except for groups with less than 3 individuals that are represented individually.

Figure 9. Cluster analysis of adult canids (dogs, foxes and wolf) and domestic ungulates (cattle, sheep/goat, pig) of A, Minferri and B, Can Roqueta. Results of the Mann-Whitney *U* test for inequality of medians and distributions are placed between the compared clusters.

Figure 10. Correlation between the isotopic signature of N and the osteometric data of certain Minferri and Can Roqueta dogs: A, robustness index; B, average height at withers; C, body mass. Squares represent young dogs while circles are adult ones. Circles in bold are individuals with vertebral pathologies.

Figure 11. Cluster analysis of canids (dogs, fox and wolf) and humans of Can Roqueta, with Mann-Whitney *U* test results between compared clusters.

Figure 12. Cluster analysis of canids (dogs and foxes) and humans of Minferri, with Mann-Whitney *U* test results between compared clusters.

Figure 13. The current ethnographic example of feeding puppies cereal by-products by the people of Ouarten tribe (El Kef, Tunisia): a) Location of the Ouarten area, b) Open landscape and isolated houses with their pens and central courtyards in the area, c) Woman classifying products and by-products by sieving during the milling process of hulled barley with a rotary quern (at her left side), d) puppies eat meal consisting of a ground cereal by-product mixed with water, e) the grinding by-product placed into a hole in a courtyard. All images from (Alonso et al. 2014)

Figure 1

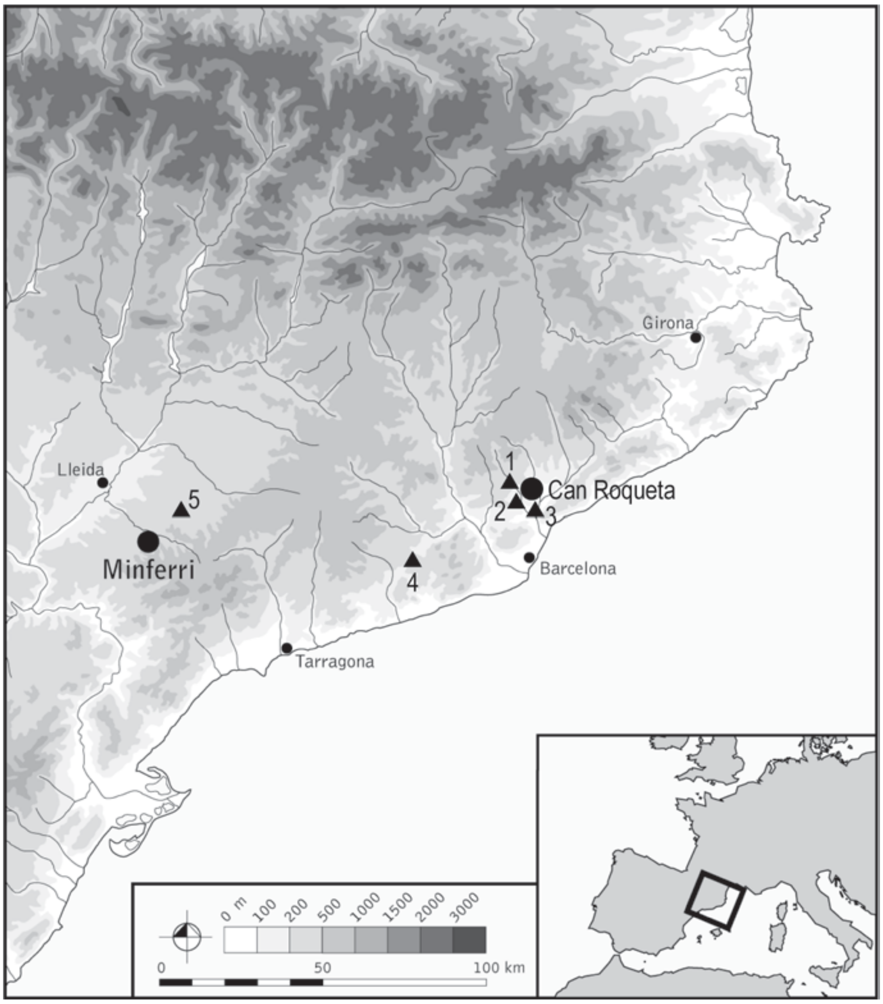
Girona
1
Can Roqueta
2
3
Lleida
5
Minferri
4
Barcelona
Tarragona
0 m
100
200
500
1000
1500
2000
3000
0
50
100 km

Figure 2

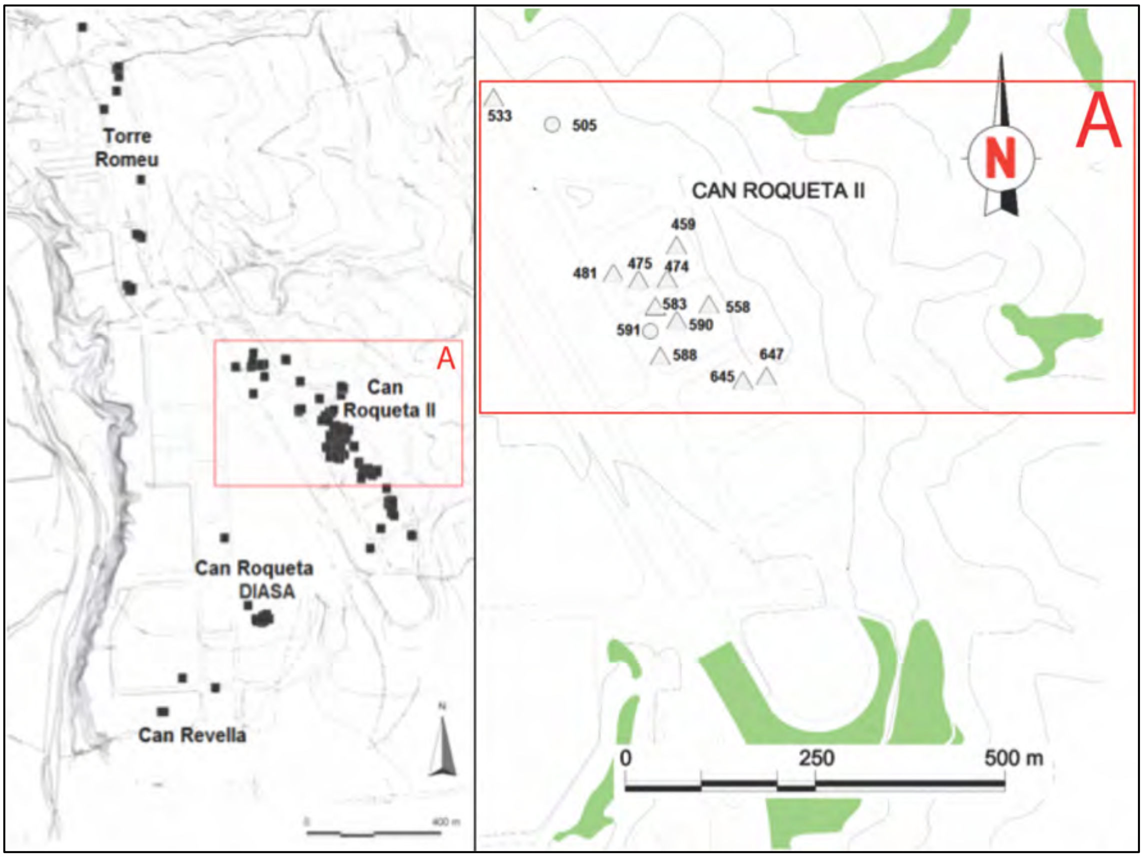
Torre
Romeu
A
Can
Roqueta II
Can Roqueta
DIASA
Can Revella
N
0
400 m
533
505
CAN ROQUETA II
459
481
475
474
583
558
591
590
588
647
645
A
N
0
250
500 m

