A Review of Oxygen and Strontium Isotope Evidence and Associated Archaeological Evidence for Migration into Britain in the 5th and 6th Centuries

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The stable isotopes of oxygen and strontium have been used to determine the number of migrants coming into Britain in the 5th and 6th centuries. The evidence from four sites, West Heslerton, Berinsfield, Eastbourne and Llandough has been reviewed. The original studies used different methods to calculate oxygen isotope values from phosphate in tooth enamel so the values were recalculated using the same equation and displayed in a standard format so that results can be compared. All three of the English studies concluded that the variation in local strontium levels was greater than the variation in the individuals studied and were therefore of little value. Although the study of oxygen isotope values is imprecise some individuals gave a clear signal that they were not from the UK. This study differed from the original studies by allowing for the possibility that more of the individuals studied could be migrants, but because the regions of Europe bordering on the North Sea have very similar oxygen isotope values to those in some parts of the UK it has not been possible to give an exact figure. The striking feature of the analysis has been the correlation between possible migrants and burials without grave goods. There were no Christian features associated with these burials so they appear to be from the poorest levels of society and they appear to be buried in cemeteries where the burials already had Germanic features. The study of Llandough demonstrated the possibility that some people may have migrated to Wales from the Mediterranean and some may have migrated from England.

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Abbreviations, Terms Used and Symbols

Isotope	A chemical element that has a different weight to normal.
Stable Isotope	An isotope that does not break down over time
^{18}O	Chemical symbol for an isotope of oxygen
^{16}O	'Normal' oxygen
$\delta^{18}O$	Difference between the ratio of ^{18}O to ^{16}O of a sample and the same ratio in an international standard, expressed in parts per thousand, ‰. In this paper often referred to as the oxygen isotope value
$\delta^{18}O_{DW}$	Oxygen isotope value of the drinking water consumed by the individual in childhood
Strontium ratio or Sr Ratio	Ratio of strontium 87 to Strontium 86
Sr conc	Strontium concentration
Ground Water	Water from springs, rivers or deep wells
Drinking Water	Water consumed. Could be from ponds, shallow wells or affected by cooking processes. Will be more enriched in ^{18}O than ground water
LALIA	Late antiquity little ice age

Abbreviations Used in Tables

Teeth

- M1 First molar
- M2 Second molar
- M3 Third molar
- P1 First pre-molar
- P2 Second pre-molar

Ages

- ADU Adult
- CHI Child
- JUV Juvenile
- YAD Young Adult

Chapter 1

Introduction, Scope, Aims and Objectives

Historical Background

In the early 5th century the Roman legions had been withdrawn from Britain and there was a dramatic change visible in the archaeological record (Higham and Ryan 2013 41-56). Urban life ceased to exist and coins were no longer being imported to pay the Roman army. Changes in funerary practices and material culture began to appear. The Romano British generally buried their dead in a Christian manner, buried in graves with no grave goods and aligned east to west. In some areas cremations became the dominant funerary rite with the cremated remains being buried in pots similar (in some cases almost identical) to those found in the lands around the North Sea, in what is now the Netherlands, northern Germany and Denmark. In other areas inhumation was still used but graves were not orientated and the burials contained grave goods, again similar to practices on the continent. The brooches found in the graves were similar to styles on the continent.

There are few historical sources for the early 5th century. Gildas, writing around the end of the 5th century or the beginning of the 6th century, describes invading Saxons killing the local population, driving them into exile or enslaving them (Giles 2009). Bede drew heavily on Gildas when writing his Ecclesiastical History of the English People (Sherley-Price 1955), and Bede was accepted as a reliable historical source. More recently however this view has been challenged and alternative scenarios proposed (eg Dark K 2000). Writers have emphasised the continuity between Roman Britain and Anglo-Saxon England and have proposed that a small number of migrants from the North Sea basin were influential in changing the culture of the indigenous inhabitants.

To resolve this issue archaeologists have turned to scientific techniques to provide unequivocal evidence for the origins and movement of people. DNA of the modern human population of Britain has been studied (Leslie et al 2015) and ancient DNA of human remains has been extracted in the hope that ethnic origins of the Anglo-Saxon population of England can be deduced (Schiffels et al 2016). Isotope evidence, mainly using isotopes of oxygen and strontium, has been used to determine how recently people have moved to Britain from continental Europe. However, values of oxygen isotope levels are very similar across eastern England and continental Europe and it was suspected that claims for origins of individuals may not have been supported by the evidence. Strontium isotope levels are quite variable and, in several cases, appear to have little value.

Scope, Aims and Objectives

The aim of this study is to review the evidence from studies of stable isotopes of oxygen and strontium for the migration of people into Britain between AD 400 and AD 600. This time period has been selected because this was the time when Britain changed from a Romano-British province into many small kingdoms, some Anglo-Saxon and some British. The review will look at the Anglo-Saxon cemeteries of West Heslerton, Berinsfield and Eastbourne because they all have graves with grave goods and well preserved skeletons from the 5th and 6th centuries and have been subjected to oxygen and strontium isotope analysis. Wasperton has not been included in this review because tooth preservation was poor and associated grave goods had often been destroyed by poor environmental conditions. Several Welsh sites are included but the Welsh study concentrates on Llandough which has a reasonable sample size.

Factors that can influence isotope levels will be reviewed. The use of technical jargon and scientific notation has been minimised so that the paper can be understood by non-scientists.

The objectives are:

- Quantify the scale of the migrations
- Estimate the time period of the migrations
- Determine the geographical origins of the migrants
- Comment upon the social status of the migrants
- Discuss the impact of the findings on the debate about whether the changes in Britain around this time were brought about by a change in people or a change in culture

Introduction to the Science

Most elements exist in more than one way. Carbon for example normally exists as Carbon 12 and this is the most abundant type of carbon. But it also exists as carbon 14 which is radioactive and carbon 13 which is stable. Stable isotopes of oxygen and strontium also exist alongside normal isotopes and the quantities of these have been used to indicate whether human remains are local to the area in which they were found or came from elsewhere. Oxygen isotope measurements give a broad indication of climate and strontium isotopes are an indication of geology. To determine the origins of skeletal remains samples are taken of tooth enamel. Tooth enamel is formed in childhood, before the age of thirteen (Hillson 1996). Once formed it is fixed and its chemical composition does not alter so the oxygen and strontium isotope measurements will reflect the isotope measurements in the area where the subject spent their childhood years. The isotope measurements in their teeth depend upon the isotope measurements of the water they drank as children.

How Oxygen 18 is measured and expressed

The stable oxygen isotope that is used in migration studies is Oxygen 18 and there is a standard method for describing the Oxygen 18 level. The ratio of Oxygen 18 to the normal oxygen isotope, oxygen 16, is calculated and compared to an international standard. The international standard material is quite high in oxygen 18 so the value calculated is often negative. A small negative number means that the sample is enriched in oxygen 18 and a large negative number means that the sample is depleted in oxygen 18. Using scientific notation the oxygen 18 levels are calculated according to the following equation:

$$\delta^{18}O = (^{18}O/^{16}O_{\text{sample}} / \ ^{18}O/^{16}O_{\text{standard}} - 1) \times 1000$$

The value is calculated in parts per thousand (‰)

The expression $\delta^{18}O$ is the most common bit of scientific notation you will see in this paper and is known as delta oxygen 18 and is a measure the ratio of oxygen 18 to oxygen 16 expressed as a comparison to an international standard.

The $\delta^{18}O$ level in groundwater has been measured across Europe and mapped by Chenery from various sources (Budd et al 2003). See Fig 1

