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Continuity or colonization in Anglo-Saxon England? Isotope evidence for mobility, subsistence practice and status at West Heslerton

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ABSTRACT

The *adventus Saxonum* is a crucial event in English proto-history. Scholars from a range of disciplines dispute the scale and demographic profile of the purported colonising population. The 5th-7th century burial ground at West Heslerton, North Yorkshire, is one of the few Anglian cemeteries where an associated settlement site has been identified and subjected to extensive multi-disciplinary post-excavation study. Skeletal and grave good evidence has been used to indicate the presence of Scandinavian settlers. A small, preliminary study using lead and strontium isotope analysis of tooth enamel, mineralised in early childhood, from Neolithic/Early Bronze Age (n = 8), Iron Age (n = 2) and Early Anglo-Saxon (n = 32) skeletons, was carried out to directly investigate this hypothesis. Results suggest that lead provides dissimilar types of information in different time periods. In post-Roman England it appears to reflect the level of exposure to circulated anthropogenic, rather than natural geological lead, thus being a cultural, rather than geographical, marker. Consequently, only strontium provides mobility evidence amongst the Anglian population, whereas both isotope systems do so in pre-Roman periods. Strontium data imply the presence of two groups: one of "local" and one of "non-local" origin, but more work is required to define the limits of local variation and identify immigrants with confidence. Correlations with traditional archaeological evidence are inconclusive. Whilst the majority of juveniles and prehistoric individuals fall within the "local" group, both groups contain juveniles, and adults of both sexes. There is thus no clear support for the exclusively male, military elite, invasion model at this site.

The *adventus Saxonum* is arguably the most tantalising and controversial migration of people to Britain. There is little agreement over its scale, whether it was indeed a “coming” or a conquest or even whether it happened at all. The evidence from both the sparse historical documents and the incomplete archaeological record is frequently contradictory and interpretation is thus fraught with difficulty. The migrants themselves left no written records and existing accounts were mostly written centuries afterwards (Hamerow, 1997). Nonetheless, there is undisputed archaeological evidence that the traditional homeland of the Anglian migrants, Angeln, was effectively depopulated during the Migration Period (Hamerow, 1994). This discontinuation of settlement activity occurred during a period of climatic deterioration to wetter or colder conditions c. A.D. 260-540 across the northern hemisphere (Chiverrell, 2001; Higham, 1992). German archaeologists accept that the mass migration of people with the concomitant replacement of the indigenous British population recorded by Gildas, Bede and the *Anglo-Saxon Chronicle* did, indeed, take place (Härke, 1998). Migration theory suggests that the absence of “small-group strategies” indicates the Anglo-Saxon settlement involved considerable numbers of people (Anthony, 1997). In the mid 19th century, it was considered valid to track this historically documented spread of Anglo-Saxon invaders on English soil by mapping distributions of early Germanic pottery and brooches (Lucy, 1999). Similarly, the arrival of new styles of housing or a sudden predilection for siting settlements on lighter soils has been attributed to the arrival of settlers with different subsistence practices and building skills (Hamerow, 1997). Such endeavours came to be largely scorned by British archaeologists in the second half of the 20th century, leading Hamerow (1994) to point out: *“The observations of a recent writer, who wonders wryly whether these “marching pots wore jackboots” (Richards, 1988) reflects the almost disdainful rejection of many archaeologists over the past 15 years or so of any suggestion of mass migration”*. Moreover, some British scholars have entirely forsaken extensive population replacement in favour of domination by a male military elite (Arnold, 1984; Higham, 1992). Unfortunately, archaeological evidence that indisputably requires either mass migration or smaller-scale, elite cultural dominance has proved elusive, and academics have questioned how the cemetery data (which constitutes the principal source of evidence in this period) is used (Lucy, 1998; 2000). For example, burial with jewellery of a style previously common in the Germanic homelands is neither proof that the deceased owned it, was born in Angeln, nor by the same token, that "she" was biologically female.

Chain migration theory predicts that permanent migrants are far more likely to follow family members to known places, or to target places where familiar social systems prevail, than to seek out alternative or new locations. Accordingly, this *"brings migrants from a specific home region to a specific destination over a known route, usually to join kin"* (Anthony, 1990; 1997). This has important implications for studies of aDNA and archaeological skeletal investigations of variation and inherited traits because such kin-focussed migration is recognised as a potential cause of significant variation in allele frequencies between populations (Rogers and Eriksson, 1988). If, as Anthony (1997) maintains, *"Cultures don't migrate; people do"*, then it is, perhaps, to them rather then the remnants of their archaeological material culture that we must look for direct evidence of migrations.

In recent years radiogenic isotopes of strontium, and less frequently lead, have been used to identify immigrants amongst ancient populations. The application assumes that the skeletal remains of indigenous populations will contain an isotope composition that is typical of the surface geology, and hence geographic area, in which they dwell (Beard and Johnson, 2000; Ericson, 1985). Anthropogenic lead contamination renders lead more difficult to analyse and interpret (Montgomery, 2002) and it has been infrequently used (but see Carlson, 1996; Molleson et al., 1986). Strontium, however, has been extensively applied to studies of human and hominid bone and tooth enamel (e.g. Ericson, 1985; Ezzo et al., 1997; Grupe et al., 1997; Price et al., 1994a,b; 2000; 2001; Sillen et al., 1998). By combining strontium with the complementary information available from lead and stable light isotopes of carbon, nitrogen and oxygen the discriminatory power of the approach can be extended (e.g. Åberg et al., 1998; Chiaradia et al., 2003; Cox and Sealy, 1997; Hall-Martin et al., 1993; Montgomery et al., 2000; Outridge and Stewart, 1999; Sealy et al., 1995; van der Merwe et al., 1990; Vogel et al., 1990).

The Anglian (5th to 7th century) cemetery at West Heslerton, North Yorkshire (Fig. 1) presents the opportunity to apply the isotope source tracing method to an extensively excavated and recorded cemetery and settlement site and compare the isotope results with the methods traditionally used in archaeology to identify the presence of migrants amongst a burial population, e.g. grave goods, skeletal traits and burial practices. Although many cemeteries are known from the Migration Period in England, it is extremely rare for their associated settlement to be identified and investigated. The distinctive Anglian (as opposed to Saxon or Jutish) nature of the female dress accessories (cruciform, square-headed, and small-long brooches, bucket pendants, braids and wrist-clasps) found in the graves strongly suggest links with both Schleswig-Holstein in northern Germany and Scandinavia, specifically western Norway and southern Sweden. Furthermore, there are indications of two distinct skeletal types being present: the minor, and perhaps foreign, group being best represented by a series of tall, gracile individuals buried with weaponry (Haughton and Powlesland, 1999a,b).

The aims of this case study are:

1) To investigate whether lead and strontium isotope analysis could identify the presence of two (or more) distinct groups within the cemetery;

2) To use geological and archaeological evidence to determine whether such groups were consistent with a local and an immigrant contingent;

3) To compare the traditional archaeological methods of identifying native Britons and Anglian immigrant burials against the isotope results and assess which, if any, supported or refuted the isotope data.

ARCHAEOLOGICAL BACKGROUND, CONTEXT AND SAMPLES

The Anglian cemetery at West Heslerton is located at the foot of the north facing scarp slope of the Yorkshire Wolds on the southern edge of the Vale of Pickering, east of the present village. The Anglian settlement is located on slightly higher ground 450m to the SW (Fig. 2). The cemetery was in use for a relatively short time (125 - 175 years) from the late 5th to the early 7th centuries and utilised an established Late Neolithic and Early Bronze Age ritual site comprising a hengiform enclosure, timber post circle, round barrows and associated burials (Fig. 2). Two square barrow Iron Age inhumations were also discovered during the digging of a pipe trench beside the A64, which now bisects the cemetery. Relative and absolute dating of graves has proved difficult. Over 100 burials have, however, been assigned to overlapping development phases on the basis of grave goods and there are indications that the cemetery developed polyfocally in family, household or kinship groupings rather than from a single centre (Haughton and Powlesland, 1999b).

Site geology

West Heslerton is located at the intersection of two environmental niches: the chalk uplands of the Yorkshire Wolds and the flat, glacial valley of the River Derwent. The Wolds are formed from the northernmost outcrop of Cretaceous chalk in Great Britain (Fig. 1). The steep, north-facing chalk scarp gives way first to gentler foothills where small deposits of clay lie between the exposed chalk knolls and then to the older, Jurassic deposits of Kimmeridge and Ampthill clay which form the valley bottom (British Geological Survey, 1979). However, between the Wolds and the flat, former fen bordering the river Derwent, the underlying Jurassic clay is covered by extensive Quaternary drift: sands and gravels of lacustrine and aeolian origin, which in the locality of the sand quarry particularly, are many metres deep (British Geological Survey, 1977). The cemetery is thus located on these free-draining sands and chalk gravels with an exposed chalk outcrop on the eastern edge. Such light, sandy soils are highly typical of many cemeteries dating from the Early Anglo-Saxon period.

Settlement and subsistence evidence

The Anglian settlement lies between the cemetery and the steep scarp of the Wolds. It sits astride a relict stream channel that was fed by an emergent spring at the centre of the southern half of the settlement (Fig. 2). It was, therefore, located at a source of freshwater but upstream from, and on higher ground than, the cemetery. The site had been used throughout the Late Iron Age and Roman periods when habitation appears to be concentrated in the valley bottom along the fen edge, but this area shows increasing wetness during the 4th century making it unsuitable for continued settlement (Haughton and Powlesland, 1999b). Such a change in environmental conditions could explain the relocation of the settlement to the drier and lighter soils of the higher land to the south during the 5th century. Plant macrofossil evidence from the Anglian settlement indicates that the majority of crops were grown on the light soils of the flat land to the north of the site rather than on the chalk uplands or the small areas of heavier, clay soils, and charcoal evidence suggests both woodland and orchards were maintained (Powlesland, 1998). The large amount of animal bone recovered consisted mainly of domestic species of cattle, sheep, horse, pig, goat, dog and cat with relatively few wild animals present. Bones of both wild and domestic birds, particularly geese, are plentiful (Powlesland, 1998). Fish bones are scarce, and whilst this can be due to their relatively poorer preservation and recovery, the excavators consider recovery to have been excellent at the site (Powlesland, 1998). However, despite the great variety of species present, sheep are considered to account for over a half and cattle a third of the total meat consumption at the site (Rahtz, 2001). On balance, therefore, it would appear that wild resources constituted only a very minor part of the diet, the bulk, including drinking water, being obtained locally from sand or chalk substrates. However, the contribution different dietary components make to the resulting enamel isotope ratio is not necessarily linked to quantity. For example, meat and milk are not only very low in strontium but strontium uptake is suppressed in protein or calcium-rich diets, whereas a vegetarian diet is strontium-rich, and strontium uptake is enhanced by high-fibre diets (Aufderheide, 1989; Burton and Wright, 1995; Ezzo, 1994; Lambert and Weydert-Homeyer, 1993; Montgomery, 2002; Underwood, 1977). Consequently, omnivores such as humans will obtain the majority of their strontium from plants with a comparatively negligible input being derived from animal sources (Burton and Price, 2000; Elias, 1980). Plant-derived strontium is, therefore, likely to make the greatest contribution to the resulting isotope ratio of human inhabitants.