Figure 3

Figure 4

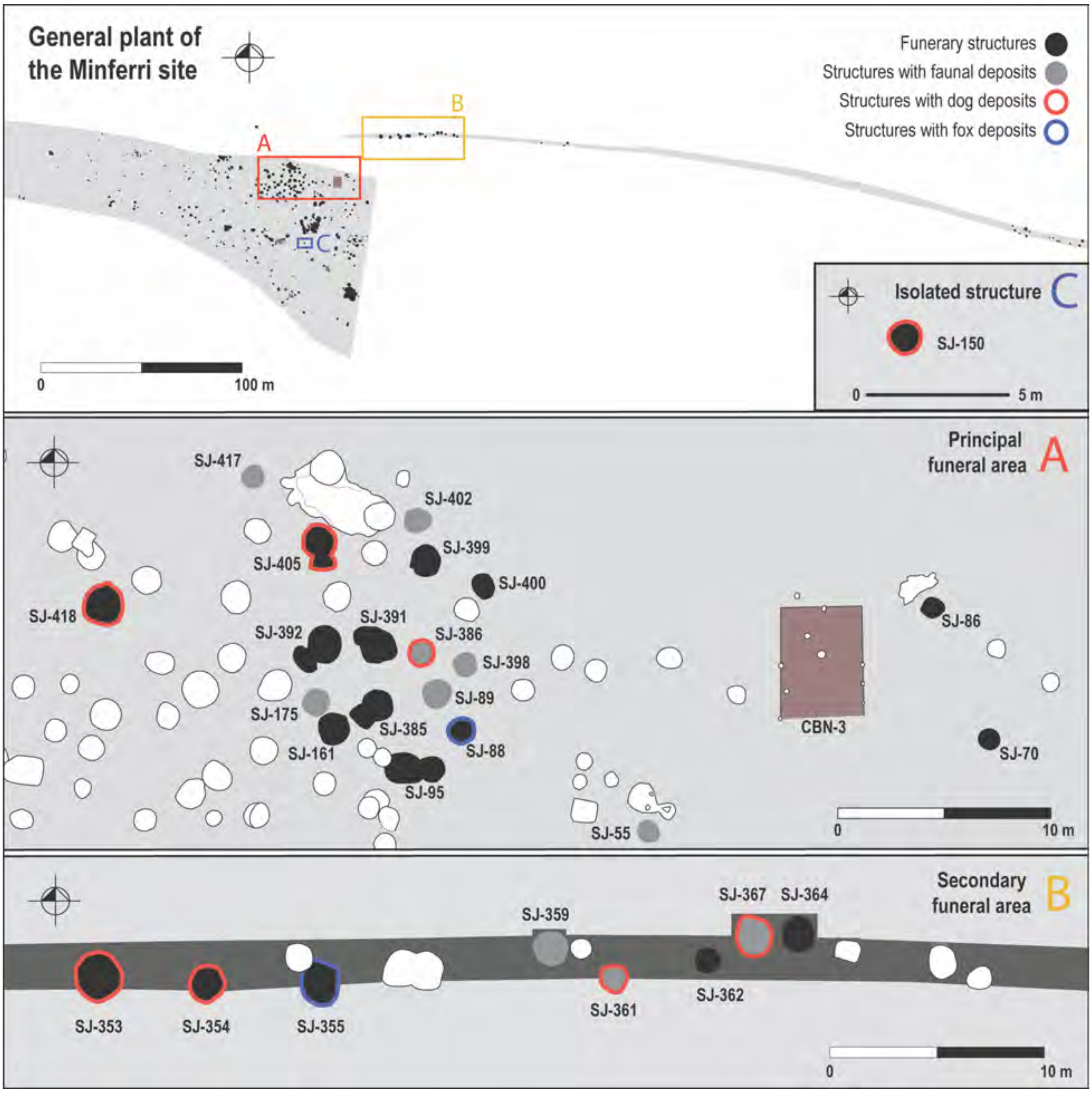
General plant of the Minferri site
Funerary structures ●
Structures with faunal deposits ●
Structures with dog deposits ○
Structures with fox deposits ○
A
B
C
0
100 m
Isolated structure C
SJ-150
0
5 m
Principal funeral area A
SJ-417
SJ-402
SJ-405
SJ-399
SJ-400
SJ-418
SJ-391
SJ-392
SJ-386
SJ-398
SJ-89
SJ-175
SJ-385
SJ-161
SJ-88
SJ-95
SJ-55
CBN-3
SJ-86
SJ-70
0
10 m
Secondary funeral area B
SJ-359
SJ-367
SJ-364
SJ-353
SJ-354
SJ-355
SJ-361
SJ-362
0
10 m

Figure 5

Figure 6

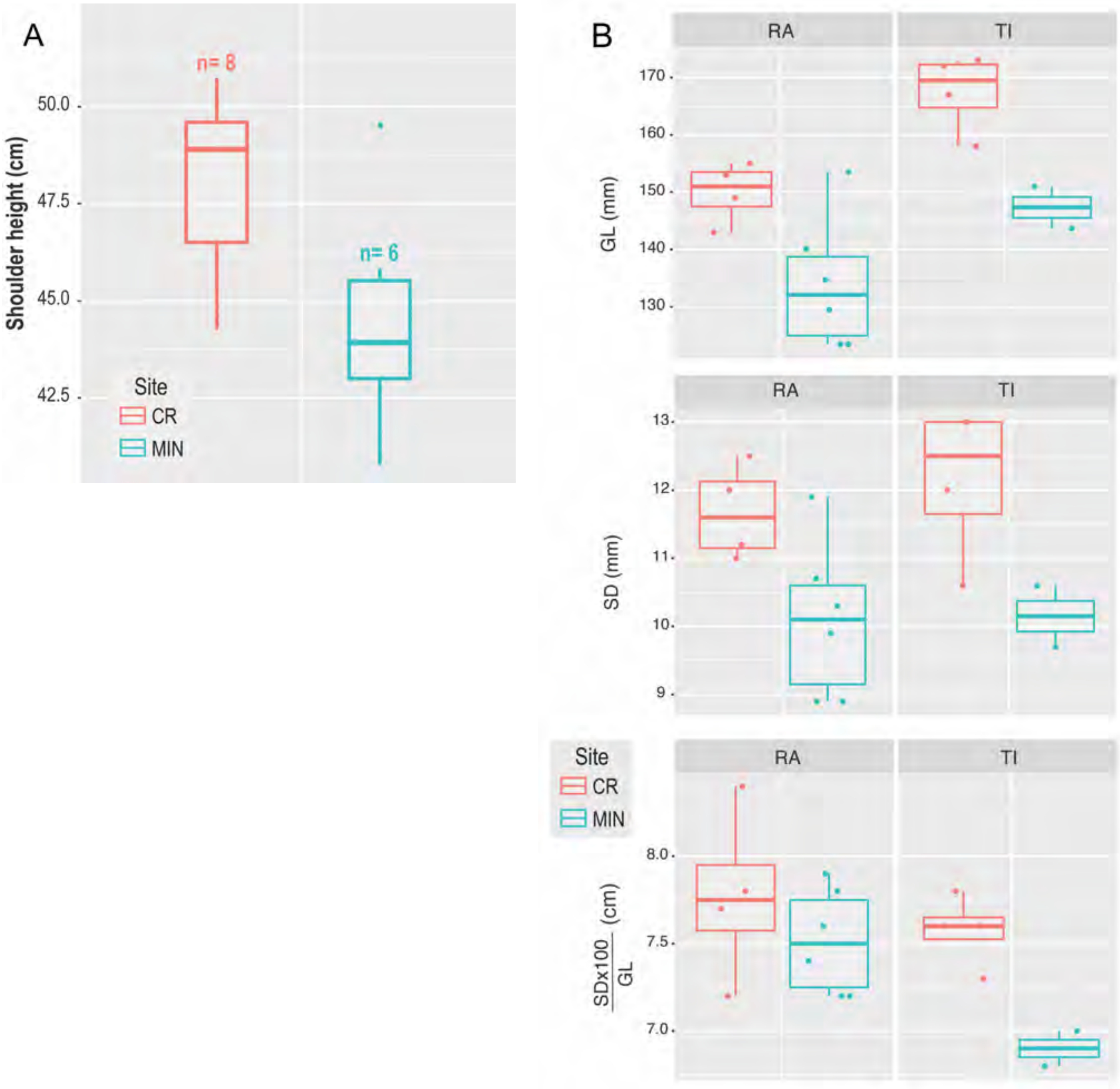
A
Shoulder height (cm)
50.0
47.5
45.0
42.5
n= 8
n= 6
Site
CR
MIN
B
RA
TI
GL (mm)
170
160
150
140
130
SD (mm)
13
12
11
10
9
$\frac{SDx100}{GL}$ (cm)
8.0
7.5
7.0
Site
CR
MIN

