# ISOTOPIC ANALYSIS OF BURIALS FROM THE EARLY ANGLO-SAXON CEMETERY AT EASTBOURNE, SUSSEX, U.K.

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## Abstract

The transition from Roman Britain to early Anglo-Saxon England, traditionally described as the *Adventus Saxonum* and associated with a large-scale invasion by Germanic peoples, has been the subject of much debate. The archaeological record does not support a replacement of the local Romano-British population with Germanic incomers, and alternative explanations for the transition argue for a much smaller contribution of Germanic immigrants. As a contribution to this debate and to address the question of the number of immigrants, we have applied strontium and oxygen isotope analysis to study residential mobility in a sample of 19 individuals from the early Anglo-Saxon cemetery at Eastbourne, Sussex, on the southern English coast. Local variation in bio-available strontium isotope ratios was established by sampling soils from different geological substrates within 19 km of the cemetery and from a small sample of domestic animals recovered from the graves. Four individuals are likely continental immigrants, three others could be, but could also originate elsewhere in the British Isles, and two women are likely immigrants from nearby communities. The identified immigrants at Eastbourne show a temporal spread and lack of wealth expressed as grave goods. This pattern is not consistent with simple models of mass invasion, elite takeover or acculturation. Our results, together with other recent findings, imply that the *Adventus Saxonum* involved diverse migratory and demographic processes.

## 1.0 Introduction

Combining strontium and oxygen isotopic ratios of human tooth enamel offers a useful tool to explore patterns of human mobility and place of origin (Evans et al., 2012; Chenery et al., 2010; Mitchell and Millard, 2009; Knudson and Price, 2007). In this paper, we employ strontium and oxygen isotopic ratios in human tooth enamel to test competing models proposed to explain the *Adventus Saxonum*, or the rapid fifth century transition from the Roman occupation of Britain to the early Anglo-Saxon period. Nineteen individuals dating between AD 450 and 600 were sampled from an early Anglo-Saxon cemetery at Eastbourne, Sussex, on the south coast of England (Fig. 1).

The *Adventus Saxonum* is a poorly understood period in British history (Crabtree, 2009) and has sparked much debate. The archaeological record for the end of the fourth century AD shows a decline in Roman building, trade goods, and other cultural activities with the rapid appearance of Germanic cultural elements especially visible in the patterning and furnishings of early Anglo-Saxon cemeteries (Henig and Booth, 2000; Lucy, 2000). Germanic cultural elements were firmly established in Britain by AD 450. Yet, the archaeological record shows cultural continuity in rural Britain (Fowler, 2002; Hamerow, 1992; Robinson, 1992), and in some places, Romano-British Christian and Germanic pagan communities appear to exist side by side (Henig and Booth, 2000).

The historic record, based primarily on the writings of Gildas (Sherley-Price, 1968), Bede (Winterbottom, 2002), and the Anglo-Saxon Chronicles (Swanton 1996), ascribes this cultural change to a large-scale continental invasion that destroyed and replaced the British population (discussed in Dark 2000). This is the ‘establishment’ model—rapid cultural change brought on by the invading culture (Bassett, 1989; Esmonde-Cleary, 1989). Because the archaeological record contradicts the ‘establishment’ model, other explanatory models have arisen. These models differ from the ‘establishment’ view in the number of immigrants and the degree of cultural continuity (for overviews, see Henson, 2006; Dark, 2000). One model gaining popularity in recent years, advocates for acculturation, possibly accompanied by the immigration of a small number of German elites (Hills, 2009, 2003; Thomas et al., 2006; Lucy, 2005, 2000; Reece, 1980). A third model argues for an initial continental immigration accompanied by cultural continuity, a pattern that mirrors the contemporary social, religious, and political transformations occurring in western Europe (Henig, 2002; Dark, 2000; Higham, 1992).

Genetic research has also contributed to the debate. A study of modern Y-chromosome DNA from Great Britain shows a strong Germanic component in east and central England (Capelli et al., 2003; Weale et al., 2002), however, it is argued that a small incoming male population having a culturally-based reproductive advantage could create this pattern (Thomas et al., 2006). Leslie et al. (2015) used a large-scale study of modern British populations to estimate that Anglo-Saxon and Viking migrations contributed less than half of the genomes of people from south eastern England. More recently, a comparison of nuclear DNA among early and middle Anglo-Saxon burials from eastern England and modern East English populations reveals that Anglo-Saxon immigrants, genetically similar to modern Dutch and Danish populations, contributed 38% to the ancestry of the eastern English. The similarity in DNA between early and middle Saxon individuals suggests continuous immigration throughout the Early and Middle Anglo-Saxon periods (Schiffels et al, 2016).

As the number and place of origin of Germanic immigrants arriving in Britain is a focal point of the debate, strontium and oxygen isotopic ratios of human tooth enamel can be used to identify the number and possible place of origin of immigrants in early Anglo-Saxon cemeteries. If a large-scale invasion of Germanic peoples occurred then most of the founding members of an early Anglo-Saxon cemetery should be continental immigrants, whereas, if acculturation was the mechanism of change, then few, if any, continental immigrants should be represented, with the majority being males in the early phases under the elite dominance model. Under the “establishment” model, up to one half of the earliest members could be continental immigrants depending on their age at immigration. To identify who is or who is not an immigrant requires knowing the local isotopic signatures and their variation. In this study, these are acquired from groundwater oxygen isotope values, soil strontium values, and strontium values from herbivore teeth recovered from the Eastbourne cemetery. This study also explores temporal patterning in the isotopic data to identify if the earliest burials are immigrants, and examines relationships between the isotopic ratio values and characteristics of burial practice to identify any differences related to place of origin.

## 2.0 Background

### 2.1 Location of the Eastbourne Anglo-Saxon Cemetery

The Eastbourne early Anglo-Saxon cemetery is located on the modern town of Eastbourne, on the eastern edge of the South Downs adjacent to the English Channel. The South Downs are an undulating chalk upland with glacially incised, steep-sided valleys.  The Eastbourne cemetery is one of two Anglo-Saxon cemeteries located on Ocklynge Ridge, a low chalk spur extending from the Downs (Figs. 1 and 2). The earlier Eastbourne cemetery is at the lower end of the ridge in a part of Eastbourne known as Upperton. A second cemetery, the Ocklynge Hill cemetery, lies further up the ridge and appears to date to the middle Saxon period

(7th and 8th century AD; Sparley-Green, 2005; Wacher, 1998; Meaney, 1964; Stevens, 1980).

The ridge top location of the Eastbourne cemetery affords an expansive view of a broad wetland to the north, the Pevensey Levels (Fig. 1). During the Roman and early Anglo-Saxon periods, this wetland was a wide, tidally-influenced bay studded with small islands. Eastward drifting shingle gradually formed a barrier across the mouth of the bay with a marsh behind it. Between the 8th and 14th centuries the marsh was reclaimed (Gasca-Tucker and Acreman, 2010; Lake, 1987).

Flowing from the Chalk Down one kilometre south of the Eastbourne cemetery is a permanent spring at Motcombe Gardens in the Old Town of Eastbourne. The settlement established here was named after the spring, “Burna” meaning stream or brook in early Medieval times; later changed to “Bourne”. By the 13th Century the pre-fix “Est”, meaning “east” was added, and the expanding settlement became Eastbourne (Spears, 1975).

## 2.2 The Romano-British to Anglo-Saxon Transition in Sussex

Archaeological investigations have revealed both a Romano-British and an early Anglo-Saxon presence in Sussex. Saxon settlements, generally confined to the South Downs and the scarp foot at the base of the Downs, do not overlap with Romano-British settlements located on the rich coastal plain (Welch, 1983; Fig. 1). One well-known Roman construction is *Anderitum*, a 4th century Shore fort built to defend the British coast from foreign invaders, located on a peninsula that once extended into Pevensey Bay (Gasca-Tucker and Acreman, 2010; Pearson, 2002).

The Anglo-Saxon Chronicles state that Sussex was initially settled by a tribe from Germany in the late 5th century: *Aelle* and his sons landed with three ships west of Eastbourne in AD 477, driving the Britons into the Weald. The account describes how *Aelle* attacked *Anderitum* in AD 491 and “killed all who lived in there” (Swanton, 2000:14). The Chronicles also state that Sussex was the last Anglo-Saxon kingdom to be converted to Christianity in ca. AD 681 (Swanton, 2000; Hill, 1978).

The South Downs between the River Ouse and Eastbourne contain five known early Anglo-Saxon cemeteries (Welch, 1983). Most are located on low chalk spurs extending from the Downs (Eastbourne, Alfriston, Jevington, and Bishopstone, Figs 1 and 2; Welch, 1983,1980). Early Anglo-Saxon settlements are adjacent to the cemeteries of Bishopstone and Highdown (Welch, 1980; Bell, 1978). Elsewhere in England, early Anglo-Saxon settlements are generally located less than 1.5 km from their cemetery (Hamerow, 1993; Lucy et al., 2009; Powlesland, 1999; West, 1985). Excavations at the Eastbourne cemetery in 1991 (Stevens, 1992a and b) revealed the possible remains of two building floors (Fig. 3, nos. 25, 39), perhaps indicating a settlement adjacent to the cemetery (Stevens, 1992a), however, a more logical place for a settlement would be nearer to the Bourne. These areas are heavily developed today and the location of the Eastbourne cemetery settlement may never be known.

