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# A multi-isotope (C, N, O, Sr, Pb) study of Iron Age and Roman period skeletons from east Edinburgh, Scotland exploring the relationship between decapitation burials and geographical origins

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ABSTRACT

Recent excavations at Musselburgh, East Lothian (Scotland) revealed twelve skeletons, radiocarbon dated to the Iron Age and Roman period. The high incidence of skeletal trauma characteristic of decapitation in those of Roman date makes this site unusual. A multi-isotope investigation of seven of these individuals was conducted to explore any link between intrusive burial practices and migration at one of Britain's most northerly frontiers. Bulk collagen analysis provided a terrestrial, $C_3$, dietary protein signal (mean $\delta^{13}C$ −20.4‰ and $\delta^{15}N$ + 11.1‰), consistent with other Romano-British studies. However, the range of $\delta^{18}O$, $^{87}Sr/^{86}Sr$ and Pb isotopes indicate more diverse origins for the Roman individuals. These results suggest that decapitation burials were afforded to migrants to the Lothian area, but is not indicative of a common origin, implying that something more complex than a shared geographic childhood origin united these individuals. The possible association of these decapitation burials with a nearby 2nd century fort suggests that they may also represent some of the earliest examples of Roman decapitation burials to be found anywhere in Britain.

## 1. Introduction

The Roman Empire was a vast suzerainty with large territorial holdings in Europe, eastern-Asia and northern-Africa, a contiguous expanse encompassing the entire Mediterranean Sea (Gamsey, 1987). Yet despite its numerous conquests, Rome's attempts to colonise Scotland amounted to no more than 'mere interludes in the Scottish Iron Age' (Keppie, 1986). The lack of continuity in Roman occupation means that the prehistoric chronology of Scotland differs from the rest of Britain. The Iron Age period in England is considered to end with the Roman conquest in AD 43, whereas in much of Scotland, the Iron Age period is considered to end in the late first millennium AD (Harding, 2004). In southern Scotland, the Iron Age co-occurred with Roman interaction during the 1st to 4th centuries AD (Harding, 2004). This intermittent Roman occupation of Scotland has cultivated profuse interest in how these discontinuous interactions between the natives and colonists influenced the existing cultures within the region.

Recent excavations at Musselburgh, East Lothian (see Figure 1) revealed twelve articulated inhumations, a number of disarticulated human remains and eight cremation deposits (Kirby, 2011). Six of the articulated inhumations were radiocarbon dated to the Iron Age (39 BC to AD 124) and the remaining six to the Roman period (AD 25–253) (Kirby, 2016). Several of these skeletons displayed evidence of trauma, with at least four of the Roman skeletons exhibiting trauma patterns consistent with decapitation (Anderson, 2011). Whilst not common, especially in Scotland, decapitation burials have been identified in both Iron Age and Roman period contexts in Britain (Philpott, 1991). Iron Age evidence for decapitation has been found at sites such as Danebury, Hampshire (Cunliffe, 1995; Craig et al., 2005) and an Iron Age cist burial in Dunbar, East Lothian (Brothwell and Powers, 1967). Decapitation burial was not a predominant burial practice in Roman Britain, but at sites where it has been identified, the crude prevalence rate is approximately 5–10% (Philpott, 1991; Roberts and Cox, 2003; Müldner et al., 2011) with the majority of examples dating to the 4th century CE

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**Fig. 1.** Location map of Musselburgh and the excavation site (after Kirby, 2016. © CFA Archaeology Ltd, reproduced with kind permission).

(Philpott, 1991). However, at the late Roman (2nd–4th century) cemetery at Driffield Terrace, York c. 80% of the skeletons, which were predominantly adult males, had been decapitated but there is currently no consensus as to why this is the case (Müldner et al., 2011; Montgomery et al., 2011; Martiniano et al., 2016).

Variations in burial practices have informed archaeological interpretations of past societies for centuries, and have been used to reconstruct almost every aspect of life from ethnicity and status to religion and gender (Ekengren, 2013). While any direct relationship between burial practices and geographic origins have long been disputed (Pearce, 2000), the unusual nature of these Roman burials at Musselburgh raises questions about the identities of these individuals and whether they share any commonalities with each other or the Iron Age individuals. This paper presents the results of the multi-isotopic analysis of seven skeletons from Musselburgh in order to ascertain the geographical origins and palaeodiet of the individuals. In addition, this data will be used to determine if there is any link between intrusive burial practices and migration of the individuals.

## 2. The Musselburgh site

Musselburgh is an archaeologically significant area as it possesses the largest known Roman civil settlement outside of a fort in Scotland (Jones, 2012a) and demonstrates both military and civilian settlement types (Thomas, 1988). The area of Musselburgh not only enjoyed an advantageous position on the land and sea routes into northern Britain (Richmond, 1981), but also contained fertile land for developing agriculture and settlements (Thomas, 1988). During the Antonine period, forts and earthworks were built along the Forth-Clyde isthmus (Breeze, 2006) and these military sites would have relied on a combination of imported and locally produced provisions (Whittaker, 2002; Jones 2012a). Musselburgh was likely a key part in this supply network, given its date, coastal location and its prominent position on Dere Street, the principle route from Eboracum (York) to Inchtuthil (Perthshire) (Hanson and Breeze, 1991, Shotter, 1996). Therefore, the presence of people from a variety of geographical origins is to be expected in Musselburgh.

Recent excavations carried out by CFA Archaeology Ltd. at Musselburgh revealed archaeological features indicative of multi-phase activity within two discrete periods, the Mesolithic and Iron Age/Roman (Kirby, 2016). Four burial pits were identified as Iron Age, one of which was a stone-lined cist. All of the pits contained fragmentary human remains, amounting to a minimum of six individuals (two pits contained double inhumations). A small number of grave goods were also recovered, including a brooch from one of the single burials (Kirby, 2016). A further six inhumation burials, all without grave goods, were identified and radiocarbon dates suggest that they are from the Roman period (Kirby, 2016). Four of the Roman period individuals from Musselburgh exhibited evidence of decapitation (see Table 1). Two skeletons displayed sharp force trauma to their cervical vertebrae and their skulls were displaced. Although the vertebrae of two other individuals were too fragmentary to observe any evidence of trauma, their skulls were also displaced (Kirby, 2016).

