Lives before and after Stonehenge: An osteobiographical study of four prehistoric burials recently excavated from the Stonehenge World Heritage Site

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ABSTRACT

Osteobiographies of four individuals whose skeletal remains were recovered in 2015–16 from the Stonehenge World Heritage Site are constructed, drawing upon evidence from funerary taphonomy, radiocarbon dating, osteological study, stable isotope analyses, and microscopic and biomolecular analyses of dental calculus. The burials comprise an adult from the Middle Neolithic period, immediately prior to the building of Stonehenge, and two adults and a perinatal infant dating from the Middle Bronze Age, shortly after the monument ceased to be structurally modified. The two Middle Bronze Age adults were closely contemporary, but differed from one another in ancestry, appearance and geographic origin (key components of ethnicity). They were nevertheless buried in very similar ways. This suggests that aspects they held in common (osteological analysis suggests perhaps a highly mobile lifestyle) were more important in determining the manner of deposition of their bodies than any differences between them in ethnicity. One of these individuals probably came from outside Britain, as perhaps did the Middle Neolithic adult. This would be consistent with the idea that the Stonehenge landscape had begun to draw people to it from beyond Britain before Stonehenge was constructed and that it continued to do so after structural modification to the monument had ceased.

1. Introduction

Study of the Late Neolithic–Early Bronze Age monument of Stonehenge and its surrounding landscape (which together comprise the Stonehenge World Heritage Site) continues to be highly significant for our understanding of British prehistory (Darvill, 2005; Parker Pearson, 2012; Parker Pearson et al., 2015a). The use of the monument and its surroundings for funerary activity is an important research focus (Parker Pearson et al., 2009; Parker Pearson, 2012; Willis et al., 2016). In this paper we report on inhumation burials recovered during excavations in 2015–16 at two sites just south of the A303 road which runs past Stonehenge: West Amesbury Farm and Druid's Lodge (Fig. 1).

The burials comprise one of Middle Neolithic and three of Middle Bronze Age date. The importance of these remains derives not only from their association with the monumental landscape but also because they come from periods that are poorly represented in terms of inhumations, both at Stonehenge and more widely in British prehistory.

The Middle Neolithic inhumation is from excavations at West Amesbury Farm, on the south-eastern slopes of King Barrow Ridge. It predates, by a century or two, the commencement of monumental activity at Stonehenge and the development of the cremation cemetery centred on the Aubrey Holes (Darvill et al., 2012; Darvill, 2013; Willis et al., 2016). The West Amesbury Farm burial comprises the only inhumation recovered from the Stonehenge WHS dating to the Middle
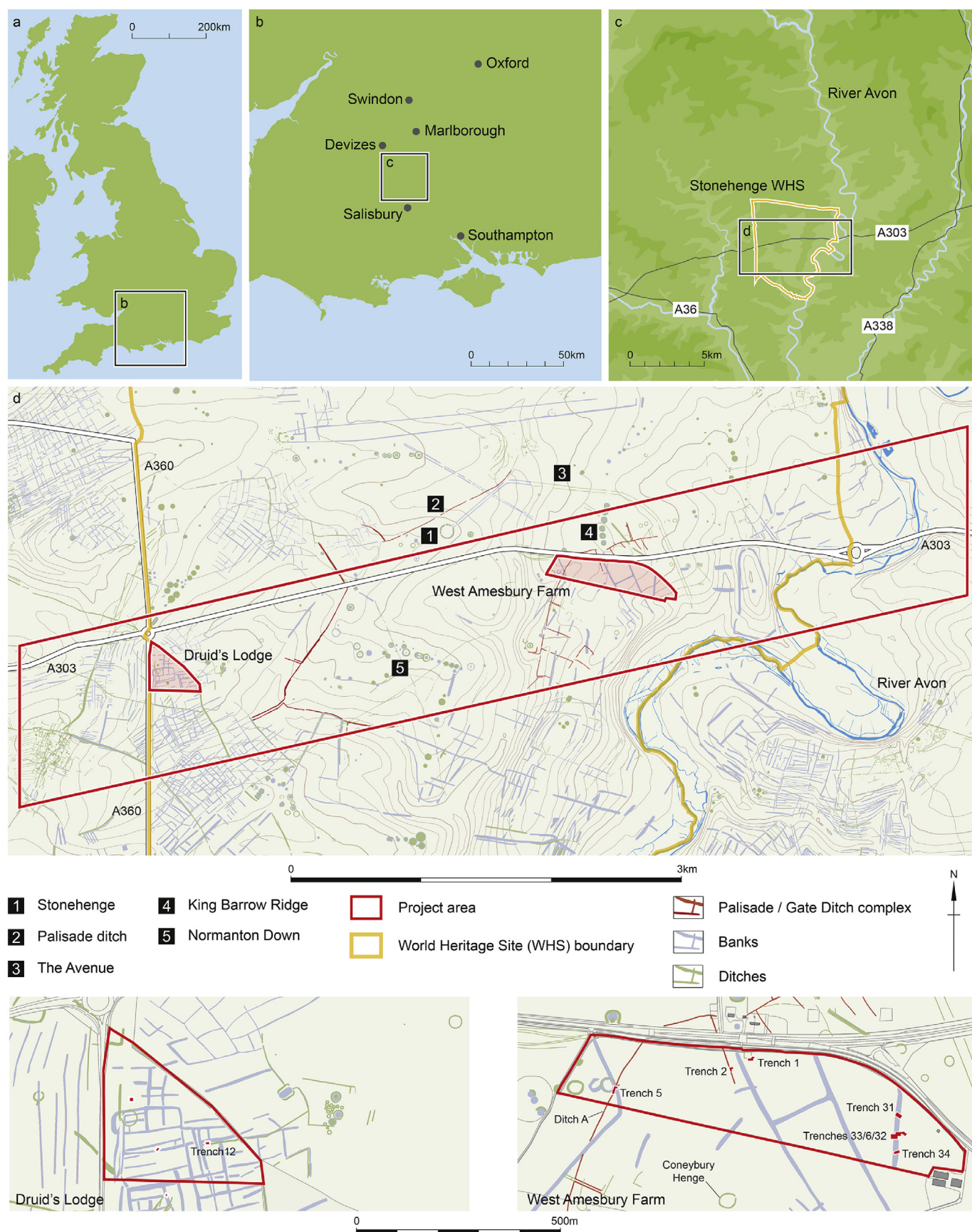
Fig. 1. (a–c) Location of the project area, (d) plan of project area with archaeological features from aerial survey, and trench locations for the Druid's Lodge and West Amesbury Farm excavations.