## 2.3 Local Isotopic Ratio Values

Oxygen and strontium isotopes in tooth enamel are obtained from a person’s diet during the period of tooth formation (Budd et al., 2004). If an individual migrates to a new area after teeth form, the isotopic values in his or her tooth enamel will differ from individuals who were raised in the new area.

### *2.3.1 Oxygen isotope ratios*

It is well established that the oxygen isotope ratio of precipitation ($^{18}O/^{16}O$, expressed as $\delta^{18}O_P$) decreases with distance from the ocean, with altitude, and with decreasing temperature (Darling et al. 2003; Faure, 1986; Gat, 1980). The British Isles receive most of their precipitation from the southwest, thus $\delta^{18}O_P$ values decrease toward the northeast (Darling et al., 2003). A similar trend can be seen in mainland western Europe (Lécolle, 1985; see Fig. 4). In humans, the $\delta^{18}O_P$ values of skeletal phosphate are controlled by the isotopic composition of groundwater (drinking water) with minor contributions from water contained in food and atmospheric oxygen (Daux et al., 2008; Chenery et al., 2010; Brettell et al., 2012). Bio-apatite in teeth and bones forms in isotopic equilibrium with body water, and the $\delta^{18}O_P$ correlates to $\delta^{18}O$ of local drinking water (Longinelli, 1984; Levinson et al., 1987; Daux et al., 2008). Therefore, the $\delta^{18}O_P$ values of locally-born, sedentary individuals will depend on the $\delta^{18}O$ of local groundwater with little variation (Longinelli, 1984; White et al., 1998; 2004). The amount of variation in a local population is not well established (White et al., 1998; Chenery et al., 2010), however, $\delta^{18}O_P$ values in locally-born, sedentary individuals drinking from the same groundwater source may vary by less than 1.0‰ (Longinelli, 1984; White et al., 1998; 2004). Enamel values may also increase by 0.6 to 0.7‰ if the diet relies heavily on cooked food and beverages (Daux et al., 2008; see also Brettell et al. 2012).

The $\delta^{18}O$ value of tap water obtained from chalk wells at Eastbourne today is -6.3 ‰ (Fig. 4; Darling et al., 2003). During the early Medieval period, the primary water source in the Eastbourne area was the Bourne. Owing to the porous nature of chalk, isotopic variations in seasonal rainfall are buffered by the isotopic values in existing pore water, resulting in values at or near the long term weighted mean of precipitation (Darling et al., 2003). Because air trajectories have remained essentially unchanged in southern Britain, there has been little variation in local oxygen isotopic values during the Holocene (Darling et al., 2003).

Drinking water $\delta^{18}O$ values in the supposed European ‘homelands’ of the Anglo-Saxons, range from –7.0 to –10.5‰ with $\delta^{18}O$ becoming progressively lower inland (Fig. 4). Oxygen isotopes should identify immigrants from inland Germany and Northern Europe, but individuals raised in western Britain, France, and the Mediterranean could have identical values to those raised in the Eastbourne area.

### *2.3.2 Strontium isotope ratios*

Humans receive most of their strontium from plant foods. The isotopic signal is derived from the local bedrock as it forms into soil, and is transmitted up the food chain without isotopic fractionation. As a result, the strontium isotope ratios in vertebrate tooth enamel mirror those of local bedrock.

The $^{87}Sr/^{86}Sr$ values in local bedrock vary by rock age and composition. Over geological time, $^{87}Sr$ is produced by the decay of $^{87}Rb$ while the abundance of $^{86}Sr$ remains fixed. Thus, older rocks have higher $^{87}Sr/^{86}Sr$ values than younger rocks, although this also depends on rock type and initial Sr/Rb and $^{87}Sr/^{86}Sr$ ratios (Faure, 1986; Capo et al., 1998). Chalk and other calcareous rocks are generally lower in $^{87}Sr$ than silicate rocks because they contain low concentrations of rubidium with values comparable to seawater (Faure, 1986).

Strontium isotope ratios are most useful in identifying immigrants when the local geological substrate is significantly different from the place of origin. The local strontium isotopic signal may be determined from bio-available soil strontium, local plants, or small mammals (Bentley, 2006), and more recently from local water values (Montgomery et al., 2006; Voerkelius et al. 2010). While bio-available strontium in soil and soil water is not perfectly correlated with the isotopic composition of parent rock, bio-available soil values are a good proxy of the ratio value passed on to humans (Capo et al., 1998; Montgomery et al. 2006; Frei and Frei, 2011).

For this study, we have obtained strontium values from soils collected within 19 km of the cemetery (Table 1) and from herbivore tooth enamel recovered from the Eastbourne graves (Table 2). The soils were collected away from developed areas, and thus, the collection points were often further from the Eastbourne cemetery than where these substrates actually outcrop (Table 1). Because the southern flank of the London Basin Syncline outcrops here, a number of Cretaceous geological formations are exposed (Fig. 2) along with more recent Quaternary and Holocene deposits: the Quaternary clay-with-flints and Head deposits, and Holocene alluvium in stream beds, beach sediments, and the Pevensey Levels (Fig. 2). Clay-with-flints, a reddish brown sandy clay with angular flints, is present on the higher chalk downs, a residual material from the dissolution of chalk combined with Paleogene sediments. The Head, a brown silty loam, is composed of soliflucted local materials (IGS, 1968). Because the geology varies in this region, the soil $^{87}Sr/^{86}Sr$ values are also likely to vary.

Seven ovicaprid (sheep) and three bovid (cattle) enamel samples recovered from the Eastbourne Anglo-Saxon graves were also analysed to identify local $^{87}Sr/^{86}Sr$ values. In combination with the soil values, the herbivore values may identify actual areas used for food production (Chenery et al., 2010). The best arable land in the region is the Lower Greensand and Head formations located on the east- and north-facing scarp of the South Downs south of the former Pevensey Bay (Fig. 2; Brandon, 1978; Welch, 1983). The upland Chalk Downs were best suited for pasture (Lake, 1987), and there is some historical evidence that early farmers grazed their animals in clearings in the dense mixed oak forest that grew on the lowland Weald and Wadhurst clays west of Pevensey Bay (Brandon, 1978).

# 3.0 Materials and Methods

## 3.1 The Eastbourne Sample

The Eastbourne burials are typical of “Germanic” burials belonging to the early Anglo-Saxon period in England (Swift, 2000; cf. Lucy, 2000; Doherty and Greatorex, 2016). The graves are irregular in spacing and orientation (Fig. 3), 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).

The first burials from the Eastbourne cemetery came to light in 1877 during excavations for the former Grange building adjacent to St. Anne’s Road. These showed no systematic grave placement and contained abundant grave furnishings dating to the 5th and 6th centuries. In the late 1980s, the Eastbourne College of Arts and Technology began developing the property next to the former Grange. During excavations for two car parks in 1991 and 1992, 27 inhumations and three early Anglo-Saxon cremations were recovered (Stevens, 1992a, 1992b). The College sold the property to a housing developer who brought in archaeologists from Archaeology South-East, University College of London, in 1997 and 1998 to excavate the cemetery (Fig. 3). These excavations revealed 192 inhumations and 12 cremations overlying late Iron Age grain/storage pits and an early Roman trackway that once flanked field systems running northeast through the centre of the cemetery (Greatorex 1997; Doherty and Greatorex 2016).

The 19 individuals selected for the current study represent some of the earliest graves in the cemetery, possibly dating between AD 375 and 600, based on their associated grave furnishings (Table 3). The sample is a mix of ages (except young children), males and females, furnished and unfurnished graves, and a variety of grave orientations and locations across the cemetery.  Where grave furnishings were absent and graves overlapped, the earlier grave was chosen.

To explore temporal patterning in these data, the 19 burials are assigned to three temporal phases based on their associated grave furnishings. Grave furnishings are thought to be personal or utilitarian items generally acquired during the life of the individual (Lucy, 2000), and this assumption is generally supported by radiocarbon dates at other Anglo-Saxon cemeteries (Scull and Bayliss, 1999; Hines and Bayliss 2013). The three temporal phases are: 1) those dating as early as AD 375, 2) those no earlier than AD 450, and 3) those dating after AD 500 (Fig. 3). The dates of the grave furnishings are listed in the Eastbourne cemetery grave catalogue (Clifford et al., 2016). Thirteen of the burials could be dated with multiple grave furnishings pointing to a similar date range. In two instances (nos. 67 and 681), however, the grave furnishings suggest different dates. In these cases, the individuals were assigned to the later phase. No. 67, buried with a Brancaster type ring mount dating to the late 4th century and an iron francisca or axe dating after AD 450, is assigned to Phase 2, while no. 681, buried with a spearhead dating between AD 450 and 550 and a Type 4 knife characteristic of a late date (AD 675-725), is assigned to Phase 3.

## 3.2 Methods

### *3.2.1 Oxygen Isotopes*

Human second permanent premolars or second molars, all forming between 2 and 8 years of age, and one third molar, forming between 9 and 12 years of age, were selected for analysis (Table 4). Using the method described in Budd et al. (2000), the enamel was separated from the dentine with a dental drill fitted with a tungsten carbide bit. Approximately 100µm of the outer surface of the enamel was removed to eliminate any possible contamination or exchange as well as all the interior dentine. The phosphate oxygen of human tooth enamel was separated using silver phosphate, a method adapted by Chenery et al. (2010) from O’Neil et al. (1994). The $\delta^{18}O_P$ analysis was performed at the British Geological Survey NERC Isotope Geosciences Laboratory (NIGL) on a Thermo Finnegan continuous flow TC/EA with a drift corrected reproducibility of 0.2‰. All standard deviations for oxygen isotopes are given as 1σ. Each sample was analysed in triplicate and corrected against an internal standard NBS120C to a value of +21.7‰ VSMOW as described in Chenery et al. (2010).