**Table 1**
$\delta^{13}C$ and $\delta^{15}N$ values from the bone and dentine samples from the Musselburgh Roman and Iron Age individuals, and a bone collagen sample from a contemporary goat/sheep.

| Sample | Element/Tissue | Period | Sex | Age | Decap. | $\delta^{13}C$ ‰ | $\delta^{15}N$ ‰ | %C | %N | C/N | %Coll |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PPCM235 | Rib | Roman | M | MA-OA | Yes | −21.0 | 11.5 | 40.6 | 15.0 | 3.2 | 11.6 |
| | PM2/Dentine | | | | | −21.0 | 10.5 | 41.7 | 15.2 | 3.2 | 8.9 |
| PPCM316 | Rib | Roman | M | MA-OA | Yes | −21.4 | 11.4 | 42.3 | 15.0 | 3.3 | 7.3 |
| | PM2/Dentine | | | | | −21.0 | 10.5 | 41.6 | 14.9 | 3.3 | 6.3 |
| PPCM323 | Rib | Roman | M | YA | | −20.0 | 9.5 | 41.7 | 15.4 | 3.2 | 10.0 |
| | PM2/Dentine | | | | | −20.4 | 11.6 | 40.9 | 14.8 | 3.2 | 10.3 |
| PPCM420 | Rib | Roman | M | A | Yes | – | – | – | – | – | – |
| | M2/Dentine | | | | | – | – | – | – | – | – |
| PPCM451 | Rib | Roman | M | MA-OA | | −19.6 | 11.4 | 42.4 | 15.6 | 3.2 | 14.6 |
| | M2/Dentine | | | | | −21.4 | 9.7 | 41.1 | 15.0 | 3.2 | 5.4 |
| PPCM630 | Rib | Roman | M | MA-OA | Yes | −19.3 | 11.9 | 42.5 | 15.6 | 3.2 | 16.3 |
| | PM2/Dentine | | | | | −19.2 | 11.4 | 41.4 | 15.0 | 3.2 | 7.5 |
| PPCM864 | Rib | Iron Age | ? | YA | | −20.8 | 11.3 | 42.0 | 15.2 | 3.2 | 9.8 |
| | PM2/Dentine | | | | | −20.8 | 11.8 | 41.4 | 14.9 | 3.2 | 12.4 |
| PPCM504 | Rib | Sheep/Goat | | | | −22.4 | 7.5 | 41.1 | 14.5 | 3.3 | 9.1 |

%Coll = Collagen yield. M = male. ? = Indeterminate sex. YA = young adult. A = adult. MA = middle adult. OA = old adult. Age categories after Buikstra and Ubelaker (1994).

## 3. Isotope analyses

### 3.1. Stable isotopes (C, N, O)

Stable isotope analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) from bone and dentine can provide quantitative data that reflects the origin of dietary proteins consumed at the time of collagen formation (DeNiro and Epstein, 1978; van der Merwe and Vogel, 1978; Schoeninger et al., 1983; Kohn, 1999; Richards et al., 2006). Carbon isotope variability is primarily a result of two distinct plant photosynthetic pathways ($C_3$ and $C_4$) in which there is discrimination against $^{13}C$ during $CO_2$ fixation (Lee-Thorp, 2008). Therefore, $\delta^{13}C$ values can distinguish between individuals that have consumed predominantly $C_3$ and/or $C_4$ plants and/or animal products based on these plant types (Ambrose et al., 1997; Camin et al., 2008; Beaumont et al., 2013), as well as marine verses terrestrial food sources (Brown and Brown, 2011: 83). Nitrogen isotope variability reflects the balance between biological nitrogen fixation, biosphere recycling and nitrogen release (Robinson, 2001). Using the $\delta^{15}N$ composition of atmospheric $N_2$ (0‰) as a baseline it is possible to distinguish between terrestrial and marine food sources as land based $\delta^{15}N$ values are generally enriched by 1–4‰ whereas ocean based $\delta^{15}N$ sources are typically enriched by 5–6‰ (Lui and Kaplan, 1989). $\delta^{15}N$ levels also vary with trophic level, there tends to be a 2–6‰ enrichment with each trophic shift due to metabolic fractionation (Schoeninger and DeNiro, 1984). This is most noticeable in marine food consumers as these food sources typically have long food chains resulting in characteristically high $\delta^{15}N$ values compared to those of terrestrial foods (Tykot, 2004). Therefore, $\delta^{15}N$ and $\delta^{13}C$ ratios can be combined to identify the relative consumption of plant, animal and marine protein in palaeodiets (Ambrose and Katzenberg, 2000).

Oxygen incorporated into hydroxyapatite is predominantly derived from ingested fluids, the isotopic composition of which fluctuates due to climatic and environmental variables such as temperature, rainfall, altitude and latitude (Darling and Talbot, 2003). Therefore, oxygen isotopes ($\delta^{18}O$) measured in human tissues are an indirect reflection of the local meteoric water composition (Kohn, 1996). As with carbon and nitrogen, oxygen also undergoes metabolic fractionation once ingested. Therefore, regression formulae must be applied to allow comparison with modern drinking water values in order to discern childhood geographical origins and palaeoclimate (Fricke et al., 1995; Chenery et al., 2012). In addition to this, $\delta^{18}O$ values can also be influenced by culturally-mediated behaviour. The processing (boiling, brewing etc.) of a significant portion of an individual's drinking water before ingestion can result in higher than expected values, and as such, interpretation must be performed with caution (Camin et al., 2008; Daux et al., 2008b; Brettell et al., 2012).

### 3.2. Strontium & lead isotopes

The isotopic analysis of strontium (Sealy et al., 1991; Price et al., 1994; Price et al., 2002) and lead (Carlson, 1996; Gulson et al., 1997; Montgomery et al., 2010), offers a more direct link between an individual and their geographic origin as both are derived from local geology. The strontium ($^{87}Sr/^{86}Sr$) characteristics of plants and local animals in different regions vary depending on the relative contributions of strontium from different underlying rocks and the presence or absence of superficial drift deposits (Bentley, 2006). Strontium is released into the environment through weathering and dissolution processes into the overlying soils, plants and animals (Bentley, 2006). In Britain, biosphere values largely range between 0.706 for basalts to 0.715 for Palaeozoic sedimentary rocks (Evans et al., 2010). With the exception of granites and gneisses, which can produce ratios approaching 0.720, very few geological terrains can produce biosphere ratios above this value (Evans et al., 2010). Strontium becomes incorporated into the hydroxyapatite lattice of human bone through ingestion of food and water (Montgomery et al., 2010). The $^{87}Sr/^{86}Sr$ ratios measured in human tooth enamel represent a weighted average of the strontium isotope sources consumed (Montgomery et al., 2010).