Figure 7

Figure 8

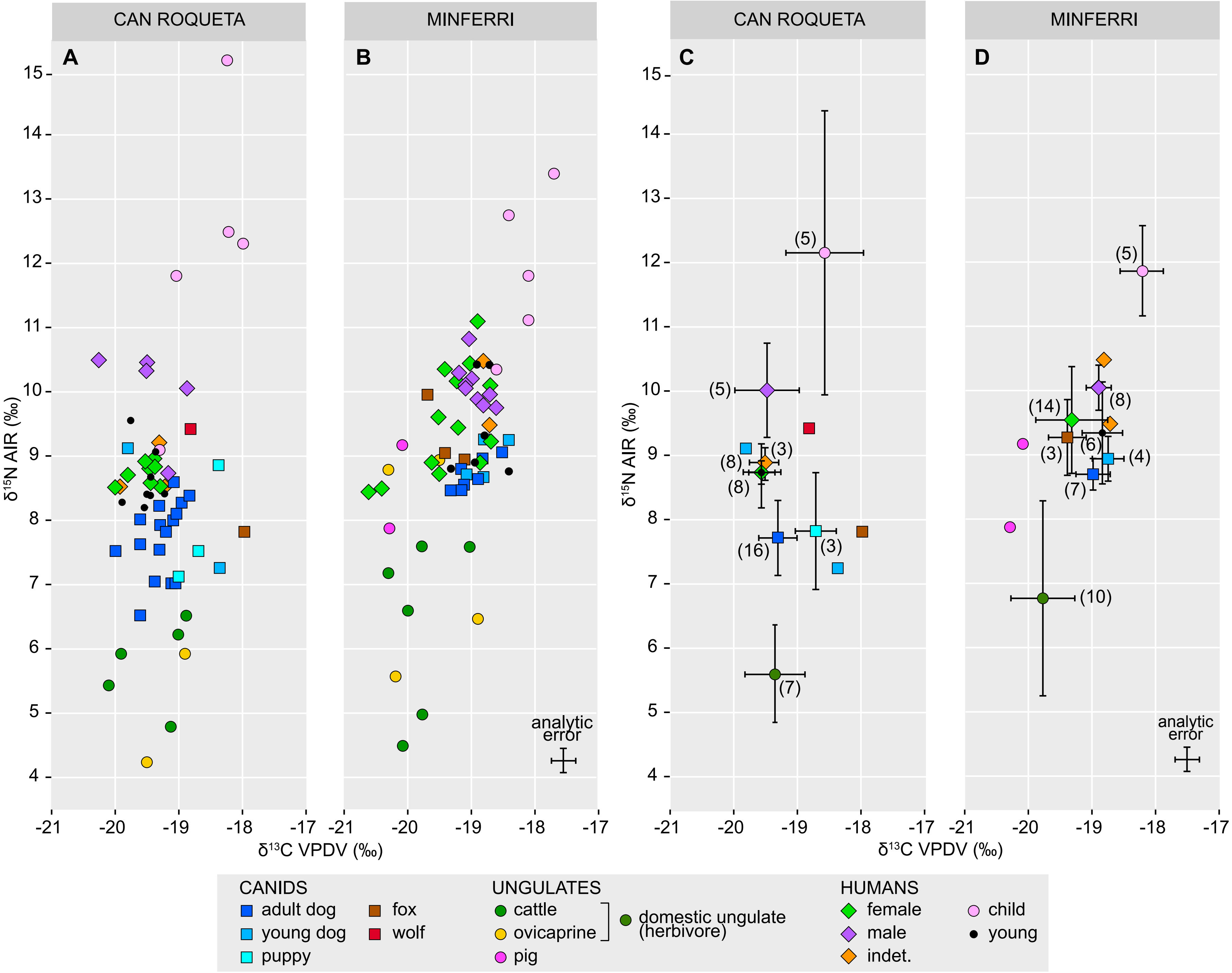
CAN ROQUETA
MINFERRI
CAN ROQUETA
MINFERRI
A
B
C
D
δ15N AIR (‰)
δ13C VPDV (‰)
15
14
13
12
11
10
9
8
7
6
5
4
-21
-20
-19
-18
-17
(5)
(5)
(3)
(8)
(8)
(16)
(3)
(7)
(5)
(14)
(8)
(3)
(6)
(4)
(7)
(10)
analytic error
CANIDS
adult dog
young dog
puppy
fox
wolf
UNGULATES
cattle
ovicaprine
pig
domestic ungulate (herbivore)
HUMANS
female
male
indet.
child
young

Figure 9

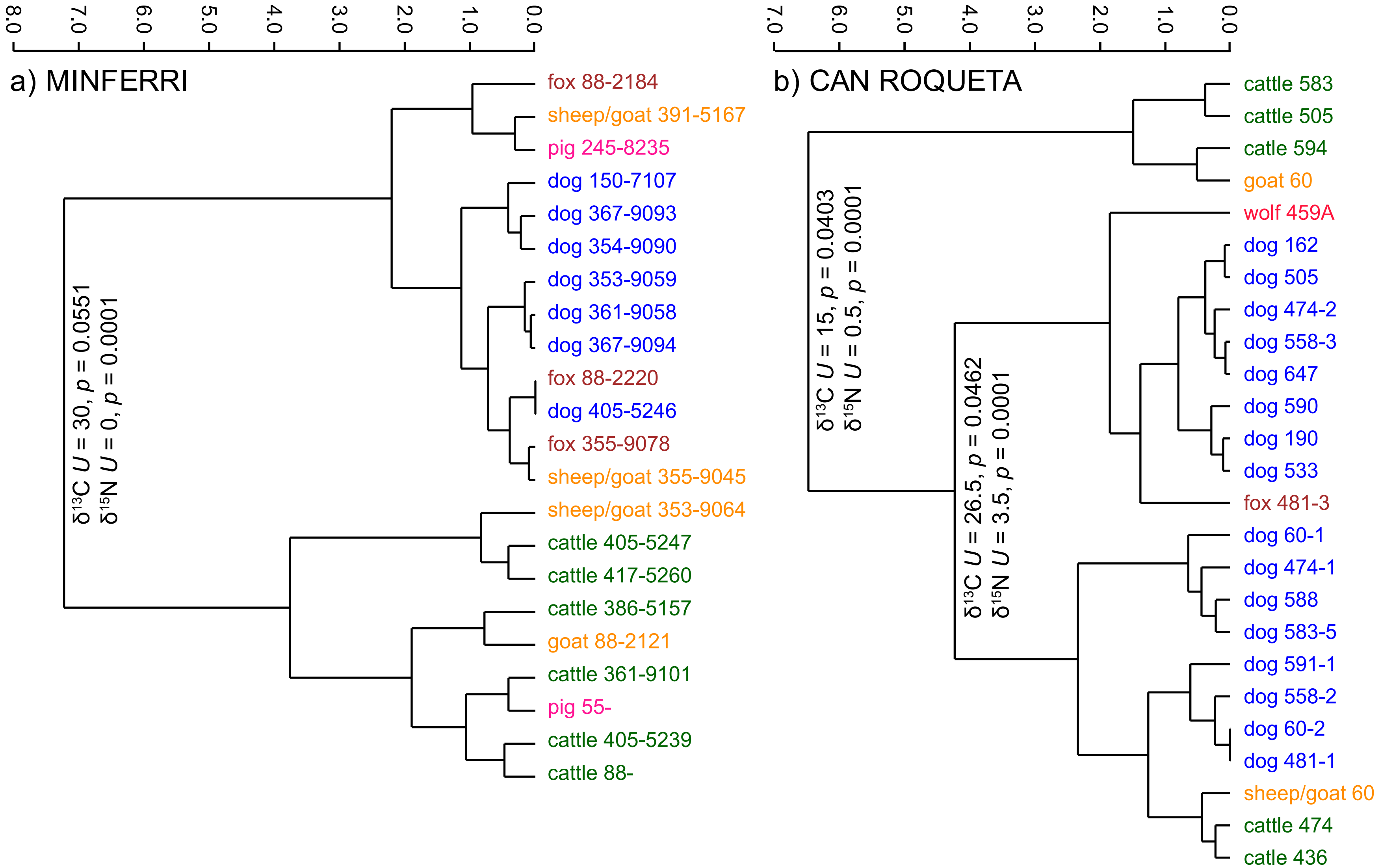
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
a) MINFERRI
fox 88-2184
sheep/goat 391-5167
pig 245-8235
dog 150-7107
dog 367-9093
dog 354-9090
dog 353-9059
dog 361-9058
dog 367-9094
fox 88-2220
dog 405-5246
fox 355-9078
sheep/goat 355-9045
sheep/goat 353-9064
cattle 405-5247
cattle 417-5260
cattle 386-5157
goat 88-2121
cattle 361-9101
pig 55-
cattle 405-5239
cattle 88-
δ^{13}C U = 30, p = 0.0551
δ^{15}N U = 0, p = 0.0001
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
b) CAN ROQUETA
cattle 583
cattle 505
catle 594
goat 60
wolf 459A
dog 162
dog 505
dog 474-2
dog 558-3
dog 647
dog 590
dog 190
dog 533
fox 481-3
dog 60-1
dog 474-1
dog 588
dog 583-5
dog 591-1
dog 558-2
dog 60-2
dog 481-1
sheep/goat 60
cattle 474
catle 436
δ^{13}C U = 15, p = 0.0403
δ^{15}N U = 0.5, p = 0.0001
δ^{13}C U = 26.5, p = 0.0462
δ^{15}N U = 3.5, p = 0.0001