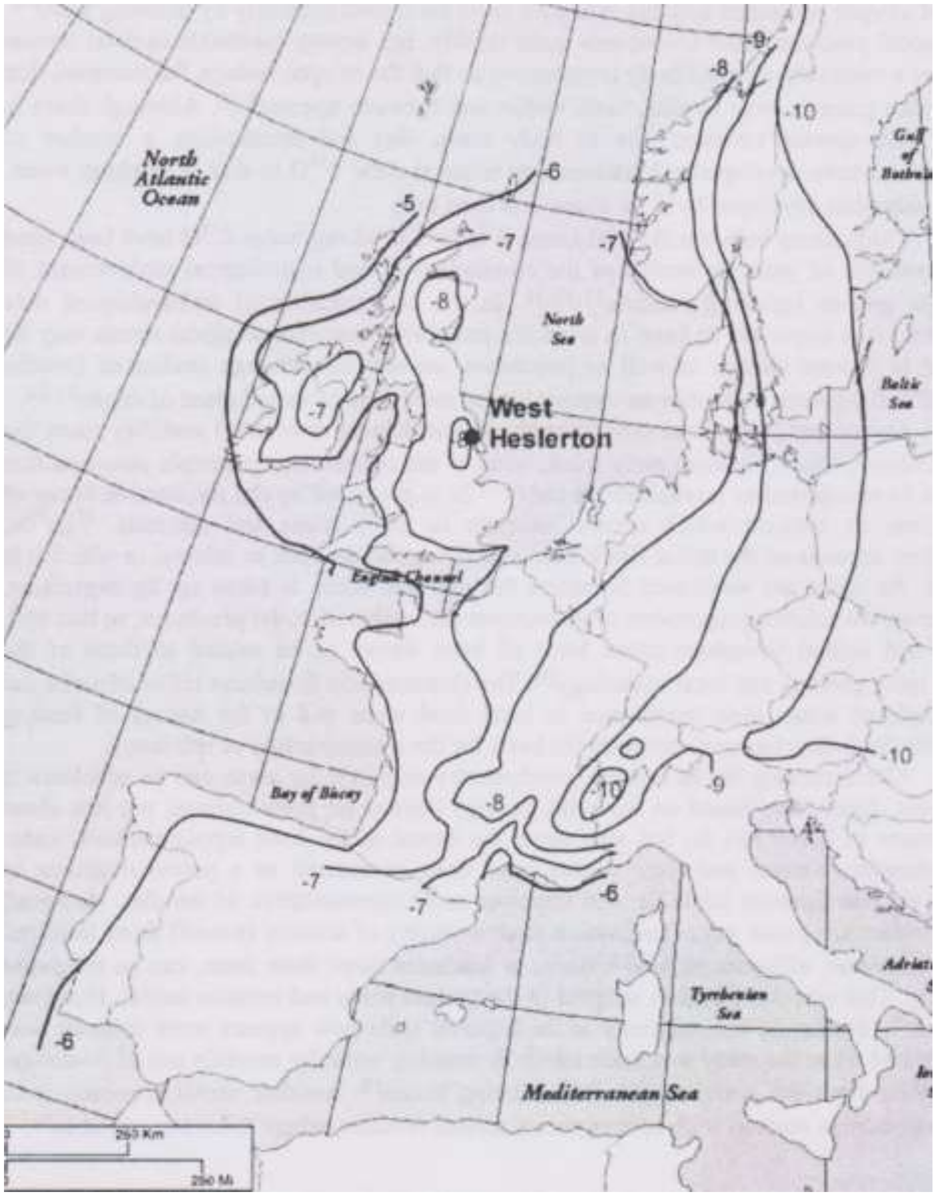


Fig 1 Groundwater $\delta^{18}O$ values in Europe. Chenery in Budd et al, 2003

How tooth enamel phosphate $\delta^{18}O$ relates to groundwater $\delta^{18}O$

The oxygen isotopes in tooth enamel are primarily found in the phosphate in the enamel and can be measured. There is a direct relationship between the $\delta^{18}O$ level in teeth and the $\delta^{18}O$ level in the groundwater of the area where they were living when their teeth were formed (Luz et al 1984, Longinelli 1984, Levinson et al 1987). Thus, by looking at local levels of oxygen isotopes and the distribution map it is possible to say if the subjects were local or non local and give possible origins. If only it were that simple.

Studies of 5th and 6th Century Migration

Several UK studies have attempted to resolve the question about the number of migrants coming into Britain in the 5th and 6th centuries. Anglo Saxon cemeteries at West Heslerton (Budd et al 2003, 2004), Berinsfield (Hughes et al 2014) and Eastbourne (Hughes et al 2018) have been excavated and the skeletal remains subjected to isotope testing. Additionally several cemeteries in Wales have been studied (Hemer et al 2013).

West Heslerton

The cemetery at West Heslerton, North Yorkshire, dates from the period AD 400 – 650 and probably originally contained about 300 burials and a small number of cremations. The cemetery was excavated in the late 1970's, and, of the 185 excavated burials, 44 (24%) contained no grave goods and the remainder had typical Anglo-Saxon assemblages (Haughton and Powlesland 1999a and 1999b). None of the graves were particularly rich; only one sword was found in the whole graveyard. Several papers have been published regarding isotope analysis at West Heslerton (Budd et al 2003, 2004, Montgomery et al 2005). The 2003 and 2004 papers deal with oxygen and strontium isotope analysis. Samples of tooth enamel from 24 individuals were analysed for $\delta^{18}O$ and converted to the drinking water $\delta^{18}O$ value that would have been taken in at the time the tooth enamel was formed. According to Budd et al (2003) for West Heslerton the authors chose a 'representative sample' of the population with well preserved permanent teeth with no signs of degradation or dental caries. However, when Montgomery et al (2005) described how the same teeth were selected for isotope analysis using lead and strontium, they called it a 'purposive selection' to include males, females, adults, juveniles, mother and child double burial, four types of grave goods and unaccompanied burials. Skeletal remains were poorly preserved in the sandy soil so the sex was sometimes determined by the grave goods. The West Heslerton cemetery dates from the late Roman period so it would be expected that the graves selected would cover a range of dates from the early Anglo-Saxon period and possibly a local and a migrant constituent. A total of 24 samples were taken for $\delta^{18}O$ analysis, 18 of whom were female, 5 male and one child whose sex could not be determined.

The analysis method used included small quantities of ^{18}O from other sources, besides that found in phosphate of tooth enamel and this is possible source of error. The formula of Levinson et al (1987) was used for the calculation of drinking water $\delta\,^{18}O$ from $\delta^{18}O$ in the phosphate of tooth enamel. The results obtained are in Table 1. Strontium values were recorded but the local variability was greater than the range of values in the skeletal remains analysed and was therefore of no value and will not be discussed further in this paper.

From their analysis the authors concluded that four of the individuals at West Heslerton, those with the most depleted $\delta^{18}O$ levels were from outside the UK, probably coming from Sweden. They concluded that the middle group were brought up locally to West Heslerton but that the individuals with the most enriched $\delta^{18}O$ levels had migrated from west of the Pennines.

Berinsfield

Berinsfield was also excavated in the 1970s and is one of the earliest Anglo-Saxon cemeteries in the upper Thames Valley. Out of 100 graves excavated 24 had no grave goods and the remainder had typical Anglo-Saxon assemblages (Boyle et al 1995 63-65) but there were no swords found. In the isotope study 19 individuals from between A.D. 450 and 550 were sampled (Hughes et al 2014). The individuals were selected based upon the style of grave furnishings and location near the centre of the cemetery. The analysed sample represents a mix of ages, sex, grave locations and orientation and grave furnishings and were split into three phases. Phase A had burials dating before the last quarter of the 5th century, phase B from the last quarter of the 5th century and phase C from the first half of the 6th century. Tooth enamel was analysed using a different method to that at West Heslerton and only $\delta^{18}O$ from phosphate in the enamel was measured. The $\delta^{18}O$ in the phosphate was then converted to a drinking water value using the formula 6 of Daux et al (2008). The drinking water values are generally more enriched than would be expected and the team speculate that the most likely cause is the consumption of heated foods and/or brewed ales (even in childhood). When foods are heated the lighter isotopes evaporate preferentially; brewing has the same effect and these phenomena have been demonstrated experimentally (Brettell et al 2012). The results are shown in Table 2. As with West Heslerton the authors note that there is considerable variation in local strontium ratios making it difficult for this technique to identify migrants. The authors conclude that only one of the 19 individuals tested was a migrant from the continent.

Eastbourne

The Eastbourne cemetery was excavated in 1997 and 1998 and uncovered 192 inhumations and 12 cremations (Hughes et al 2018). The Eastbourne burials are typically Germanic (Doherty and Greatorex 2016). The graves are irregular in spacing and orientation and contain typical Germanic style grave furnishings such as brooches, beads, rings, toilet sets, belt buckles, and other objects of personal dress as well as weapons, shields, knives, pottery and food items (Clifford et al 2016). Three swords and two franciscas (a type of throwing axe) were found. 19 individuals were selected for isotope analysis from the earliest phases of the cemetery, phase 1 dating as early AD375, phase 2 no earlier than AD450 and phase 3 after AD500. Tooth enamel phosphate was measured using the silver phosphate method and the equivalent $\delta^{18}O$ for drinking water was calculated using equation 4 of Daux et al 2008. The authors conclude that four individuals were likely migrants from the continent, three others could be (although they could also be from elsewhere in the UK) and two women were probably from nearby communities.