### *3.2.2 Strontium Isotopes*

Strontium isotope and concentration analysis on human tooth enamel was performed at the British Geological Survey NERC Isotope Geosciences Laboratory (NIGL) following the method described in Evans et al. (2006). The mechanically cleaned samples were transferred to a clean (class 100, laminar flow) working area, and cleaned ultrasonically in high purity water to remove dust, rinsed twice in high purity acetone, dried down and then weighed into pre-cleaned Teflon beakers. The samples were mixed with $^{84}$Sr tracer solution and dissolved in Teflon distilled 16M $HNO_3$. They were converted to chloride form and strontium was separated and collected using Dowex resin columns. Strontium was loaded into a single RE Filament with TaF following the method of Birck (1986) and the isotope composition and concentrations were measured on a Thermo Triton multi-collector mass spectrometer at NIGL. The international standard for $^{87}Sr/^{86}Sr$, NBS987, gave a value of 0.710222 ± 8 ($2\sigma$, N=35) for static analysis. All strontium ratios were corrected to a value for the standard of 0.710240 for NBS987. Blank amounts were approximately 100pg.

The soil and herbivore strontium ratios were analysed at the Department of Earth Sciences, University of Durham, England. Soil samples were leached overnight in 10% v/v acetic acid (Romil UpA) to extract total exchangeable cations, which include only labile (and therefore ancient bioavailable) strontium. Leachates were evaporated to dryness. Tooth enamel samples of ~40-100mg were cleaned in deionised water. Both leachates and enamel samples were then dissolved in 16M $HNO_3$ (Romil UpA) for analysis. Based on the method of Charlier et al. (2006), strontium was extracted as a fraction eluted from a column of Sr-Spec (a crown-ether based exchange chromatography medium, Eichrom). The isotope ratios were measured on a Thermo Neptune PIMMS. The international standard for $^{87}Sr/^{86}Sr$, NBS987, gave a value of 0.71022 ± 8 ppm (2s, n=35) for static analysis. All strontium ratios were corrected to a value of 0.710240 for NBS987. Blank amounts were approximately 100 pg.

Statistics are calculated using the Statistical Package of Social Sciences, ver. 9 (SPSS). A significant relationship is indicated by a p-value of less than 5%.

## 4.0 RESULTS

### 4.1 Soil $^{87}Sr/^{86}Sr$

As expected, the soil $^{87}Sr/^{86}Sr$ leachate values vary, ranging from 0.7075 to 0.7127 (Table 1; Fig. 5). The soils on Upper Cretaceous chalk, including the cemetery soil (0.7075), show the lowest values, and those on the Lower Cretaceous Wadhurst (0.7127) and Ashdown (0.7120) formations which outcrop more than 12 km north of the cemetery (Fig. 2), show the highest values. Soils within 2 km of the cemetery, the chalk, Gault clay, Head, clay-with-flints, and alluvium (Table 1), are less than 0.7091. The Chalk Downs appear to contribute significantly to the alluvium samples which are only slightly higher in $^{87}Sr/^{86}Sr$ than the chalk samples (Frei and Frei, 2013; Montgomery et al., 2006). The strontium isotope ratios increase significantly with the age of the bedrock (One-way Anova F=92.49, p<0.001, n=19).

### 4.2 Herbivore $^{87}Sr/^{86}Sr$

The seven ovicaprids recovered from the Eastbourne Anglo-Saxon graves reveal a mean strontium isotope ratio of 0.7089 with a standard deviation of .0009. The bovid mean is higher, 0.7093, with a standard deviation of 0.0007 (Table 2). The herbivore values provide another estimate of the strontium isotope signal of locally-born individuals at Eastbourne. The herbivore values also correspond closely to the Head (0.7086) and Gault (0.7091) soil leachate values from formations outcropping within 2 km of the cemetery (Fig. 2).

The ovicaprid values are bimodal (Fig. 5, data from Table 2) with one group reflecting lower values similar to the soils on alluvium, clay-with-flints, and Head deposits, all outcropping within 1 km of the cemetery, and another group with higher values closer to the soils on the Gault and Weald outcrops, 2 to 4 km northwest of the cemetery. Two of the three bovids have values comparable to the local Head and Gault formations (0.7088 and 0.7090), while the third reveals a high value slightly less than the Weald soil leachate, and similar to the higher ovicaprid values (0.7101; Figure 5).

### 4.3 Human $^{87}$Sr/$^{86}$Sr and δ$^{18}$O$_P$

The human $^{87}$Sr/$^{86}$Sr mean is 0.7093 with a range of 0.0027 (sd=0.0007); the δ$^{18}$O$_P$ mean for the human sample is 17.9‰ with a range of 2.3‰ (sd=0.7‰; Table 4). The human strontium mean is identical to the bovid mean; however, Fig. 5 shows that a some human values are much higher than the herbivore values. Regardless, all human and herbivore strontium values fall within the range of the measured soil leachate values (Fig. 5).

The human δ$^{18}$O$_P$ and $^{87}$Sr/$^{86}$Sr values, when plotted together (Fig. 6), reveal a tight group of ten individuals in the lower right of the plot with very similar δ$^{18}$O$_P$ and $^{87}$Sr/$^{86}$Sr values. The $^{87}$Sr/$^{86}$Sr mean of this group is 0.7089 (sd=0.0002; range=0.0006), a value identical to the Ovicaprid mean, and the δ$^{18}$O$_P$ mean is 18.4‰ (sd=0.3‰; range=0.8‰). The remaining nine individuals are quite dispersed with generally lower δ$^{18}$O$_P$ values and a wide range of strontium isotope ratios. The $^{87}$Sr/$^{86}$Sr mean of the more dispersed group is 0.7100 (sd=0.00084; range=0.0027), and the δ$^{18}$O$_P$ mean is 17.4‰ (sd=0.6‰; range=1.9‰). The homogeneity of the isotopic ratios of the former group and their similarity to the herbivore values, implies that these are the locally-born individuals while the latter group are immigrants. The $^{87}$Sr/$^{86}$Sr mean of the “local” group is equidistant between the soil leachate values from the Gault Clay (0.7091) and Quaternary Head (0.7086), both outcropping within 2 km of the Eastbourne Cemetery (Fig. 2).

When the human $\delta^{18}O_P$ values are converted to $\delta^{18}O_{dw}$ values using the Daux et al. (2008) Equation No. 4 (Fig. 6, top axis), the overall sample mean of -6.3‰ is identical to the local $\delta^{18}O$ tap water value of -6.3‰ (Fig. 6). The “local” group mean of -5.5‰ is slightly higher than expected.

The non-locals can be subdivided into three main groups, two individuals with local oxygen isotope ratios and extremely high strontium isotope ratios (Nos. 64 and 264), three individuals with local strontium isotope ratios and lower oxygen isotope ratios (Nos. 51, 796, and 355), and four individuals with both higher $^{87}Sr/^{86}Sr$ and lower $\delta^{18}O_P$ values (Nos. 57, 270, 309, and 481).

### 4.4 Correlation with Cemetery Features

Non-parametric statistical tests are applied to these data to identify possible relationships between the human isotopic values and burial practice. Because sample sizes are small for these tests, the results must be treated with some caution. Associations were tested between the oxygen and strontium isotope ratios, local vs. non-local groups identified from isotopic ratios, age, sex, cemetery phase, grave orientation, grave cluster, and number of grave items (as a measure of individual wealth; see Taylor, 2001; Arnold, 1988; Harrington and Welch 2014; data from Table 3 and Fig. 3). A significant relationship appeared between grave cluster and phase (chi-square=15.8, p=0.045, df=8, n=13), with a tendency for older graves to be located at the south end of the cemetery.

Further parametric and nonparametric testing involving the interval and ratio scale variables (number of grave items and isotope ratios) reveal significant relationships between local/non-local groups and number of grave furnishings (Mann Whitney U test=19.5, p=0.034, n=19) and the strontium isotope ratio and sex (Mann

Whitney U test=6.0, p=0.028, n=14). The first relationship implies that local individuals were wealthier because they were buried with more grave furnishings. The second reveals a tendency for females to have higher strontium isotope ratios than males. This may reflect dietary differences, but the meaning is unclear. No significant relationship exists between temporal phase and local vs. non-local origin indicating that immigrants arrived throughout the sampling period. A similar pattern was seen in an isotopic study of individuals from the Berinsfield Anglo-Saxon cemetery in Oxfordshire (Hughes et al., 2014; Millard et al., 2005).