Lead isotope ratios in pre-industrial societies tend to reflect those of the local underlying geology (Erel et al., 1994; Montgomery et al., 2000; Komárek et al., 2008). Societies with metallurgical technologies however tend to exhibit elevated skeletal lead concentration, which are accompanied by a clustering of lead isotope ratios. These homogenised lead isotope ratios tend to reflect the predominant lead sources available to that particular population (Montgomery et al., 2010; Millard et al., 2014). This 'cultural focusing' shifts skeletal lead isotope ratios away from geogenic lead congruent with geographical provenance, towards ratios converging around the dominant anthropogenic ore sources utilised in a particular cultural sphere (Gulson et al., 1997; Kamenov and Gulson, 2014). These anthropogenic skeletal lead isotope ratios are therefore indicative of socio-cultural provenance (Carlson, 1996; Montgomery et al., 2005) and can be effective in differentiating between cultural groups within skeletal populations, as individuals exposed to foreign lead sources should stand out from those exposed to local lead, making migrants from other countries relatively easy to identify (Montgomery, 2002).

## 4. Materials and methodology

### 4.1. C and N isotopic analysis

Bone and dentine samples were collected from seven individuals and cleaned and abraded to a depth of > 100 μm using a tungsten carbide dental drill. Collagen extraction was carried out using a modified Longin, (1971) method, briefly summarised here: bone and dentine samples (c. 200 mg) were demineralised in refrigerated 0.5 M HCl for several weeks and then thoroughly washed in Millipore Alpha Q (MQ) water before gelatinisation in a pH 3 solution of HCl at 75 °C for 24–36 hours. The samples were then filtered, frozen and freeze-dried before being weighed into tin capsules and analysed in duplicate using a Thermo Scientific Delta V Advantage isotope ratio mass spectrometer in the Stable Isotope Biogeochemistry Laboratory, Durham Geochemistry Centre (DGC), Durham University. Calibration using internal reference samples (e.g., Glutamic Acid, Glycine, SPAR and Urea) and international reference standards (e.g., USGS 24, USGS 40, IAEA 600, IAEA N1, IAEA N2) determined a standard deviation of ± 0.1‰ (1σ) for collagen carbon and nitrogen isotopes. Replicate analysis of collagen samples averaged a standard deviation of ± 0.2‰ (1σ).

### 4.2. O isotope analysis

Enamel samples from 2nd premolars and 2nd molars were cut using a diamond tipped rotary dental saw and transferred to the National Environmental Isotope Facility (NEIF) where they were prepared following the method as outlined by Chenery et al. (2012): core enamel samples were ultrasonically cleaned and rinsed using MQ water before being crushed to a fine powder and loaded into vials on a hot block set at 90 °C. The vials were then evacuated and anhydrous phosphoric acid added, the resultant $CO_2$ was cryogenically collected and analysed using a GV IsoPrime dual inlet mass spectrometer. An in-house carbonate reference material (KCM) was calibrated against NBS19 reference material to normalise the $\delta^{18}O$ values to the VPDB scale. The reproducibility of KCM was ± 0.06‰ (1σ; n = 9). The resultant $\delta^{18}O_c$ values were converted to the VSMOW scale (see Coplen, 1988), $\delta^{18}O_p$ values were calculated using Chenery et al. (2012) and $\delta^{18}O_{dw}$ values were calculated using Eq. (4) (Daux et al., 2008a)

### 4.3. Sr isotope analysis

Core enamel samples were prepared for strontium analysis using column chemistry methods outlined in Font et al. (2008) at the Arthur Holmes Isotope Geology Laboratory, DGC, Durham University. Purified strontium samples were taken up in 1 ml of 3% $HNO_3$ and analysed by Multi-Collector Inductively Coupled Plasma Mass Spectrometry (MS-ICP-MS) using a ThermoFisher Neptune MC-ICP-MS. Samples were introduced into this using an ESI PFA50 nebuliser and a micro-cyclonic spray-chamber. Samples were tested prior to analysis to determine the concentration of Sr in the purified cut and diluted to yield an $^{88}Sr$ beam of ~20 V. Each individual measurement comprised a static multi-collection of all the Sr isotopes in 1 block of 50 cycles with 4-second integration time per cycle, total measurement time 3.5 mins. Instrumental mass bias was corrected for using an $^{88}Sr/^{86}Sr$ ratio of 8.375209 and an exponential law. Corrections for inferences from Rb and Kr on $^{87}Sr$ and $^{86}Sr$ were performed using $^{85}Rb$ and $^{83}Kr$ as the monitor masses but in all cases the intensity of monitor mass was < 0.1 mV and therefore insignificant. The mean $^{87}Sr/^{86}Sr$ value and reproducibility for the international isotope reference material NBS987 during the analytical session in which samples were analysed was 0.710268 ± 0.000015 (2σ; n = 10), total procedural blanks processed along with the samples were < 10 pg for Sr.

### 4.4. Pb isotope analysis

Pb isotope analyses were successfully carried out on tooth enamel on all seven individuals. Enamel samples, prepared as described in Evans et al. (2018), were cleaned ultrasonically in high purity water, rinsed, dried, leached for 5 min in a mixture of dilute HCl and $HNO_3$, rinsed clean with deionised water, dried and finally placed into pre-cleaned Teflon beakers. The samples were then dissolved in Teflon distilled 8 M $HNO_3$, dried down, and taken up in 0.5 M HBr. The Pb was separated using AG 1X8 anion exchange resin, and taken up in 2% $HNO_3$ ready for isotope analysis.

