THE ISOTOPES AT CARLISLE CATHEDRAL *by* JANET MONTGOMERY and JACQUELINE TOWERS

Rib samples from eighteen humans and seven domesticated animals (cow, pig, sheep) were subjected to carbon and nitrogen isotope analysis of bone collagen (Table 19. Teeth were taken from the five skeletons with extant dentition (Sk 7, Sk 25, Sk 27, Sk 28, Sk 57) and were subjected to carbon and nitrogen isotope analysis of dentine collagen and strontium, oxygen and carbon isotope analysis of enamel.

Collagen was extracted using the modified Longin method (Brown et al. 1988; O'Connell and Hedges 1999). Cortical rib and dentine samples of ~300 mg were air abraded to remove surface dirt, weighed and de-mineralised in 0.5 HCl at ~ 4°C. Samples were rinsed in de-ionised water, denatured at 70°C for 48 hours in HCl solution at pH3 and then filtered with 8µm Ezee® filters and 30,000nm ultrafilters. The resultant collagen was freeze dried prior to weighing.

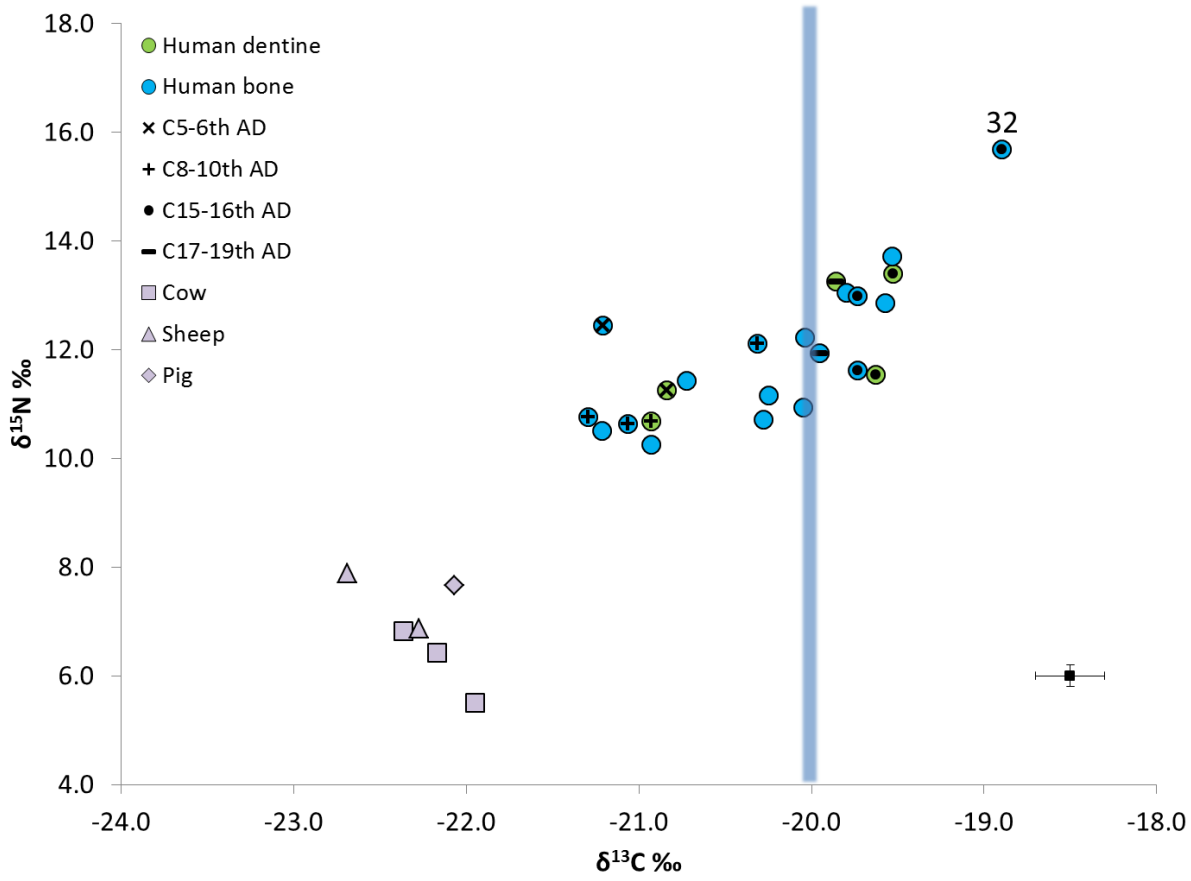
Samples were measured in duplicate by IRMS using a Thermo Flash EA 1112 and a Delta plus XL via a Conflo III interface in the University of Bradford Stable Light Isotope Laboratory. The results are expressed using delta notation in parts per thousand (per mil or ‰) relative to the international standards PDB for carbon and AIR for nitrogen. Error estimated on the reproducibility of laboratory and international standards was determined as ±0.2 ‰ (1 sd) or better.

