J. A. LEE-THORP · A. VAUGHAN · P. DITCHFIELD · L. T. HUMPHREY

17. ISOTOPE ECOLOGY OF THE SECTOR 10 BURIALS

17.1 INTRODUCTION

The Taforalt human burials excavated from Sector 10 consist of a relatively large number of tightly packed and intercutting adults and infants, as described in **Chapters 15** and **16**. According to the radiocarbon dating programme (**Chapter 4**), inhumation took place over a relatively short period of time, coincident with the rapid climate warming c. 15,000-14,000 cal BP, following the Last Glacial Maximum. Coupled with an apparently sudden appearance of intense occupation, several observations emerge from the physical anthropology. One is the poor oral health, and second is the relatively large number of infants in addition to adults. Together, they may suggest a rapidly expanding population and appearance of a large, perhaps semi-sedentary, community contributing to exchange of oral pathogens, as well as to the involvement of a cariogenic diet (**Chapter 16**), possibly abundant sweet acorns (**Chapter 6**) having been identified as a possible dietary staple. Further, since Taforalt is within striking distance of the coast (40 km from the present coastline), if the inhabitants were transhumant, marine foods may have featured in the diet without showing up in the deposits.

The impetus for an isotopic study therefore arose from questions about the diets of the hunter-gatherers in this North African Mediterranean biome during the rapid warming period following the LGM. The number of individuals in Taforalt Sector 10 is unusual amongst Late Pleistocene/early Holocene forager sites, where burials are rare and usually isolated. So far, isotope studies to assess the nature of forager diets in the western Mediterranean coastal fringes have been limited to just a few individuals in younger sites (Mannino et al. 2011; 2012; Salazar-Garcia et al. 2014), where the results were inconclusive on the matter of marine inputs. This contrasts with observations from other Mediterranean-type coastal biomes, such as southern African coastal foragers who clearly consumed significant but variable amounts of marine foods, thereby allowing inferences to made about territorial group boundaries (Sealy 2006). A further aim of the present study was to assess the isotopic composition of infants compared to adults, as, elsewhere, their trophic distinctions have been used to identify breastfeeding and weaning processes (Fuller/Fuller/Harris/Hedges 2006; Nitsch/Humphrey/Hedges 2011; Prowse et al. 2008; Schurr 1998). This approach is rarely feasible amongst foragers due to low numbers of comparable individuals (but see Clayton/Sealy/Pfeiffer 2006; Eerkens/Berget/Bartelink 2011). Adult and infant human bone collagen carbon and nitrogen isotope compositions, compared against those of a range of coeval fauna, were used to address these questions.

17.2 STABLE ISOTOPES IN HUMAN ECOLOGY

The principles of applying carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotopes to clarify dietary ecology and environments are well-rehearsed. For carbon, the primary distinctions reside in plants at the base of all foodwebs, which are predicated partly on the sources of carbon (whether atmospheric CO_2 or carbon dissolved in seawater), and partly according to photosynthetic pathway of terrestrial plants. Plants reliant on the ancient C_3 RuBisCo-mediated pathway are strongly depleted in the heavier isotope ^{13}C, compared to

tropical grasses and sedges following the C_4 pathway, with global average values of c. $\delta^{13}C$ [66] = -26‰ and -12‰ respectively (O'Leary 1981). The C_3 pathway is sensitive to climate influences, especially low relative humidity (Farquhar/Ehleringer/Hubick 1989), so that C_3 vegetation typical along the coastal fringes of North Africa, with warm dry summers, tends to be more positive, thus shifting the entire foodweb. Vegetation in the desert zones to the south almost certainly included C_4 grasses and sedges, especially during the Late Pleistocene/early Holocene 'greening' episode driven by increased monsoonal precipitation. Finally, marine trophic systems are distinctly ^{13}C-enriched compared to typical terrestrial systems dominated by C_3 vegetation, starting with the different source of carbon for primary producers.