## 5.0 DISCUSSION

### 5.1 Oxygen isotopes

The $\delta^{18}O_P$ mean of the “local” group when converted to its drinking water value (Daux et al., 2008, Equation 4) is -5.5‰ (Daux et al., 2008), a value that is 0.8‰ higher than the Eastbourne $\delta^{18}O_{dw}$ value, but given calibration uncertainties of at least 1‰ at 95% confidence (Daux et al. 2008; Pollard et al. 2011) this difference is of uncertain significance. A systematic increase in the local $\delta^{18}O_P$ over the value predicted from $\delta^{18}O_{dw}$ is seen at other early medieval sites in England (Brettell et al., 2012; Hughes et al, 2014). The causes of this may be a warmer climate, drinking from water sources that experience evaporative enrichment such as lakes or ponds (Evans et al., 2012), or consumption of heated foods and beverages (Daux et al., 2008; Brettell et al., 2012; Tuross et al., 2017). Because there is no evidence of significant climatic change during this period (Darling 2003), it is more likely that the cause is evaporative enrichment either at the water source or from consuming water in heated or brewed forms. If the Eastbourne community was obtaining water from the Bourne, evaporative enrichment is a possibility if the spring formed a small pond as it does today. The men, women, and children of Anglo-Saxon England are known to have consumed cooked foods and ales which would increase the $\delta^{18}O$ composition of their body water. The milk of sheep and cows is also higher in $\delta^{18}O$ relative to local water values, so consumption of milk products in later childhood could increase the oxygen ratio in tooth enamel (Brettell et al., 2012).

## 5.2 Place of Origin and Burial Practice

The “local” group from the Eastbourne Anglo-Saxon cemetery consists of five males (nos. 111, 157, 233, 681, 753), two females (nos. 190, 650), one adolescent (no. 381), and two of unknown sex (nos. 61, 67). The significant relationship between the “local” group and the number of grave furnishings reveals that these individuals appear wealthier than those belonging to the “non-local” group. Four of the men have weapons, and the fifth, a rich assortment of brooches. One individual of unknown sex was buried with a francisca (a weapon of French origin), a slate hone stone, belt fittings, and a Brancaster type ring dating to the late fourth century (no. 67). The adolescent and female graves are also well furnished (Table 3). Only one individual within the “local” group lacks grave furnishings (no. 61). With the exception of the adolescent who was buried alone in the southeast part of the cemetery, the “local” individuals are all buried among other graves in the central and western parts of the cemetery. The “local” group is represented by all temporal phases.

The scattered nature of the “non-local” isotopic ratios implies diverse origins. Two women (nos. 64 and 264) have local $\delta^{18}O_P$ values but strontium values characteristic of the Lower Greensand, Weald clay, Tunbridge Wells and Ashdown formations, all outcropping a few kilometres distant from the Eastbourne cemetery; Fig. 2). Because they are women and demonstrate local $\delta^{18}O_{dw}$ values, they were likely raised nearby on geological substrates with higher strontium isotope ratios; joining the Eastbourne community as wives, servants or slaves (Pelteret, 1980). No. 264, a woman of some wealth dating to Phase 1, was buried in what appears to be an older cluster of east-west oriented graves at the south end of the cemetery, while no. 64 lacking grave furnishings, is buried in the dense core of the cemetery.

Three others (nos. 51, 796, and 355) reveal almost identical $\delta^{18}O_P$ values (ca. 17.0‰, or -7.8 ± 0.5‰ when converted to groundwater values; Daux et al. 2008 Equation 4) and low strontium values similar to the "local" group. The $\delta^{18}O_P$ values would place them at the low end of U.K. values, 17.7 ± 0.9‰ (Chenery et al., 2010; Evans et al., 2012) while the strontium values are typical of Upper Cretaceous carbonates and the Gault formation (Evans et al. 2012; Montgomery et al. 2006) that outcrop elsewhere along the London Syncline in southern and central England. These values, in combination, may also occur in the coastal regions of western Germany, Denmark, and northern France (Fig. 4; Voerkelius et al. 2010; Frei and Frei 2011). Nos. 51 and 355 are of unknown sex, were buried with few grave furnishings (Table 3), and could not be assigned to a temporal phase. No. 796 is a young male with weapons, dating to Phase 2. Nos. 51 and 796 were buried in the dense central core of the cemetery, while no. 355 was buried among several graves overlying a cluster of Iron Age pits east of the cemetery core. These individuals may or may not be continental immigrants.

Four of the outliers (nos. 57, 270, 309, 481) reveal higher strontium and lower oxygen isotope ratios when compared to the "local" group. No. 270 has a $\delta^{18}O_P$ of 16.5‰, slightly lower than the U.K. range of values (16.8‰-18.6‰; Chenery et al., 2010; Evans et al., 2012). When converted to its drinking water value (-8.7 ± 0.5‰), this individual likely originated in central or northern Europe where high strontium isotope ratios also occur (Fig. 4; Voerkelius et al., 2010). This individual is possibly a female, buried without any grave furnishings (Clifford et al., 2016). Her status as an outsider is emphasized by the isolated position of her grave in the southeast part of the cemetery.

The $\delta^{18}O_P$ and strontium isotope ratio of no. 481, 17.6‰ and 0.7100 respectively, fall within the range of U.K. values, however, the $\delta^{18}O_P$ value when converted to a drinking water value of -6.8±0.5‰ suggests a southern England or French origin (Fig. 4). This individual is a young male, buried with an iron pin at his shoulder and a late 4th century Brancaster type ring (Clifford et al., 2016) that places him in Phase 1. His status as an outsider is emphasized by the isolated position of his grave in the southeast part of the cemetery.

Nos. 57 and 309 show nearly identical $\delta^{18}O_P$ values (ca. 17.2‰ and 17.3‰) that are slightly less than the U.K. average, 17.7 ± 0.9‰ (Chenery et al., 2010; Evans et al., 2012). When the oxygen values are converted to drinking water values (-7.3 ± 0.5‰ and -7.5 ± 0.5‰) and combined with their higher strontium values (0.7100), these individuals could originate in north and east England where $\delta^{18}O_{dw}$ values are lower (Fig. 4) and higher strontium values more common (Evans et al., 2012; Montgomery et al., 2006). This same combination of values can also be found in western Europe (Fig. 4; Voerkelius et al. 2010; Frei and Frei 2011). Nos. 57 and 309 are both males lacking grave furnishings. No. 57 was buried in a small linear, non-overlapping cluster of graves at the far west end of the cemetery; no. 309, in a small cluster of non-overlapping, east-west trending graves at the south end of the cemetery near other outliers (Fig. 3).

In summary, nine individuals appear to be immigrants in the Eastbourne sample, but only no. 270 can be definitely assigned a continental origin. Two women were likely born within nearby communities, while six others could originate from western Europe or northern and eastern England. These individuals are associated with fewer grave furnishings, and are more often buried in isolated parts of the cemetery.

### 5.3 Adventus Saxonum

A community following Germanic burial practices was established at Eastbourne by at least 450 BP, well before AD 477 when *Aelle* and his three sons supposedly arrived in Sussex. The isotopic data show that once established, it received a flow of immigrants from diverse places at least through Phase 2. None of the three models presented above, all based on an initial Germanic immigration to Britain, offers a good explanation for this pattern. If the cemetery began as the result of a large-scale German invasion, then the invaders, predominantly men bearing arms, should occur in the early to middle phase burials. This is not seen here. Four of the five weapon-bearing males sampled at Eastbourne have local isotopic values and all date to the second and third phases of cemetery use, not the founding phase, arguing against the establishment and cultural continuity models. The immigration of a small number of German male elites is also not supported because the Eastbourne immigrants, both men and women, exhibit little wealth and only one was buried with weaponry. In fact, Harrington and Brookes (2016:220) note that there is a general “absence of the concentrations of weaponry” at Eastbourne that characterize other early Anglo-Saxon sites to the west.

The Eastbourne data more closely match patterns identified by Schiffel et al. (2016) in a nuclear DNA study of Iron Age and Anglo-Saxon individuals from three cemeteries in eastern England. This study points to genetic mixing of incomers and "locals", i.e. no strong segregation between immigrants and the indigenous population, and the possibility of continuous immigration throughout the Early Saxon period. Their results also suggest that the immigrants were less wealthy than the indigenous population (Schiffel et al., 2016), a pattern also seen at West Heslerton (Budd et al., 2003).

### 5.4 Grazing practices and local residency patterns.

The human $^{87}Sr/^{86}Sr$ values are averages of the substrates where food was raised. The mean $^{87}Sr/^{86}Sr$ of the local group approximates the $^{87}Sr/^{86}Sr$ values of Gault and Head substrates outcropping within 2 km of the cemetery where the settlement's agricultural fields were likely located. The community associated with the cemetery may have occupied the ridge adjacent to the cemetery, in a similar topographic position to other early Anglo-Saxon settlements in Sussex, or perhaps closer to the Bourne, the primary water source. Because these areas are heavily developed today, the location of the Eastbourne settlement may never be known.

The herbivore $^{87}Sr/^{86}Sr$ values are also averages of the substrates where they graze. The Eastbourne sheep values are bimodal with one group showing values similar to the upland chalk and the other group with higher values more characteristic of the Weald or Lower Greensand formations at the scarp foot. The bimodality implies different grazing patterns, but when averaged, they approximate the "local" human mean. Variation in ovicaprid grazing patterns points to independent, non-specialized farming practices, characteristic of other early Anglo-Saxon settlements (Crabtree, 2014, O'Connor, 2014).

Two of the three bovid strontium isotope ratios are comparable to local human values suggesting that these animals were raised on or near the agricultural fields.

The third bovid, with a higher ratio characteristic of the Lower Greensand or Weald, 4-5 km away, was likely brought into the Eastbourne community.

## 6.0 CONCLUSIONS

The community buried in the early Anglo-Saxon cemetery at Eastbourne, which was founded in the early to mid-5th century, received a flow of immigrants of diverse origins at least through Phase 2 of the cemetery or AD 500. Two of the incomers were women who moved no further than from surrounding villages. A third woman originated in continental Europe. The other six incomers, both men and women, could have originated from western Europe or other parts of England. Most of the immigrants display little wealth.