Wales

Hemer at al (2013) studied oxygen and strontium isotope values in 33 individuals from four different sites across South Wales, Llandough, Brownslade, Porthclew and West Angle Bay. At Llandough 15 individuals were sampled, 10 at Brownslade, 5 at Porthclew and 3 at West Angle Bay. Nine of the burials were carbon dated but because of the lack of grave goods and the lack of carbon dating for most of the samples, dating was difficult. Most of the carbon dates were 7th and 8th century but the only sample from LLandough was between AD370 and AD640. The authors concluded that it is possible that the individuals with enriched oxygen isotope values not found in the UK could have been from a warmer region, possibly the Mediterranean. The formula of Levinson et al (1987) was used for the calculation of drinking water $\delta^{18}O$ from $\delta^{18}O$ in the phosphate of tooth enamel.

Fig 2. Location of Sites mentioned in the text

Chapter 2

Methods

Scientific Background

These four studies are the largest from 5th and 6th century Britain but they employ a bewildering array of analytical techniques and calculations. They use different calculations for converting the $\delta^{18}O$ value in the phosphate in tooth enamel to a value that would be found in the drinking water where they grew up. Chenery et al (2010) in their technical appendix to a study of Roman Gloucester summarised, in their table A4, how the different calculations gave different answers. At the time their favoured calculation, with regard to how close the results came to the expected results was the formula of Levinson (Levinson et al 1987) but with a correction of -1.4 applied to the measured $\delta^{18}O$ value for phosphate in tooth enamel. Although they didn't admit this at the time they also appear to have applied the -1.4 correction to measured $\delta^{18}O$ values in their 2004 study of the early Anglo-Saxon cemetery at West Heslerton. Chenery and Evans were contributors to the 2010 paper that came to the conclusion that the corrected Levinson formula was the most useful and they also contributed to the Berinsfield study in 2014 and the Eastbourne study in 2018. They used a different formula in 2014 (Daux et al 2008 equation 6) and another formula in 2018 (Daux et al 2008 equation 4).

Pollard et al (2011) published a paper that reviewed the calculation formulae then in use. Their analysis demonstrated that the margin of error was much higher than that being quoted. To quote directly from their paper:

'For certain regression equations, the uncertainty in $\delta^{18}O_w$ is calculated to be greater than the total range measured across the United Kingdom (and the western part of continental Europe) especially if the Levinson et al (1987) calibration, or variants of, is used. This suggests that some of the localisation hypotheses produced in the recent years using calculated $\delta^{18}O_w$ values compared to groundwater or meteoric $\delta^{18}O_w$ maps remains statistically unproven.'

This could explain why Chenery and Evans switched to using the formulae of Daux. Pollard recommended three things in his paper – better calibration data, improving the calculation without using a regression step and finally determine location from $\delta^{18}O_P$ directly. This last recommendation would require a distribution map of the $\delta^{18}O$ values in the phosphate in teeth to be built from people known to have been brought up in the area. In 2012 Evans, Chenery and Montgomery (Evans et al 2012) took on board Pollards third point and re-examined data from analyses in the NERC Isotopes Geosciences Laboratory over the previous 15 years. They split Britain into two zones and determined $\delta^{18}O$ values for phosphate in tooth enamel from lower rainfall areas and from higher rainfall areas so that the calculation to convert $\delta^{18}O$ in phosphate in teeth to drinking water values would become unnecessary. Unfortunately, this very broad division has little practical use and for the Berinsfield and Eastbourne data the authors continued to convert $\delta^{18}O$ values from phosphate in teeth to drinking water values where the distribution across Europe is well known.

Method statement

The first step in this analysis has been to recalculate the data from West Heslerton, Berinsfield, Eastbourne and Llandough so they all use the same calculation, Daux equation 4, and put the results on graphs of the same size and frequency distribution so that all four sites can be compared. Equation 4 was used for this study simply because it was the equation used most recently by the authors. It gives almost identical results to equation 6 at more enriched $\delta^{18}O$ levels and exaggerates the $\delta^{18}O$ depletion at the depleted end of the scale. For example grave 6 from Berinsfield had a $\delta^{18}O$ level of -7.4 using equation 6 and -7.7 using equation 4. Only the Llandough data has been used from the Welsh data as this had the highest number of individuals sampled and was from the correct time period for this study (admittedly from only one carbon date). The West Heslerton and Llandough $\delta^{18}O$ drinking water values were originally calculated from measured $\delta^{18}O$ values from phosphate in tooth enamel using the equation of Levinson. This equation introduces errors and other equations are preferred (Pollard 2011). To correct this error the $\delta^{18}O$ value of phosphate in tooth enamel has been calculated from the original data and this then used to calculate a $\delta^{18}O$ value for drinking water using equation 4 of Daux. For Berinsfield the $\delta^{18}O$ value for phosphate in tooth enamel was used to calculate the $\delta^{18}O$ value for drinking water using Daux's equation 4 rather than equation 6. For Eastbourne equation 4 was already used. It is not possible to amalgamate the data from the four sites because they all have different local drinking water $\delta^{18}O$ values.

The data from each site has been tabulated, together with a summary of grave goods found with each burial. The data has been sorted by the calculated $\delta^{18}O$ value of drinking water at the area in which the individual spent their pre-teen years. The most depleted $\delta^{18}O$ values are at the top of the table and the most enriched at the bottom. The tables have been used to construct a frequency graph for each site with the $\delta^{18}O$ values in 0.5‰ intervals. The local groundwater values are indicated by an orange bar.

Factors that can affect $\delta^{18}O$

Choice of tooth

It is important that the correct teeth are chosen for analysis. Only sound teeth should be selected to reduce the risk of contamination. The 2nd and 3rd molars are preferred (Evans et al 2012). Other teeth form earlier in childhood when they may be being breastfed. Breastfeeding is known to enrich $\delta^{18}O$ values (Wright and Schwarcz 1998).

Cooking, Brewing and Stewing

It has been demonstrated that the $\delta^{18}O$ value in phosphate in tooth enamel can be linked directly to the $\delta^{18}O$ value in local drinking water (Luz et al 1984, Longinelli 1984, Levinson et al 1987). But what is the impact if children take in their water, not directly from the water source, but after cooking or brewing? Brettell et al (2012) conducted experiments to determine the effect of various processes on the $\delta^{18}O$ value consumed. In Britain ale was the most commonly consumed alcoholic drink and was drunk by children (Garmonsway 1939 47). The experiments demonstrated that brewing could increase the $\delta^{18}O$ value by 1.3‰. If children had hot drinks such as a herbal tea this could raise the $\delta^{18}O$ value by 0.4‰ and if they ingested liquid from a stewpot that had been simmering for hours this could raise the $\delta^{18}O$ value by over 10‰, a massive impact on the $\delta^{18}O$ consumed. Daux et al (2008) concluded that for modern humans consuming a standard diet the $\delta^{18}O$ value of ingested water is 1.05 – 1.2‰ higher than the local ground water.

The relationship between the $\delta^{18}O$ value in phosphate in tooth enamel and local drinking water has already been discussed in some detail. To establish the relationship the various authors took tooth enamel samples from various cultures from a very wide geographical area. The extent of the use of brewed and heated liquids in the diet of the different cultures is not known; it could be more or less than the samples for which we are trying to determine the $\delta^{18}O$ value. The experiments of Brettell et al (2012) demonstrated that the errors could be large but without detailed information about the medieval diet and the diet of those involved in the calibration of the relationship between the $\delta^{18}O$ value in phosphate in teeth and drinking water, quantifying the errors is just speculation.

Climate Change

If rainfall patterns were different in the early Anglo-Saxon period this will impact upon $\delta^{18}O$ values in ground water and therefore values in phosphate in teeth. Petra Dark summarised the evidence for climate change in the first millennium (Dark P 2000 27). Dark tabulated results from texts, Greenland ice cores, glacier movements, lake sediments, tree rings and peat deposits. In the early Anglo-Saxon period (AD 400-530), up to the LALIA (Late antiquity little ice age) four of the measures indicate a cooler climate, two warmer with one don't know, so there isn't a consensus on what the climate was doing. Any impact on rainfall and hence $\delta^{18}O$ values is even more obscure. Most authors assume that the climate in the early Anglo-Saxon period was similar to the present, but this is not known with any certainty, so this is another possible source of error. Budd et al (2004) estimate that even if the mean annual temperature was 0.5 °C less than today this would reduce mean annual rainfall and therefore drinking water $\delta^{18}O$ values by no more than 0.2‰. The climate deteriorated suddenly in the mid 530's as a result of a catastrophic event, probably a series of large volcanic eruptions, that obscured sunlight for several years and had an impact on the climate that lasted more than 100 years (Buntgen et al 2016). Any child that was growing up in this period, if it survived the resultant famine, could well have anomalous $\delta^{18}O$ values in the phosphate of their tooth enamel. However all three English studies deliberately selected burials from the early Anglo-Saxon period so most of the samples will be pre-LALIA.