Enamel was removed from the teeth samples using tungsten carbide dental burrs and diamond edged saws for strontium and oxygen isotope analysis. 3-5 mg of enamel powder was soaked in 1.8 ml of NaOCl solution (~1.7% v/v) for 30 minutes, agitated, rinsed in deionised water and then leached in 1.8ml 0.1M Acetic acid (CH_3COOH) solution for 10 minutes. The resultant sample was dried in a freeze dryer prior to weighing. Oxygen and carbon isotope ratios were measured using a Finnegan Gasbench II coupled to a Thermo Delta V Advantage continuous flow isotope ratio mass spectrometer (CF-IRMS). Enamel carbonate was reacted with phosphoric acid (103%) at 70°C to release CO_2, which was analysed with CO_2 from a reference supply. Values of $\delta^{18}O_{VSMOW}$ and $\delta^{13}C_{VPDB}$ were calibrated to the measured and accepted values of two internal and one international standard. Analytical precision was ± 0.2‰ for both $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VSMOW}$ (1σ).

Table 19. Isotope data for Carlisle skeletons

Sample No.	Date cal AD	Element	Tissue	$\delta^{13}C_{coll}$ ‰	$\delta^{15}N_{coll}$ ‰	$\delta^{13}C_{carb}$ ‰	$\delta^{18}O_{carb}$ ‰	Sr ppm	$^{87}Sr/^{86}Sr$
Humans									
CAR-1		Rib	Bone	-20.0	10.9				
CAR-7	770-980	Tooth	Dentine	-20.9	10.7				
		Tooth	Enamel			-15.3	25.9	73	0.71018
		Rib	Bone	-21.1	10.6				
CAR-13		Rib	Bone	-19.8	13.1				
CAR-14		Rib	Bone	-19.6	12.9				
CAR-16		Rib	Bone	-19.5	13.7				
CAR-25	420-570	Tooth	Dentine	-20.8	11.2				
		Tooth	Enamel			-15.5	26.1	113	0.71002
		Rib	Bone	-21.2	12.4				
CAR-27	1450-1640	Tooth	Dentine	-19.5	13.4				
		Tooth	Enamel			-13.8	25.9	89	0.71046
		Rib	Bone	-19.7	13.0				
CAR-28	1450-1640	Tooth	Dentine	-19.6	11.5				
		Tooth	Enamel			-14.3	26.6	51	0.71064
		Rib	Bone	-19.7	11.6				
CAR-32	1410-1610	Rib	Bone	-18.9	15.7				
CAR-42		Rib	Bone	-20.7	11.4				
CAR-44	890-1040	Rib	Bone	-21.3	10.8				
CAR-52		Rib	Bone	-20.9	10.2				
CAR-53		Rib	Bone	-21.2	10.5				
CAR-54	780-990	Rib	Bone	-20.3	12.1				
CAR-56		Rib	Bone	-20.0	12.2				
CAR-57	1680-1940	Tooth	Dentine	-19.9	13.3				
		Tooth	Enamel			-13.1	24.7	80	0.70963
		Rib	Bone	-20.0	11.9				
CAR-59		Rib	Bone	-20.2	11.2				
CAR-64		Rib	Bone	-20.3	10.7				
Animals									
Cow		metacarpal	Bone	-22.0	5.5				
Cow		tibia	Bone	-22.2	6.4				
Cow		mandible	Bone	-22.4	6.8				
Pig		tooth	Bone	-22.1	7.7				
Sheep		femur	Bone	-22.7	7.9				
Sheep		humerus	Bone	-22.3	6.9				