The Eastbourne results are not consistent with a mass migration or smaller invasion of Germanic people as proposed by the establishment and cultural continuity models, respectively. Acculturation accompanied by a small contribution of male elites is also not demonstrated by the Eastbourne data because the immigrants are both men and women showing no evidence of elite status. The isotopic results and cemetery dating fail to support the conquest of Sussex by *Aelle* and his sons in AD 477 as portrayed in the Anglo-Saxon Chronicles. Our results, when combined with previous isotopic studies of Anglo-Saxon burials and genomic data suggest that the *Adventus Saxonum* involved diverse migratory and demographic processes, and thus new, more nuanced models are needed to better understand the transition from Roman Britain to Anglo-Saxon England.

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# TABLES

**Table 1. Isotopic ratios and characteristics of soil leachates collected from geological formations in the Eastbourne area.**

| Sample No. | Geological Formation | Lithology | Abbreviation in Fig. 5 | Chrono-stratigraphy | East Longitude (decimal degrees) | North Latitude (decimal degrees) | Distance to Collection Point (km) | Minimum distance to outcrop (km). | Sr (ppm) | $Sr^{87}/Sr^{86}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| E1 | Lower Chalk | Chalk | LCh | Upper Cretaceous | 0.27219 | 50.77630 | 0 | 0 | 443.9 | 0.707497 |
| E2 | Clay-with-flints | Reddish brown clay with flints | cf | Early Quaternary | 0.25005 | 50.75746 | 3 | 2 | 16.0 | 0.712041 |
| E3 | Clay-with-flints | Reddish brown clay with flints | cf | Early Quaternary | 0.25370 | 50.75122 | 3 | 2 | 40.4 | 0.708515 |
| E4 | Lower Chalk | Marly chalk | LCh | Upper Cretaceous | 0.18669 | 50.81459 | 7 | 0 | 589.1 | 0.708201 |
| E5 | Upper Chalk[1] | Chalk | UCh | Upper Cretaceous | 0.17380 | 50.80897 | 8 | 1 | 560.2 | 0.708579 |
| E6 | Gault clay | Grey mudstone | G | Lower Cretaceous | 0.19336 | 50.82794 | 8 | 2 | 64.4 | 0.710523 |
| E7 | Weald clay | Mudstone | We | Lower Cretaceous | 0.19429 | 50.86292 | 11 | 4 | 21.6 | 0.708265 |
| E8 | Tunbridge Wells | Sandstone and silty mudstone | TWS | Lower Cretaceous | 0.29946 | 50.90223 | 14 | 5 | 13.0 | 0.708049 |
| E9 | Wadhurst | Shaley mudstone | Wa | Lower Cretaceous | 0.31970 | 50.90884 | 15 | 12 | 30.4 | 0.707482 |
| E10 | Ashdown | Mudstone | As | Lower Cretaceous | 0.34696 | 50.93756 | 19 | 14 | 10.9 | 0.707398 |
| E11 | Alluvium | Clay, silt, sand | Al | Holocene | 0.31204 | 50.86080 | 10 | 1 | 132.3 | 0.709081 |
| E12 | Alluvium | Clay, silt, sand | Al | Holocene | 0.32966 | 50.82945 | 7 | 1 | 379.4 | 0.710372 |
| E13 | Head | Silty loam and chalky wash | He | Quaternary | 0.22470 | 50.82101 | 6 | .5 | 214.6 | 0.710639 |
| E14B | Lower Greensand | Glauconitic silts/sands | LGS | Lower Cretaceous | 0.20216 | 50.83328 | 8 | 3 | 12.9 | 0.712730 |

## Table 2: Herbivore $^{87}Sr/^{86}Sr$ results.

| Sample/Excavation No.[1] | Species | Tooth | $^{87}Sr/^{86}Sr$ |
|---|---|---|---|
| EA03 (295) | Bovid | Md M | 0.709035 |
| EA04 (471) | Bovid | L md M3 | 0.708760 |
| EA07 (504B) | Bovid | Mx M | 0.710058 |
| Mean for bovids | | | 0.709284. |
| Standard deviation for bovids | | | 0.000684 |
| EA01 (85) | Ovicaprid | Mx M | 0.708641 |
| EA02 (158) | Ovicaprid | R md M1/2 | 0.708341 |
| EA05 (474) | Ovicaprid | L mx M2 | 0.710228 |
| EA06 (504A) | Ovicaprid | Mx M | 0.709822 |
| EA08 (641) | Ovicaprid | R mx M | 0.707890 |
| EA09 (745) | Ovicaprid | R md M1/2 | 0.709413 |
| EA10 (769) | Ovicaprid | R mx M3 | 0.708257 |
| Mean for ovicaprids | | | 0.708942 |
| Standard deviation for ovicaprids | | | 0.000883 |

[1] Sample Number (Skeleton Number)

## Table 3: Human skeletal sample and associated burial characteristics.

| Skeleton (Grave) | Date | Phase | Cluster | Orientation | Sex | Age | No. Grave Items | Associated Grave Furnishings |
|---|---|---|---|---|---|---|---|---|
| 51 (52) | | | north | SW/NE | | 45+ | 1 | unidentified Cu alloy object |
| 57 (1056-1057) | | | west | N/S | m | 18-46 | 0 | none |
| 61 (4) | <500 | 2 | central | N/S | | 18-45 | 0 | none |
| 64 (63) | | | central | SW/NE | f | 18-29 | 0 | none |
| 67 (66) | 450-500 | 2 | central | N/S | | 18-29 | 12 | francisca (450-500), slate hone stone, Brancaster type ring (375-400), belt or bag fittings, Fe rod, Cu ring, keys, and other objects |
| 111 (110) | 475-700 | 2 | central | N/S | m | 30-45 | 2 | Swanton Type H1/2 spearhead, Evison Type 1 knife 1 (475-700) |
| 157 (156) | 475-700 | 2 | north | N/S | m | 30-45 | 4 | Fe shield boss,2 disc-headed rivets, Evison Type 1 knife (475-700), Swanton Type H3 spearhead (475-500) |
| 190 (189) | 500-550 | 3 | central | SW/NE | f | 18-45 | 16 | Cu button brooch (500-550), Marzinzik Type 1.10a-I oval belt buckle (400-600), Evison Type 2 knife (475-675), 4 sets of beads, purse group of objects including chatelaine, strap mount, late Roman coin (Constantine I), strap mount, vessel fitting plats, etc. |
| 233 (232) | 475-700 | 2 | north | NW/SE | m | 18-29 | 3 | Swanton Type H2 spearhead (450-550), Evison Type 1 knife (Harke 475-700); knife fragment |
| 264 (263) | 400-500 | 1 | south | E/W | f | 30-45 | 7 | 2 applied saucer brooches (400-500), 5 sets of glass and amber beads at hips, neck, mid-chest and left of chest |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 270 (269) | | | south | E/W | f | 30-45 | 0 | none |
| 309 (308) | | | south | E/W | m | 18-29 | 0 | none |
| 355 (354) | | | isolated-E | N/S | | 18-45 | 3 | Cu alloy tweezers on slipknot wire ring, Fe pin, 3 amber beads; not datable |
| 381 (380) | 400-500 | 1 | isolated-E | SW/NE | | 12-17 | 8 | knife frag, Marzinzik Type 1.10 belt buckle loop, 5 Fe arrowheads (400-500), carinated pottery bowl with out-turned rim and faceted cordon (400-500) |
| 481 (472) | 375-400 | 1 | Isolated-E | SW/NE | m | 18-29 | 2 | Incised peacock intaglio for square bezel ring setting-Brancaster type (375-400), pin at left shoulder |
| 650 (649) | 475-700 | 2 | west | N/S | f | 18-45 | 2 | Cu alloy quoit brooch with Fe pin (400-525), Evison Type 1 knife (475-700) |
| 681 (680) | 675-725 | 3 | west | N/S | m | 18-45 | 4 | Swanton Spearhead H2 (450-550), Evison Type 4 knife (675-725), Shepherds crook head pin, Marzinzak Type 1.11a-i Fe belt buckle |
| 753 (752) | 475-525 | 2 | north | SW/NE | m | 30-45 | 7 | Small long brooch (475-525), annular/penannular brooch, buckle and plate with silver inlay and floral design (Marzinzik Type 11.5; 475-525), knife, tweezers, strap mount fragments, amber bead |
| 796 (795) | 475-550 | 2 | north | N/S | m | 18-29 | 3 | Swanton Type H2 spearhead (450-550); Evison Type 1 knife (475-700), spear ferrule |