Water Source

The distribution map of $\delta^{18}O$ values in groundwater in Europe is not necessarily the same as drinking water. If people drank water from ponds or shallow wells this water may have undergone evaporative enrichment whereby the lighter isotopes evaporate preferentially with water left behind being enriched in ^{18}O. Evans et al (2012) thought that this would alter drinking water values by less than 0.5‰ in Britain but that the effect could be higher in a region with large lakes, eg Denmark.

Summary of technical analysis

Different analytical techniques give different $\delta^{18}O$ values for phosphate in tooth enamel from the same sample. This can be corrected by comparing against results of a standard sample but it is not known if the correction should be the same for a range of values. When the $\delta^{18}O$ value for phosphate in teeth is known the conversion to drinking water values is problematic with no agreement on the best formula to use. These unknowns make the margin of error comparatively large. There are also other factors which can affect the $\delta^{18}O$ drinking water value and these are difficult to quantify, increasing the uncertainty. Climate change could change the $\delta^{18}O$ value in either direction but a 0.5 deg C fall in temperature could reduce the $\delta^{18}O$ value by around 0.2‰. All the other factors tend to enrich the ^{18}O value so the $\delta^{18}O$ increases. In any analysis it would be expected that 'locals', brought up in the area, would have a $\delta^{18}O$ equivalent drinking water value that reflected this and have a higher value than local ground water.

Chapter 3

The Results and Discussion

Results

The data sets for the four different sites are contained in Tables 1, 2 , 3 and 4. The data has been sorted by the calculated drinking water $\delta^{18}O$ value with the most depleted value at the top and the most enriched value at the bottom. The graphs from the data are shown in Fig 2. All the graphs are on the same scale and the local ground water $\delta^{18}O$ value is shown by the orange bar. This orange bar is simply to indicate the position of the measured values relative to the ground water value of $\delta^{18}O$. West Heslerton, Berinsfield and Eastbourne are similar in that most of the $\delta^{18}O$ values are enriched relative to local ground water. This would be expected because most processes that are likely to affect the value (cooking, brewing, evaporative enrichment) will all shift the data in the same direction. In all cases there are some measurements that are depleted relative to the local drinking water. The precision of the calculated drinking water values of $\delta^{18}O$ has been challenged by Pollard et al (2011). He believes that the 95% error range when using the Daux calculation is likely to be around 1.5‰. It is important to bear this in mind when analysing the data; minor differences in $\delta^{18}O$ values should not be over-analysed.

		Table 1			West Heslerton					
Sample	Sex	Age at Death	Tooth	$\delta^{18}O$ in phosphate in tooth enamel	$\delta^{18}O$ drinking water. Calc using Levinson	$\delta^{18}O$ drinking water. Calc using Daux eq 4	Sr ratio 87/8	Sr conc.	Migrant/Local?	Grave Goods
G166	F	ADU	M2	15.6	-11.2	-10.2	0.708796	172	Prob. Migrant	None
G117	F	JUV	M2	16.3	-9.7	-9.0	0.70848	34.1	Prob. Migrant	Beads, purse mount
G133	F	ADU	P1	16.4	-9.5	-8.8	0.710228	50.5	Prob. Migrant	None
G159	F	ADU	M2	16.5	-9.3	-8.6	0.70899	72.3	Prob. Migrant	Bead
G132	F	YAD	M3	16.7	-9.0	-8.4	0.709132	72.4	Migrant/Local?	Two annular brooches, Beads, Copper alloy items, iron pendant, purse group, walnut amulet, latchlifters
G151	M	ADU	M3	16.7	-9.0	-8.4	0.70861	79.4	Migrant/Local?	Spear, furrule, knife, buckle
G149	M	ADU	P1	16.7	-8.9	-8.3	0.71057	58.2	Migrant/Local?	None
G114	F	ADU	M1	17.0	-8.4	-7.9	0.709364	69.6	Migrant/Local?	Brooch, iron ring, beads
G144	F	ADU	P1	17.0	-8.3	-7.9	0.709064	84.2	Migrant/Local?	Spear, knife, buckle
G173	F	ADU	M3	17.0	-8.3	-7.9	0.710482	111	Migrant/Local?	Brooch, wire ring, annular brooch (x2), beads, wrist clasps, buckle, knife, latchlifters
G139	F	ADU	M2	17.0	-8.2	-7.8	0.709189	77.4	Migrant/Local?	Annular brooch (x2), pendant, beads, girdle hangers, latchlifters, lace tags, ivory purse ring
G164	F	ADU	P1	17.5	-7.2	-7.0	0.710808	47	Local	Spear, knife, buckle,
G97	F	CHI	M2	17.5	-7.1	-6.9	0.709895	68	Local	Annular brooch (x2), small long brooch
G122	F	JUV	M2	17.5	-7.1	-6.9	0.709767	65.7	Local	Equal arm brooch, beads, vessel fragments, knife
G100	F	CHI	M1	17.6	-7.0	-6.8	0.709002	49.6	Local	Knife, necklet, annular brooch
G75	M	ADU	M2	17.6	-6.9	-6.8	0.709865	49.6	Local	Spear, knife
G101	U	CHI	M2	17.7	-6.7	-6.6	0.708757	56.2	Local	Dress pin
G102	F	ADU	P2	17.7	-6.6	-6.6	0.710339	73.8	Local	Annular brooch (x2), beads, buckle, stud, belt plate, strap end, vessel repair,
G84	F	ADU	M3	17.8	-6.6	-6.5	0.709485	102	Local	Cruciform brooch, small long brooch
G109	M	YAD	M1	17.8	-6.5	-6.5	0.709532	42.3	Local	Buckle, copper alloy rivets
G145	M	ADU	M1	17.9	-6.4	-6.3	0.709549	101	Local	None
G89	F	ADU	P1	17.9	-6.3	-6.3	0.709792	53.7	Local	Iron annular brooch (x2), beads, wrist clasp (x2), buckle
G113	F	ADU	M2	17.9	-6.3	-6.2	0.708228	99.6	Local	Annular brooch (x2), silver bead, irpn bead, beaver tooth pendant, beads, silver ring, copper alloy discs, purse mounts, latchlifters, girdle hangers, walnut amulet
G78	F	ADU	P2	18.1	-5.9	-6.0	0.709502	49.1	Local	Cruciform brooch (x2), wire circlet, small long brooch, annular brooch, beads

Table 2 Berinsfield

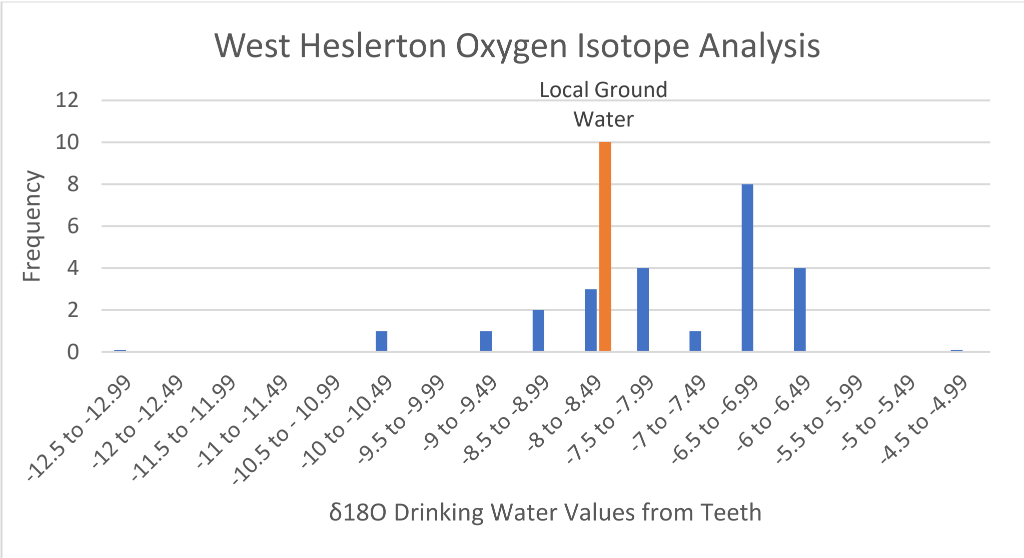
Grave I	Sex	Age at Death	Tooth	$\delta^{18}O$ in phosphate in tooth enamel	$\delta^{18}O$ drinking water. Calc using Daux Eq 6	$\delta^{18}O$ drinking water. Calc using Daux Eq 4	Migrant/Local?	Sr ratio	Sr conc	Phase	Grave Goods
6	M	25-34	P2	17.1	-7.4	-7.7	Migrant/Local?	0.709795	78.9	B	Shield boss, knife, late Roman belt fitting
81	?	18-24	M2	17.3	-7.1	-7.3	Migrant/Local?	0.708364	60.5	?	None
4	M	18-24	M2	17.5	-6.8	-7.0	Migrant/Local?	0.711151	90.7	?	None
141	M	35-49	P2	17.5	-6.8	-7.0	Migrant/Local?	0.709321	45.7	B	Spearhead, ferrule, shield boss, iron knife,
10	F	Adult	P2	17.6	-6.6	-6.8	Migrant/Local?	0.709157	47.5	?	Unknown (disturbed prior to excavation)
30	M	35-49	P2	17.6	-6.6	-6.8	Migrant/Local?	0.70882	79	C	Iron knife
61	?	8-12	P2	17.6	-6.6	-6.8	Migrant/Local?	0.709302	64.6	C	Spearhead, knife, decorated pot
73	F	18-24	P2	17.6	-6.6	-6.8	Migrant/Local?	0.709433	37.2	B	Pair saucer brooches
18	F	18-24	P2	17.7	-6.5	-6.6	Migrant/Local?	0.709258	75.1	C	Pair button brooches
1	?	Adult	P2	17.8	-6.3	-6.5	Migrant/Local?	0.709245	86.4	A	Shield boss, knife,
150	?	13-17	P2	17.8	-6.3	-6.5	Migrant/Local?	0.709732	64.9	B	Pair of disc brooches, iron knife, iron arrowhead
20	M	35-49	P2	18	-6	-6.1	Migrant/Local?	0.708959	56.8	A	Iron spearhead, knife
8	F	25-34	P2	18.1	-5.9	-5.9	Local	0.709128	92.7	A	Equal arm brooch, disc brooch, knife, amber beads
49	F?	50+	M3	18.1	-5.9	-5.9	Local	0.709066	92.7	B	Bulls eye disc brooches, amber beads
152	F?	18-24	P2	18.1	-5.9	-5.9	Local	0.709463	77.3	?	Iron nail, Roman coin
26	M	35-49	M2	18.2	-5.7	-5.8	Local	0.709339	78.9	B	Spearhead, knife, Roman coin (364-388)
42	F?	Adult	P2	18.2	-5.7	-5.8	Local	0.708328	76.2	B	Pair cast saucer brooches
5	F	18-24	M2	18.3	-5.5	-5.6	Local	0.709493	75.1	B	Pair bulls eye disc brooches, 12 amber beads
54	F?	25-34	M2	18.3	-5.5	-5.6	Local	0.709427	49.1	C	Pair of saucer brooches, knife