Neolithic (ca. 3300–2900 cal BC), and thus can provide unique insights into life in this landscape in the centuries immediately prior to the first monumentalisation at Stonehenge, around ca. 3000 cal BC. In a broader context, by the Middle Neolithic, most long barrows and causewayed enclosures had ceased to be used for the deposition of human remains, with most being found in pits, as cremations or disarticulated elements (Carver, 2011; Harding and Stoodley, 2017).

Two of the Middle Bronze Age burials are also from the West Amesbury Farm excavations. They were buried in what can be interpreted as the eastern counterpart to the Palisade/Gate Ditch complex, a Middle Bronze Age boundary around the central funerary landscape of Stonehenge and Normanton Down (Fig. 1d; Bowden et al., 2015; Pollard et al., 2017; Roberts et al., 2017). The third, a perinatal infant, comes from excavations at Druid's Lodge, a site 3 km to the west. The remains were found in deposits from the Middle Bronze Age infilling of another palisade ditch just west of the western part of the Palisade/Gate Ditch complex. The Middle Bronze Age (ca.1500–1100 cal BC) is an important period in the Stonehenge landscape because it is when Stonehenge ceases to be structurally modified – although some use of the monument continues (Pollard et al., 2017) - and the landscape beyond the Palisade/Gate Ditch complex sees the first large scale field systems laid out (Bowden et al., 2015). These burials are the only articulated adult inhumations of Middle Bronze Age date from the Stonehenge WHS, and generally in the Middle Bronze Age, cremation dominates funerary practice in the region (Brück, 2000, 289–290). Because of the paucity of inhumed remains, the skeletal biology, mobility and diet of Middle Bronze Age British populations are poorly understood, a situation that stands in contrast to the important studies (e.g. Brodie, 1994; Parker Pearson et al., 2016; Pellegrini et al., 2016; Olalde et al., 2018) that have been carried out on human remains from the Early Bronze Age, a period where inhumations are more plentiful.

Roberts et al. (2017) have explored the landscape implications of some of the burials described in this paper, and the ditch complexes in which they lay. Here we present an integrated overview of the analysis of the skeletal remains, including results of radiocarbon, osteological, stable isotopic, metaproteomic and microscopic analyses.

2. Materials

The Middle Neolithic burial (individual 8301) lay in a stratigraphic sequence between two Middle Neolithic pits (Fig. 2), toward the eastern part of the West Amesbury Farm site. The burial cut [93240] was rectilinear in its central portion, cut into the natural chalk, and difficult to discern where it truncated the earlier of the two pits, [93208]; the other pit [93233] disturbed and partly truncated the inhumation. The human remains were poorly preserved, and comprised an apparently fairly complete, though fragmented cranium with articulated mandible, and fragments of several post-cranial bones. The skull lay on its left side, facing northeast.