Samples

All the Anglian tooth samples were taken from Site 2 and specifically from areas 2B and 2BA south of the A64 trunk road (Fig. 2) which contain the highest proportion of early graves (Haughton and Powlesland, 1999b). Putative migrants were sought in graves exhibiting evidence of Scandinavian or Germanic material culture or burial rites, and from graves containing assemblages suggesting inhumation had occurred early in the life of the cemetery. One permanent tooth was analysed from each of 32 Anglian individuals plus an additional deciduous tooth from G97, making 33 teeth in total (Table 1). Samples were chosen to include males and female adults, juveniles, a “mother” and “child” double burial and from the four grave-good classifications of Lucy (1998), i.e. weapons, jewellery, “other” neutral types of grave goods and unaccompanied burials. In addition, two burials from the Iron Age and six from the Late Neolithic/Early Bronze Age were also analysed bringing the total number of individuals to 40 (41 teeth). Sampling was, therefore, not random but rather a “purposive selection” which Cowgill (1975) defines as fitting when *“our resources, the nature of our data, and the nature of critical test implications derived from competing hypotheses are all such that we can define obvious criteria of relevance, and use these criteria as a basis for picking a manageable number of intrinsically important observations”.* That is, this study consisted of a targeted, restricted, preliminary exploration of the isotopic characteristics of specific groups within the population. The individual skeletons were chosen according to current archaeological theories of what attributes may, or may not, indicate non-British birth, in order to optimise the probability of obtaining both indigenous and non-indigenous individuals.

Nevertheless, as is often the case with archaeological studies subject to the vagaries of preservation and recovery, the “ideal” sample selection was not available. Of particular regret was the inability to obtain tooth samples from: a sufficient number of adult crouched burials without Anglian grave goods; G87 which had the earliest grave goods in the cemetery; any of the four graves containing bucket pendants, an artefact originating in Schleswig-Holstein, N. Germany during the 4th century and believed by Hines (1984) to be such an odd invention that their presence in 5th century England can only result from direct influence from this region. As these three categories were possible indicators of indigenous Britons in the first case and (insofar as any burial assemblage relates to individual origins) early immigrants in the second and third, this was unfortunate but only one of many processes that introduce bias in the incomplete data set. However, as Baxter (2003) has recently pointed out *“there is an* *important role for non-random sampling informed by archaeological common sense, judgement and expertise. Sometimes this may be all that is needed."*

Teeth were graded for attrition, root development, and gross macromorphological preservation of both the enamel and dentine prior to sampling using the grading systems given in Montgomery (2002) in order to investigate the relationship between these variables and diagenetically altered teeth. The results are discussed therein. However, with the probable exception of G98, an incompletely mineralised tooth, no evidence was found that the predominantly poor skeletal preservation observed at this site (Cox, 1990), the burial soil (i.e. chalk or sand), nor the presence of grave goods, had compromised the strontium or lead isotope integrity of the core enamel samples (Montgomery, 2002).

METHODS

Core enamel was removed from the tooth samples and mechanically cleaned using tungsten carbide dental tools following the procedure given in Montgomery (2002). All further preparation was carried out within a class 100, HEPA-filtered laboratory facilities at the NERC Isotope Geosciences Laboratory (NIGL), Keyworth, UK. The laboratory procedure used ion exchange chromatography and Teflon-distilled reagents to individually isolate, prepare and spike the lead and strontium content of the tooth matrix prior to instrumental analysis. Isotope dilution was used to obtain lead and strontium concentrations using ^{208}Pb and ^{84}Sr spikes respectively. Lead was separated first from the tooth matrix using Dowex 1 x 8, 200-400 mesh anion exchange resin. Strontium was separated from the resulting eluent using standard Dowex AG50W X12 cation exchange resin. The isotope compositions of strontium and lead were measured using a Finnegan MAT262 thermal ionisation multi-collector mass spectrometer. The reproducibility of the international strontium standard, NBS

987, during a period of analysis did not exceed ±0.000030 (2σ) or ±0.004% (2σ). All samples were corrected to the accepted value of $^{87}Sr/^{86}Sr$ = 0.710235 to ensure that there was no induced bias through mass spectrometer drift over the 18 months of data collection. Strontium isotope data are presented as $^{87}Sr/^{86}Sr$ ratios. Lead isotope fractionation was monitored with suitable sized (20ng) runs using NBS 981 and data were corrected for fractionation using the associated standards run. Errors (2σ) on the lead isotope ratios were determined as ±0.16% for $^{208}Pb/^{204}Pb$, ±0.13% for $^{207}Pb/^{204}Pb$ and ±0.01% $^{206}Pb/^{204}Pb$. Laboratory contamination, monitored by procedural blanks for both lead and strontium, was negligible. Data are presented in Table 2.

RESULTS AND DISCUSSION

Cultural focussing of lead between the Anglian and prehistoric inhabitants

The lead plot (Fig. 3) illustrates the relative compositions of Anglian and prehistoric enamel samples with respect to a three-component system of English ore field lead composition and the two local burial soils. The data generally follow the Stacey and Kramer growth curve (Ludwig, 1994) and lie towards the lower side of the main English ore field. All the Anglian data fall between the values for the local soils, chalk marking the most radiogenic endmember, and sandy soil the least radiogenic endmember of the dataset. The two Iron Age individuals (WHIA-1 & WHIA-2) are widely separated. WHIA-1 plots at a significantly more radiogenic position in lead isotope space than any other sample being well separated from WHIA-2, which is closer to the centre of the range of Anglian $^{206}Pb/^{204}Pb$ values but below the main field of data due to a lower $^{208}Pb/^{204}Pb$ ratio.

The prehistoric enamel-lead concentrations are low and remarkably uniform: $\underline{x}$ = 0.06 ± 0.02ppm (1σ, n = 8) with only WHIA-2 exceeding 0.08ppm (Table 2). These concentrations are of the same magnitude as a Bronze Age human and Iron Age herbivores from Cnip, Lewis (Montgomery 2002). They are consistent with the suggestion based on a study of Neolithic and Bronze Age burials at Monkton-up-Wimbourne, Dorset (Montgomery et al., 2000) that prehistoric people have enamel-lead concentrations and isotope ratios that derive from natural exposure to country rock lead and represent background environmental values (Budd et al., 2000).

Anglian lead concentrations are an order of magnitude greater than those from the prehistoric individuals, but nevertheless are still mostly well within the range of what is considered today to be low lead exposure, i.e. < 2ppm (Gulson, 1996; Gulson and Wilson, 1994). Thirty of the 33 enamel samples produced an average lead concentration of 0.34 ± 0.23ppm (1σ, $n = 30$). The remaining three individuals have lead concentrations >1ppm: G75 - 8.16ppm; G78 - 1.66ppm; G133 - 2.96ppm. The mean enamel-lead concentration of 0.34ppm is an order of magnitude lower than concentrations obtained from English burials from both the preceding late Roman period and the later Mediaeval period (Montgomery 2002), and comparable with concentrations obtained from pre-metallurgical Neolithic chalk burials from southern England, i.e. 0.15 – 0.68ppm, $\underline{x} = 0.31$ppm, $n = 7$ (Montgomery, 2002; Montgomery et al., 2000). These considerations imply that although the majority of the Anglian population had no great exposure to anthropogenic ore lead, the local country rock signature at West Heslerton contributed <10% of the lead burden and was swamped by lead from anthropogenic sources. At this site it is only fortuitous that the ore lead signature lies between the chalk and sand endmembers.

Figure 4 plots lead concentration against composition and illustrates what we have termed “cultural focussing” of lead burdens. There is an inverse correlation between the spread of isotope ratios and lead concentration. At low lead concentrations there is a range of ^{207}Pb/^{206}Pb ratios between 0.838 and 0.855. This range narrows down to a single peak, defined by several samples which have Pb concentrations ≥1ppm and $^{207}Pb/^{206}Pb$ = 0.846. The restriction of the greatest lead concentrations to $^{207}Pb/^{206}Pb$ ratios of 0.846 implies that whilst low lead concentrations can be obtained over a wide range of lead ratios, concentrations ≥1ppm can only be obtained from a source, or sources, of $^{207}Pb/^{206}Pb$ = ~0.846. Clearly, this source is lead-rich and most likely to be of anthropogenic, rather than geological origin. Results from other post-metallurgical Roman and late Mediaeval British individuals with >1ppm lead follow the same trend. They define an even tighter cluster than the West Heslerton Anglian population and have $^{207}Pb/^{206}Pb$ between 0.846 and 0.849 (Montgomery, 2002). Such lead ratios are typical for English ore lead (Table 3).

Characterising the isotope fingerprint of a population is not the same process as characterising an ore-deposit. The former is the result of one or more dietary inputs of varying concentrations and ratios, during a restricted childhood period with a single resulting weighted mean value. The latter is characterised by many separate determinations of specific and discrete ore samples. Obtaining a Pb isotope value from an individual is, therefore, somewhat akin to producing a pewter bowl by combining and homogenising several pieces of scrap metal, those of a small farming community represented by many such pewter bowls. The community would, therefore, be expected to have a small range of values normally distributed about a mean. Any outliers would have had one, or more, very different dietary inputs during childhood. It follows that under these circumstances outliers, rather than being the result of normal statistical spread may have a valid and important reason for being so. As Shennan (1988) states: *"When such peculiarities as skewness, multiple peaks or the presence of outliers (values very different from the bulk of the observations) do exist, the shape of the distribution, rather than its central tendency or dispersion, is likely to be its most important characteristic"*.