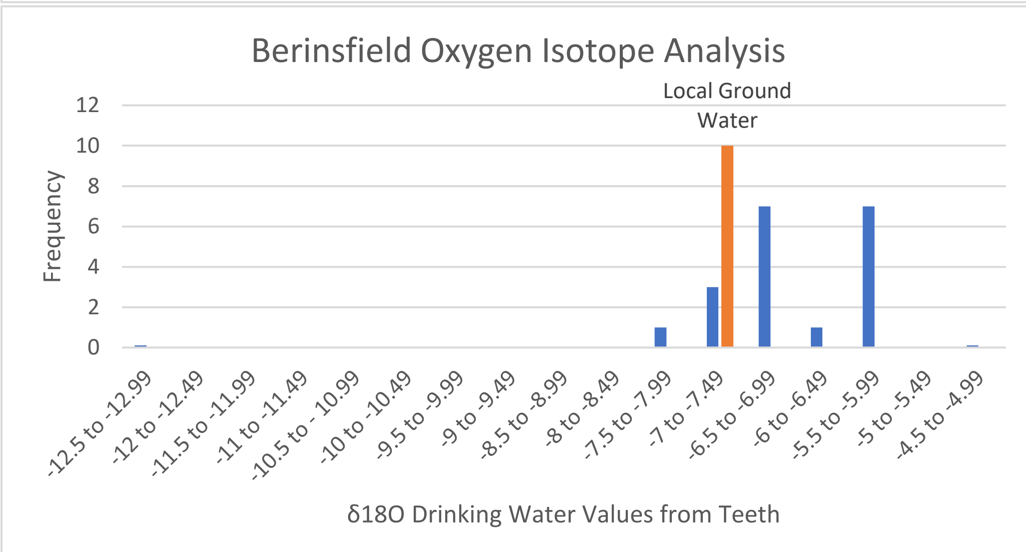
Table 3 Eastbourne

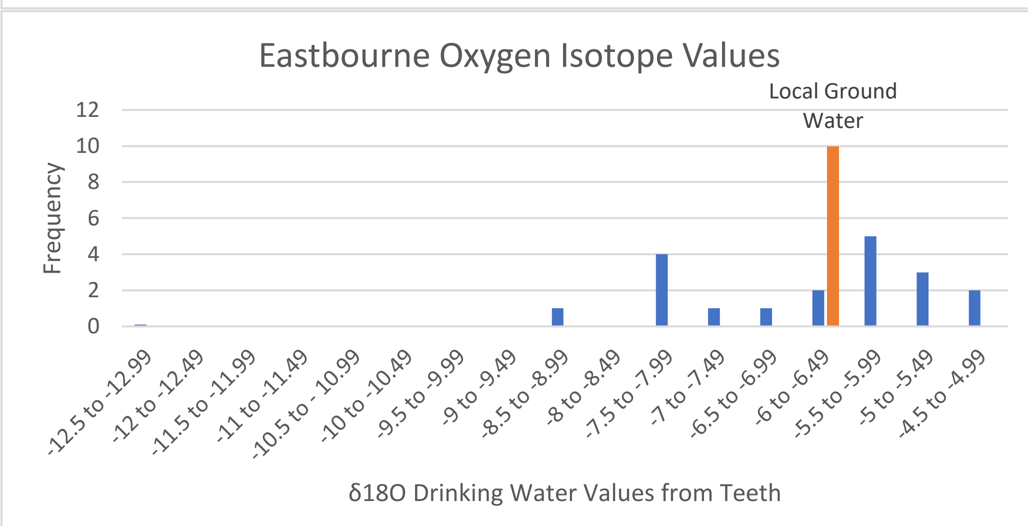
Sample	Sex	Age	Tooth	$\delta^{18}O$ in phosphate in tooth enamel	$\delta^{18}O$ drinking water. Calc using Daux Eq 4	Sr ratio	Sr conc.	Phase	Migrant/Local?	Grave Goods
270	F	30-45	P2	16.5	-8.7	0.710514	60.5		Prob. Migrant	None
51	?	45+	P2	17	-7.8	0.708638	76.9		Migrant/Local?	Copper alloy object
796	M	18-29	P2	17	-7.8	0.708835	88.7	2	Migrant/Local?	Spearhead, knife, spear ferrule
355	?	18-45	P2	17.1	-7.7	0.709336	72.7		Migrant/Local?	Copper alloy tweezers, iron pin, 3 amber beads
57	M	18-46	P2	17.2	-7.5	0.709669	61.4		Migrant/Local?	None
309	M	18-29	P2	17.3	-7.3	0.710002	51.8		Migrant/Local?	None
481	M	18-29	P2	17.6	-6.8	0.710079	72.7	1	Migrant/Local?	Incised peacock intaglio for square bezel ring setting, pin
264	F	30-45	P2	17.9	-6.3	0.710084	62.9	1	Migrant/Local?	2 applied saucer brooches, 5 sets of glass and amber beads
681	M	18-45	P2	18	-6.1	0.708898	88.9	3	Migrant/Local?	Spearhead, knife, shepherds crook head pin, iron belt buckle
67	?	18-29	P2	18.1	-5.9	0.709193	65.5	2	Local	Francisca (450-500), slate hone stone, Brancaster type ring, belt or bag fittings, iron rod, copper ring, keys and other
650	F	18-45	M3	18.1	-5.9	0.70908	81.2	2	Local	Copper alloy quoit brooch, knife
64	F	18-29	P2	18.2	-5.8	0.711291	64.9		Local	None
111	M	30-45	P2	18.2	-5.8	0.708818	43.3	2	Local	Spearhead, knife
381	?	12-17	P2	18.2	-5.8	0.708681	77	1	Local	Knife fragment, belt buckle loop, 5 iron arrowheads, carinated pottery bowl
61	?	18-45	P2	18.4	-5.4	0.708819	80.1	2	Local	None
233	M	18-29	P2	18.5	-5.2	0.70903	49.2	2	Local	Spearhead, knife, knife fragment
190	F	18-45	M2	18.6	-5.1	0.709084	68.8	3	Local	Copper button brooch, oval belt buckle, knife, 4 sets of beads, purse group of objects, late roman coin, strap mount,
157	M	30-45	P2	18.7	-4.9	0.70864	93.6	2	Local	Iron shield boss, 2 disc headed rivets, knife, spearhead
753	M	30-45	P2	18.8	-4.7	0.708683	95.1	2	Local	Small long brooch, annular/penannular brooch, buckle and plate with silver inlay, knife, tweezers, strap mount