The primary application of $\delta^{15}N$ in diet studies relies on the stepwise trophic level isotope effects observed in ecosystems (Minigawa/Wada 1984) that occur during *in vivo* protein metabolism (O'Connell 2017). The marine baseline for primary producers is higher in $\delta^{15}N$, compared to those in terrestrial systems, and, coupled with longer marine trophic chains, the net result is that strongly marine diets are ^{15}N-enriched compared to terrestrial diets (Schoeninger/DeNiro 1984). There is some complexity in the general picture. First, local environmental conditions control soil nitrogen balance and $\delta^{15}N$ and thus that of plants and animals (Robinson 2001). The $\delta^{15}N$ values in arid-climate foodwebs tend to be higher (Handley et al. 1999), although highly variable (Craine et al. 2009), and digestive physiologies for different mammalian taxa may introduce further distinctions (Ambrose 1991). The stepwise trophic enrichment is often reported as c. 3-4‰ between prey-predator pairs but the range can be greater and is influenced by physiology. In humans, the offset with dietary protein is higher (c. 5‰) (O'Connell et al. 2012). Infants entirely dependent on breastmilk form a special case as they obtain all nutrition from their mothers and consistently show offsets of 1.5-2‰ (Fuller/Fuller/Harris/Hedges 2006), an observation that has been used to address duration of breastfeeding and infant nutrition in the past (Schurr 1998). Studies initially measured bone collagen $\delta^{15}N$ in skeletons aged by standard physical anthropology methods (e.g. Clayton/Sealy/Pfeiffer 2006; Prowse et al. 2008; Nitsch/Humphrey/Hedges 2011) but more recently researchers have measured dentine increments that reflect early life history in surviving adults (e.g. Eerkens/Berget/Bartelink 2011; Sandberg/Sponheimer/Lee-Thorp/van Gerven 2014).

Finally, a trophic effect is also observed in $\delta^{13}C$, roughly $^1/_3$ the magnitude compared to $\delta^{15}N$, and the combined directional effect in an ecosystem is useful in separating sources and effects.

17.3 MATERIALS AND METHODS

Adult and infant human bone collagen $\delta^{13}C$ and $\delta^{15}N$ composition was compared against the values obtained for coeval fauna in the site, either from the immediate burial environment or from Sector 8. This approach is required to provide both an isotopic baseline for the Taforalt environment at the time and to assess likely dietary sources for humans. We included bone samples of identified fauna from Sector 8 in addition to those associated with the burial zone to increase the numbers of specimens and taxa (**Chapter 9**). Of the 23 faunal samples, 10 are from Sector 10. The Barbary sheep (*Ammotragus*) is best represented. For the humans, adults are in the minority (n = 4), and infants (n = 7) of which 3 are perinates, in the majority.

Collagen preparation followed standard procedures for acid demineralisation and preservation assessment used in the Oxford Radiocarbon Accelerator Unit (e.g. Brock/Higham/Ditchfield/Bronk Ramsey 2010).

66 Stable isotope ratios are by convention expressed as per mil in the δ notation relative to an international standard, as $\delta^{13}C$‰ or $\delta^{15}N‰ = (R_{unknown}-1)/ R_{std}$ x 1000, where the standards are PDB and AIR respectively.

Most of the samples reported here were associated with radiocarbon dates (**Chapter 4**) allowing the associated carbon and nitrogen isotope determinations on the ORAU's SerCon CF-IRMS system to be used, as well as independent determinations in the SERCON 20/22 CF-IRMS system in the Stable Isotope Laboratory. In both cases an internal alanine standard was used and, in the latter case, samples were measured in duplicate or triplicate and the results averaged. Where measured by both methods, the results were comparable within standard error (± 0.2 for both isotopes). Collagen preservation was assessed by C/N ratios, which are required to fall between 3.0 and 3.5 for well-preserved collagen (Brock/Higham/Ditchfield/Bronk Ramsey 2010).

17.4 RESULTS AND DISCUSSION

The $\delta^{13}C$ and $\delta^{15}N$ results for both faunal samples from Sectors 10 and 8 and the human samples from Sector 10 are reported in **table 17.1**, along with their C/N ratios, and, in the case of humans, their developmental age. Faunal and human samples that yielded poorly preserved collagen are not shown. From the bivariate plot of the isotope data (**fig. 17.1**), it can be seen that faunal $\delta^{13}C$ and $\delta^{15}N$ values are lower than those of the humans, as well as more variable.

The faunal data-set has a mean $\delta^{13}C$ of -21.11 ± 0.73‰, showing that local vegetation was entirely C_3. An outlier Barbary sheep sample with suspiciously low $\delta^{13}C$ and $\delta^{15}N$ values (compared to the rest), but acceptable C/N, was retained in the calculations. Combined with a $\delta^{15}N$ mean of +6.42 ± 1.72‰, these data suggest there is little evidence for strong regional aridity of the sort one might expect in a modern hot/dry Mediterranean climate. However, a smaller number of equids, gazelle and Barbary sheep show higher $\delta^{13}C$ and $\delta^{15}N$ values (**fig. 17.1**). Given the several taxa in this group, we can discard distinct digestive physiologies as a cause, and so the data suggest either that these specimens came from different, drier ecozones (possibly further afield) or that they reflect short-term climate shifts within the timespan of the accumulation of deposits. This was, after all, a period of rapid climate change. We do not have enough data for each of the herbivore taxa to deduce whether there is any significant distinction in herbivore faunal values between Sectors 10 and 8. The bustard as the single omnivore has higher $\delta^{13}C$ and $\delta^{15}N$ values of -20.5‰ and +9.5‰ respectively; the specimen was in firm association with the burials (and thus of the same period), so these values are consistent with an omnivore in the same environment as the bulk of the fauna and humans.