The normal distribution of the Anglian lead data (Fig. 5) supports the interpretation that the Anglian individuals buried at West Heslerton are a single statistical population with respect to their exposure to lead. The composition of the lead is consistent with English ore, but cannot exclude alternative overseas ore sources of similar composition to the English ore fields. It would, perhaps, be instructive to examine the ore composition of the Scandinavian jewellery associated with some of the burials to make a more direct comparison with metal ware sources. The prehistoric data clearly demonstrate the variability amongst individuals prior to the large-scale lead extraction that occurred during the Roman period (Fig. 5). It contrasts sharply with the increasing homogeneity seen in individuals exposed to lead in later periods (Montgomery, 2002). The mean value and standard deviation of all individuals at West Heslerton ($\underline{x} = 0.846 \pm 0.0054$, 2σ) is, however, within the range of known English ore lead (Table 3). The lead data, therefore, does not demand an explanation in terms of origin outside England, although as a result of the considerable exportation of lead from Britain to Continental Europe during the preceding Roman Period (Tylecote, 1992), neither can it rule it out.

Population discrimination using strontium isotope analysis

Figure 6 plots enamel strontium composition against concentration. Included on the diagram are the isotope ratios of leached soils (chalk and sand) from the site, and seawater composition. This latter endmember is included as an estimate because at all sites investigated to date (Montgomery, 2002), local enamel ^{87}Sr/^{86}Sr ratios do not cluster in a normal distribution around the soil/bedrock leaches but tend to fall between them and the value for modern seawater (^{87}Sr/^{86}Sr ~0.7092), which is the source of meteoric water. Inputs to the biosphere from meteoric water may thus introduce a bias to bioavailable strontium towards that of sea/rainwater (Montgomery, 2002) and are thus an important variable to consider

(Beard and Johnson, 2000). For example, an individual with $^{87}Sr/^{86}Sr = 0.7078$ is highly likely to have origins in a region where $^{87}Sr/^{86}Sr < 0.7078$ can be obtained and conversely, origins for an individual with $^{87}Sr/^{86}Sr = 0.7143$ should be sought in regions where $^{87}Sr/^{86}Sr > 0.7143$ can be obtained, in order to balance the dietary input from meteoric water.

Enamel strontium values form a string of data points between 0.7082 and 0.7110. Twenty-one of the forty individual analysed from all periods fall between the local geological end members of the sandy soil leach and sea/rainwater. Only one sample (G113) plots within the range of the local sandy soils and none approach that of the chalk. The remaining enamel samples plot above the value of modern seawater, up to a maximum value of 0.711080 (2BA229). However, rather than forming the normal distribution expected from a single sedentary community, the $^{87}Sr/^{86}Sr$ ratios suggest bi-modality; there is only a single individual between 0.70919 and 0.70948. Whereas the Anglian $^{207}Pb/^{206}Pb$ data from West Heslerton is almost symmetrically distributed (Fig. 5), supporting the interpretation that the individuals at this site belonged to a single statistical population, the strontium data from West Heslerton shows a significant skew or bimodality indicative of a more complex system, rather than the normal statistical spread expected from a sedentary community consuming the same bulk diet.

Non-parametric box and whisker plots display the $^{87}Sr/^{86}Sr$ ratio data (Fig. 7). Enamel ratios of the individuals dying in childhood (n = 13), i.e. with a short life span, have a different and much more tightly constrained distribution than those who attained adulthood. In the Anglian plots particularly, the boxes do not overlap. As enamel retains childhood compositions, this difference should not arise as a function of different access to food products between adults and children; core enamel provides a direct comparison between the childhood diets of all individuals (Montgomery, 2002). The juvenile distribution also coincides with the local parameters (Fig. 6 & 7) suggesting that the majority of individuals who died at a young age were of local origin; a reasonable premise, given that the window in which they could have undertaken a long-distance migration is small.

Three hypotheses have been formulated to explain the distribution of the Anglian $^{87}Sr/^{86}Sr$ data at West Heslerton:

1) As suggested by Price et al. (2002) the chalk, sand and rainwater ratios are insufficient to fully characterise the range of $^{87}Sr/^{86}Sr$ environmental parameters (although this does not seem to be so for lead), and an important and more radiogenic (i.e. >0.711) $^{87}Sr/^{86}Sr$ food source exists nearby;

2) The Anglian inhabitants were importing food from a region with a more radiogenic $^{87}Sr/^{86}Sr$ signature and given the earlier comments regarding the small contribution of animal-derived foods to total dietary strontium, this is most likely to be plants;

3) The West Heslerton dietary $^{87}Sr/^{86}Sr$ signature, like that for lead, lies within the environmental parameters and individuals falling outside this have moved to the area from elsewhere.

Can a case be made, therefore, that the sample of individuals taken from West Heslerton consists of an immigrant and an indigenous population? The Anglian adult distribution appears to be at least bi-modal, providing evidence of a significant difference in childhood diet amongst the two groups. This observation is supported by its co-incidence with the most radiogenic environmental endmember (i.e. 0.7092) and the predominance of juveniles and prehistoric individuals inside the environmental parameters. This may arise from the presence of a local and one, or more, non-local groups in the cemetery, e.g. from northern Europe and western Norway (Budd et al., in press). To investigate whether any archaeological criteria supports this interpretation, samples were grouped according to $^{87}Sr/^{86}Sr$ ratios into two groups (Table 4): those with $^{87}Sr/^{86}Sr$ ratios ≤0.7092 which will be referred to henceforth as the “local” population; and those with $^{87}Sr/^{86}Sr$ ratios >0.7092 will be referred to as the putative “non-local” population.

COMPARISON OF POSSIBLE ARCHAEOLOGICAL INDICATORS OF MIGRATION WITH STRONTIUM ISOTOPE SUBDIVISIONS

Spatial and temporal organisation within the cemetery

Precise dating and chronology is often problematic in Anglian cemeteries and at West Heslerton many burials had a wide date range that encompassed 100 to 200 years. Nevertheless, of the Anglian burials analysed, twenty-two could be assigned to a development phase of the cemetery. Burials occurring early in the life of the cemetery were not confined to the non-local group, nor were later burials confined to the local group (Table 5). The presence of non-locals in all phases is consistent with migration stream theory, where movement can continue for many years between the place of origin and settlement (Anthony, 1990). There appears to be more non-local burials in the earlier phases when burials are ranked by the earliest possible phases dates but this trend disappears when latest possible phase dates are used. Also, as many burials were chosen specifically because they had early dates, this may simply be an artefact of the non-random sampling. Local and non-local burials are dispersed throughout area 2BA and follow no discernible cluster or pattern (Fig. 8). This supports the excavator’s interpretation of polyfocal cemetery development, i.e. burial in household groups rather than spreading out chronologically from a single origin. Arranging burials in household groups will cause subsequent generations to be buried amongst the initial founding burials. Neither is there any evidence for the clustering of local individuals, which might have indicated the presence of “British” households at West Heslerton.

Skeletal indicators

Females are evenly distributed between both residence groups. All the males that were securely sexed by osteological methods fall into the non-local group, although the local group contained three fragmentary weapon burials where sex could not be determined with certainty (Table 4). However, given the presence of three female weapon burials at the site it cannot be presumed that these are male. Although the few juveniles that were accorded burial in the cemetery were clearly special in some way and cannot therefore be regarded as representative of West Heslerton juveniles as a whole, eight of the ten analysed fall into the local group. The two non-local juveniles, a child of 8-9 years (G97) and an adolescent of 12-15 years (G122), were both buried with jewellery. Third molars were analysed from six burials, of which three fell into the non-local group (G84, G102 and G173) suggesting they must have moved after crown mineralization, i.e. during adolescence and early adulthood. As two were females and the third a jewellery burial where sex was undetermined, this would suggest that the non-local contingent included adult females of marriageable age. The non-local adult female (G102) and local child (G101) double burial adds weight to this conclusion.

The number of skeletons recovered from West Heslerton is not large enough nor sufficiently well preserved to justify statistical assessments of most metric or non-metric traits (Cox, 1999). The significance of non-metric traits in this context is derived from the observed familial heritability of non-metric traits in both humans and animals (Buikstra and Ubelaker, 1994). The precise embryology of most traits is poorly understood but the expression of certain cranial and dental traits is considered to be unaffected by function and relatively immune to non-genetic developmental factors both *in utero* and *in vivo* (Scott and Turner, 1997; Tyrrell, 2000). Extra cusps were noted on the teeth of four Anglian individuals (Cox, 1999), three of these were analysed (G98, G113 and G166) and all three fell into the local group, the latter two being adult female prone burials. Thirteen burials at West Heslerton had congenitally absent M3's (Cox, 1990; 1999). Seven Anglian and one Early Bronze Age burial (2BA283) were analysed from this group; all but one fell into the non-local group, although this was one of the Anglian skeletons (G139 a Phase II-III burial) rather than the prehistoric individual. In his study of genetically controlled dental traits recorded amongst Romano-British and Anglo-Saxon cemetery populations, Lloyd-Jones (1999) concluded that the two populations could not be conclusively separated by this approach. It may, however, be worth re-assessing such work in the light of the results presented here which suggest that Anglo-Saxon cemeteries contain migrants from both Britain and abroad. G158, a robust male weapon burial and the tallest recorded individual, was also among the non-local burials. However, not all the securely sexed, non-local males were tall; G145, a burial with no extant grave goods, was of noticeably short stature (Cox, 1999).

Burial practice

Ucko (1969) observed *"burial customs in society after society reflect different categories of people, categories which are sometimes defined on purely social grounds and sometimes on physical characteristics which may, of course, also have an associated social definition."* At West Heslerton, there is no significant correlation between ^{87}Sr/^{86}Sr ratio and either burial position (e.g. crouched, flexed, extended), burial side (e.g. left, right, prone, supine) or grave alignment (e.g. north, south). According to Faull (1977), crouched and prone burials in this region indicate native British burials, particularly when Anglian grave goods are absent. However, they occur in both the local and the non-local groups. The majority of crouched burials are those of juveniles, a finding perhaps explained more by the fact that at West Heslerton it was a favoured burial rite for children, than that they were native Britons. Nonetheless, all crouched juvenile burials did fall within the local group, whereas of the two juveniles who did not, one was flexed and one was extended.

G149 is a crouched burial with no extant grave goods and, therefore, a strong contender for a “native” burial, but his $^{87}Sr/^{86}Sr$ ratio is one of the highest found at West Heslerton and indicates an origin on more radiogenic and perhaps older lithologies which, in England, are found to the north or west (Fig. 1). It is possible, therefore, that he moved to West Heslerton from surrounding non-Anglian areas. Of the prone burials (3 local, 2 non-local), four were furnished with Anglian jewellery and therefore, unlikely to represent the burials of native slaves. The female without burial goods (G166) is, however, local as are the two prone and possibly live burials (Haughton and Powlesland, 1999b), that contained amongst the burial assemblage the walnut amulets that appear to be unique to this site (Table 6).