Figure 10

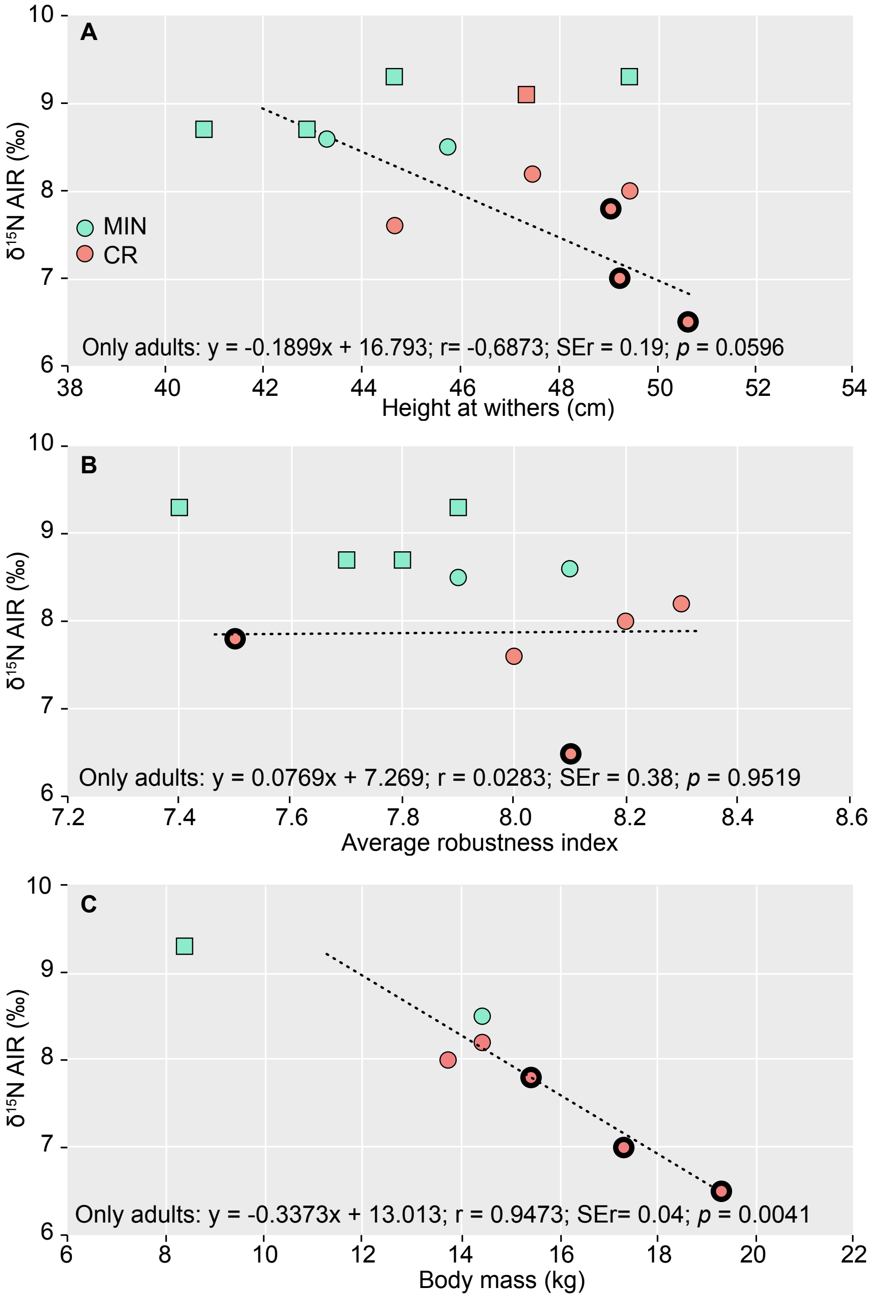
A
δ¹⁵N AIR (‰)
10
9
8
7
6
MIN
CR
Only adults: y = -0.1899x + 16.793; r= -0,6873; SEr = 0.19; p = 0.0596
38
40
42
44
46
48
50
52
54
Height at withers (cm)
B
δ¹⁵N AIR (‰)
10
9
8
7
6
Only adults: y = 0.0769x + 7.269; r = 0.0283; SEr = 0.38; p = 0.9519
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
Average robustness index
C
δ¹⁵N AIR (‰)
10
9
8
7
6
Only adults: y = -0.3373x + 13.013; r = 0.9473; SEr= 0.04; p = 0.0041
6
8
10
12
14
16
18
20
22
Body mass (kg)

Figure 11

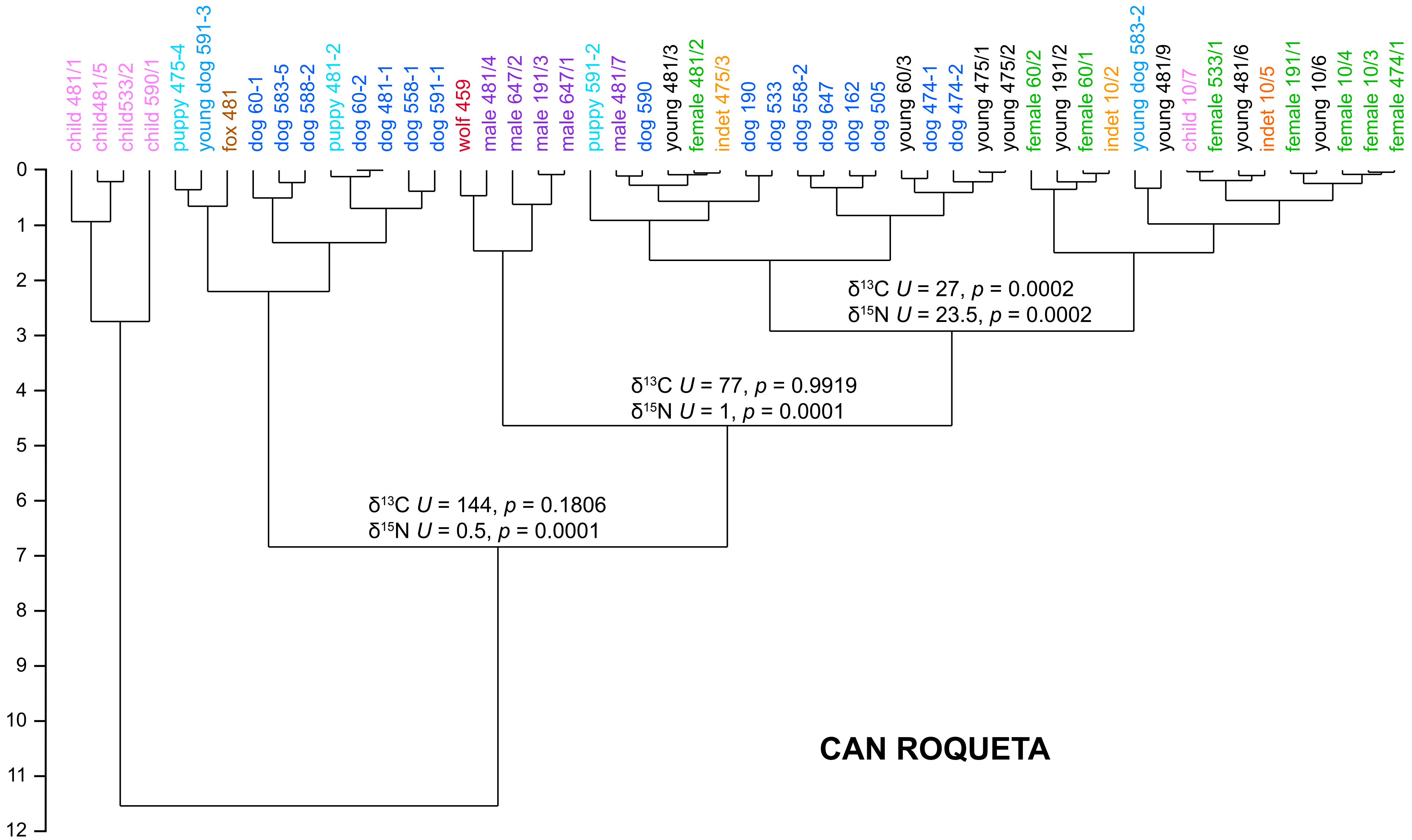
child 481/1
child481/5
child533/2
child 590/1
puppy 475-4
young dog 591-3
fox 481
dog 60-1
dog 583-5
dog 588-2
puppy 481-2
dog 60-2
dog 481-1
dog 558-1
dog 591-1
wolf 459
male 481/4
male 647/2
male 191/3
male 647/1
puppy 591-2
male 481/7
dog 590
young 481/3
female 481/2
indet 475/3
dog 190
dog 533
dog 558-2
dog 647
dog 162
dog 505
young 60/3
dog 474-1
dog 474-2
young 475/1
young 475/2
female 60/2
young 191/2
female 60/1
indet 10/2
young dog 583-2
young 481/9
child 10/7
female 533/1
young 481/6
indet 10/5
female 191/1
young 10/6
female 10/4
female 10/3
female 474/1
0
1
2
3
4
5
6
7
8
9
10
11
12
δ^{13}C $U = 27$, $p = 0.0002$
δ^{15}N $U = 23.5$, $p = 0.0002$
δ^{13}C $U = 77$, $p = 0.9919$
δ^{15}N $U = 1$, $p = 0.0001$
δ^{13}C $U = 144$, $p = 0.1806$
δ^{15}N $U = 0.5$, $p = 0.0001$
CAN ROQUETA