Pb isotope analysis of the samples was conducted using a Nu Instruments Nu Plasma, MC-ICP-MS. Prior to analysis, each sample was filtered (Millipore 0.25 μm PFA) and spiked with a Thallium (Tl) solution, which was added to allow for the correction of instrument induced mass bias. Samples were then introduced into the instrument via an ESI PFA50 nebuliser and a micro-cyclonic spray-chamber attached to a de-solvating unit, (Nu Instruments DSN 100). For each sample, five ratios were simultaneously measured ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$, $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$). Each individual acquisition consisted of 1 block of 60 cycles, with 5-second integration time per cycle, following a 60 s de-focused baseline.

The precision and accuracy of the method was assessed through repeat analysis of a NBS 981 Pb reference solution, (also spiked with Tl). The average values obtained for each of the mass bias corrected NBS 981 ratios were then compared to the known values for this reference, (Thirlwall, 2002: data mass bias corrected using a $^{207}Pb$-$^{204}Pb$ double spike. $^{206}Pb/^{204}Pb$ = 16.9417 ± 29, $^{207}Pb/^{204}Pb$ = 15.4996 ± 31, $^{208}Pb/^{204}Pb$ = 36.724 ± 09, $^{207}Pb/^{206}Pb$ = 0.91488 ± 08 and $^{208}Pb/^{206}Pb$ = 2.1677 ± 24. Errors = ppm 2sd). All sample data were subsequently normalised, according to the relative deviation of the measured reference values from the true. The analytical errors for each of the sample ratios are propagated relative to the reproducibility of the NBS 981, to take into account the errors associated with the normalisation process. Average 2SD reproducibility for following sample ratios is $^{206}Pb/^{204}Pb$ = 0.024%; $^{207}Pb/^{204}Pb$ = 0.022%; $^{208}Pb/^{204}Pb$ = 0.026%; $^{207}Pb/^{206}Pb$ = 0.006%; and $^{208}Pb/^{206}Pb$ = 0.001%. The normalised sample data is presented in Table 3. Total procedural blanks are < 60 pg.

Trace element analysis to determine lead concentration results was conducted using inductively coupled plasma mass spectrometry (ICP-MS) using an Agilent 7500cx ICP-MS fitted with a CETAC ASX-520 autosampler with an average reproducibility (2 sd) of 0.01%. The transfer of samples to the ICP-MS from the autosampler was controlled by a CETAC ASXpress + vacuum pump. Multi-element quality control check standards were analysed at the start and end of each run and after no more than every 20 samples. To overcome polyatomic interferences the ICP-MS collision cell was operated in He mode at a flow rate of 5.5 ml $min^{-1}$ for all analytes except Se, for which $H_2$ gas was used at 4.5 ml $min^{-1}$. Quantitative data analysis was carried out using MassHunter Workstation software (Agilent).

## 5. Results

### 5.1. C and N isotopes

Collagen was successfully extracted from six of the seven pairs of bone and dentine samples (see Table 1). The $\delta^{13}C$ values from the Roman period bone samples range between –21.4‰ and –19.3‰ (mean, −20.4‰ ± 0.9‰, 1σ), whereas $\delta^{15}N$ values range between +9.5‰ and +11.9‰ (mean, +11.1‰ ± 0.9‰, 1σ). The $\delta^{13}C$ and $\delta^{15}N$ value from the Iron Age bone sample is −20.8‰ and +11.3‰ respectively, which are close to the Roman period means. For the dentine samples, the $\delta^{13}C$ values from the Roman period individuals range between −21.4‰ and −19.2‰ (mean, −20.6‰ ± 0.8‰, 1σ),

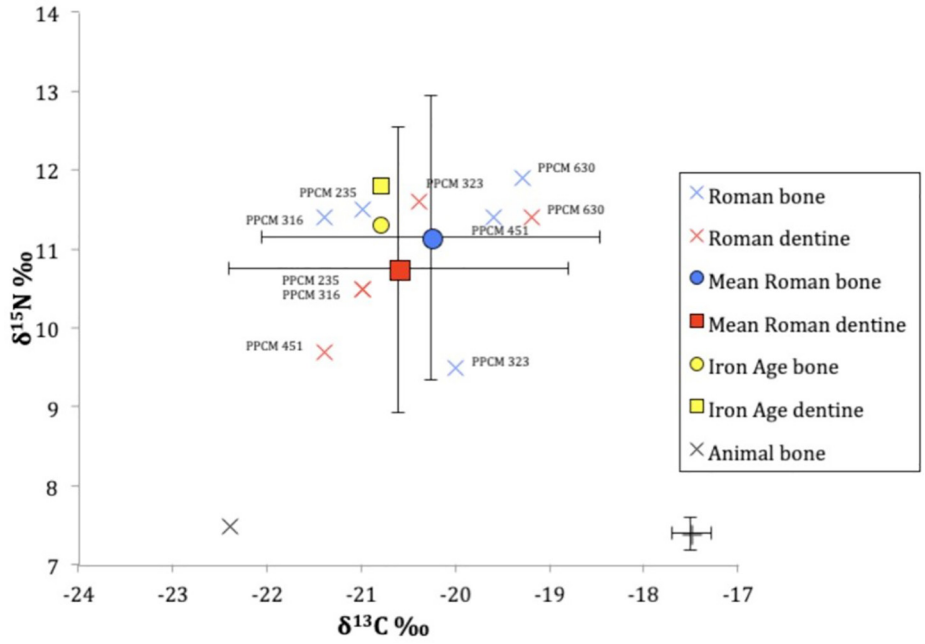


**Fig. 2.** $\delta^{13}C$ and $\delta^{15}N$ values from the Musselburgh individuals and animal bone sample. The mean $\delta^{13}C$ and $\delta^{15}N$ ( ± 2σ) for the Roman Musselburgh individuals are also shown.

whereas $\delta^{15}N$ values range between +9.8‰ and +11.6‰ (mean, +10.7‰ ± 0.8‰, 1σ). The Iron Age individual had a dentine $\delta^{13}C$ value of −20.8‰ and a $\delta^{15}N$ value of +11.8‰.