The two adult Middle Bronze Age inhumations were deposited in graves cut through the primary fill of a linear ditch (Figs. 1 and 3). Aerial photography and geophysical survey demonstrate that this ditch is approximately 280 m long, extending from immediately west of the Avenue, across King Barrow Ridge and around Coneybury Hill (Fig. 1; Barber and Small, 2017; Bowden et al., 2015: 72–3; Linford et al., 2015). Grave [91591], which contained individual 8102, was cut to the north by grave [91522], which contained individual 8101 (Figs. 3 and 4). In both cases gross skeletal survival was excellent. Both inhumations were orientated with the head to the north. In 8102, the body lays on its back with the shoulder blades and vertebral column on the grave floor, with the lower limbs flexed on the left, and the upper limbs drawn tightly up to the torso. The skull was on the left side facing east. Skeleton 8101 has a similar posture, but the lower limbs were less tightly flexed and lay to the right. The skull lay on its right side facing west. The right upper limb was drawn up toward the torso, the left extended southwards toward 8102. Both grave fills were composed of near-

identical deposits to the primary ditch fills. This, alongside the referencing of 8102 by the posture of 8101, and radiocarbon dating discussed below, allow us to consider these inhumations to be near-contemporary with each other, and close to contemporary with the digging of the ditch. No grave goods were associated with either burial, but the grave fills were rather loosely packed with void spaces, suggesting that organic body wrappings, or other items since decayed, may once have been present.

Middle Bronze Age perinatal burial (8201) was recovered from the infilling material associated with the closure of a palisade ditch marking a boundary that probably originated in the Early Bronze Age (Figs. 1 and 5). There was no grave cut, and the bones were not recognised as human on site so the posture of the corpse is uncertain.

3. Methods

In the main body of this paper we present summaries of methods and results. A full account of these is given in the separate photogrammetric, osteological, radiocarbon dating, stable isotope and dental calculus reports located online (Supplementary Material, Reports 1–5).

3.1. Theoretical approaches

The dominant approach in osteoarchaeology is statistical analysis of large data sets in order to test hypotheses relating to broad archaeological or historical questions (Zuckerman and Armelagos, 2011). Although such population-based approaches form the foundation of osteoarchaeology as a scientific discipline, they may result in a tendency toward reducing individual human beings to the status of single data points, which potentially blunts our ability to understand the richness of individual lived experience in the past. A solution to this potential weakness of population-based biocultural studies may lie in the 'osteobiographic' approach, in which skeletal data are used to attempt to construct narratives of individual lives. In order to most fully realise the potential of an osteobiographic approach, studies need to be grounded in social theory. Key to this are the concepts of identity (Insoll, 2007), and life-course theory (Giele and Elder, 1998). Identity is a social construct concerning who people thought they were, how they displayed this, and how others perceived it (Knudsen and Stojanowski, 2011: 231). Identity is multidimensional. It depends, inter alia, upon aspects that study of skeletal remains can potentially shed light upon, such as age, sex, ancestry, relationship with place, dietary preferences, the effects of disease and injury, and patterns of physical activity, including division of labour (White et al., 2009). There are also facets of identity that may be more difficult to identify in the archaeological record, such as religious beliefs, and social and political affiliations and allegiances. A life-course approach recognises the mutability of identity, and that at any one point in an individual's life, identity is contingent upon previous social and biological life experiences, as well as upon changing social and physical environments in which a person may find themselves (Agarwal, 2016). There is a synergy between the adoption of these theoretical orientations into archaeology and innovations in scientific methodologies for analysing human remains. Study of skeletal tissues that form at different times and remodel at different rates may allow temporal order of dietary changes, disease episodes etc. within an individual's life-span to be teased out (discussion in Mays et al., 2017). This may help us to construct narratives of individual lives. The present study is informed by the above considerations.