**Table 4. Human oxygen and strontium Isotope values from the Eastbourne Anglo-Saxon Cemetery**.

| Sample | Tooth[1] | $^{87}$Sr/$^{86}$Sr | Sr ppm | δ $^{18}$O$_p$ | Standard Dev. | δ $^{18}$O$_{dw}$ [2] | Standard Dev. | Replicate Msmts. |
|---|---|---|---|---|---|---|---|---|
| 51 | P2-R md | 76.9 | .708638 | 17.00 | 0.12 | -7.8 | 0.01 | 3 |
| 57 | P2-R md | 61.4 | .709669 | 17.20 | 0.19 | -7.5 | 0.22 | 3 |
| 61 | P2-R mx | 80.1 | .708819 | 18.40 | 0.23 | -5.4 | 0.39 | 3 |
| 64 | P2-R md | 64.9 | .711291 | 18.20 | 0.11 | -5.8 | 0.19 | 2 |
| 67 | P2-L md | 65.5 | .709193 | 18.10 | 0.17 | -5.9 | 0.29 | 3 |
| 111 | P2-L md | 43.3 | .708818 | 18.20 | 0.12 | -5.8 | 0.21 | 3 |
| 157 | P2-L md | 93.6 | .708640 | 18.70 | 0.14 | -4.9 | 0.24 | 3 |
| 190 | M2-L mx | 68.8 | .709084 | 18.60 | 0.07 | -5.1 | 0.11 | 2 |
| 233 | P2-R md | 49.2 | .709030 | 18.50 | 0.05 | -5.2 | 0.09 | 2 |
| 264 | P2-R md | 62.9 | .710084 | 17.90 | 0.24 | -6.3 | 0.42 | 3 |
| 270 | P2-R md | 60.5 | .710514 | 16.50 | 0.18 | -8.7 | 0.22 | 2 |
| 309 | P2-L md | 51.8 | .710002 | 17.30 | 0.19 | -7.3 | 0.33 | 3 |
| 355 | P2-R md | 72.7 | .709336 | 17.10 | 0.06 | -7.7 | 0.11 | 3 |
| 381 | P2-L md | 77.0 | .708681 | 18.20 | 0.14 | -5.8 | 0.24 | 3 |
| 481 | P2-R md | 72.7 | .710079 | 17.60 | 0.19 | -6.8 | 0.32 | 3 |
| 650 | M3-R md | 81.2 | .709080 | 18.10 | 0.09 | -5.9 | 0.15 | 3 |
| 681 | P2-R md | 88.9 | .708898 | 18.00 | 0.13 | -6.1 | 0.23 | 3 |
| 753 | P2-R mx | 95.1 | .708683 | 18.80 | 0.14 | -4.7 | 0.24 | 3 |
| 796 | P2-L mx | 88.7 | .708835 | 17.00 | 0.16 | -7.8 | 0.07 | 2 |
| Mean |  | 71.3 | .709335 | 17.86 |  | -6.4 |  |  |
| Std. Dev. |  | 14.8 | .000742 | 0.67 |  | 1.2 |  |  |

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[1] P2 = second premolar; M2 = second molar; M3 = third molar

[2] $\delta^{18}O_{dw}$ calculated from $\delta^{18}O_{P}$ using Equation 4 of Daux et al. (2008).

## FIGURE CAPTIONS

Fig. 1. Roman and Anglo-Saxon sites near the Eastbourne Anglo-Saxon cemetery (dashed lines = elevation contours).

Fig. 2. Geology of the Eastbourne area (adapted from IGS, 1968, 1979) showing soil sampling locations (**+**) and archaeological sites. While sample no. 2 plots on the Upper/Middle Chalk, the soil characteristics and isotope values identify the sample as clay-with-flints.

Fig. 3. Distribution of the Anglo-Saxon graves in the Eastbourne cemetery.
Sampled graves are numbered and shaded by phase date. Grave clusters listed in Table 3 and discussed in the text are also shown (adapted from Doherty and Greatorex, 2016 and Sibun, n.d.).

Fig. 4. Oxygen isotope values (in ‰ SMOW) for modern European drinking water (compiled by C. Chenery from Darling et al., 2003 and Lécolle, 1985, British Geographical Survey, National Environmental Research Council, U.K.).

Fig. 5. Comparison of human and animal $^{87}Sr/^{86}Sr$ values (with standard deviations) to soil leachate $^{87}Sr/^{86}Sr$ values collected from geological outcrops within 19km of the Eastbourne Anglo-Saxon cemetery (abbreviations given in Table 1).

Fig. 6. Human $^{87}Sr/^{86}Sr$ and $\delta^{18}O_p$ values. Bottom axis shows $\delta^{18}O_p$; top axis, $\delta^{18}O_{dw}$ calculated from Daux et al., (2008) Equation 4.

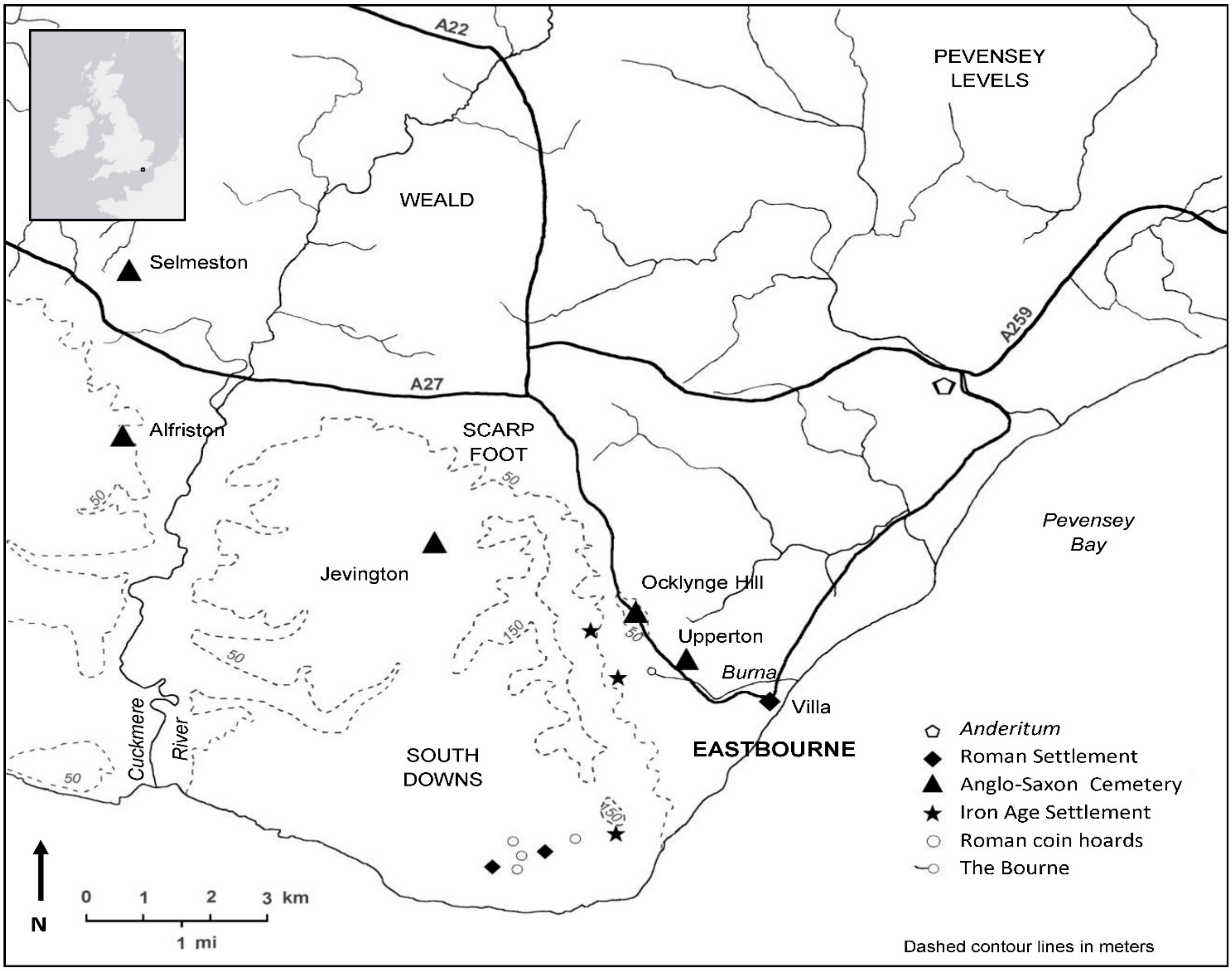

A22
PEVENSEY LEVELS
WEALD
Selmeston
A259
A27
Alfriston
SCARP FOOT
50
Pevensey Bay
Jevington
Ocklynge Hill
150
Upperton
50
Burna
Villa
Cuckmere River
EASTBOURNE
SOUTH DOWNS
50
150
Anderitum
Roman Settlement
Anglo-Saxon Cemetery
Iron Age Settlement
Roman coin hoards
The Bourne
N
0 1 2 3 km
1 mi
Dashed contour lines in meters