The carbon and nitrogen isotope ratios obtained from the Musselburgh samples are all within 2σ of the group mean (see Fig. 2); therefore there are no outliers within the skeletal assemblage. However, when comparing the carbon and nitrogen isotope ratios from the bone samples with those from the dentine samples from each skeleton, four of the Musselburgh Romans (PPCM235, PPCM316, PPCM323 and PPCM451) had carbon and nitrogen isotope ratios that differed by more than 1σ, indicating a change in diet between childhood and adulthood.

### 5.2. O and Sr isotopes

The oxygen and strontium results are displayed in Table 2. The calculated $\delta^{18}O_p$ values for the Roman individuals range from 16.4‰ to 18.5‰ (mean 16.0 ± 0.9‰, 1σ), and the $\delta^{18}O_p$ value for the Iron Age individual was 17.5‰. $\delta^{18}O_{dw}$ values were calculated using Equation 4 Daux et al. (2008a,b). The Roman individuals range from −5.3‰ to −8.8‰ (mean −7.6 ± 1.4‰, 1σ), and the $\delta^{18}O_{dw}$ value for the Iron Age individual was −7.1‰. Only the Iron Age individual exhibited $\delta^{18}O_{dw}$ values consistent with the estimated ranges for the Musselburgh area (see Fig. 3).

The strontium isotope ratios for the Roman individuals range from 0.70896 to 0.71411 (mean 0.71222), and the strontium for the Iron Age individual was 0.70973. The crown dentine strontium isotope ratios for two of the Roman individuals (PPCM323 and PPCM451) differ from their respective enamel values, indicating that these individuals may not have originated from the area in which they were buried, and that diagenesis has shifted the dentine strontium isotope ratios towards the labile soil strontium (Montgomery et al., 2007). The Roman individuals showed a wide range of strontium isotope ratios, with three Roman individuals (PPCM235, PPCM316 and PPCM451) exhibiting unusually high values of ~0.71400.

### 5.3. Pb isotopes

Lead isotope ratios were obtained for all of the individuals (see Table 3). Fig. 4 shows them plotted against datasets from well-provenanced Roman coins (Butcher and Ponting, 2014) and the Mendips ore field data (Haggerty et al., 1996), which provide comparative ranges for Mediterranean and English lead isotope ratios respectively. Additional Roman migration studies offered further comparative data and are also included here (Montgomery et al., 2010; Shaw et al., 2016).

The $^{207}Pb/^{206}Pb$ ratios for the Musselburgh individuals ranged from 0.844 to 0.853. When compared with published Roman tooth enamel

**Table 2**
Measured $^{87}Sr/^{86}Sr$ and $\delta^{18}O_c$ and calculated $\delta^{18}O_p$ and $\delta^{18}O_{dw}$ values for enamel and dentine samples from the Musselburgh Roman and Iron Age individuals. $\delta^{18}O_p$ and $\delta^{18}O_{dw}$ values were calculated using equations in Chenery et al. (2012), $\delta^{18}O_{dw}$ values were equated using equation 4 in Daux et al. (2008a,b).

| Sample | Element/Tissue | Period | Sex | Age | Decap. | Sr ppm | $^{87}Sr/^{86}Sr$ | 2SE | $\delta^{18}O_c$ | $\delta^{18}O_p$ ‰ | $\delta^{18}O_{dw}$ ‰ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PPCM235 | PM2/Enamel | Roman | M | MA-OA | Yes | 124 | 0.71411 | 0.000013 | 25.3 | 16.4 | −8.8 |
| PPCM316 | PM2/Enamel | Roman | M | MA-OA | Yes | 125 | 0.71403 | 0.000015 | 25.5 | 16.6 | −8.5 |
| PPCM323 | PM2/Enamel | Roman | M | YA | | 220 | 0.70896 | 0.000012 | 25.3 | 16.4 | −8.5 |
| | PM2/Dentine | | | | | – | 0.70995 | 0.000033 | – | – | – |
| PPCM420 | M2/Enamel | Roman | M | A | Yes | 45 | 0.71245 | 0.000016 | 25.3 | 16.4 | −8.8 |
| PPCM451 | M2/Enamel | Roman | M | MA-OA | | 79 | 0.71397 | 0.000014 | 26.5 | 17.4 | −6.7 |
| | M2/Dentine | | | | | – | 0.71135 | 0.000018 | – | – | – |
| PPCM630 | PM2/Enamel | Roman | M | MA-OA | Yes | 160 | 0.70980 | 0.000018 | 27.3 | 18.5 | −5.3 |
| PPCM864 | PM2/Enamel | Iron Age | ? | YA | | 89 | 0.70973 | 0.000017 | 26.3 | 17.5 | −7.1 |
| | PM2/Dentine | | | | | – | 0.71014 | 0.000028 | – | – | – |

M = male. ? = Indeterminate sex. YA = young adult. A = adult. MA = middle adult. OA = old adult. Age categories after Buikstra and Ubelaker (1994)).

**Table 3**
Pb isotope ratios for enamel samples from the Musselburgh Roman Individuals.

| Sample | Element | Period | Sex | Age | Decap. | Pb ppm | $^{206}Pb/^{204}Pb$ | $^{207}Pb/^{204}Pb$ | $^{208}Pb/^{204}Pb$ | $^{207}Pb/^{206}Pb$ | $^{208}Pb/^{206}Pb$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PPCM235 | PM2/Enamel | Roman | M | MA-OA | Yes | 1.82 | 18.3372 | 15.6376 | 38.4341 | 0.8528 | 2.0961 |
| PPCM316 | PM2/Enamel | Roman | M | MA-OA | Yes | 0.61 | 18.4663 | 15.6367 | 38.5100 | 0.8468 | 2.0855 |
| PPCM323 | PM2/Enamel | Roman | M | YA | | 0.35 | 18.5377 | 15.6528 | 38.4793 | 0.8443 | 2.0757 |
| PPCM420 | M2/Enamel | Roman | M | A | Yes | 2.17 | 18.3821 | 15.6296 | 38.3994 | 0.8503 | 2.0891 |
| PPCM451 | M2/Enamel | Roman | M | MA-OA | | 2.20 | 18.3783 | 15.6313 | 38.3900 | 0.8505 | 2.0890 |
| PPCM630 | PM2/Enamel | Roman | M | MA-OA | Yes | 6.57 | 18.4395 | 15.6321 | 38.4515 | 0.8478 | 2.0854 |
| PPCM864 | PM2/Enamel | Iron Age | ? | YA | | 0.13 | 18.3396 | 15.5947 | 38.3280 | 0.8504 | 2.0900 |