Grave goods

There is no correlation between $^{87}Sr/^{86}Sr$ ratio and the four broad grave good classifications, i.e. weapons, jewellery, other and none. All four categories occur in both local and non-local groups (Table 6), thus indicating social status is not associated with a presumed local or non-local origin. Males with and without weapons are found in the non-local group. However, G74, the only sword burial and thus a possible contender for a founder burial (Hills, 1999), and which also contained fabric reminiscent of examples found in southern Schleswig and northern Germany (Walton Rogers, 1999), is non-local.

The three burials containing wrist-clasps amongst the grave assemblage (G89, G97 and G173) all fall into the non-local group. Hines (1984) regarded this functional sleeve fastener as the artefact most likely to indicate the presence of immigrants from Norway amongst burial populations. G122, a non-local juvenile, is an early Phase II jewellery burial and contained a mid 5th century brooch, the only equal-armed brooch found at West Heslerton. The distribution of the generic form is restricted to Norway and Sweden, and this specific type is believed to originate from a Norwegian source (Haughton and Powlesland, 1999b; Hines, 1984). Moreover, G78 and G84 (local), contained the earliest cruciform brooches (early 6th century) found at West Heslerton as well as early 6th century Scandinavian style small-long brooches. All three burials containing cruciform brooches were non-local.

Local burials included G159 and G154, which were accompanied by a single amber bead, indicative of an early burial during this period (Haughton and Powlesland, 1999b). G139 (local) contained a scutiform pendant dating from the beginning of the 5th century. These pendants are believed to be amulets with some religious, rather than just decorative or functional, significance. As a consequence they are considered to demonstrate the movement of ideas and beliefs, and therefore possibly people, form western Norway (Hines, 1984). This example is a type that is known from Migration Period Norway and Denmark, first appearing around the beginning of the 5th century (Haughton and Powlesland, 1999b). The ubiquitous annular brooch occurs in both groups and does not appear to be indicative of origin. However, this finding may simply be a matter of their greater frequency and the same situation may result if burials containing other brooch types could be analysed in similar numbers. Ultimately, the great variety of burial practices and grave good types resulted in no one type being analysed in great numbers, and therefore precludes any firm non-statistical or statistical inferences being drawn. The same applies to the preliminary skeletal observations. Nevertheless, the study has raised several interesting lines of enquiry and there is no reason to presume that an exclusive correlation between first generation immigrants and a specific brooch type must necessarily be observed; jewellery, particularly in the case of juvenile burials, may be an heirloom or an offering from the participants in the funeral rite (Ucko, 1969).

Possible Anglian origins

Are two groups of people present within the Anglian community and if so, can any constraints be placed on the origins of the non-local population? In favour of bimodality are the non-normal distribution of strontium isotope compositions and the concomitant large standard deviation of the data (0.7094 ± 0.0013, 2σ) for a single local population. However, the bimodality, if real, does not correlate conclusively with any conventional methods of archaeological subdivision such as grave goods, skeletal variations, or burial practice; the sample numbers in most cases are too small. We must stress that the $^{87}Sr/^{86}Sr$ ratios obtained at West Heslerton for the 'non-local' group are in no way exceptional for England, but they do require a more radiogenic source than appears to exist in the environs of the site where it is believed the inhabitants were sourcing their food and water.

A search for geographical origins can currently only be accomplished by extrapolation of likely biosphere values from current understanding of the isotope composition of surface rocks and is thus a very general set of possibilities. If an overseas origin was the cause, then it is likely to have similar geology to the area of NW England (Fig. 1). Chalk or limestone are improbable candidates, as these would favour values below the current seawater value of 0.7092. It cannot be young volcanic basalts (<0.707), and it is unlikely to arise from old Precambrian cratonic areas as these would be expected to generate radiogenic values >0.71. This last option is significant as the artefactual evidence, from brooches in particular, suggests a strong link with Norway, a country dominated by old cratonic and granitic rocks. Environmental data shows that Norway and Sweden generate environmental and food chain $^{87}Sr/^{86}Sr$ values ranging from around 0.7092 in coastal regions which are dominated by marine inputs, to >0.78 inland with the majority in the region of 0.72 – 0.74 (Åberg, 1995; Åberg et al., 1999; Andersson et al., 1990; Land et al., 2000). Unfortunately, there is little directly comparable data for human teeth, but Norwegian mediaeval teeth give $^{87}Sr/^{86}Sr$ ratios ranging from 0.71087 for coastal Bergen up to 0.73232 from inland sites (Åberg et al., 1998). No Anglian $^{87}Sr/^{86}Sr$ ratios fall within this range at West Heslerton but the more radiogenic burials such as G164 ($^{87}Sr/^{86}Sr = 0.710808$) are similar and may signify a coastal Norwegian origin. However, in the absence of more extensive data from contemporary Norwegian and Swedish coastal dwellers, it is difficult to propose origins in Norway and Sweden on geological grounds for the majority of the "non-local" group, as their $^{87}Sr/^{86}Sr$ ratios do not appear sufficiently radiogenic even if there was considerable dietary input of marine derived strontium to balance that obtained from the radiogenic rock.

Secondly, could the putative non-local population have arrived at West Heslerton from Denmark or northern Europe? There is a significant difference in geological age and lithology between Norway and Denmark. The surface geology of Denmark and NW Europe dates from the Tertiary and Quaternary periods with Cretaceous chalk cropping out in the north and east of Denmark and the southern tip of Sweden. Danish chalk deposits are younger than English deposits, which have been subjected to extensive erosion of the more recent upper beds, so that none remain in England today (Ager, 1961). Denmark is, therefore, geologically younger than NE England. Consequently, an origin in Denmark, which has extensive deposits of chalk, could be expected to produce $^{87}Sr/^{86}Sr$ signatures well below the proposed West Heslerton watershed of 0.7092, whereas individuals of Norwegian origin would possess $^{87}Sr/^{86}Sr$ ratios >0.7092. Unfortunately, a Danish origin may, therefore, overlap and be indistinguishable from indigenous inhabitants at West Heslerton.

Finally, the possibility that all the strontium ratios are explicable though local variation must be considered. Clearly, there is no reason on archaeological grounds to suspect Scandinavian origins for the two prehistoric individuals 2BA229 (Neolithic/Early Bronze Age) and WHIA-2 (Iron Age) which are the two most radiogenic samples at West Heslerton. Their presence strongly suggests such elevated ratios may also be derived from Britain and precludes a Norwegian/Swedish origin being the only explanation for the most radiogenic Anglian samples. However, the prehistoric individuals need not have been born and raised at West Heslerton. Given the clustering of the prehistoric juveniles within the local environmental endmembers, it is possible to propose that these two prehistoric outliers are indeed migrants to the area, if only from other regions of Britain. There are several areas of Britain, principally in the north and west, where such radiogenic signatures could be, and have been, obtained (e.g. Montgomery, 2002; Montgomery et al., 2000). This being so, the Norwegian artefactual influences amongst the Anglian population may simply demonstrate cultural trading and communication links with Norway, which may have originated with first generation settlers but the cemetery population represents subsequent indigenous generations. It is worth noting, however, that the general direction of population movement in England during this period is understood to be from east to west and south to north and not the other way around. Nevertheless, if these radiogenic individuals were indeed indigenous Britons, they raise interesting questions about the incentives driving the voluntary or forced migration of people from the north or west into areas such as east Yorkshire, which were traditionally Anglian during this period.

The technique is still relatively new, and as a consequence there is currently no data available to show what $^{87}Sr/^{86}Sr$ ratios contemporary individuals who remained behind in the putative homelands of the Anglian immigrants, such as Schleswig-Holstein and Denmark, actually had. The presence at West Heslerton of immigrants from both western Scandinavia and northern Europe cannot be ruled out. This level of complexity could account for the spread of ratios and the multi-modality suggested by the data. Anthony's (1997) assertion that *"migration is not an exception, but a constant"* appears well-attested by this dataset. As a result, it is presently only possible to say that the non-local group do not appear to have isotope signatures that would indicate a childhood origin at West Heslerton but not possible to provenance them with any degree of certainty.

CONCLUSIONS

The first aim of this case study was to investigate whether combined strontium and lead isotope analysis could identify the presence of two distinct groups within the cemetery. This objective was achieved but the two isotope systems split the sample population on different lines. Lead isotope and concentration data produced two clearly identifiable groups: Anglian and prehistoric. This grouping resulted from the change from predominantly geological to predominantly anthropogenic lead sources between these periods and the concomitant severing of the link between geology and origins, which is present in the prehistoric individuals. Lead isotopes, therefore, gave no clear information about the geographical origins of the Anglian individuals but rather an indication of status and access to metal products within their cultural sphere. Lead exposure is an order of magnitude greater in the Anglian population than the preceding Iron Age and Early Bronze Age. This rise in exposure appears to reflect metal use and circulation, and is accompanied by a progressive "cultural focussing" of the lead isotope ratios towards the lower centre of the English ore field (Fig. 4).

When viewed in conjunction with the archaeological evidence, the $^{87}Sr/^{86}Sr$ data points to at least two groups at West Heslerton. One group falls within the environmental end-members for the site and includes most of the juveniles and prehistoric individuals, which supports the suggestion that it represents the immediate local variation. The other group is more radiogenic and suggests a greater contribution from older or more rubidium-rich lithologies, but no individuals are sufficiently radiogenic to point irrefutably to a Norwegian or Swedish origin, nor rule out an English one. Apparent non-local individuals have either moved to West Heslerton from an area of higher $^{87}Sr/^{86}Sr$ ratios or were importing considerable amounts of food from such an area. The second observation is not consistent with the hypothesis that crops and livestock were being grown and grazed in the immediate locality of the site and may point to larger-scale trading in foodstuffs. This would seem to be inconsistent with a small, self-sufficient farming community but may confirm the observation that West Heslerton was a proto-urban settlement (Powlesland, 1998). Future analysis of carbonised grains, small contemporary animals and archaeological herbivores from the settlement site may help to further refine the local strontium range (Price et al., 2002). It was, however, not the case that everyone buried in this sedentary farming settlement consumed the same childhood diet.