Fig. 1

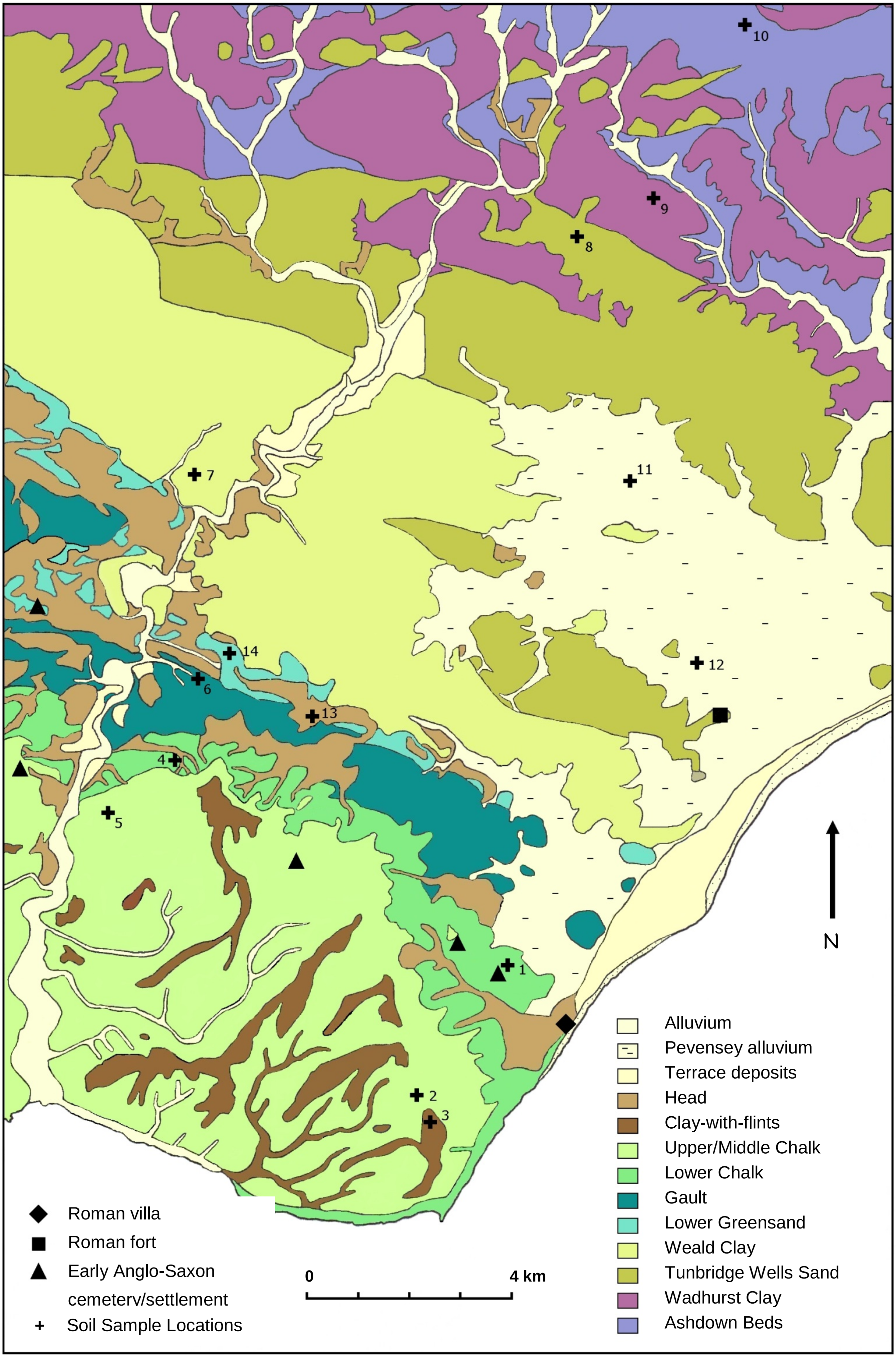

10
9
8
7
11
14
6
13
12
4
5
1
2
3
N
◆ Roman villa
■ Roman fort
▲ Early Anglo-Saxon cemeterv/settlement
+ Soil Sample Locations
0
4 km
Alluvium
Pevensey alluvium
Terrace deposits
Head
Clay-with-flints
Upper/Middle Chalk
Lower Chalk
Gault
Lower Greensand
Weald Clay
Tunbridge Wells Sand
Wadhurst Clay
Ashdown Beds

Fig. 3

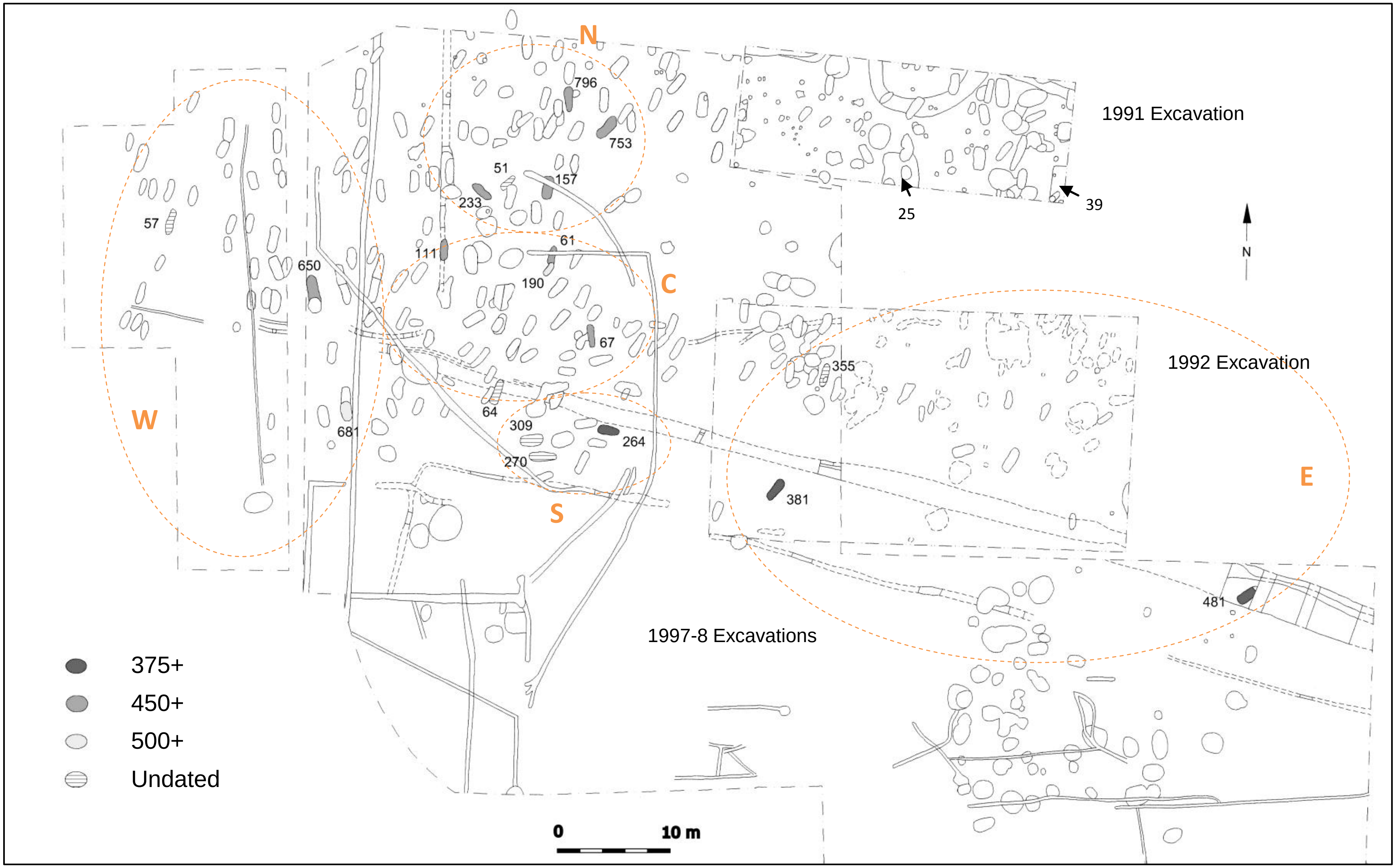

N
796
753
51
157
233
61
111
650
57
190
C
67
355
64
309
264
270
681
W
S
381
E
481
1991 Excavation
25
39
N
1992 Excavation
1997-8 Excavations
● 375+
● 450+
○ 500+
▤ Undated
0
10 m