For strontium, cleaned enamel chips were sealed in containers and transferred to the clean laboratory suite at the NERC Isotope Geosciences Laboratory. Enamel samples were leached and ultrasonicated in deionised water, dried, weighed and spiked with ^{84}Sr prior to dissolution in HCl. Strontium was separated from the enamel matrix using quartz resin-filled (Dowex) columns. Samples were measured by Triton Thermo Finnegan multi-collector mass spectrometer (TIMS). Single rhenium filaments were prepared following the method of Birck (1986). The international strontium isotope standard NBS987 gave the accepted value of 0.71025 ± 0.00001 (2σ, n=16,), producing an external reproducibility of ± 0.0013% during the analysis of these samples. Procedural blanks were generally <100 pg and represented a negligible contribution.



Illus.38. A plot of carbon and nitrogen isotope data for the Carlisle humans and animals. Individuals to the left of the blue line have $\delta^{13}C$ values that indicate their protein came from predominantly terrestrial sources. Analytical error is shown as ± 0.2 ‰ (1sd).

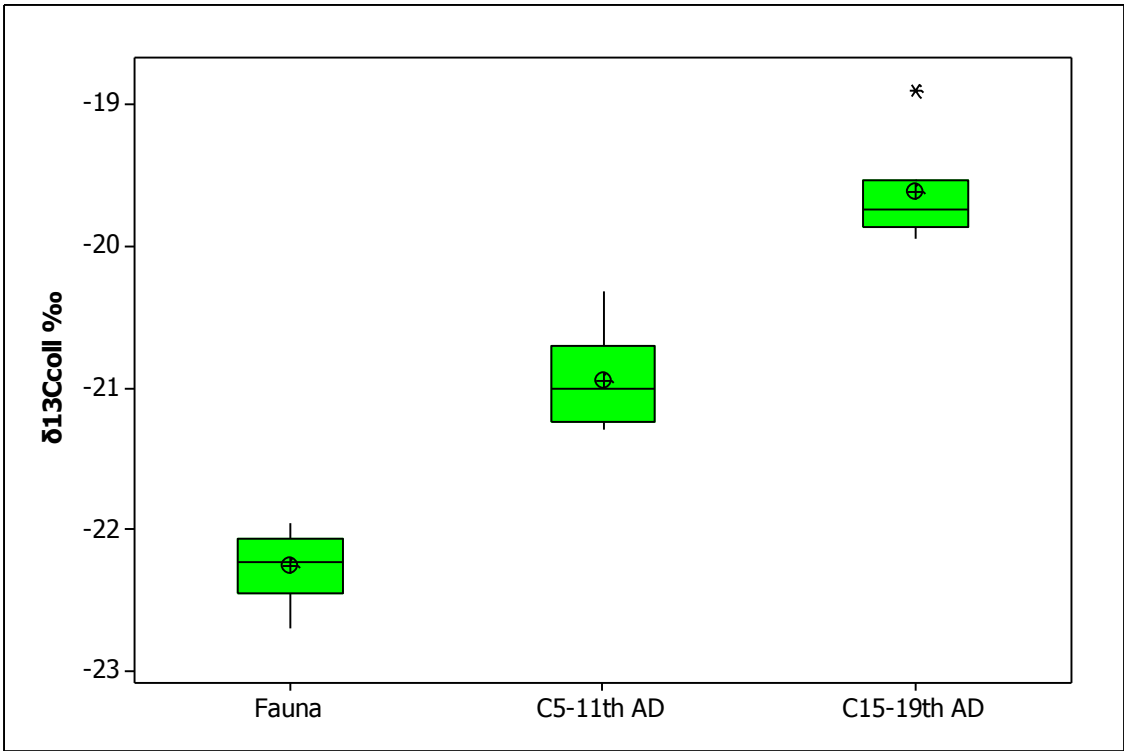
CARBON AND NITROGEN ISOTOPES

Carbon and nitrogen isotope data of bone and tooth collagen are displayed in Illustration 38. Such data provide information about dietary protein consumption rather than whole diet (Ambrose and Norr 1993; Jim et al. 2004). As would be expected in England prior to the fourteenth century AD, all faunal and the majority of human samples are strongly suggestive of a diet composed of solely, or predominantly, C_3 terrestrial protein (Jay and Richards 2007; Müldner and Richards 2007). The mean $\delta^{13}C$ value of animals is -22.3 ‰ and $\delta^{15}N$ = 6.9 ‰ (n = 6). For humans, the mean of bone and dentine values is $\delta^{13}C$ = -20.2 ‰ and $\delta^{15}N$ = 12.0 ‰ (n = 23), and only one individual (Sk 32 an infant) has a $\delta^{13}C$ value higher than 19.5 ‰. The animal-human relationship is broadly consistent with the single trophic level shift of *c.* 1.5 ‰ for $\delta^{13}C$ and 4-5 ‰ for $\delta^{15}N$ normally observed between fauna and humans in the same food chain in Britain (Jay and Richards 2007), although the linear trend in the data towards higher values of both $\delta^{13}C$ and $\delta^{15}N$ suggests there may be some contribution from

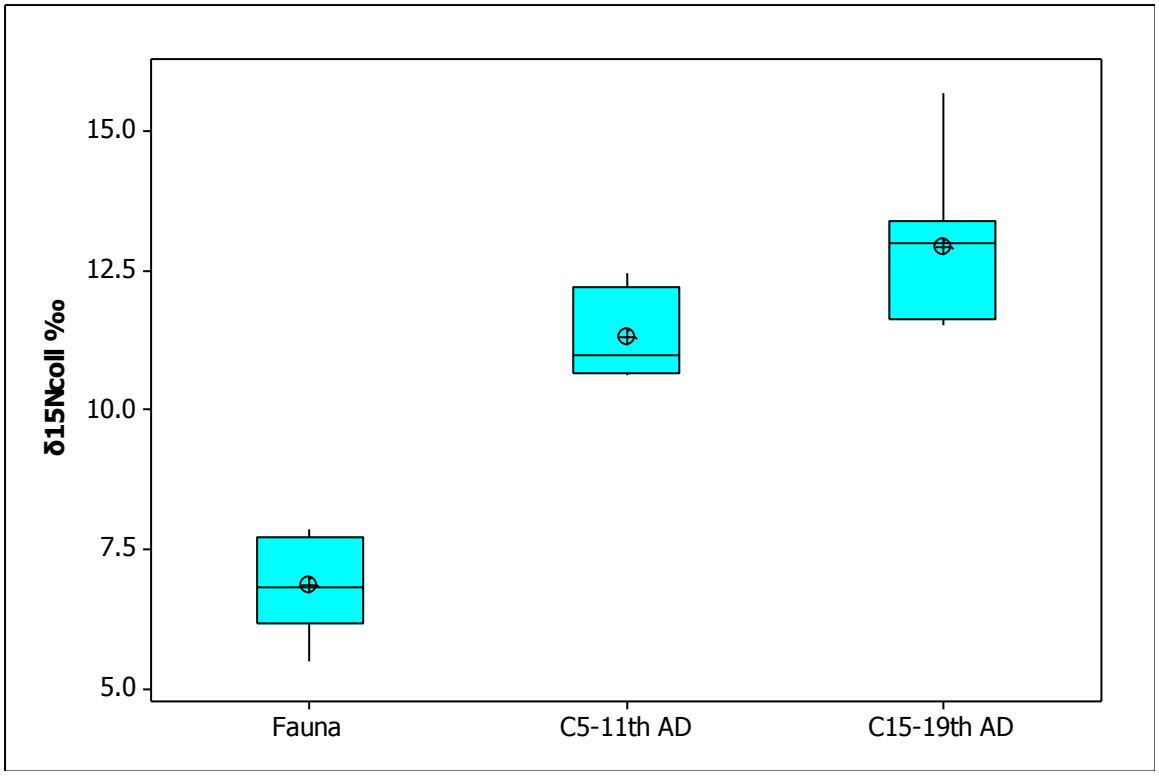
marine protein for some of these individuals in addition to Sk 32 (Schwarcz and Schoeninger 1991). A further complication is that six faunal samples are unlikely to represent the contemporary husbandry practices and diets of all the humans given that they date from the fifth to nineteenth centuries AD.

Illustrations 39-40 use only the dated individuals and illustrates the diachronic rise in $\delta^{15}N$, and particularly $\delta^{13}C$, for the humans: all the individuals with $\delta^{13}C$ values higher than -20.2 ‰ date to the fifteenth to nineteenth centuries. Only a small number of individuals have been dated, but the trend is consistent with other datasets from Britain and may be associated with the onset of increased fish consumption in Britain during the fourteenth century AD (Müldner and Richards 2007).