The observed difference in $^{87}Sr/^{86}Sr$ ratios is not one of differing status between adults and children as all enamel ratios derive from childhood diet. Neither is it likely that it is one of differing social status between two groups. Males and females are found equally in both groups, and the Anglian children in neither group can be deemed of low social status: firstly because they were buried in the cemetery, which is unusual for infants and young children in this period (Cox, 1999); and secondly, because the majority were buried with jewellery or weapons. This would also be supported by the settlement evidence, which provides little support for two different status groups at the site. Individuals from both groups were spread throughout the cemetery supporting the hypothesis that the cemetery developed polyfocally rather than from a single origin. Furthermore, the $^{87}Sr/^{86}Sr$ ratio difference between the two groups does not appear to be one of changing subsistence practices with time, as individuals from all phases of cemetery development occur in both groups. Accordingly, the study’s second aim, to use geological and archaeological evidence to determine whether such groups were consistent with a local and an immigrant contingent, has been successfully addressed but the origin, or origins, of the immigrant population is still uncertain.

The third aim of the study, to assess the traditional archaeological methods of identifying native Britons and Anglian immigrant burials against the isotope results to see which, if any, supported or refuted such methods is more problematic. When combined with archaeological indicators traditionally used to identify Anglo-Saxon immigrants there are suggestions that some may hold promise as indicators of first generation Anglian settlers (e.g. wristclasps, cruciform brooches, non-metric dental traits) but it must be stressed that the numbers involved are currently too small to be statistically significant. They may, however, provide a guide for future sampling strategies at sites from this period. Weapon burials (both male and female) and those from the series of tall, gracile individuals occurred in both groups, as did burials with none and other types of goods. The non-local group also contained females, juveniles and males of other status, providing no positive evidence for a solely male, immigrant, warrior elite at this site. There was no correlation between the side, position or alignment of the body within the grave and $^{87}Sr/^{86}Sr$ ratio group, which might have provided indications of a surviving British contingent.

The following general conclusions relevant to future studies can be drawn:

1. Lead isotopes produce a clear trend between geologically related prehistoric groups and the later Anglian inhabitants, i.e. from less to more like English ore.
2. This “cultural focussing” of the enamel-lead isotope ratios towards the centre of the lead ore field is accompanied by a rise in enamel-lead concentration.
3. If this lead isotope focussing proves to be a distinctive characteristic of English (and British) populations during certain periods, it would provide a mechanism to identify immigrant populations focussed on a different ore source.

4. ^{87}Sr/^{86}Sr ratios remain indicative of geological origins in all periods so far investigated.
5. There is a clear need to define the "local" environmental ^{87}Sr/^{86}Sr signature before conclusions can be drawn between immigrant and local populations beyond the immediate burial ground. Juvenile burials are likely to produce the most "locals."

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Tables

TABLE 1. West Heslerton enamel samples

Skeleton code	Period	Tooth	Sex[a]	Age at death[b]	Burial soil
G73	Anglian	M_2L	Mgg	Middle aged/old adult	Sand
G74	"	P^1R	Mgg	Young adult	Sand
G75	"	M^2R	Mgg	Adult	Sand
G78	"	P^2R	F	Young adult	Sand
G84	"	M_3L	F	Young adult	Sand
G89	"	P^1L	?F	Young adult	Neolithic ditch fill
G97	"	M^2R	Fgg	Child	Chalk
G97	"	dm^2L	Fgg	Child	Chalk
G98	"	M_2L	Mgg	Child	Sand
G100	"	M^1R	Fgg	Infant/child	Chalk
G101	"	P_2L	n/k	Child	Chalk
G102	"	M^3R	F	Young adult	Chalk
G109	"	M^1L	M	Young adult	Sand
G113	"	M^2R	F	Young adult	Chalk/ditch fill
G114	"	$M^{1or2}L$[c]	F	Young adult	Sand
G115	"	M_3L	?M	Young adult	Sand
G117	"	M^2L	Fgg	Adolescent	Sand
G122	"	M^2L	Fgg	Adolescent	Sand
G132	"	M_3R	Fgg	Adolescent	Sand
G133	"	P^1L	F	Young/middle aged adult	Sand
G139	"	M^2R	F	Young adult	Sand

G144	“	P^1L	F	Middle aged adult	Sand
G145	“	M^1L	M	Adult	Sand
G149	“	P_1L	M	Middle aged adult	Sand
G151	“	M_3L	Mgg	Young adult	Sand
G154	“	M^1L	Fgg	Child	Sand
G158	“	C^1R	M	Young/middle aged adult	Chalk
G159	“	M_2L	F	Young adult	Sand and chalk gravel
G162	“	M_1L	Fgg	Child	Sand
G164	“	P_1L	F	Adult	Sand
G166	“	M^2R	F	Adult	Chalky sand
G169	“	M_1L	n/k	Infant	Chalk
G173	“	M^3R	Fgg	Adult	Sand/hill wash
WHIA-1	Iron Age	P^1R	n/k	Adult	Sand
WHIA-2	Iron Age	P_1R	M	Young adult	Sand
IR266	Neolithic/EBA	P_1L	n/k	Child	Sand
IR271	Neolithic/EBA	P_1L	n/k	Child	Sand
IR304	Neolithic/EBA	P_2R	n/k	Child	Sand
2BA229	Neolithic/EBA	M^1R	M	Adult	Sand
2BA283	Neolithic/EBA	M^3R	F	Adult	Sand
2BA589	Neolithic/EBA	M^3R	n/k	Adult	Sand

[a] gg indicates gender attributed using grave goods only, e.g. weapons = male, jewellery = female

[b] Age categories assigned according to Buikstra and Ubelaker (1994)

[c] tooth could not be fully identified

Data from Haughton and Powlesland (1999a,b) and Montgomery (2002).

TABLE 2. Strontium and lead isotope data for West Heslerton enamel and soil samples

Sample code	Sr ppm	^{87}Sr/^{86}Sr normalised	Pb ppm	^{206}Pb/^{204}Pb	^{207}Pb/^{204}Pb	^{208}Pb/^{204}Pb	^{208}Pb/^{206}Pb	^{207}Pb/^{206}Pb
G73	62.1	0.709101	0.19	18.53	15.61	38.43	2.075	0.843
G74	76.4	0.710061	0.37	18.44	15.59	38.32	2.078	0.846
G75	49.6	0.709865	8.16	18.45	15.60	38.32	2.077	0.846
G78	49.1	0.709502	1.66	18.46	15.62	38.37	2.078	0.846
G84	102	0.709485	0.20	18.47	15.63	38.39	2.079	0.847
G89	53.7	0.709792	0.21	18.38	15.59	38.25	2.081	0.848
G97 perm	68.0	0.709895	0.19	18.41	15.58	38.30	2.080	0.846
G97 dec	47.6	0.709606	0.13	18.38	15.61	38.30	2.084	0.850
G98	79.4	0.708498	0.19	18.24	15.60	38.12	2.090	0.855
G100	49.6	0.709002	0.41	18.44	15.60	38.34	2.079	0.846
G101	56.2	0.708757	0.21	18.47	15.63	38.40	2.079	0.846
G102	73.8	0.710339	0.48	18.48	15.64	38.44	2.080	0.846
G109	42.3	0.709532	0.26	18.49	15.61	38.40	2.078	0.844
G113	99.6	0.708228	0.23	18.43	15.59	38.29	2.078	0.846
G114	69.6	0.709364	0.26	18.51	15.62	38.41	2.076	0.844
G115	64.8	0.708664	0.99	18.43	15.60	38.33	2.079	0.846
G117	34.1	0.708480	0.37	18.48	15.61	38.40	2.078	0.845
G122	65.7	0.709767	0.87	18.42	15.59	38.28	2.078	0.846
G132	72.4	0.709132	0.26	18.44	15.59	38.30	2.077	0.845
G133	50.5	0.710228	2.96	18.43	15.59	38.28	2.077	0.846
G139	77.4	0.709189	0.15	18.50	15.63	38.40	2.076	0.845
G144	84.2	0.709064	0.28	18.50	15.61	38.41	2.076	0.844
G145	101	0.709549	0.14	18.47	15.59	38.33	2.076	0.844

G149	58.2	0.710570	0.55	18.47	15.60	38.34	2.076	0.845
G151	79.4	0.708610	0.28	18.58	15.61	38.49	2.071	0.840
G154	79.0	0.708857	0.26	18.45	15.61	38.36	2.080	0.846
G158	67.0	0.709937	0.49	18.43	15.62	38.40	2.084	0.848
G159	72.3	0.708990	0.15	18.51	15.62	38.41	2.076	0.844
G162	118	0.709014	0.94	18.44	15.61	38.36	2.080	0.846
G164	47.0	0.710808	0.41	18.52	15.64	38.51	2.079	0.844
G166	172	0.708796	0.35	18.42	15.59	38.32	2.081	0.847
G169	69.9	0.709032	0.19	18.49	15.64	38.46	2.080	0.846
G173	111	0.710482	0.21	18.42	15.61	38.32	2.080	0.847
WHIA-1	19.8	0.708465	0.05	18.74	15.71	38.70	2.065	0.838
WHIA-2	49.8	0.711006	0.11	18.51	15.57	38.31	2.070	0.841
IR266	33.8	0.708849	0.08	18.40	15.58	38.30	2.082	0.847
IR271	47.4	0.709057	0.04	18.34	15.60	38.26	2.086	0.850
IR304	36.6	0.709010	0.06	18.62	15.69	38.62	2.074	0.842
2BA229	256	0.711080	0.06	18.43	15.58	38.25	2.075	0.845
2BA283	63.9	0.709572	0.05	18.38	15.60	38.26	2.081	0.849
2BA589	56.0	0.708973	0.05	-	-	-	-	-
Sand – a[1]	-	0.708245	-	18.17	15.57	38.03	2.094	0.857
Sand – w[2]	-	0.708379	-	18.32	15.59	38.21	2.086	0.851
Chalk – a[1]	-	0.707408	-	18.62	15.60	38.62	2.074	0.838
Chalk – w[2]	-	0.707414	-	no Pb detectable				

[1] weak acetic acid leach

[2] deionised water leach

TABLE 3. Estimated range of Pb isotope ratios for anthropogenic English Pb

Pb isotope ratio	Estimated range of English ore values[1]
$^{206}Pb/^{204}Pb$	18.2 – 18.6
$^{207}Pb/^{204}Pb$	15.60 – 15.75
$^{208}Pb/^{204}Pb$	38.0 – 38.7
$^{207}Pb/^{206}Pb$	0.840 – 0.858
$^{208}Pb/^{206}Pb$	2.065 – 2.085
$^{206}Pb/^{207}Pb$	1.165 – 1.190

[1] Data from Bacon et al. (1996); Haggerty et al. (1996); Rohl (1996).