Table 4 Llandough

Sample	Sex	Age	Sample	δ18O tooth enamel	δ18O ground water	C14 date (2σ)	
LLD126	M	35-45	M2	17.6	-6.8		Possible migrant from England
LLD470	U	13-17	M2	18	-6.1		Local
LLD72	F	35-45	M2	18.1	-5.9		Local
LLD362	M	0.45	M2	18.2	-5.8		Local
LLD93	F	>45	M2	18.4	-5.4		Local
LLD601	U	18-25	M2	18.4	-5.4		Local
LLD2	F	25-35	M2	18.5	-5.2	AD370-640	Local
LLD474	F	25-35	M2	18.5	-5.2		Local
LLD380	F	18-25	M2	18.6	-5.1		Local
LLD409	M	35-45	M2	18.6	-5.1		Local
LLD415	F	18-25	M2	18.6	-5.1		Local
LLD98	M	35-45	M2	18.7	-4.9		Local
LLD376	M	35-45	M2	18.7	-4.9		Local
LLD972	F	18-25	M2	19	-4.4		Possible migrant from Mediterranean
LLD10	M	35-45	M2	19.2	-4.0		Possible migrant from Mediterranean







Figs 3(a), 3(b) and 3(c)

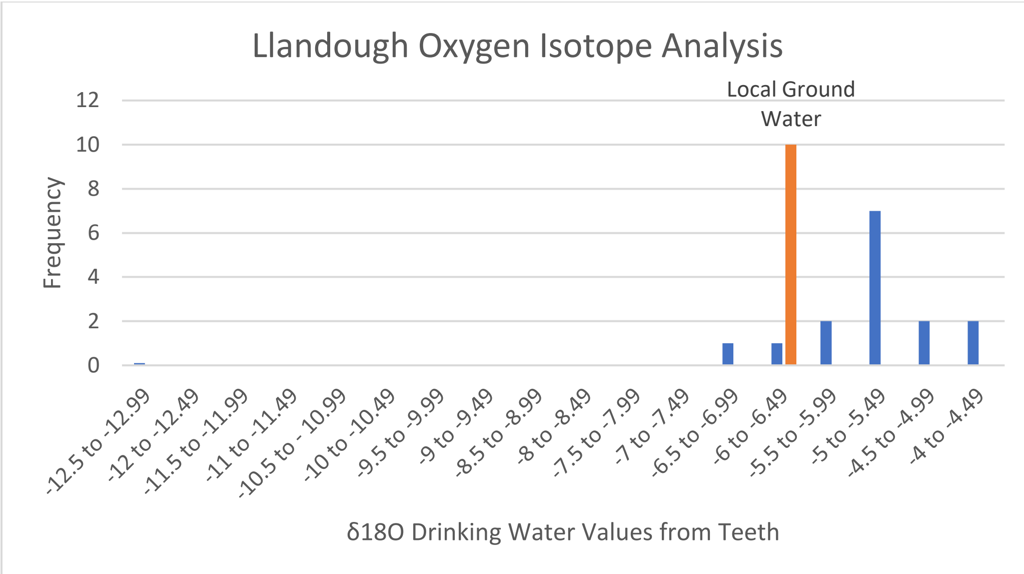


Fig 3(d)

Discussion

The West Heslerton graph (Fig 3a) shows that there are some individuals that have drinking water $\delta^{18}O$ values that are more depleted or about the same as local drinking water. The most depleted value (-10.2‰) probably (95% confidence) lies in the range -9.5‰ to -11‰. This places their childhood in a band covering most of southern Sweden, northern Germany on the Baltic coast and central Europe running down to the Alps (see fig 1). The next most depleted (-9.0‰) lies in the range -8.5‰ to -10‰. Their origin is most likely outside of the UK slightly to the west of the previous individual. The next two individuals lie in the range -8‰ to -9.5‰ and again their most probable origin is slightly to the west of the previous individual, possibly eastern Sweden, the Danish islands of Funen or Sjaeland, northern Germany or somewhere further south. After this, identifying the origins of individuals becomes more contentious. Three individuals have drinking water $\delta^{18}O$ values that are close to local drinking water. But as we have seen most processes (cooking, brewing, stewing, evaporative enrichment) all tend to enrich an individuals drinking water $\delta^{18}O$ value, so these individuals are not likely to be local (or they would have a drinking water $\delta^{18}O$ value enriched relative to local drinking water). The range for these three individuals is -7.5‰ to -9‰. They could come from southern Norway, most areas of Denmark, the North Sea coast of Germany or further south in Germany or France. And of course they could, with the range of values stated, be fairly local to West Heslerton. The next group of four individuals with values between -7.0‰ and -8.5‰ could also have UK or continental origins. The most enriched individuals on the right hand side of the graph are most likely to be people brought up in the local area whose drinking water $\delta^{18}O$ value has been enriched by one or more of the processes mentioned.

From their analysis Budd et al concluded that only four of the individuals were continental migrants because they gave a clear oxygen isotope signal that could not have come from anywhere in the UK. However, an additional seven individuals could have come from continental Europe or the UK, but it is not possible, using oxygen isotope analysis alone, to distinguish between those brought up in West Heslerton and individuals brought up on the other side of the North Sea. Budd et al also concluded that thirteen of the individuals had come from elsewhere in the UK, west of the Pennines because the $\delta^{18}O$

values were enriched compared to local drinking water. A more likely explanation is that the $\delta^{18}O$ values were enriched by one or more of the processes described earlier and the individuals were probably brought up in the local area. The authors point out that there appear to be two distinct groups of people (a bimodal distribution), and although they propose that this consisted of four migrants, seven who could be migrants or have a local origin and thirteen who were migrants from the west, the most likely scenario is that the population consists of eleven continental migrants and thirteen locals.

Budd et al (2004) were quite happy to accept, from the $\delta^{18}O$ values, that there were migrants from Scandinavia or elsewhere in Continental Europe (they didn't speculate on possible origins) but to then suggest that there were no migrants from Frisia, Angeln, Saxony or the Jutland peninsula is not consistent with other evidence. The historical evidence may be open to dispute but the artefactual evidence (eg Myers 1977) strongly indicates influences from these regions.

As the authors themselves admit the local variation in strontium isotope ratios is so large that this technique is of little value.

Berinsfield shows a slightly different distribution to West Heslerton. There is a narrower spread of drinking water $\delta^{18}O$ values, the most depleted value being -7.7‰ which has a 95% probability of lying in the range -7.0‰ to -8.5‰. This individual could have a continental origin or come from elsewhere in the UK. The next three individuals lie in the range -6.5‰ to -8.0‰ and could have UK or continental origins. Seven individuals lie in the range -6.5‰ to -6.99‰ (95% probability of -6.0‰ to -7.5‰). This range means that they could be of UK or continental origin. The remaining eight individuals are probably locals. Unusually, 13 of the teeth selected for analysis were second pre-molars and it is known that premolars form early in childhood and $\delta^{18}O$ drinking water values could be enriched by breast feeding. Evans et al (2012) showed that the second premolar gave the most enriched value. Had M1,M2 or M3 teeth been chosen it is possible that that the dataset would be more depleted (but only by a maximum of 0.4‰) and tend to favour more continental migrants.

Hughes et al concluded that only one of the 19 individuals may have been a migrant from Europe and they claimed that this supported the acculturation theory, ie that there were only a small number of migrants from the continent but this small number had a such an influence on the local population that the locals copied burial practices, styles of adornment, language and material goods of the incomers. However, their analysis does not take into account the imprecise nature of the measurements or the overlap in values between eastern England and the other side of the North Sea. This is very important as their paper has been used by others as evidence for a small number of migrants (eg Oosthuizen 2019 40) whereas it is possible that as many as 11 of the individuals had a continental origin.

Eastbourne has a wider spread of values similar to West Heslerton. One outlier has a drinking water $\delta^{18}O$ value of 8.7 and is probably continental in origin. There is a group of 8 that are more depleted than the local drinking water and these could be of continental or UK origin. 10 individuals have drinking water $\delta^{18}O$ values that are more enriched than the local drinking water and the most likely explanation is that these are local. Similarly to Berinsfield, a high proportion of the teeth sampled were second premolars (16 out of 19). Hughes et al placed greater reliance on strontium ratios but reached broadly the same conclusions from the isotope evidence. They also had one probable migrant and 8 possibles but thought that two of these could have an origin within a few kilometres of the Eastbourne cemetery because of the strontium isotope ratio that was characteristic of outcrops of the Lower Greensand, Weald clay, Tunbridge Wells and Ashdown formations.