Figure 12

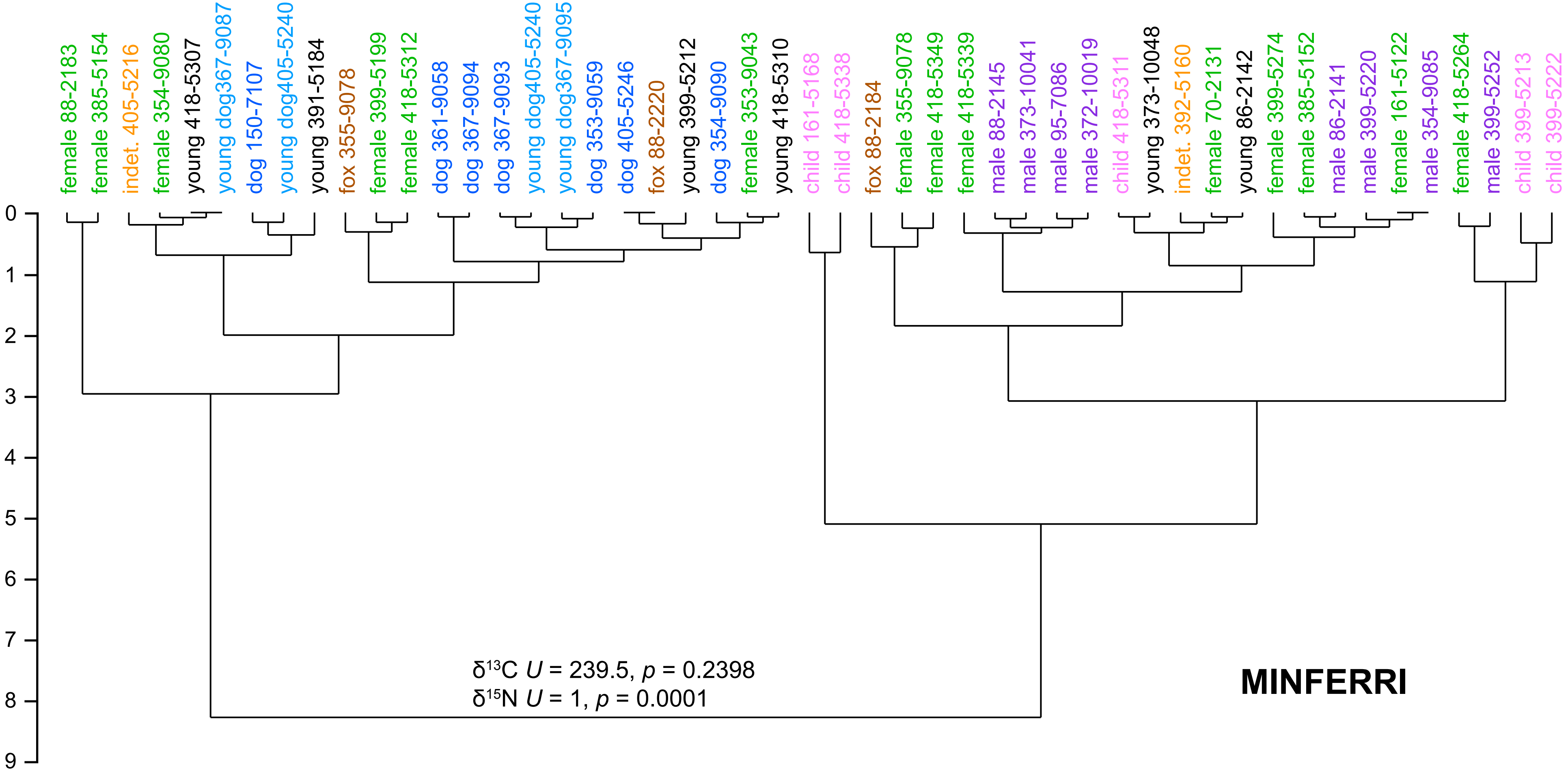
female 88-2183
female 385-5154
indet. 405-5216
female 354-9080
young 418-5307
young dog367-9087
dog 150-7107
young dog405-5240
young 391-5184
fox 355-9078
female 399-5199
female 418-5312
dog 361-9058
dog 367-9094
dog 367-9093
young dog405-5240
young dog367-9095
dog 353-9059
dog 405-5246
fox 88-2220
young 399-5212
dog 354-9090
female 353-9043
young 418-5310
child 161-5168
child 418-5338
fox 88-2184
female 355-9078
female 418-5349
female 418-5339
male 88-2145
male 373-10041
male 95-7086
male 372-10019
child 418-5311
young 373-10048
indet. 392-5160
female 70-2131
young 86-2142
female 399-5274
female 385-5152
male 86-2141
male 399-5220
female 161-5122
male 354-9085
female 418-5264
male 399-5252
child 399-5213
child 399-5222
0
1
2
3
4
5
6
7
8
9
δ¹³C U = 239.5, p = 0.2398
δ¹⁵N U = 1, p = 0.0001
MINFERRI