TABLE 4. Burial rite of Anglian individuals in “local” and “non-local” groups

1. Local $^{87}Sr/^{86}Sr \leq 0.7092$					2. Non-local $^{87}Sr/^{86}Sr > 0.7092$				
Skeleton code	Sex[1]	Grave[2] goods	Position[3]	Side[4]	Skeleton code	Sex	Grave goods	Position	Side
G73	U	W	Fl	Su	G74	U	W	Fl	Rt
G98	Juv	W	Fl	Lt	G75	U	W	Ex	Su
G100*	Juv	J	Cr	Rt	G78	F	J	Ex	Su
G101*	Juv	N	Cr	Lt	G84	F	J	n/k	Rt
G113*	F	J	Fl	Pr	G89	?F	J	Ex	Pr
G115	?M	W	Fl	Lt	G97*	Juv	J	Ex	Su
G117	Juv	O	Cr	Lt	G102*	F	J	Cr	Rt
G132	Juv	J	Bn	Pr	G109	M	O	Fl	Su
G139	F	J	Cr	Su	G114	F	J	Bn	Pr
G144	F	W	Ex	Su	G122	Juv	J	Fl	Su
G151	U	W	Ex	Su	G133	F	N	Ex	Su
G154	Juv	J	Cr	Rt	G145	M	N	Fl	Su
G159	F	O	Ex	Su	G149	M	N	Cr	Rt
G162	Juv	N	Fl	Lt	G158*	M	W	Ex	Su
G166	F	N	Fl	Pr	G164	F	W	Fl	Su
G169*	Juv	N	n/k	n/k	G173	U	J	Fl	Lt

[1] Sex: M = male, F = female, U = undetermined, Juv = juvenile

[2] Grave goods: W = weapons, J = jewellery, O = other, N = none

[3] Position: Ex = extended, Fl = flexed, Cr = crouched, Bn = bound

[4] Side: Su = supine, Pr = prone, Lt = left, Rt = right

* indicates burials made directly into chalk

Burial rite data from Haughton and Powlesland (1999a,b)

TABLE 5. Distribution of phased burials between local and non-local groups

	Local group	Non-local group
Earliest possible phase[1]		
I (450-500AD)	4	7
II (500-550AD)	5	3
III (550-600AD)	2	1
Latest possible phase		
II (500-550AD)	2	3
III (550-600AD)	6	5
IV (600-650AD)	3	3

[1] Phasing follows that given in Haughton and Powlesland (1999b)

TABLE 6. Incidence of selected grave good types in Anglian jewellery burials

Skeleton code	Annular brooch	Cruciform brooch	Small Long brooch	Equal Armed brooch	Wristclasp	Girdle-hanger	Latch- lifter	Purse & Walnut amulet	Vessel
1. Local $^{87}Sr/^{86}Sr$ ratios ≤0.7092									
G100	x								Pottery
G113	x					x	x	x	
G132	x						x	x	
G139	x					x	x		Pottery
G154			x						
2. Non-local $^{87}Sr/^{86}Sr$ ratios >0.7092									
G78	x	x	x						
G84		x	x						
G89	x				x				
G97	x		x		x				
G102	x								Wood
G114	x								
G122				x					Wood
G173	x	x			x		x		

X = present

Grave good data from Haughton and Powlesland (1999b)

Figures

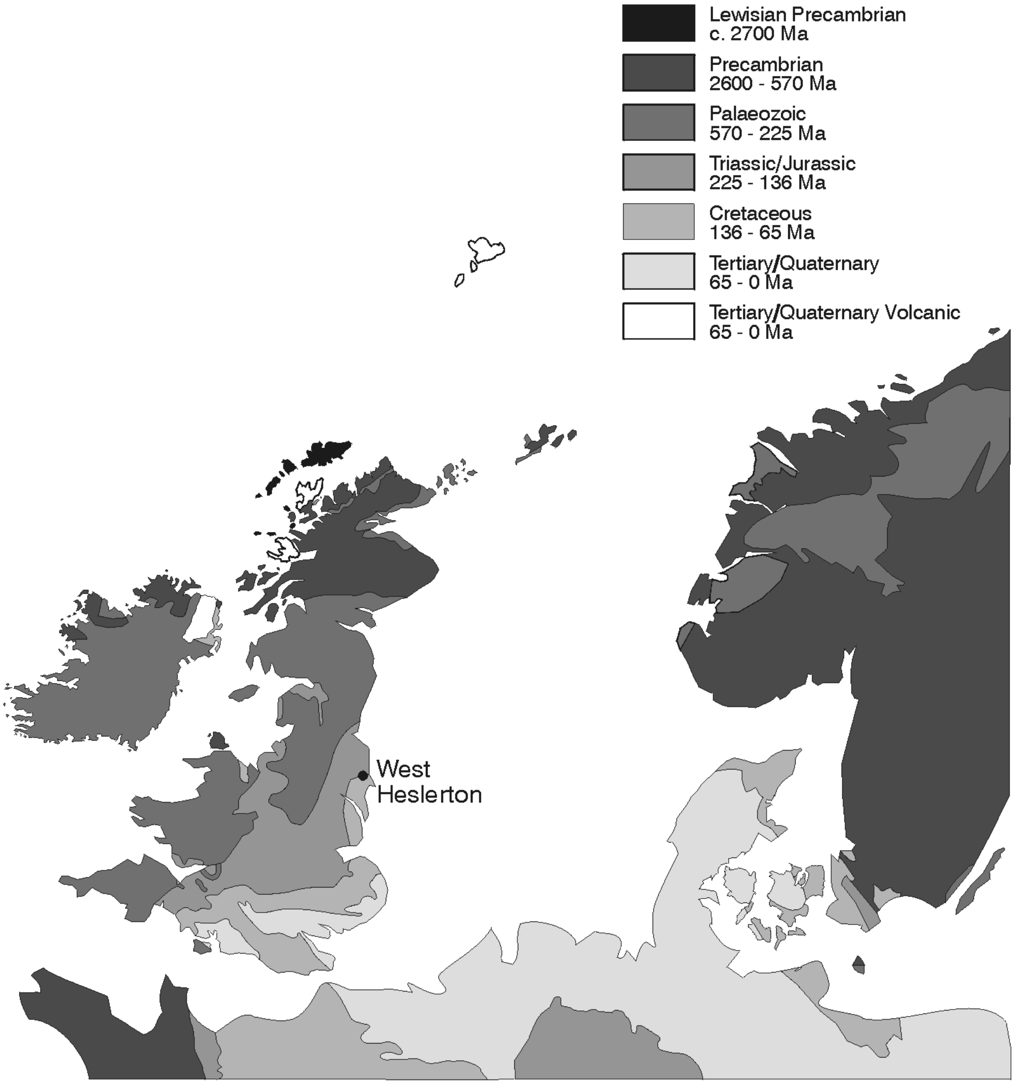


Fig. 1 Simplified geology map of northern Europe showing variations in the age of the surface rocks and the location of West Heslerton. Here, the Cretaceous chalk that forms the hills of the Yorkshire Wolds to the south of the site, abuts the Jurassic clays of the valley bottom to the north.

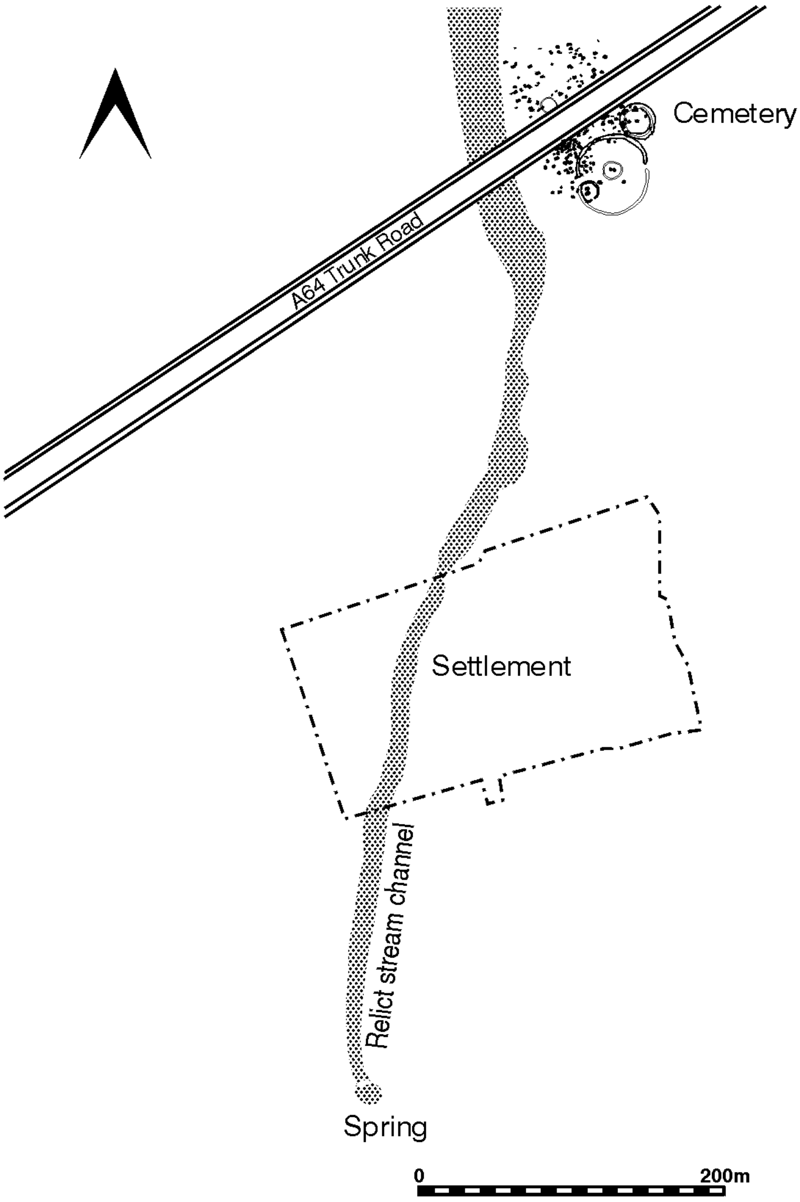


Fig. 2 Plan of the West Heslerton cemetery and settlement sites. The circular structures within the cemetery date from the Neolithic and Early Bronze Age and include a large Neolithic hengiform enclosure, timber post circle, Early Bronze Age round barrows and associated burials. All Anglian samples were taken from areas 2B and 2BA which are south of the A64 trunk road. The area underneath the A64 is unexcavated. Adapted from Haughton and Powlesland (1999b).