M = male. ? = Indeterminate sex. YA = young adult. A = adult. MA = middle adult. OA = old adult. Age categories after Buikstra and Ubelaker (1994).

data the diverse nature of the individuals is evident. While five of the six Roman Musselburgh individuals have lead ratios that plot within the Mendips ore field, only two individuals (PCMM316 and PPCM630) had $^{207}Pb/^{206}Pb$ ratios that correspond with the main cluster of English Roman enamel samples and the anthropogenic range (0.845–0.849) identified by Montgomery et al. (2010) (see Fig. 4). The remaining Roman individual (PPCM235) exhibited the highest $^{207}Pb/^{206}Pb$ ratios, plotting within the Mediterranean field as identified by Butcher and Ponting (2014). The $^{207}Pb/^{206}Pb$ ratios for the Iron Age individual (PPCM864) are also higher than those from the comparative English enamel samples, plotting in a similar position to individuals PPCM420 and PPCM451, at the upper end of the Mendips ore field.

## 6. Discussion

### 6.1. Dietary reconstruction

The $\delta^{13}C$ and $\delta^{15}N$ values for the Roman Musselburgh individuals are congruent with a terrestrial $C_3$ diet, which is consistent with consumption patterns observed at other Romano-British sites (Müldner and Richards, 2007; Redfern et al., 2010; Chenery et al., 2011; Cheung et al., 2012). When compared to the animal bone from the Musselburgh site, the Roman individuals exhibit a mean $^{15}N$ enrichment of 3.6‰. This trophic shift is similar to that seen in other Romano-British sites (Müldner and Richards, 2007; Chenery et al., 2011) and indicates that these individuals consumed a diet containing some form of animal protein. Compared to other Romano-British sites, the Musselburgh individuals have low $\delta^{13}C$ values and high $\delta^{15}N$ values (Richards et al., 1998; Redfern et al., 2010; Cheung et al., 2012; Chenery et al., 2011; Müldner et al., 2011). This could indicate a higher proportion of $^{15}N$-enriched terrestrial foods or freshwater fish protein in their diet. The only other site with similarly high $\delta^{15}N$ values is Driffield Terrace, York, in which a number of individuals are thought to have diverse geographical origins (Müldner and Richards, 2007). Low carbon and high nitrogen isotope ratios have also been discussed for individuals from Roman York (Müldner and Richards, 2007; Müldner, 2013; Eckardt et al., 2014), from which it was concluded that riverine fish, pork and higher quantities of animal products such as eggs and milk could have produced the observed values. Given the proximity of Musselburgh to the River Esk, it would be plausible that the inhabitants had access to

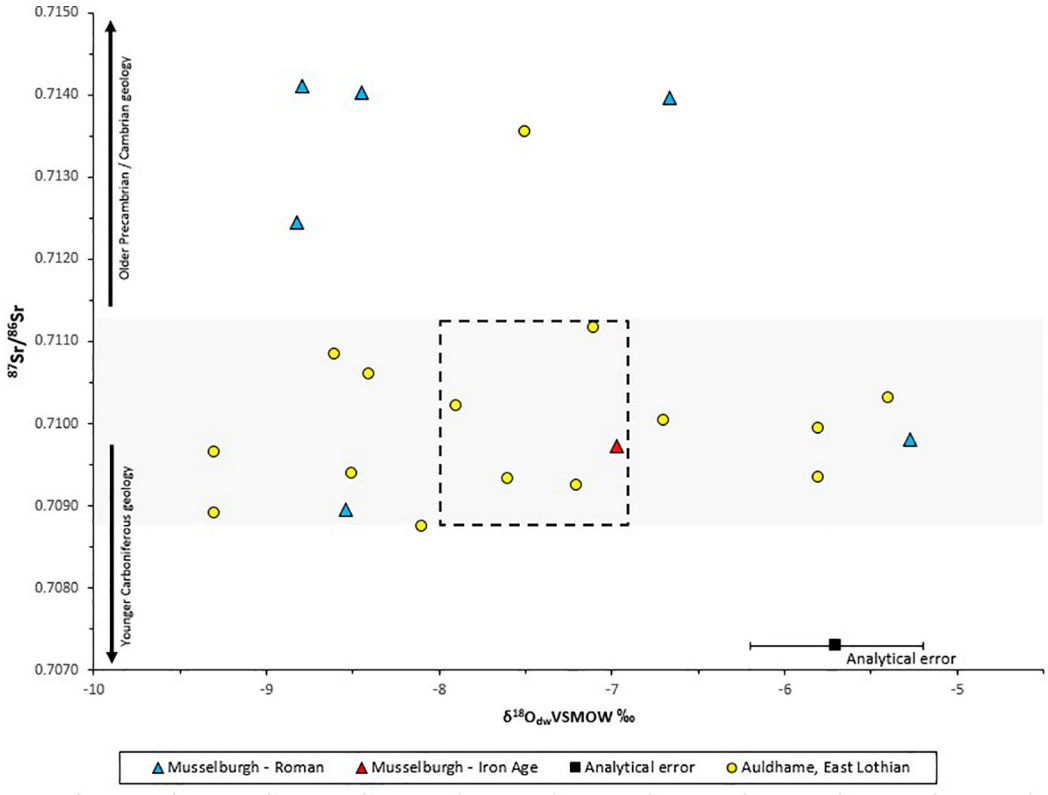


**Fig. 3.** $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw}$ values for enamel samples from the Musselburgh Roman ($n = 6$) and Iron Age ($n = 1$) individuals. Also showing the estimated $\delta^{18}O_{dw}$ range of −8.0 to −7.0 ‰ (dashed box) and $^{87}Sr/^{86}Sr$ isotope ratios (0.7088–0.711) for the Lothian area (shaded area and dashed box). Comparative data for Auldhame, East Lothian from Lamb et al. (2012).