Summary of English Isotope Analysis

	West Heslerton, Budd et al	West Heslerton This paper	Berinsfield Hughes et al	Berinsfield This paper	Eastbourne Hughes et al	Eastbourne This paper
Probable continental migrants	4	4	1		1	1
Possible continental migrants or UK origin		7	1	12	6	8
Elsewhere in UK	13		2		2	
Locals	7	13	15	7	10	10

Table 5 Summary of Results of Oxygen Isotope Analysis

The main conclusions from this analysis are that there could be significantly more migrants from continental Europe and Scandinavia than the published papers suggest, and there is no need to propose migrants from the west of Britain to explain the results found.

Welsh (Llandough) Isotope Analysis

One of the mysteries of the post-Roman period is the invisibilty of the native population and, in part, this was responsible for the acculturation theories; the Romano-British didn't disappear, they simply adopted Anglo-Saxon culture. However, according to Gildas, the locals were slaughtered, or enslaved, or they fled to the hills and woods (Giles 2009). There is some archaeological evidence for the reuse of hill forts at this time (eg Alcock 1975) so perhaps there is some truth in his writings. Is there any isotope evidence to support either of these views?

Hemer et al (2013) looked at burials at several sites in Wales dating from the 5th to 7th centuries in an effort to find evidence of migrants from the Mediterranean. There is archaeological evidence for trade between the south west of Britain and the Mediterranean in the post-Roman period (Cunliffe 2001 478-481). The site with the most burials, Llandough, has been re-examined. The oxygen isotope values of the drinking water for the 15 individuals have been recalculated using the same formula as West Heslerton, Berinsfield and Eastbourne (Daux equation 4) (see Table 6). The recalculation does have an impact on the results. The most enriched value from Llandough becomes -4.0 instead of -3.4. This is more enriched than any known source in Britain and may be evidence of a migrant from the Mediterranean. With the other sites Hemer et al sampled there were 33 individuals altogether and four were more enriched than any British or Irish areas, although this may be explained by the various enrichment processes already discussed.

Looking at the frequency distribution of oxygen isotope values for Llandough there is one outlier on the most depleted oxygen isotope values. LLD126 has a drinking water oxygen isotope value of -6.8 which is more than two standard deviations from the mean. This individual probably has an origin to the east of Llandough, probably somewhere in Britain. There is another burial, BS 530 from another site which lies on the edge of the 2 standard deviation range who may also be a migrant from the East. One of the problems with this data is that the burials are not well dated. One Llandough burial has a wide range of dates from Carbon 14 analysis, AD370-640 but there are few grave goods for a more accurate estimate.

Strontium Isotope Analysis

Strontium isotope analysis was carried out in all three English papers in an effort to distinguish people brought up locally from those outside the area. The technique measures the ratio of strontium 87 to strontium 86 and varies with the geology of the area and how this translates into labile strontium. To be used successfully local strontium levels need to be measured and in their Eastbourne analysis Hughes et al (2018) did extensive measurements of soil leachate values and strontium ratios in cows and sheep from graves in the Anglo-Saxon cemetery. The range of strontium ratios in humans and animals was smaller than the range of values in the soil in a 15km radius. My conclusion from this is that none of the samples have a clear signal from the strontium ratio for non-local origin. Budd et al (2004) and Hughes et al (2014) in the analysis of West Heslerton and Berinsfield also commented upon the wide range of local strontium ratios. To quote Budd et al (2004):
'This very large local environmental strontium isotope range is a major obstacle to the interpretation of the archaeological data as it appears that the range of locally bioavailable strontium isotope ratios is as great as that of a large area of northern England. Under such circumstances there may be no clear correlation between tooth enamel $^{87}Sr/^{86}Sr$ ratios and geographic location.'

Hughes et al (2014) also commented upon the use of the strontium isotope ratio:

'All human $^{87}Sr/^{86}Sr$ values lie within the range of variation exhibited by local soils and most of the herbivores'

These direct quotations support the conclusions from Eastbourne, so in all three English cases studied, the local variability in soil $^{87}Sr/^{86}Sr$ values is greater than the variability in humans making it impossible to distinguish migrants from locals using this method. Hemer et al (2013) did not sample the local environment for strontium ratios, they only estimated the range.

If strontium isotope analysis is of limited value are there any correlations between the conclusions from oxygen isotope analysis and other factors such as the time of the burial, sex of the individual and the grave goods with which they were buried?

Correlation Between Isotope Analysis and Other Factors

West Heslerton

The selection of burials for isotopic investigation at West Heslerton was not random or representative. Graves that were chosen exhibited evidence of Germanic or Scandinavian culture or were from graves that were thought to come from the earliest phase of the use of the cemetery (Montgomery et al 2005). Haughton and Powlesland (1999a 81) thought that the overall date for use of the cemetery was c AD 475 to c AD 650.

Of the 24 individuals studied at West Heslerton, 18 are female, 5 male and one child unidentified. Some of the skeletons were sexed from their grave goods and the dangers of this are illustrated by G164. The skeletal evidence is for a female but the grave goods include a spear and buckle, so if this individual had been sexed from grave goods it would probably have been identified as a male (Haughton et al 1999b 288).

Table 1 shows the isotope results from West Heslerton sorted into order by $\delta^{18}O$ values. The most depleted values are at the top and the conclusion from the isotope analysis (both the original paper and this re-evaluation) was that the first four were probably migrants from continental Europe or southern Scandinavia. These four were all females (three adults and one juvenile) but given the preponderance of females in the sample this may not be significant. The three adults had only one bead between them but the juvenile had a selection of 23 beads and a purse mount. Only two other graves were unaccompanied, G149 a male who could be a migrant or local and G145, a male who was probably local. The unaccompanied graves showed a variety of burial positions (see Table 1).

There are no discernible patterns in the 19 individuals from West Heslerton who were buried with grave goods. Annular brooches, for example, were spread across the range of oxygen isotope values and a very rare item, a walnut amulet, was found in G159 that had an oxygen isotope value of -8.95 and another was found in G113 that had a value of -6.25. There is one conclusion from Budd et al (2004) that can be discounted. As mentioned earlier the individuals were selected on the basis of Germanic or Scandinavian grave goods. Budd asserts that 13 individuals were first generation migrants from west of the Pennines. It is highly unlikely that a group of people moved to West Heslerton from west of the Pennines and in less than a generation every single one of them acquired Germanic or Scandinavian material culture and burial practices. Far more likely is that these people had enriched oxygen isotope values because of their cooking practices, giving children beer to drink, giving them water from ponds or some other practice that enriched their oxygen isotope levels above the drinking water level.

In all the graves at West Heslerton there was only one grave with a sword (G74) and unfortunately the teeth from this skeleton were not preserved very well so could not be subjected to isotope analysis.

Berinsfield

At Berinsfield nineteen individuals were selected for analysis. These were selected on the basis of style of grave furnishings and location near the centre of the cemetery which should have sampled the earliest graves. The cemetery is earlier than West Heslerton. Wheras West Heslerton was dated from AD 475, Berinsfield dates from the early to mid 5th century to the early 7th century (Boyle et al 1995). Graves were assigned to phases in the first 100 years of cemetery use, phase A are burials before the last quarter of the 5th century, phase B are burials in the last quarter of the fifth century and phase C, burials from the first half of the 6th century. Of the 19 individuals nine were female, six male and four unidentified. Table 2 shows the results of the isotopic analysis, sorted by oxygen isotope levels with the most depleted values at the top.

Out of the 19 graves two, G81 and G4, had no grave goods. These two were both young adult males and both were amongst the most depleted oxygen isotope levels, and therefore, in this group, amongst the most likely to be continental migrants. Two the graves, G26 and G152 contained a Roman coin, although in G152 this may not have been deliberately buried with the body (Hughes et 2014 Table 1). Both these graves have been identified as ‘locals’ so it is possible that these two individuals (one male, one female) were conscious of their Roman past and had kept these momentos. Otherwise there is little to distinguish the 12 possible migrants from the 7 possible locals; both groups had individuals from all three phases.

Eastbourne

The Eastbourne cemetery contains typically Germanic burials belonging to the early Saxon period. The graves are irregular in spacing and orientation and contain typical Germanic style grave furnishings such as brooches, beads, rings, toilet sets, belt buckles and other objects of personal dress, as well as weapons, shields, knives pottery and food items (Hughes et al 2018, Clifford et al 2016 33-51). The 19 graves selected were from the earliest part of the cemetery and were assigned to one of three phases. Phase 1 was those dating as early as 375, phase 2 those no earlier than 450 and phase 3 those dating after AD 500. The selection included different grave orientations, males and females, young and old.

Five of the 19 graves contained no grave goods. The skeleton with the most depleted oxygen isotope value (and therefore most likely to be from continental Europe or Scandinavia) had no grave goods and of the six samples with the most depleted levels three had no grave goods. One of the graves contains a Roman coin.