Figure 13

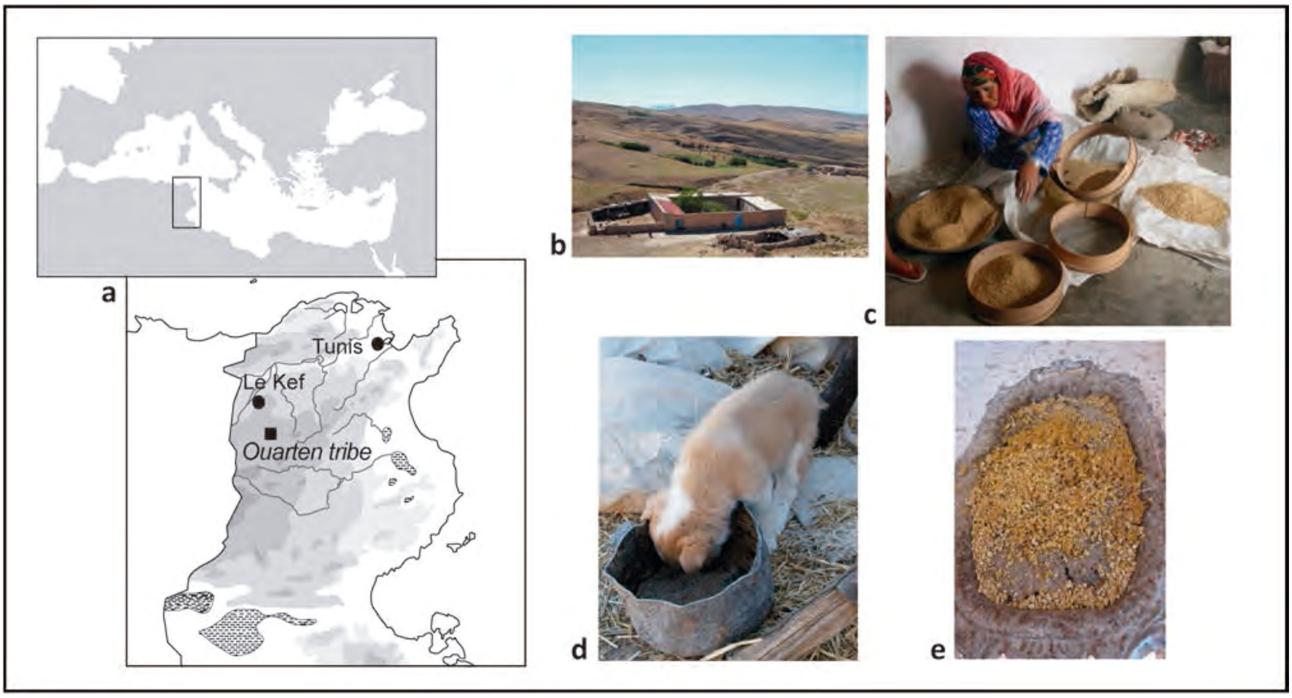

Table 1

Site-Zone	Structure	cal BC ±2σ	Functional interpretation	Human	Dog	Fox	Wolf	Pig	Sheep	Goat	*Caprinae*	Catlle
CRCRV	60	E-MBA	FS	3(3)	2(2)			2	6	1(1)	2(1)	
CRII	436		FS	6				4	1			4(1)
CRII	459 A	1932-1630	FS	32	1		1(1)		2	3	2	8
CRII	474	E-MBA	FS	1(1)	2(2)				4	1		3(1)
CRII	475	E-MBA	FS	3(3)	1(1)			1	1	1		2
CRII	481	1940-1734	FS	9(8)	2(2)	1(1)		1	3	1		1
CRII	505	1638-1435	NFS		1(1)			6	2	1		3(1)
CRII	533	E-MBA	FS	2(2)	1(1)				1			
CRII	558	E-MBA	FS	1	2(2)				1		1	4
CRII	583	E-MBA	FS	1	5(2)			5	3	1		2(1)
CRII	588 A	E-MBA	FS	1	1(1)				1	2		1
CRII	590		FS	1(1)	1(1)			4		2	2	3
CRII	591	1742-1546	NFS		3(3)			3	1		2	3
CRII	594		NFS		1			3	1			3(1)
CRII	645	E-MBA	FS	3				1		2		1
CRII	647	E-MBA	FS	2(2)	1(1)							
CRTR	10	1784-1500	FS	8(6)								
CRTR	162	1778-1605	NFS		1(1)			1	1	1		1
CRTR	190	E-MBA	NFS		1(1)			1		1		
CRTR	191	1413-1193	FS	3(3)				1	1		1	1
			TOTAL MNI(sampled)	**76(29)**	**26(21)**	**1(1)**	**1(1)**	**33(3)**	**29**	**17(1)**	**10(1)**	**40(5)**
MIN-2	55	1766-1517	NFS					1(1)				
MIN-2	86	-	FS	2(2)								
MIN-2	88	1935-1501	FS	3(2)		2(2)				9(1)		2(1)
MIN-2	95	-	FS	1(1)								
MIN	150	-	NFS		1(1)							
MIN-2	161	-	FS	2(2)								
MIN-2	245	-	NFS					1(1)				
MIN-9	353	-	FS	1(1)	1(1)						1(1)	1(1)
MIN-9	354	-	FS	2(2)	1(1)							
MIN-9	355	-	FS	1(1)		1(1)					1(1)	
MIN-9	361	-	NFS		1(1)							1
MIN-9	367	-	NFS		4(4)							1
MIN-2	386	1877-1639	NFS		1			1				3(1)
MIN-2	372	-	FS	1(1)								
MIN-2	373	-	FS	2(2)								
MIN-2	385	-	FS	2(2)								
MIN-2	391	-	NFS	1(1)							1(1)	1
MIN-2	392	-	FS	1(1)								
MIN-2	399	-	FS	8(7)								
MIN-2	405	1744-1539	FS	1(1)	3(3)							3(2)
MIN-2	417	-	NFS									1(1)
MIN-2	418	-	FS	11(8)								
			TOTAL MNI(sampled)	**39(35)**	**12(11)**	**3(3)**		**3(2)**		**9(1)**	**3(3)**	**12(6)**

Table 2

Structure	Individual	Age Categories	Age	Sex	Average of Shoulder height (cm)
CRII 459	*C. familiaris* 459	adult			44.3 *
CRII 459	*Canis* cf. *lupus*	adult			
CRII 474	*C. familiaris* 474-1	adult	18-30 m		49.5
	C. familiaris 474-2	adult	18-30 m		47.5
CRII 475	C. familiaris 475	puppy	1 m		
CRII 481	*V. vulpes*	old		female	
	C. familiaris 481-1	adult	12-14 m		49.3 *
	C. familiaris 481-2	puppy	2-4 m		
CRII 505	*C. familiaris* 505	adult	30 m		49.1
CRII 533	*C. familiaris* 533	adult	12 m		
CRII 558	*C. familiaris* 558-1	adult			
	C. familiaris 558-2	adult	12-24 m		
CRII 583	*C. familiaris* 583-4	young	6 m		47.4 *
	C. familiaris 583-5	adult	12 m		44.7 *
CRII 588	*C. familiaris* 588	adult	>12		
CRII 590	*C. familiaris* 590	adult	12-24 m		
CRII 591	*C. familiaris* 591-1	adult	30 m		50.7
	C. familiaris 591-2	puppy	1-3 m		
	C. familiaris 591-3	young	5-6 m		
CRII 647	*C. familiaris* 647	adult	24-36 m		
CRTR 162	*C. familiaris* 162	adult	18 m		
CRTR 190	*C. familiaris* 190	adult	12 m		
CRCRV 60	*C. familiaris* 60-1	adult	30-48 m		
	C. familiaris 60-2	old	7y		
MIN 88	*V. vulpes* 1 (2184)	adult	30 m	female	
	V. vulpes 2 (2220)	adult	42 m	male	
MIN 150	*C. familiaris* (7107)	adult			
MIN 353	*C. familiaris* (9059)	adult	54 m		43.3 *
MIN 354	*C. familiaris* (9090)	adult			
MIN 355	*V. vulpes* (9078)	adult	18 m	male	
MIN 361	*C. familiaris* (9058)	adult	24 m		45.8
MIN 367	*C. familiaris* 1 (9093)	adult	18 m		
	C. familiaris 2 (9094)	adult	42 m	male?	
	C. familiaris 3 (9095)	young	6-8 m	female?	40.8
	C. familiaris 4 (9087)	young	6-8 m	male?	44.7
MIN 405	*C. familiaris* 1 (5240)	young	8-9 m	female?	42.9
	C. familiaris 2 (5240)	young	9-10 m	male?	49.5
	C. familiaris 3 (5246)	adult	15-18 m		