Human bone and dentine results display comparable distributions, and for three of the individuals the difference between childhood (dentine) and adult (bone) values is negligible, indicating no measurable change in dietary protein. For the remaining two individuals there is a difference in $\delta^{15}N$ of *c.*1 ‰ between dentine and bone collagen, although the shift is in opposite directions (Sk 25 has a higher bone value, Sk 57 a higher dentine value). This suggests the shifts are recording different dietary changes and cannot both be ascribed to the same process. Neither, however, would indicate a significant change from a childhood diet rich in marine fish to one based on terrestrial protein.



Illus.39. Carbon isotope ratios for Carlisle humans and animals



Illus.40. Nitrogen isotope ratios for Carlisle humans and animals

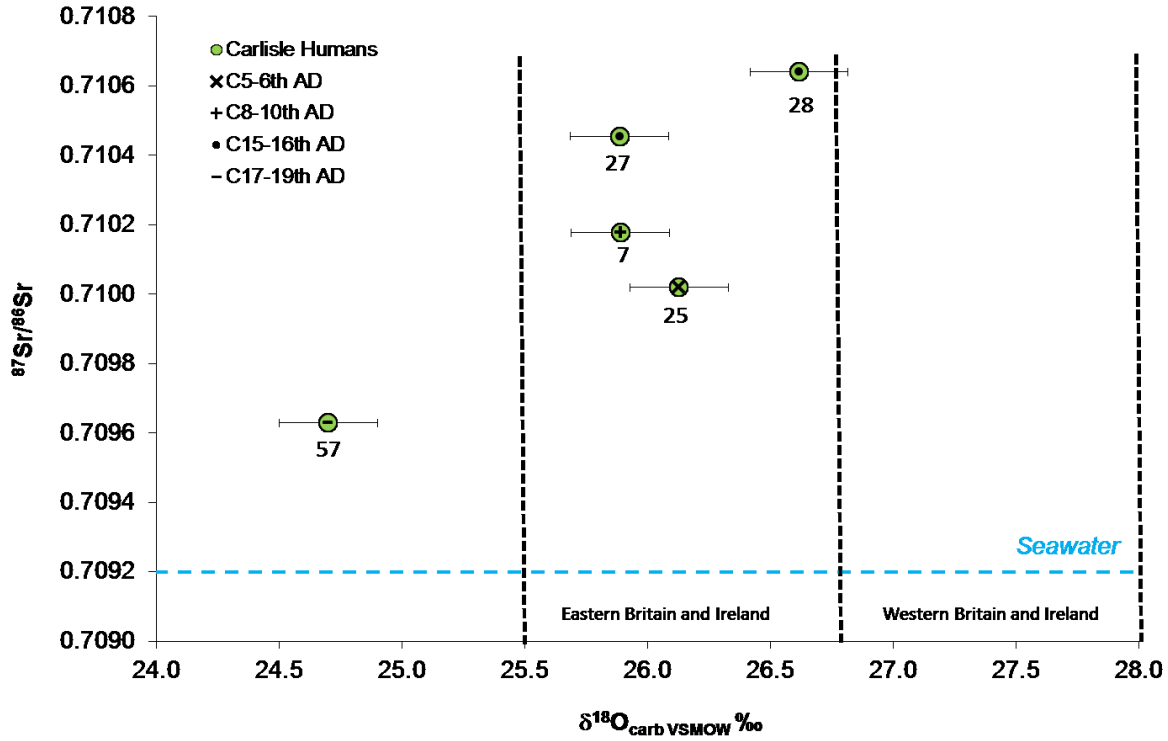
STRONTIUM ISOTOPES

The strontium isotope data for the five humans ranges from 0.7096 to 0.7106 and the concentrations from 51 to 113 ppm. Both these parameters are within the normal range of values that would be expected for humans inhabiting a region of sedimentary Triassic rocks, such as those found in the Carlisle region, on the western seaboard of Britain (Evans et al. 2012). Such isotope ratios are, however, very common and can be found in many locations across Britain, Ireland and further afield (Montgomery et al. forthcoming). They are, thus, not unique in any way to the Carlisle area.