Summary of Correlation of grave goods with isotope results

Taking the results from West Heslerton, Berinsfield and Eastbourne together there is a correlation between depleted values of oxygen isotopes (and therefore most likely to be of continental or Scandinavian origin) and the lack of grave goods. At West Heslerton there are four graves with no grave goods and one more with just a single amber bead found inside the cranium. Of these five graves, three are amongst the four graves with the most depleted oxygen isotope levels. At Berinsfield there are two graves with no grave goods. These are amongst the three skeletons with the most depleted oxygen isotope levels. At Eastbourne there are five graves with no grave goods and three of these are amongst the six with the most depleted oxygen isotope levels. All three sites have been ranked by oxygen isotope values with the most depleted at the top. Table 6 shows the distribution of the graves with grave goods in the data set (yellow blocks are those with no grave goods).

Out of all the graves at West Heslerton, Berinsfield and Eastbourne only four swords have been found, one at West Heslerton, none at Berinsfield and three at Eastbourne. Generally they are the burials of ordinary folk; there is not much sign of a military elite or a ruling class.

Table 6

Position in data of graves with no grave goods

Position	West Hes.	Berinsfield	Eastbourne	
1				Most depleted Oxygen 18 levels
2				(most likely to be migrants from Europe)
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				Most enriched oxygen 18 levels
				(least likely to be migrants from Europe)

Table 7 lists the burials from the three English cemeteries with no grave goods that were selected for isotope analysis and records the orientation of the graves. Out of 12 graves with no grave goods, three have graves that are orientated East/West, four are North/South and the others somewhere in between. There is no dominant orientation. The conclusion is that these people, buried with no grave goods, are not the remnants of a Romano-British Christian community; they are likely to be migrants and the lack of grave goods could indicate that they were amongst the poorest members of society. They could be slaves or they could be what we would call today 'economic migrants'; people who have nothing who are coming to Britain for a better life.

		Table 7			
	Orientation of Graves with no grave Goods				
West Heslerton					
Sample No	Sex	Age at Death	Tooth	δ18O drinking water. Calc using Daux Eq 4	Grave orientation
GN166	F	ADU	M2	-10.2	E/W
GN133	F	ADU	P1	-8.8	SW/NE
GN159	F	ADU	M2	-8.6	W/E
GN149	M	ADU	P1	-8.3	NW/SE
GN145	M	ADU	M1	-6.3	NE/SW
Berinsfield					
Grave No.	Sex		Tooth	δ18O drinking water. Calc using Daux Eq 4	
81	?		M2	-7.3	N/S
4	M		M2	-7.0	N/S
Eastbourne					
Sample	Sex	Age	Tooth	δ18O drinking water. Calc using Daux Eq 4	
270	F	30-45	P2	-8.7	E/W
57	M	18-46	P2	-7.5	N/S
309	M	18-29	P2	-7.3	E/W
64	F	18-29	P2	-5.8	SW/NE
61	?	18-45	P2	-5.4	N/S

Chapter 4

Conclusions

The samples chosen for oxygen isotope analysis will never be a representative sample of the population of Britain in the early Anglo-Saxon period. They will only be a sample of those people that used inhumation as a burial rite because nobody has successfully analysed cremated bone for isotopes. Cremation was practised widely in Northern Germany and most of the Danish peninsula before the Anglo-Saxon period and in Britain this burial rite was widely used in north Humberside, Lincolnshire and Norfolk and the use of this rite has been used to denote 'Anglian' areas. However, cremation was not the only burial rite practised in Anglian areas, nor was cremation limited to the areas mentioned above, so inhumation burials might be biased towards non-migrants.

This paper has reviewed the evidence from isotopes for the nature of the movement of people into Britain in the early medieval period. Until the late 20th century the picture had been fairly straightforward. Large numbers of Jutes, Angles and Saxons (Bede) packed up their belongings, sailed across the North Sea and settled in central and eastern England before spreading westwards. There were so many of them the local population was swamped. The newcomers could be easily identified from their burial practices; they either cremated their dead and buried the remains in pots similar to ones that had been used in their Germanic homelands or they buried their dead with grave goods. Bede tells us the names of the founders of the Anglo-Saxon kingdoms and how they defeated the British in battle. But what if our interpretation of the archaeological evidence is tainted by our reliance on written sources that we know are unreliable? Alternative views have been expressed in the last quarter of the 20th century. Richard Reece, for example, believed that the Anglo-Saxons did not migrate in significant numbers, but that Anglo Saxon fashions became dominant in eastern England in the early 5th century (Reece 1988). Higham (1992) proposed a much longer continuity of Romano-British institutions. Ken Dark (2000) had little faith in Gildas or Bede and reviewed the archaeological evidence for the Saxon 'invasion'. He found examples of continuity that implied that the old order had not simply been swept away and replaced by something completely different. Generally these new interpretations did not rely upon mass invasion by Anglo-Saxons to explain the archaeology and the numbers of migrants has been the subject of much debate and science is being used to attempt to provide some objective evidence.

The scientific tool being reviewed in this paper is the use of stable isotopes of oxygen to determine the approximate geographical area where an individual was brought up. The main problem with this technique is that it lacks precision. The values obtained by analysis have a wide margin of error and the geographical area that can be associated with a value is large. Nevertheless, sometimes the analysis gives a clear signal that an individual comes from somewhere other than the UK. To get a clear signal the individual needs to come from as far east as Sweden and could include a large swathe of continental Europe. There are other individuals who could be migrants from Europe or Scandinavia but these people will have an oxygen isotope value that could also indicate an origin in England. Generally the number of migrants could be larger than the published papers suggest. The Berinsfield paper for example concludes that there is evidence for only one migrant out of the population of 19 individuals. This conclusion was used to support the theory that there were a low number of migrants coming into the country in the early 5th century and most of the population were people who had acquired Anglo-Saxon characteristics by acculturation. This paper argues that there could be many more migrants coming to England but the evidence is so imprecise it is difficult to distinguish between those brought up in West Heslerton, Berinsfield or Eastbourne with those from Bergen, Ribe or Issendorf. The published papers are not evidence of low numbers of migrants and it would be surprising if there were migrants from Sweden but none from Norway, Denmark, northern Germany or the Low Countries.

There is no need to propose large numbers of migrants from other parts of Britain to explain the results found in the three sites examined. The most likely reason for a population having a more enriched oxygen isotope value than expected is evaporative enrichment by processes such as cooking, stewing, brewing or drinking from a shallow water supply.

There was one unexpected finding. The individuals buried with no grave goods frequently give a clear signal that they were migrants. As mentioned above these people are not remnants of a Romano-British Christian community; they could be slaves of other migrants, or they could be economic migrants, coming to Britain with nothing in the hope of a better life. The migrants were not bringing a Germanic culture with them; the culture of the Romano-British population was already Germanic before the migrants arrived. The following scenario is proposed:

- The Romano-British way of life began to alter in the second half of the fourth century, especially after the Barbarian Conspiracy of 367.
- The number of Roman troops in Britain declines as they are withdrawn to fight continental incursions by Barbarians and to support claimants to the throne
- Britons, having supported the empire for centuries feel abandoned by Rome and turn their back on a Roman lifestyle
- Some villas are abandoned (Faulkner 2000 72) but land ownership doesn't change
- British made belt fittings and buckles become more common, indicating a change in fashion and need to carry a weapon (Russell and Laycock 2010 157-173)
- The culture gradually becomes more Germanic. Ken Dark (2000 20) identified a thin scatter of tutulus and supporting arm (Germanic) brooches across Norfolk, Suffolk and Lincolnshire in late Roman Britain.
- After the collapse of the system of Saxon shore forts migrants start to arrive in Britain. These are mainly economic migrants and refugees hoping to carve out a living in a relatively quiet corner of Europe. Despite the withdrawal of the Roman army the total population remains about the same and land use, especially in eastern England, is largely unaltered (Dark P 2000 151)
- Migrants continue to trickle into Britain
- The migrants acquire Germanic goods and practices from the native population as they make a living in Britain
- Some of the pro-Roman middle classes move to Wales
- The migrants eventually make up 40%-50% of the population (Leslie et al 2015, Schiffels et al 2016)

Although many authors have now dismissed historical evidence for the coming of the Anglo-Saxons as origin myths created by 6th and 7th century Anglo-Saxon kingdoms there is still some attachment to the dating sequences that they assumed. Myers (1977) for example identified some of the urns used in British cremation fields as having late 4th century counterparts in Northern Germany. Despite the fragility of pottery and its short shelf life the accepted start date for the British cremation sites is around AD 420. Perhaps now it is time to re-evaluate dating on archaeological grounds alone.

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