Table 3

Specimen	Humerus GL	SH	Humerus SD		SDx100/GL
CRII 474-1	147	47.8	12		8.2
CRII 474-2	145	47.1	12		8.3
CRII 459	147	47.8	11		7.5
CRII 583-5	138	44.7	11		8.0
CRII 505	150	48.8	11.2		7.5
CRII 591	154	50.2	12.5		8.1
MIN 353	134	43.3	10.8		8.1
MIN 361	137.4	44.5	10.9		7.9
MIN 405-1	132.5	42.8	10.4		7.8
MIN 405-2	148.4	48.2	11.7		7.9
MIN 367-4	136.1	44.0	10.5		7.7
MIN 367-3	125.6	40.4	9.3		7.4
	Radius GL	SH	Radius SD		SDx100/GL
CRII 481-1	149	49.3	12.5		8.4
CRII 583-4	143	47.4	11		7.7
CRII 505	155	47.3	11.2		7.2
CRII 591	153	49	12		7.8
MIN 361	140.1	46.5	10.3		7.4
MIN 405-1	129.5	43.1	9.9		7.6
MIN 405-2	153.5	50.8	11.9		7.8
MIN 367-4	134.7	44.8	10.7		7.9
MIN 367-3	123.5	41.2	8.9		7.2
	Ulna GL	SH	Ulna SD		SDx100/GL
CRII 588	170	47.9	-		-
	Femur GL	SH	Femur SD	BW	SDx100/GL
CRII 474-1	167	51.1	12	13.8	7.2
CRII 474-2	158	48.3	12.2	14.5	7.7
CRII 481-1	-	-	13	17.4	-
CRII 505	-	-	12.5	15.5	-
CRII 591	172	52.7	13.5	19.4	7.8
MIN 361	153.7	47.0	12.2	14.5	7.9
MIN 405-1	141	43.0	10.1	8.4	7.2
	Tibia GL	SH	Tibia SD		SDx100/GL
CRII 474-1	167	49.7	13		7.8
CRII 474-2	158	47	12		7.6
CRII 505	153	51.1	11.2		7.3
CRII 591	172	50.8	13		7.6
MIN 361	151	45.3	10.6		7.0
MIN 405-1	143.7	42.9	9.7		6.8
MIN 367-1	152.2	45.4	-		-

Table 4

Structure	Individual	species	Sex	% C os	% N os	yield %	%C col	%N col	C/N	δ 13C VPDV (‰)	δ 15N AIR (‰)
CRII 436	474	*Bos taurus*		6.27	1.23	7.3	35.4	13.4	3.1	-18.9	6.1
CRII 474	436	*Bos taurus*		6.08	1.04	7.4	33.9	13.1	3.0	-19.0	6.2
CRII 505	505	*Bos taurus*		5.12	0.63	5.2	28.3	8.5	3.6	-20.1	5.4
CRII 583	583	*Bos taurus*		5.04	0.80	3.9	23.9	8.4	3.3	-19.9	5.9
CRII 594	594	*Bos taurus*		7.56	2.13	8.2	40.1	15.0	3.1	-19.1	4.8
CRV 60	60	*Ovis/Capra*		5.14	0.85	4.7	24.6	8.6	3.3	-18.9	5.9
CRV 60	60	*Capra hircus*		5.90	1.33	10.9	40.2	14.8	3.2	-19.5	4.2
MIN 353	9064	*Ovis/Capra*		4.26	0.77	8.8	38.6	14.3	3.1	-20.2	5.6
MIN 355	9045	*Ovis/Capra*		4.65	0.95	9.3	39.9	14.7	3.2	-19.5	9.0
MIN 88	2121	*Capra hircus*		8.02	2.20	16.8	40.7	15.3	3.1	-18.9	6.5
MIN 391	5167	*Ovis/Capra*		6.00	1.49	8.9	40.3	14.9	3.2	-20.3	8.8
MIN 88	2121	*Bos taurus*		6.35	1.65	10.1	39.8	14.8	3.1	-20.0	6.6
MIN 353	9101	*Bos taurus*		10.25	3.02	32.0	40.5	15.1	3.1	-19.8	7.6
MIN 386	5157	*Bos taurus*	M	5.38	1.26	15.0	38.1	14.4	3.1	-19.0	7.6
MIN 405	5239	*Bos taurus*	F	4.16	0.78	3.9	38.3	14.1	3.2	-20.3	7.2
MIN 405	5247	*Bos taurus*	M	3.95	0.70	3.8	36.0	13.5	3.1	-20.1	4.5
MIN 417	5260	*Bos taurus*	F	5.71	1.40	7.8	38.3	14.5	3.1	-19.8	5.0
MIN 55	-	*Sus domesticus*	F	4.69	0.74	2.7	38.3	13.9	3.2	-20.3	7.9
MIN 245	8235	*Sus domesticus*		5.66	1.27	3.2	38.3	14.3	3.1	-20.1	9.2

Table 5

Structure	Species. Individual	% C os	% N os	yield %	% C col	% N col	C/N at	$\delta^{13}C_{VPDV}$ (‰)	$\delta^{15}N_{AIR}$ (‰)
CRII 459	*Canis* cf. *lupus*	6.90	1.65	13.4	34.9	12.5	3.3	-18.8	9.4
CRII 474	*C. familiaris* 474-1	4.62	0.87	5.9	25.8	8.6	3.5	-19.6	8.0
	C. familiaris 474-2	4.59	0.89	3.5	25.9	9.1	3.3	-19.3	8.2
CRII 475	*C. familiaris* 475	4.74	0.46	6.1	34.9	12.7	3.2	-18.7	7.5
CRII 481	*V. vulpes*	nd	nd	3.9	38.1	14.2	3.2	-18.0	7.8
	C. familiaris 481-1	nd	nd	4.3	30.6	11.0	3.3	-19.1	7.0
	C. familiaris 481-2	nd	nd	6.7	25.2	8.7	3.4	-19.0	7.1
CRII 505	*C. familiaris* 505	nd	nd	4.7	12.2	33.2	3.2	-19.2	7.8
CRII 533	*C. familiaris* 533	3.76	0.58	4.6	37.2	13.6	3.2	-18.9	8.3
CRII 558	*C. familiaris* 558-1	7.03	1.37	13.5	41.4	15.2	3.2	-19.4	7.0
	C. familiaris 558-2	5.60	0.55	7.2	35.0	12.9	3.2	-19.1	8.0
CRII 583	*C. familiaris* 583-4	5.27	0.25	3.5	24.4	9.1	3.1	-19.8	9.1
	C. familiaris 583-5	5.78	1.31	5.1	36.0	12.9	3.3	-19.6	7.6
CRII 588	*C. familiaris* 588	1.04	5.08	7.7	39.8	14.6	3.2	-19.3	7.5
CRII 590	*C. familiaris* 590	0.91	4.77	8.4	36.5	13.5	3.2	-19.1	8.6
CRII 591	*C. familiaris* 591-1	5.46	1.12	5.4	12.6	35.2	3.3	-19.6	6.5
	C. familiaris 591-2	5.05	0.92	10.5	39.9	14.9	3.1	-18.4	8.8
	C. familiaris 591-3	6.97	1.26	14.4	41.1	15.1	3.2	-18.3	7.2
CRII 647	*C. familiaris* 647	4.87	0.72	4.1	38.0	13.9	3.2	-19.0	8.1
CRTR 162	*C. familiaris* 162	3.86	0.36	6.5	30.2	11.0	3.2	-19.3	7.9
CRTR 190	*C. familiaris* 190	6.14	0.74	7.8	37.0	13.7	3.1	-18.8	8.4
CRCRV 60	*C. familiaris* 60-1	4.69	0.90	6.7	15.4	5.2	3.5	-20.0	7.5
	C. familiaris 60-2	4.82	0.84	4.1	32.6	11.6	3.3	-19.1	7.0
MIN 88	*V. vulpes* 1 (2184)	4.29	0.73	9.3	39.6	14.4	3.2	-19.7	10.0
	V. vulpes 2 (2220)	4.28	0.90	9.8	38.3	14.2	3.1	-19.1	8.9
MIN 150	*C. familiaris* (7107)	8.41	2.31	32.2	42.7	15.5	3.2	-18.5	9.1
MIN 353	*C. familiaris* (9059)	4.08	0.70	3.7	35.9	13.3	3.1	-19.1	8.6
MIN 354	*C. familiaris* (9090)	4.66	0.95	9.1	37.2	13.7	3.2	-18.8	9.0
MIN 355	*V. vulpes* (9078)	4.66	0.81	9.9	39.6	14.5	3.2	-19.4	9.1
MIN 361	*C. familiaris* (9058)	8.28	2.11	16.7	40.4	14.9	3.2	-19.3	8.5
MIN 367	*C. familiaris* 1 (9093)	4.11	0.66	8.1	35.8	13.3	3.1	-18.9	8.7
	C. familiaris 2 (9094)	3.91	0.76	9.0	38.3	14.2	3.1	-19.2	8.5
	C. familiaris 3 (9095)	4.81	0.96	8.3	40.0	14.9	3.1	-19.0	8.7
	C. familiaris 4 (9087)	4.57	0.83	8.6	39.9	14.9	3.1	-18.8	9.3
MIN 405	*C. familiaris* 1 (5240)	6.10	1.47	13.0	40.5	15.1	3.1	-18.8	8.7
	C. familiaris 2 (5240)	7.25	1.93	16.1	41.3	15.4	3.1	-18.4	9.3
	C. familiaris 3 (5246)	6.64	1.68	14.4	40.4	15.1	3.1	-19.1	8.9