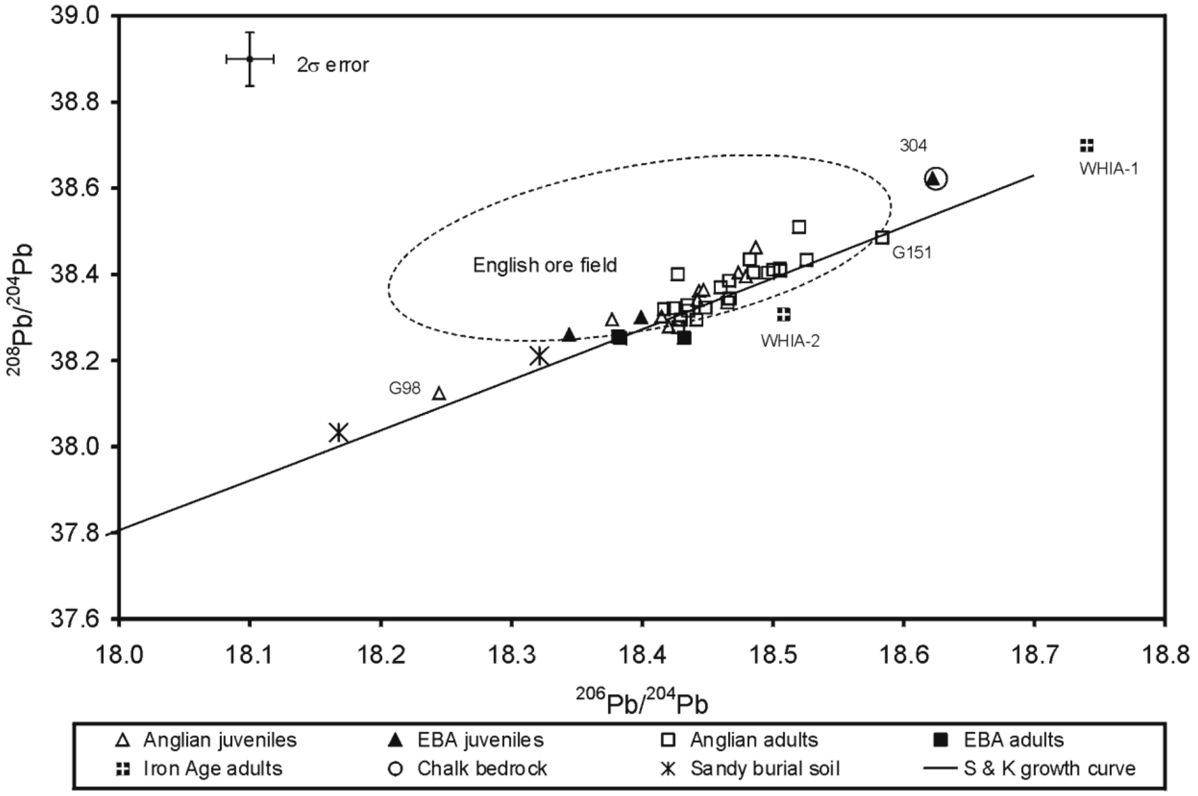


Fig. 3 Plot of $^{206}Pb/^{204}Pb$ versus $^{208}Pb/^{204}Pb$ ratios for West Heslerton enamel samples. Note that the majority of Anglian samples cluster around the Stacey and Kramer (S & K) lead ore growth curve (Ludwig, 1994) and in the lower centre of the English ore lead field but also fall between the two local soil end members of the chalk and the sand. Early Bronze Age (EBA) and Iron Age individuals are more scattered.

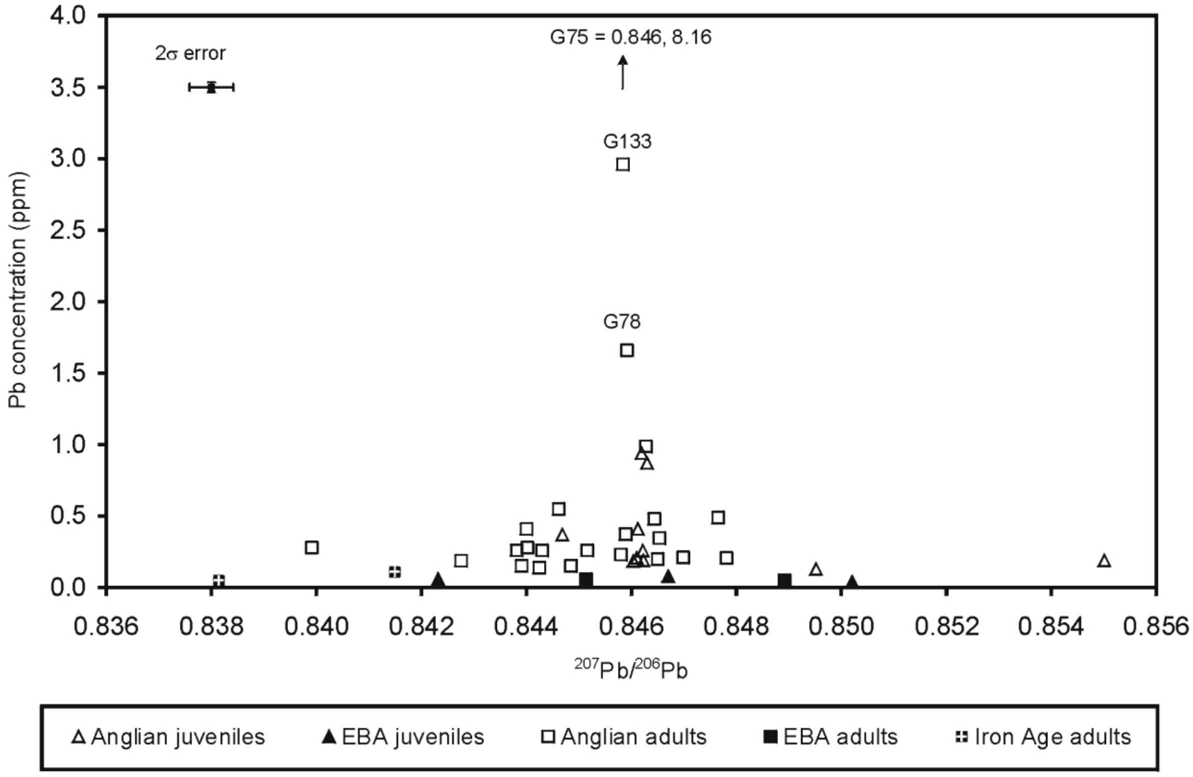
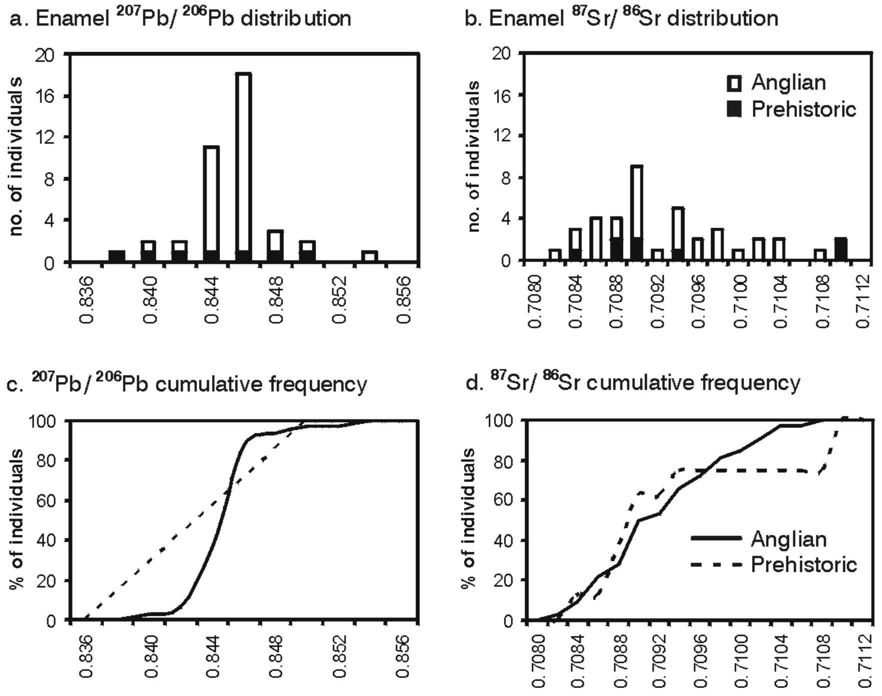


Fig. 4 Plot of ^{207}Pb/^{206}Pb versus lead concentration (parts per million) for West Heslerton enamel samples. Note that all enamel samples with lead concentrations >0.8ppm are from the Anglian population and have ^{207}Pb/^{206}Pb ratios of 0.846. Iron Age and Early Bronze Age (EBA) samples are scattered, but of uniformly low concentration.



e. Numerical summary of ^{207}Pb/^{206}Pb data

	Minimum		Lower hinge		Median		Upper hinge		Maximum
Ratio	0.838		0.844		0.846		0.846		0.855
Interval		0.006		*0.002*		*0*		0.009	
Spread			0.008		0.002		0.009		

f. Numerical summary of ^{87}Sr/^{86}Sr data

	Minimum		Lower hinge		Median		Upper hinge		Maximum
Ratio	0.708228		0.708915		0.709160		0.709880		0.711080
Interval		687		*245*		*720*		1200	
Spread			932		965		1920		

Fig. 5 Statistical analysis of the ^{207}Pb/^{206}Pb and ^{87}Sr/^{86}Sr ratios for the West Heslerton enamel samples. Note that although it exhibits a high degree of kurtosis (a), the ^{207}Pb/^{206}Pb data appears to be normally distributed (c and e), compared to the non-normality of the ^{87}Sr/^{86}Sr data (d). Only one individual is present in the ^{87}Sr/^{86}Sr range 0.7092-0.7094 (b) and the distribution is clearly asymmetric (f). In sections (e) and (f) the values for interval and spread are multiplied by 10^5 for clarity.