OXYGEN ISOTOPES

The carbonate oxygen isotope data for the five humans ranges from 24.7 to 26.6 ‰. There is currently very little comparative British data from enamel carbonate against which to compare these values, as the majority of published human oxygen isotope data has been obtained from phosphate. Conversion to phosphate using an established equation (Chenery et al. 2012) gives a comparable phosphate oxygen range of 15.8 to 17.8 ‰. These values are low for humans inhabiting the west coast of Britain (Evans et al. 2012; Montgomery et al. 2009) and would be more commonly found further east (Illus.41), but given their large date

range (fifth to nineteenth centuries), it is unlikely that they share a common origin. The lowest value of 24.7 ‰ (Sk 57) is rarely found amongst individuals from Britain. It points to origins at higher altitude, latitude (such as Scandinavia) or, possibly, on the east coast of either Britain or Ireland. However, this individual dates to the post-medieval period during the Little Ice Age and at a time when worldwide travel and trade was taking place. There may, therefore, be many factors that can explain this value, either through climate change or origins elsewhere.

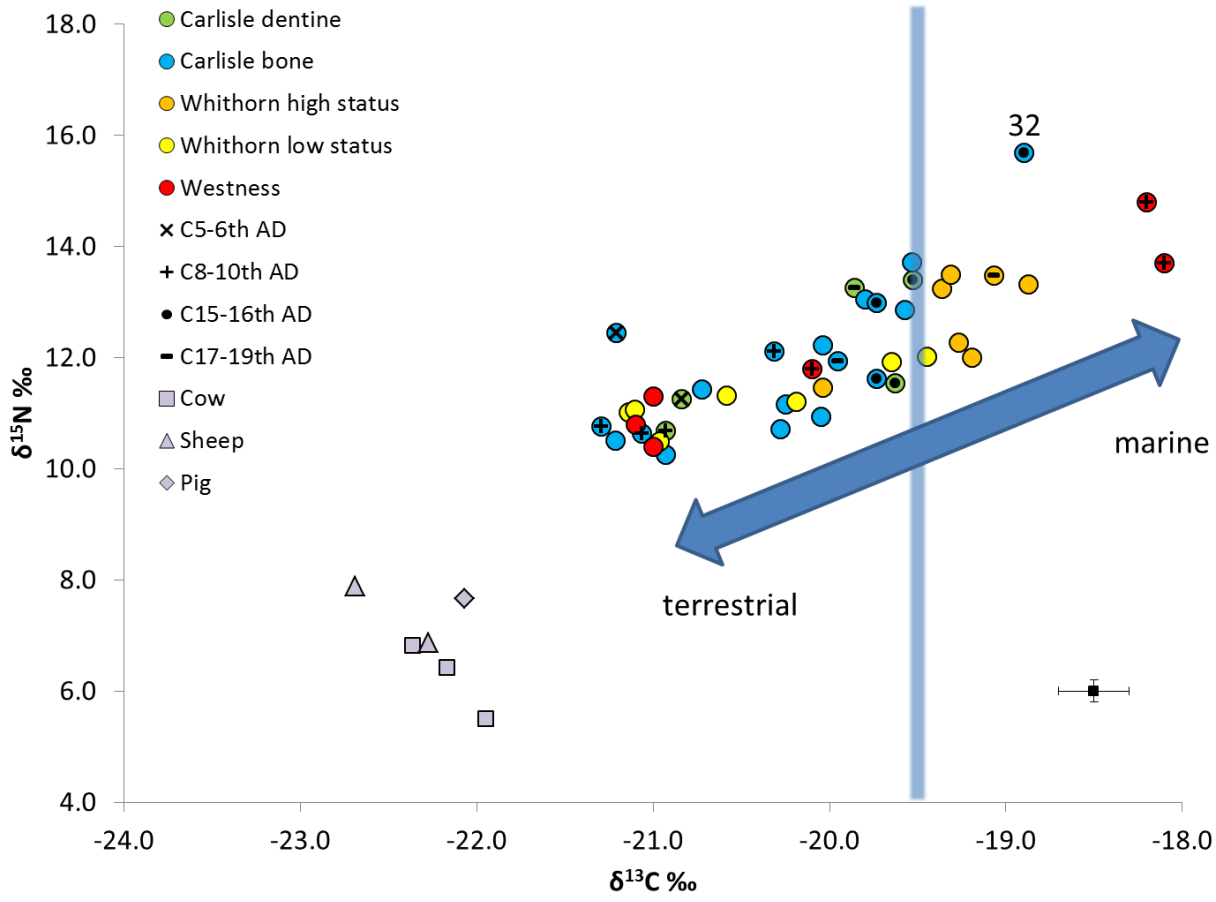


Illus.41. A plot of strontium and oxygen isotope data for the Carlisle humans. Black dashed lines indicate expected ranges of oxygen isotopes in humans originating from the east and west coasts of Britain and Ireland. 2sd analytical errors are within symbol for strontium isotopes and are ±0.2 ‰ (1sd) for oxygen isotopes.

DISCUSSION

The carbon and nitrogen isotope data indicate that a dietary shift occurs in the Carlisle population between the eleventh and fifteenth centuries, with no evidence for marine protein consumption in individuals dating prior to the eleventh century (Illus 39-40). This is in line with previous larger-scale studies of medieval diet in Britain (Müldner and Richards 2007). As can be seen from Illustration 42, comparative data from the medieval site on the western

seaboard at Whithorn also fits this linear dietary trend, with the earlier lay population sitting amongst the Carlisle individuals with a terrestrial diet, and the higher status fourteenth-fifteenth-century clerics extending the trend due to increased consumption of marine protein. Beyond these individuals lie two burials excavated from the Viking cemetery at Westness in the Orkney Islands. Carbon, nitrogen and oxygen isotopes have shown that these two male skeletons had a marine protein diet (Illus. 42) and were of Scandinavian origin, thus suggesting if a marine diet is found in Britain prior to the thirteenth century, it may be an indicator of non-British origins (Barrett and Richards 2004; Montgomery et al. forthcoming). At Carlisle, however, only three individuals dated to the Viking period, and all had a terrestrial diet. All the individuals who had higher $\delta^{13}C$ and $\delta^{15}N$ that might be indicative of a marine diet dated to the fifteenth to nineteenth centuries AD.