FIG. 4

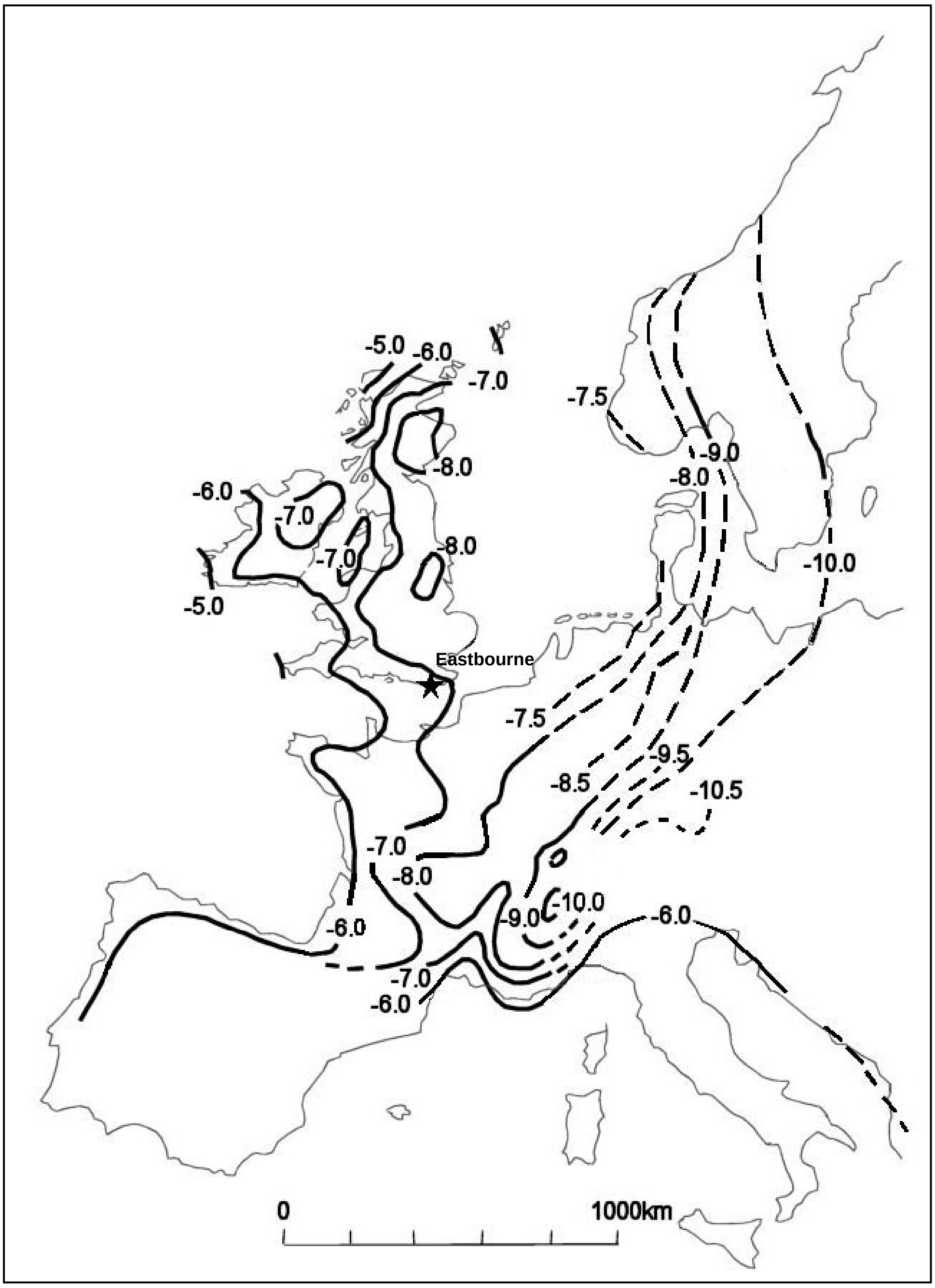

-5.0
-6.0
-7.0
-7.5
-8.0
-9.0
-8.0
-6.0
-7.0
-7.0
-8.0
-10.0
-5.0
Eastbourne
-7.5
-9.5
-8.5
-10.5
-7.0
-8.0
-10.0
-9.0
-6.0
-6.0
-7.0
-6.0
0
1000km

**FIG.5**

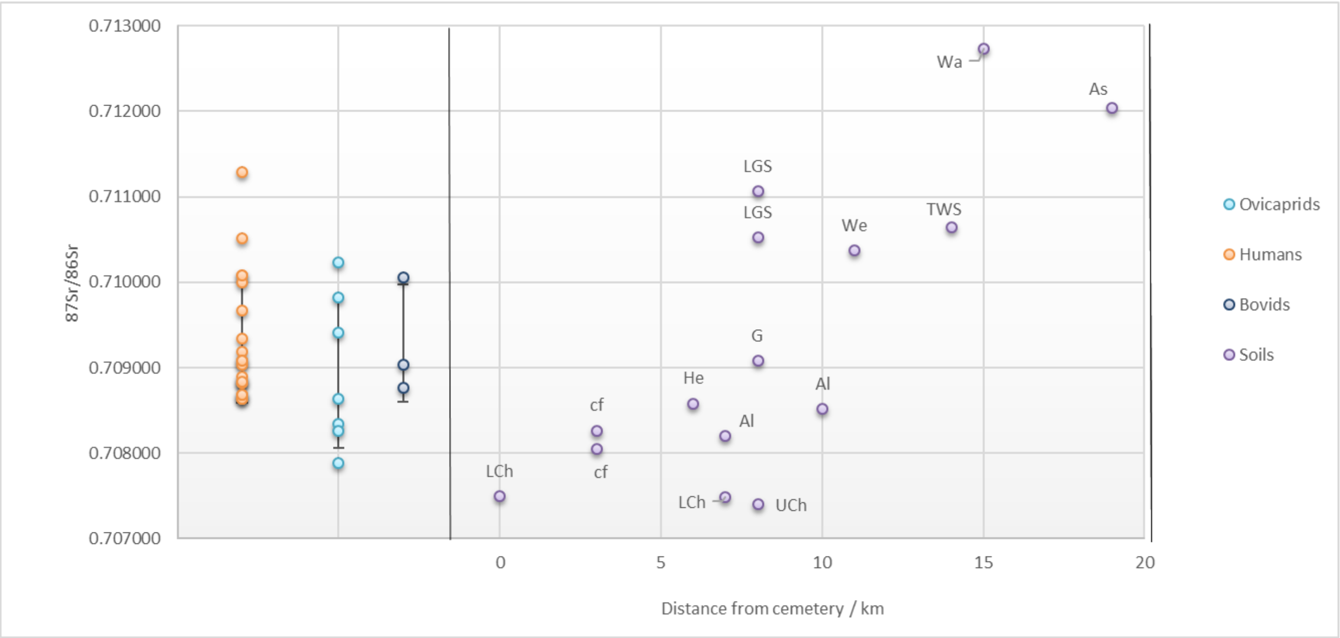
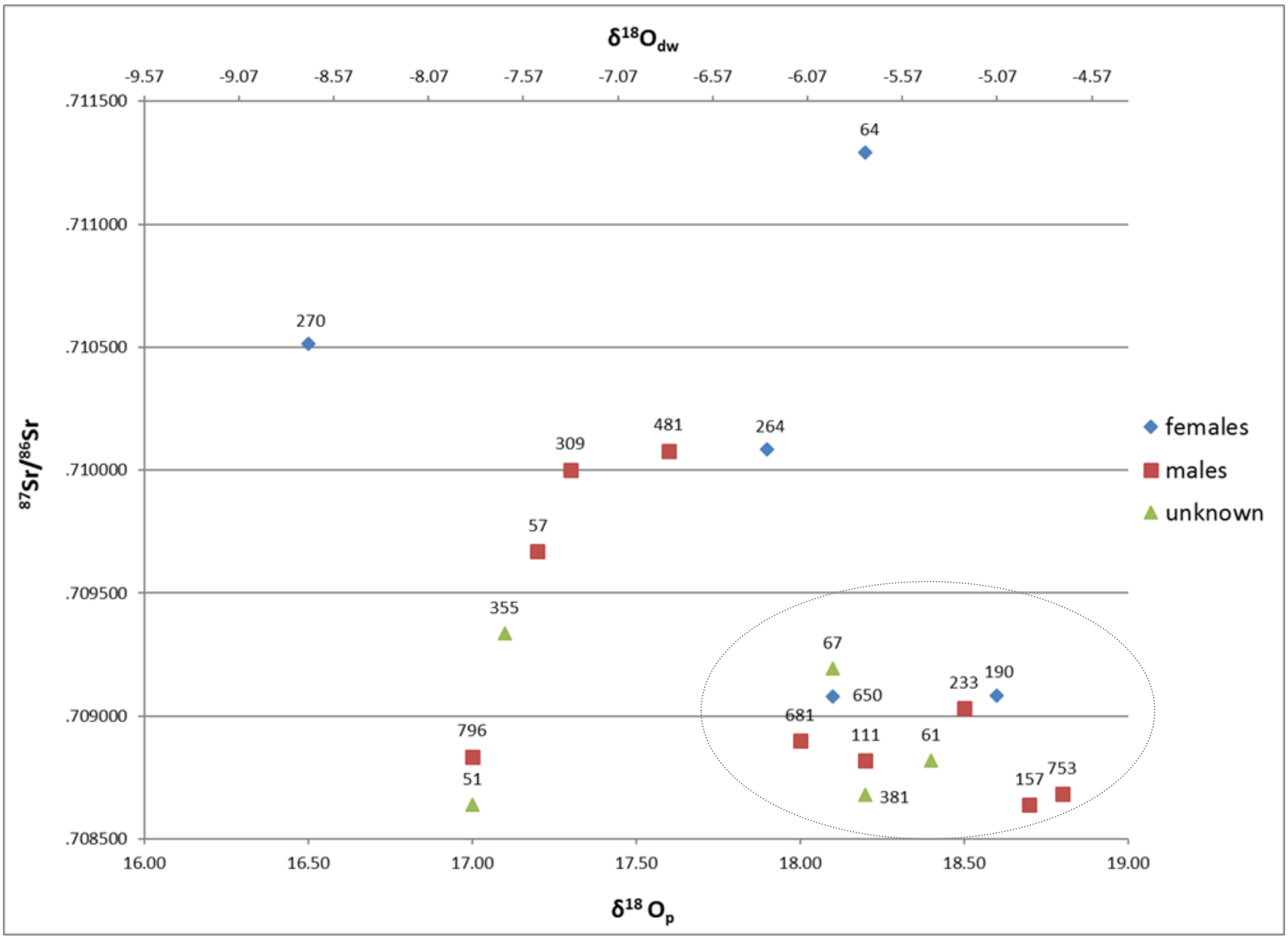

0.713000
0.712000
0.711000
0.710000
0.709000
0.708000
0.707000
87Sr/86Sr
0
5
10
15
20
Distance from cemetery / km
Wa
As
LGS
LGS
TWS
We
G
He
Al
Al
cf
cf
LCh
LCh
UCh
Ovicaprids
Humans
Bovids
Soils

**FIG. 6**


$\delta^{18}O_{dw}$
-9.57
-9.07
-8.57
-8.07
-7.57
-7.07
-6.57
-6.07
-5.57
-5.07
-4.57
.711500
.711000
.710500
.710000
.709500
.709000
.708500
$^{87}Sr/^{86}Sr$
64
270
481
264
309
57
355
67
190
650
233
681
796
111
61
51
157
753
381
16.00
16.50
17.00
17.50
18.00
18.50
19.00
$\delta^{18}O_p$
females
males
unknown