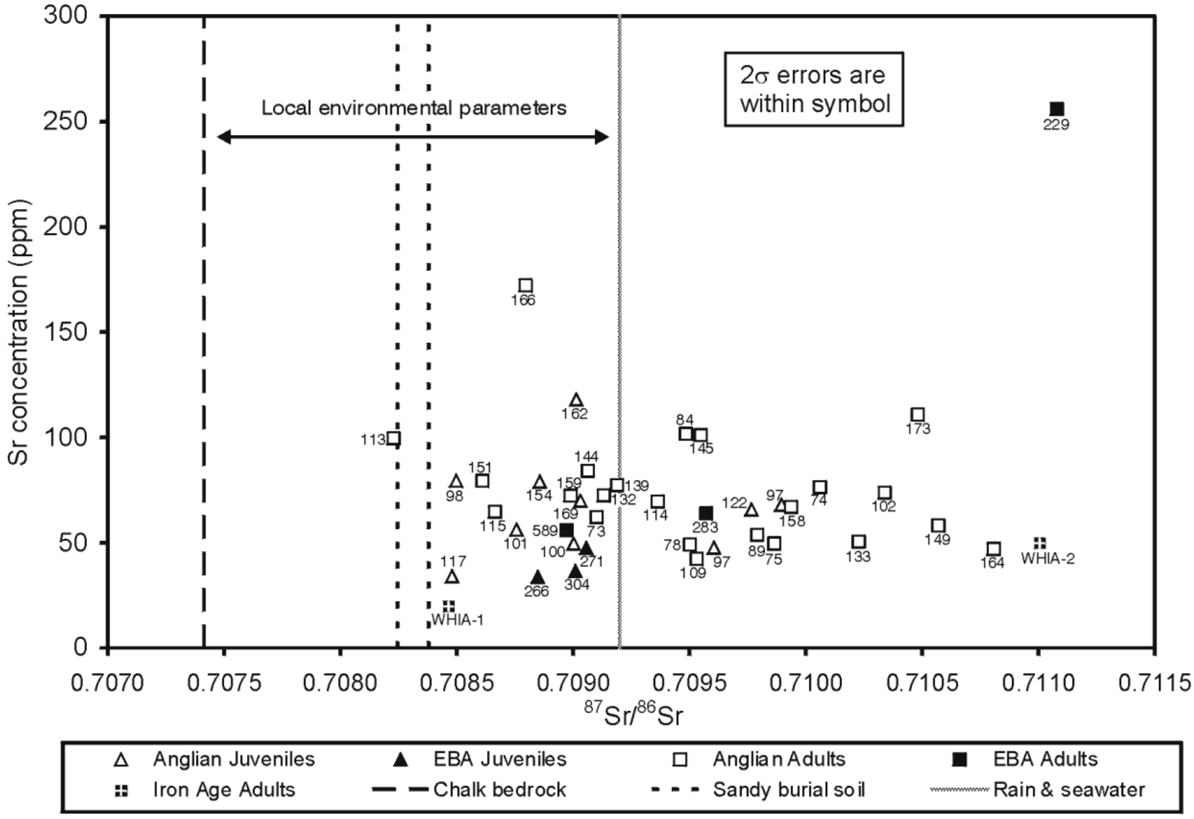


Fig. 6 Plot of $^{87}Sr/^{86}Sr$ ratios versus strontium concentration (parts per million) for enamel samples from West Heslerton. Note the absence of points between G139 and G114, which coincides with the watershed to the right of the rain/seawater site endmember of 0.7092. All three Neolithic/Early Bronze Age (EBA) juveniles and eight out of ten Anglian juveniles fall to the left of this ratio.

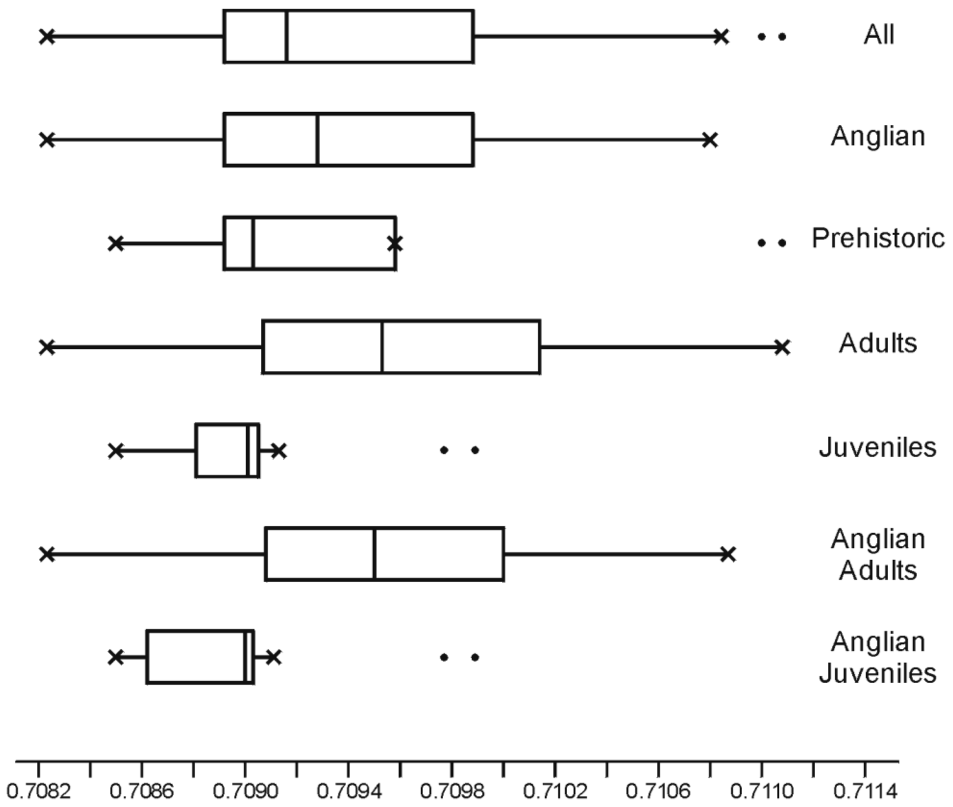


Fig. 7 Box and whisker plots of the $^{87}Sr/^{86}Sr$ data for West Heslerton enamel samples. The vertical line indicates the median value and 50% of individuals are enclosed within the box. The crosses delineate the actual range of the data with dots representing possible outliers. Note that both prehistoric individuals and all juveniles have a distribution tending toward the lower $^{87}Sr/^{86}Sr$ compositions (i.e. <0.7092) obtained from the environmental endmembers.

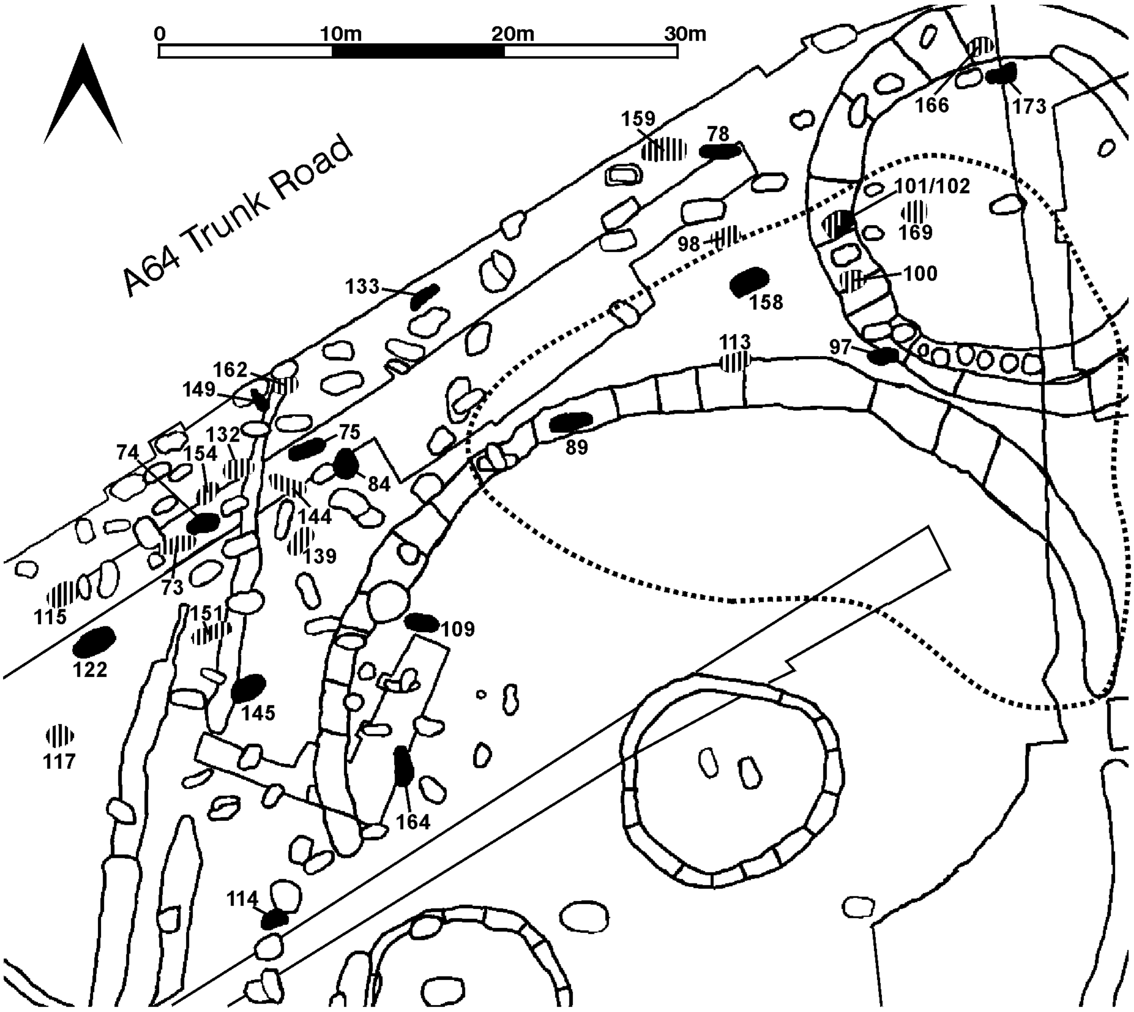


Fig. 8 Plan showing the locations of "local" (hatched) and "non-local" (black fill) burials at West Heslerton. Unanalysed burials are filled white. Note that in the adult female (102) and child (101) double burial, the adult female is in the non-local group and the child is in the local group. The dotted line on the right of the diagram defines the extent of the chalk outcrop. Adapted from Haughton and Powlesland (1999b).