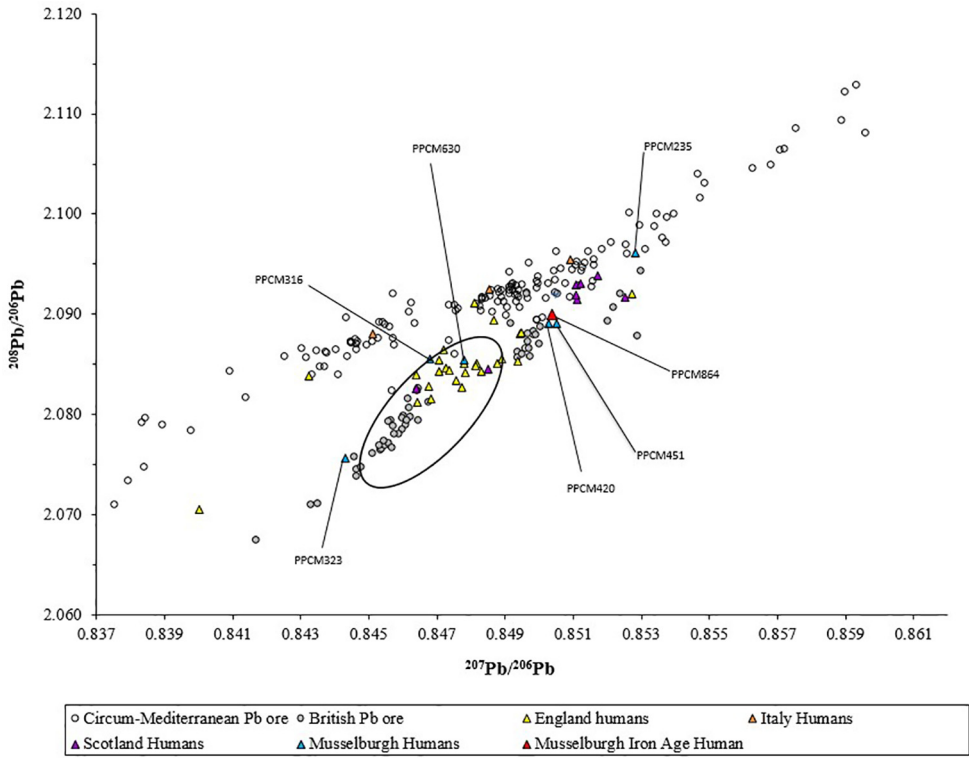


**Fig. 4.** Bivariate plot showing Pb isotope results for the Musselburgh individuals in relation to comparative datasets. Data for comparative contemporaneous human enamel samples: England enamel samples from Shaw et al. (2016) and Montgomery et al. (2010), Scotland and Italy enamel samples from Montgomery et al. (2010). British ore field data from Haggerty et al. (1996), and the Circum-Mediterranean ore field data from Ponting and Butcher (2015). The black oval represents the range for anthropologic lead ore ratios for England and Wales (Montgomery et al., 2010).

freshwater fish for their diet. From archaeological evidence at Inveresk and the surrounding area, it is evident that people were consuming $^{15}$N-enriched foods, particularly pork, salmon, eel, oysters, mussels, poultry and eggs (Barnetson, 1988; Howard, 1988). However, other factors such as soil management methods (e.g. manuring) could have contributed to the relatively high nitrogen isotope ratios (Jones, 2012b). As the Musselburgh carbon and nitrogen isotope ratios are inconsistent with previously published Romano-British studies that show evidence for a substantial amount of marine fish consumption (Müldner and Richards, 2007), it is unlikely that marine products contributed to their $^{15}$N enrichment. Considering the proximity of Musselburgh to the coast, it is interesting that marine resources were not utilised. Archaeozoological studies in Britain have shown that marine fish contributed very little to Iron Age diets (Dobney and Ervynck, 2007) and made up a very small proportion of assemblages at Romano-British sites (Locker, 2007). This suggests that longstanding economic, subsistence and sociocultural factors affecting marine fish consumption persisted through the Iron Age and Roman period (Dobney and Ervynck, 2007), and may be reflected in the palaeodiet of the individuals at Musselburgh.

### 6.2. Migration at a Scottish frontier

The Iron Age individual (PPCM864) exhibited an $^{87}$Sr/$^{86}$Sr ratio and $\delta^{18}O_{dw}$ value that was consistent with local origins in the East Lothian area (see Fig. 3). This individual also had a very low lead burden which is inconsistent with exposure to the anthropogenic lead pollution of the Roman Empire and in line with prehistoric lead levels (Montgomery, 2002; Montgomery et al., 2010). The lead isotope ratios from this Iron Age individual are also comparable with other prehistoric individuals from Scotland, indicating exposure to low level geogenic lead sources (Montgomery et al., 2005, 2010). Therefore, this individual provides a good baseline against which to compare the intrusive Roman burials at Musselburgh. Considering the local isotope ratios provided by the Iron Age individual, it is clear that the Roman individuals at Musselburgh exhibit extremely variable tooth enamel isotope characteristics and do not appear to have originated from the Lothian area of Scotland. When compared to other Romano-British sites, few Roman period individuals have strontium isotope ratios as high as those found at Musselburgh. In fact, British values above 0.714 are rare in all periods (Evans et al., 2012). The only individual that displays higher strontium isotope ratios was recorded at Driffield Terrace, York, and when considered in conjunction with a high $\delta^{18}O$ value, it was concluded that this individual was likely to have originated from an area with more radiogenic geology, such as Sardinia, Corsica, northern Italy or northern Africa (Montgomery et al., 2011).

The drinking water values ($\delta^{18}O_{dw}$) in Britain range from −4‰ in the west, to −9‰ in the Scottish Highlands and Pennines, with the Lothian region of Scotland expected to product $\delta^{18}O_{dw}$ values between −7 and −8‰ (Meier-Augenstein, 2017; Darling and Talbot, 2003). As such, all of the Musselburgh individuals have $\delta^{18}O_{dw}$ values consistent with childhood origins within the British Isles (see Fig. 3). However, the strontium and lead isotope ratios for the Musselburgh individuals suggest more diverse origins.