Illus.42. A plot of carbon and nitrogen isotope data for the Carlisle humans and animals with selected comparative data. Individuals to the left of the blue line have $\delta^{13}C$ values that indicate their protein came from predominantly terrestrial sources. Data sources (Montgomery et al. 2009; Barrett and Richards 2004).

One of these individuals, Sk 32, had noticeably elevated values compared to the remainder of the population. This individual was a child, and its $\delta^{13}C$ and $\delta^{15}N$ values are consistent with a breastfed infant due to the trophic level shift associated with feeding from its mother (Jay et al. 2008).

The strontium isotope ratios for the five individuals are, as mentioned above, common values which are found in a wide range of localities and geological terrains. They do not, therefore, rule out local origins nor origins in Scandinavia, because such values have been found amongst Viking burials in Westness and Dublin who have originated in places considerably colder than the British Isles and who would appear to be of Scandinavian origin (Montgomery et al. forthcoming) and in Denmark (Price et al. 2011). The oxygen isotope data indicates none of the five individuals have values consistent with origins on the western seaboard of Britain, although the uncertainties involved with the interpretation of such data are considerable and assignation of origin based only on oxygen isotopes should be approached with caution (e.g. see Pollard et al. 2011). Nonetheless, Sk 57 has an unusually low $\delta^{18}O$ value for human populations from Britain, and this post-medieval individual may have origins overseas.

CONCLUSIONS

The eighteen humans from Carlisle span approximately 1,400 years, and the carbon and nitrogen isotope data show a diachronic change in diet over this time period. They also identify a breastfed infant dating to the fifteenth to sixteenth centuries. There is no evidence for the consumption of marine protein amongst any of the individuals who date prior to the fifteenth century, and the dietary isotopes therefore provide no evidence for the presence of individuals of Scandinavian origin, as was found for two male burials at Westness. There is evidence for a change in diet between childhood and adulthood for two individuals, one of early medieval and one of late medieval date. The strontium isotope data obtained from five individuals is consistent with origins in the Carlisle region, but these are common values and can be obtained in many places in Britain. They are thus not particularly diagnostic; however, they do not rule out Scandinavian origins.

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