The overall means and standard deviations for humans ($\delta^{13}C$ = -18.91 ± 0.19‰; $\delta^{15}N$ = +11.25 ± 0.97‰) stand in contrast to the faunal data in two respects. First, they are less variable than the fauna, as can be observed from **figure 17.1** and from the standard deviations. The difference in variability is marked for $\delta^{13}C$ and less so for $\delta^{15}N$, since the human $\delta^{13}C$ data are very tightly clustered while the latter are more variable (see below). Nevertheless, the observation holds overall. This pattern is commonly observed in many studies, especially from the Neolithic onwards where there are sufficient numbers of fauna and humans to assess distinctions in variability. We cannot be certain but here it *may* reflect a common, standard dietary regime amongst the Taforalt individuals, an observation consistent with remains of food waste in the site. Next, the overall human-fauna trophic offset in $\delta^{15}N$ is +4.8‰, or +4.2‰ if we include only adults, and in $\delta^{13}C$ +1.2‰. This is consistent with observations for a larger trophic offset amongst humans set out by O'Connell et al. (2012). Thus, the values for both $\delta^{13}C$ and $\delta^{15}N$ are entirely consistent with the terrestrial faunal data, given expected isotopic offsets between the trophic levels. Therefore, we conclude that there is little evidence for involvement of marine foods. Further, even if sweet acorns were an important energy source, the cave's inhabitants clearly had access to reasonable amounts of animal proteins.

Fauna				
Taxon	Sector	$d^{13}C$ ‰	$d^{15}N$ ‰	C/N
Ammotragus	8	-20.3	4.8	3.5
Ammotragus	8	-19.5	5.7	3.3
Ammotragus	8	-20.6	6.3	3.4
Ammotragus	8	-20.1	4.3	3.4
Ammotragus	8	-20.8	5.8	3.3
Ammotragus	8	-19.7	8.5	3.3
Ammotragus	8	-22.4	3.4	3.3
Ammotragus	8	-19.2	8.4	3.3
Ammotragus	8	-20.5	5.4	3.3
Ammotragus	8	-20.2	3.2	3.2
Ammotragus	8	-18.9	6.6	3.3
Ammotragus	8	-20.2	4.8	3.3
Ammotragus	8	-19.9	6.3	3.3
Ammotragus	10	-19.6	6.7	3.4
Ammotragus	10	-21.2	6.5	3.4
Ammotragus	10	-20.2	5.7	3.4
Bos	10	-19.6	6.6	3.5
Equus	10	-20.2	8.1	3.2
Equus	10	-20.2	9.5	3.5
Equus	10	-19.9	6.6	3.5
Gazella	10	-19.6	6.8	3.4
Gazella	10	-19.4	8.1	3.3
Otis tarda	10	-20.5	9.5	3.3
Humans				
Individual	Age	$d^{13}C$ ‰	$d^{15}N$ ‰	C/N
4?	Adult	-18.8	11.4	3.3
5	17-25 years	-19.0	9.7	3.2
6	8-10 months	-19.0	12.0	3.3
7	perinatal	-19.2	10.1	3.4
8	2-3 months	-19.0	11.3	3.2
9	5-6 months	-18.9	12.1	3.2
11	perinatal	-18.9	12.0	3.4
12	perinatal	-18.6	10.9	3.5
13	17-25 years	-18.9	10.4	3.4
14	17-25 years	-18.6	10.9	3.3
Surface infant, Individual '20'	8-10 months	-19.1	12.9	3.2

Tab. 17.1 List of the faunal and human samples whose bone collagen isotopic composition is reported in this study, along with C/N ratios. Sectors are reported for the fauna but, since all humans were from Sector 10, their estimated developmental ages are shown in Column 2 instead.

If we then examine isotope distinctions according to developmental age (**fig. 17.1** and **tab. 17.1**), it is readily apparent that there are no differences in $\delta^{13}C$ but that there are distinctions in $\delta^{15}N$. The latter make little sense unless one separates perinates from infants. Three of the four infants have higher $\delta^{15}N$ than the adults (by 1.5‰), while two of the three perinates are consistent with adult values. This is entirely consistent with expectations and the model of Nitsch/Humphrey/Hedges (2011), since perinates should reflect the maternal values. Breastfeeding infants (dependent solely on breast milk) should reflect maternal values plus a small 'trophic' offset. Even the youngest infant (2-3 months) already has higher values ($\delta^{15}N = +11.3$‰) than the adults (mean $\delta^{15}N$ +10.62 ± 0.72‰). It is interesting that the offset in breastfeeding infants has