Table 6

Funerary structure	Individual	Age group	Sex	bone	% C os	% N os	yield %	%C col	%N col	C/N	δ 13C VPDV (‰)	δ 15N AIR (‰)
CRII 474	474/1	adult	female	rib	6.00	1.19	7.0	39.9	14.6	3.2	-19.5	8.9
CRII 475	475/1	young		vertebra	4.71	0.78	4.5	37.9	14.0	3.2	-19.4	8.4
	475/2	young		mix-	3.60	0.60	7.5	37.2	13.4	3.2	-19.5	8.4
	475/3	adult		humerus	3.83	0.68	8.3	38.5	14.0	3.2	-19.2	8.5
CRII 481	481/1	child		rib	4.48	0.84	8.3	37.3	13.7	3.2	-19.0	11.8
	481/2	adult	female	rib	4.65	1.03	4.7	41.5	15.2	3.2	-19.3	8.5
	481/3	child		rib	4.77	0.81	4.5	39.8	14.6	3.2	-19.2	8.4
	481/4	adult	male	rib	4.63	0.81	4.3	38.6	14.3	3.2	-18.9	10.0
	481/5	child		skull	5.01	0.72	4.6	39.5	14.5	3.2	-18.2	12.5
	481/6	young		rib	6.81	1.52	5.2	39.6	14.3	3.2	-19.3	9.1
	481/7	adult	male	rib	5.55	1.02	6.4	39.8	14.5	3.2	-19.2	8.7
	481/9	young		diaphisis	4.19	0.79	4.2	39.8	14.4	3.2	-19.8	9.6
CRII 533	533/1	adult	female	skull	3.64	0.59	5.2	37.0	13.6	3.2	-19.4	9.0
	533/2	child		rib	5.28	0.63	3.6	38.9	14.1	3.2	-18.0	12.3
CRII 590	590/1	child		orbita	4.77	0.91	8.4	36.5	13.5	3.2	-19.1	8.6
CRII 647	647/1	adult	male	rib	5.00	0.93	5.2	39.9	14.6	3.2	-19.5	10.4
	647/2	adult	male	mix-	4.44	0.61	3.5	39.2	14.2	3.2	-20.2	10.5
CRTR 10	10/2	adult		rib	3.36	0.58	3.6	36.3	13.2	3.2	-19.9	8.5
	10/3	adult	female	mix -	3.22	0.58	3.8	37.2	13.6	3.2	-19.5	8.8
	10/4	adult	female	rib	3.43	0.63	3.5	37.4	13.6	3.2	-19.4	8.8
	10/5	adult		rib	4.46	1.00	9.8	39.1	14.2	3.2	-19.3	9.2
	10/6	young		rib	3.28	0.53	3.6	36.5	13.3	3.2	-19.4	8.7
	10/7	child		rib	4.33	0.98	5.4	38.2	14.0	3.2	-19.4	9.0
CRTR 191	191/1	adult	female	rib	nd	nd	4.2	39.2	14.3	3.2	-19.4	8.6
	191/2	young		rib	nd	nd	3.9	39.4	14.1	3.2	-19.9	8.3
	191/3	adult	male	humerus	4.51	0.94	9.9	40.6	14.7	3.2	-19.5	10.3
CRCRV 60	60/1	adult	female	coxal	4.47	0.46	3.6	34.0	12.3	3.2	-19.9	8.5
	60/2	adult	female	rib	3.97	0.55	7.1	35.1	12.8	3.2	-19.8	8.7
	60/3	young		tibia	3.81	0.54	3.9	36.5	13.3	3.2	-19.5	8.2
MIN 70	2131	adult	female	tibia	nd	nd	22.6	42.8	15.5	3.2	-19.0	10.4
MIN 86	2141	adult	male	rib	nd	nd	21.9	42.6	15.5	3.2	-19.2	10.3
	2142	young		rib	nd	nd	23.3	42.6	15.5	3.2	-18.9	10.4
MIN 88	2145	adult	male	rib	12.01	3.67	21.0	40.9	14.8	3.2	-18.9	9.9
	2183	adult	female	diaphisis	3.71	0.80	12.0	39.0	14.2	3.2	-20.4	8.5
MIN 95	EN-135 (7086)	adult	male	radius	nd	nd	16.8	42.3	15.4	3.2	-18.7	9.9
MIN 161	EN-173 (5122)	adult	female?	diaphisis	nd	nd	16.3	42.2	15.3	3.2	-19.1	10.1
	EN-439 (5168)	child		humerus	nd	nd	11.8	42.0	15.3	3.2	-17.7	13.4
MIN 353	9043	adult	female	ulna	6.34	1.47	16.5	38.8	14.3	3.2	-18.9	8.9
MIN 354	9080	adult	female?	ulna	4.85	0.97	5.4	38.5	14.1	3.2	-18.7	9.3
	9085	adult	male	radius	nd	nd	9.1	41.0	14.9	3.2	-19.1	10.1
MIN 355	9078	adult	female	femur	3.84	0.74	9.7	39.4	14.3	3.2	-19.5	9.6
MIN 372	10019	adult	male	rib	nd	nd	8.8	40.5	14.9	3.2	-18.6	9.8
MIN 373	10041	adult	male	rib	nd	nd	10.0	41.8	15.2	3.2	-18.8	9.8
	10048	young		diaphisis	nd	nd	10.6	40.3	14.7	3.2	-18.7	10.4
MIN 385	EN-441(5152)	adult	female	ulna	nd	nd	10.9	40.8	14.7	3.2	-19.2	10.2
	EN-442 (5154)	adult	female	rib	nd	nd	18.4	41.6	15.2	3.2	-20.6	8.4
MIN 391	EN-452 (5184)	young		temporal	nd	nd	13.8	41.9	15.3	3.2	-18.4	8.8
MIN 392	EN-440 (5160)	adult		tibia	nd	nd	12.6	41.3	14.8	3.3	-18.8	10.5
MIN 399	EN-408 (5199)	adult	female	rib	nd	nd	21.3	42.2	15.4	3.2	-19.6	8.9
	EN-411 (5212)	young		rib	nd	nd	20.4	41.7	15.1	3.2	-19.3	8.8
	EN-411 (5213)	child		diaphisis	nd	nd	19.0	41.2	15.0	3.2	-18.1	11.1
	EN-414 (5220)	adult	male	rib	nd	nd	19.6	41.2	15.1	3.2	-19.0	10.2
	EN-416 (5222)	child		femur	nd	nd	16.4	41.5	15.2	3.2	-18.1	11.8
	EN-420 (5252)	adult	male	rib	nd	nd	17.6	41.8	15.2	3.2	-19.0	10.8
	EN-426 (5274)	adult	female	rib	nd	nd	19.5	41.0	15.1	3.2	-19.4	10.4
MIN 405	EN-413 (5216)	adult		diaphisis	4.70	0.97	10.2	38.3	14.0	3.2	-18.7	9.5

MIN 418	EN-421 (5264)	adult	female?	fibula	nd	nd	13.9	41.1	15.0	3.2	-18.9	11.1
	EN-444 (5307)	young		rib	nd	nd	20.3	41.4	15.2	3.2	-18.8	9.3
	EN-448 (5310)	young		rib	nd	nd	17.8	41.7	15.3	3.2	-19.0	8.9
	EN-448 (5311)	child		rib	nd	nd	17.2	42.1	15.5	3.2	-18.6	10.4
	EN-448 (5312)	adult	female	rib	nd	nd	16.9	41.5	15.2	3.2	-19.5	8.7
	EN-445 (5338)	child		rib	nd	nd	22.5	42.1	15.3	3.2	-18.4	12.8
	EN-446 (5339)	adult	female	rib	nd	nd	16.4	41.6	15.3	3.2	-18.7	10.1
	EN-447 (5349)	adult	female	rib	nd	nd	22.8	41.3	15.2	3.2	-19.2	9.4