In contrast to the rest of the Musselburgh assemblage, individuals PPCM323 and PPCM630 exhibit low strontium isotope ratios more typical of Mesozoic and Cenozoic sediments (Evans et al., 2010). This limits the efficacy of their strontium isotope ratios in constraining their area of geographical origin, as these sediment types are prevalent throughout Europe and most of Britain. However, these strontium isotope ratios are consistent with the expected range for the Lothian region of Scotland, and are similar to previously published data for a small population from Auldhame, approximately 30 km to the east of Musselburgh (Lamb et al., 2012) (see Fig. 3). It is clear that decapitated male PPCM630 does not originate from the local area. Despite the rather common and therefore undiagnostic $^{87}$Sr/$^{86}$Sr ratio (0.7098), PPCM630's $\delta^{18}O_{dw}$ value (−5.3‰) is too high for origins in the Lothian area and most of eastern Britain, with a value more consistent with areas of western or southern Britain. PPCM630 also has the highest lead burden amongst the Musselburgh group, with an enamel lead concentration of 6.5 ppm. When interpreted in conjunction with the lead isotope ratios, PPCM630 plots tightly with contemporary burials from England (see Fig. 4) and within the English ore field (Haggerty et al., 1996). These results indicate anthropogenic exposure to English lead ore (Montgomery, 2002; Montgomery et al., 2010) and suggests that

this individual spent his childhood within southern Britain. Conversely, individual PPCM323 has a low lead concentration of 0.35 ppm, suggesting natural, geogenic exposure (≤0.5 ppm). The lead isotope ratios obtained from PPCM323 were not consistent with Scottish lead ore, instead plotting in the lower end of the English ore field (Haggerty et al., 1996). When combined with the undiagnostic strontium isotope ratio (0.70896) and low oxygen value (−8.5‰), it is possible PPCM323 spent their childhood in the Pennine region of Britain.

Decapitated individual PCM316 had a low $\delta^{18}O_{dw}$ value (−8.5‰) consistent with origins in eastern Britain or northern Europe and a high $^{87}Sr/^{86}Sr$ ratio (0.71403) indicative of a childhood spent in a region with a granitic terrain. However, PPCM316's lead burden was low (0.61 ppm) and accompanied by lead isotope ratios inconsistent with Scottish ore sources (Rohl, 1996). This data suggests low level exposure to anthropogenic lead sources from younger lead ores such as those found in England (Rohl, 1996). Very similar lead isotope ratios have been obtained from a male burial at Driffield Terrace whose $\delta^{18}O_{dw}$ value and aDNA indicate that origins in the Levant are extremely likely (Martiniano et al., 2016). However the high $^{87}Sr/^{86}Sr$ ratio and low $\delta^{18}O_{dw}$ value make such origins for PPCM316 unlikely. Like individual PPCM316, individuals PPCM420 and PPCM451 had high strontium isotope ratios indicative of origins in regions with older Palaeozoic terrains. These two individuals were also linked in their lead isotope characteristics. Their low lead concentrations (2.2 ppm) and lead isotope ratios indicate low level childhood exposure to anthropogenic lead pollution from ore sources found in Scotland (Rohl, 1996). Skeletal preservation is notoriously poor in northern Scotland and there are very few comparative sites with which to compare the Musselburgh individuals. Nonetheless, a small Beaker period assemblage from northern Scotland exhibits the same high strontium and low oxygen isotope ratios seen in PPCM316 and PPCM420 (Pearson et al., 2016). Similar lead and strontium isotope characteristics have also been obtained from a child excavated in Roman London. This individual is thought to originate from Germany (Shaw et al., 2016), and while origins in western Europe are certainly possible for these individuals, origins within the Scottish Highlands cannot be ruled out. Although found to have similarly high strontium isotope ratios to PPCM316 and PPCM451, decapitated individual PPCM235 also had high $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ isotope ratios (see Fig. 4). Anthropogenic lead isotope ratios as high as these are not common in Romano-British burials and are inconsistent with English and Scottish lead ore sources (Haggerty et al., 1996; Rohl, 1996). British lead ore is old and therefore tends to produce $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ isotope ratios lower than those observed in PPCM235. Therefore, PPCM235's lead isotope ratios are indicative of a childhood spent outside Britain, in a region of Europe where lead exposure would have been to predominantly younger lead sources, such as those in Spain or Italy (Moore, 2019). Human lead isotope data from regions of the Roman Empire outside of Britain are scarce. However, a small number of individuals from Italy (Montgomery et al., 2010) and Spain (Moore, 2019) have similar $^{208}Pb/^{206}Pb$ isotope ratios to PPCM235. The placement of PPCM235's isotope ratios within the circum-Mediterranean ore field provided by Butcher and Ponting (2014) also supports childhood origins within the Mediterranean (see Fig. 4). Although the carbon, nitrogen and oxygen isotopes for PPCM235 were consistent with origins in Britain these values have also been recorded in Roman individuals in Mediterranean regions (Prowse et al., 2004; Craig et al., 2009; Rissech et al., 2016; Alaica et al., 2019). Therefore, it is probable that PPCM235 spent their childhood in a Mediterranean region of the Roman Empire.

When considering the geographic origins of the four decapitated individuals (PPCM235, PPCM316, PPCM420 and PPCM630), there is no correlation between decapitation and childhood geographic origins. Individuals PPCM316 and PPCM630 appear to have spent their childhoods in England, while PPCM420 appears to originate in Scotland and PPCM235 has an isotopic composition consistent with origins in the Mediterranean. The diverse nature of this group of decapitated individuals is in keeping with the findings of previous studies exploring links between decapitation burials and geographic origin (Müldner et al., 2011; Tucker et al., 2014).

## 7. Conclusions

Using a multi-isotope approach, this study has explored the link between intrusive burial rites and geographic origins in Scotland, and like the majority of human provenance studies, the results have affirmed the current understanding that a multifarious relationship exists between the two. It is apparent from the isotopic data that the decapitation burials at Musselburgh do not represent the continuation of a native Iron Age population. Furthermore, while their commonality as migrants to southern Scotland links the decapitation burials, the individuals do not share a common geographical origin, suggesting that something more complex than simply a shared ethnicity unites the individuals. The Musselburgh decapitation burials represent the earliest known examples of Roman inhumation and decapitation in Britain (Kirby, 2016), and their apparent ethnic diversity coupled with a shared burial rite reflects the cosmopolitan nature of the Roman army.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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