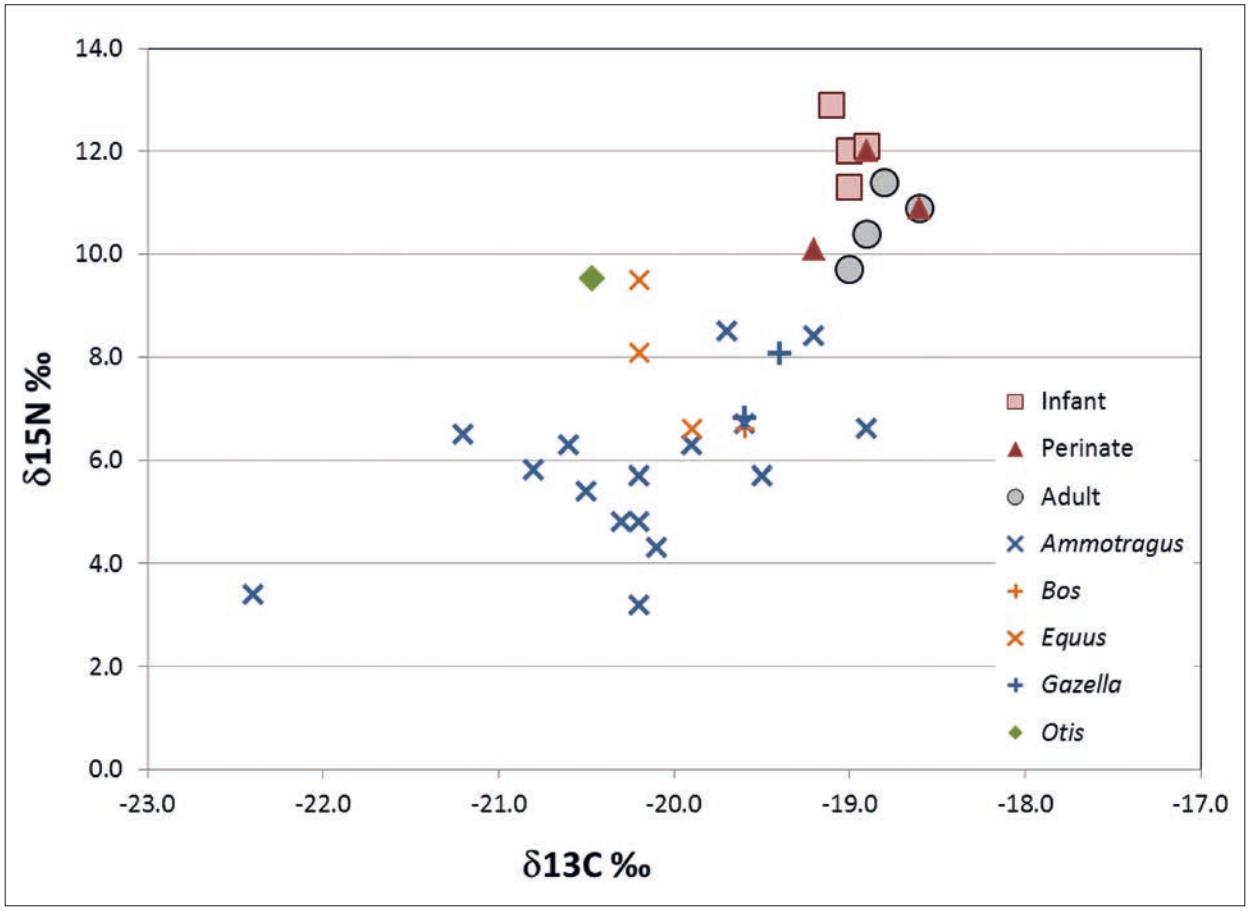

Fig. 17.1 Bivariate plot of the $\delta^{13}C$ and $\delta^{15}N$ data reported in **tab. 17.1**.

never been found to be of the same magnitude trophic increase as shown in ecological studies or the calculations of O'Connell et al. (2012). The metabolic explanation outlined by O'Connell (2017) may suggest an explanation, if human breastmilk requires less metabolic 'rearrangement' of nitrogen than that required for other proteins found in meat, nuts and vegetables. Bone turnover rates and intake of non-milk foods especially after 5-6 months may also be relevant factors.

17.5 SUMMARY

We can conclude that the environment during the cave's occupation was largely mesic, based on the faunal isotope data although there are some hints of arid episodes and/or distinct exploited ecozones. The individuals buried in Sector 10 showed trophic offsets in both $\delta^{13}C$ and $\delta^{15}N$ consistent with diets that included reasonable amounts of animal protein but not marine foods. Thus there is no clear dietary evidence for significant transhumance between the site and the coast. The humans are remarkably invariant in $\delta^{13}C$, suggesting highly uniform sources of dietary carbon, while $\delta^{15}N$ variability amongst infants is consistent with current models that place perinates at the maternal level, followed by a rapid trophic shift related to nursing.

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