3.2. Burial practice and funerary taphonomy

In the absence of grave goods or elaborate grave construction, the position of the corpse is the key aspect of burial practice that can be studied archaeologically in an articulated burial. The position of the bones of a skeleton in a grave, as found upon excavation, depends both
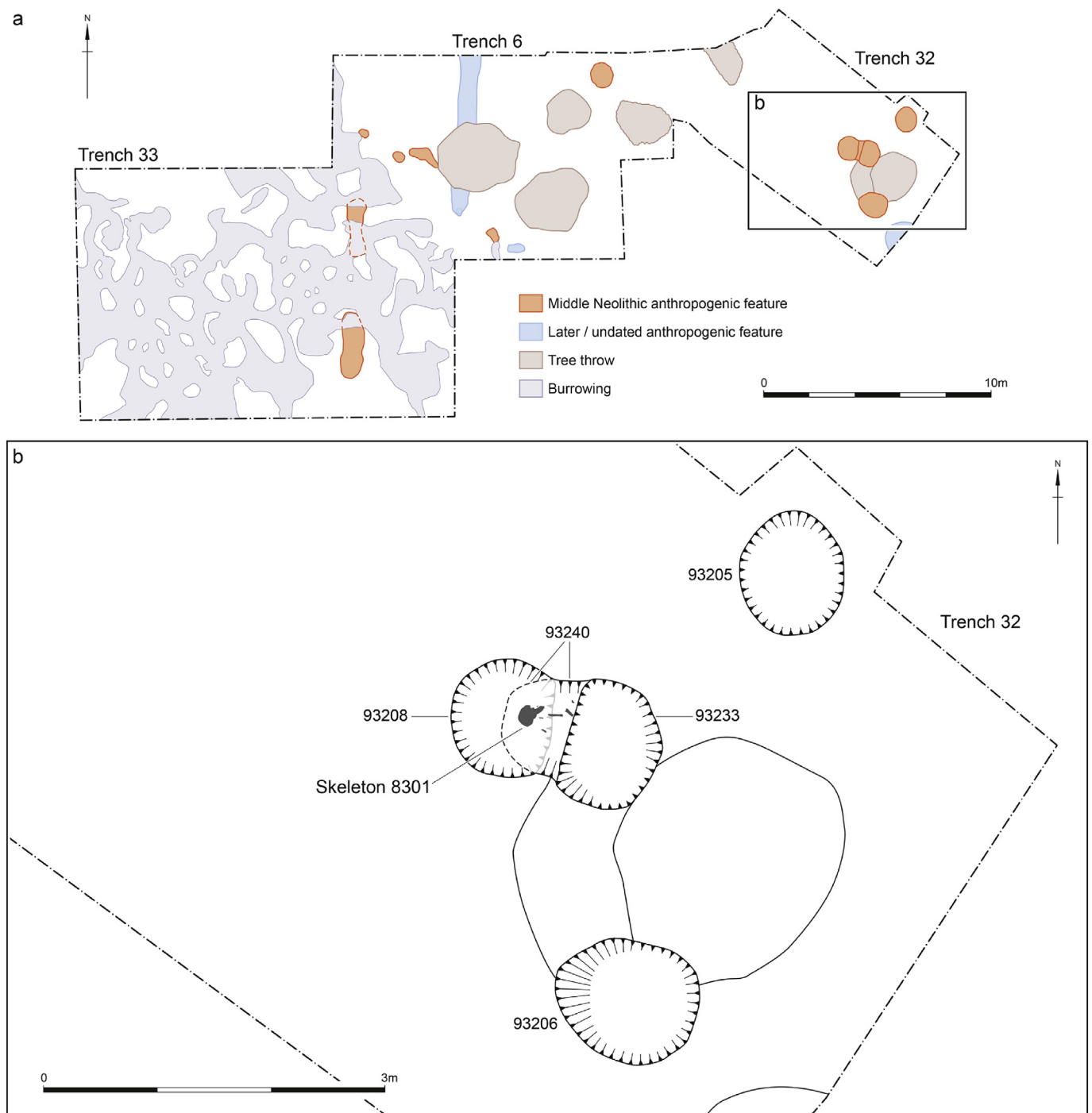
Fig. 2. Location of Skeleton 8301, West Amesbury Farm.

on the original posture of the body when it was deposited, and on any post-depositional movement of the remains (Knüsel and Robb, 2016). In an articulated burial, the latter principally reflects bone movement as the body collapses as the soft tissues, including the ligaments that maintain joint integrity, decay. In the current work, detailed site photography, including photogrammetry (see Supplementary Report 1), was used to accurately record the position of the skeletal remains as found. This evidence, together with the principles of funerary taphonomy, as outlined by Duday (2006, 2009), are used in order to attempt to discern the original placement of the corpses.

3.3. Laboratory studies of the skeletal remains

3.3.1. Radiocarbon dating

Bone samples from the four individuals were submitted to the Oxford Radiocarbon Accelerator Unit (ORAU), the Scottish Universities Environmental Research Centre (SUERC) and the [14]CHRONO Centre, Queen's University, Belfast. The samples dated at SUERC were pretreated and measured by Accelerator Mass Spectrometry (AMS) following the methods outlined in Dunbar et al. (2016). The sample dated at Queen's University Belfast was pretreated and measured by AMS following the methods described in Reimer et al. (2015). Samples measured at ORAU were pretreated and combusted as described in Brock et al. (2010), graphitised (Dee and Bronk Ramsey, 2000) and
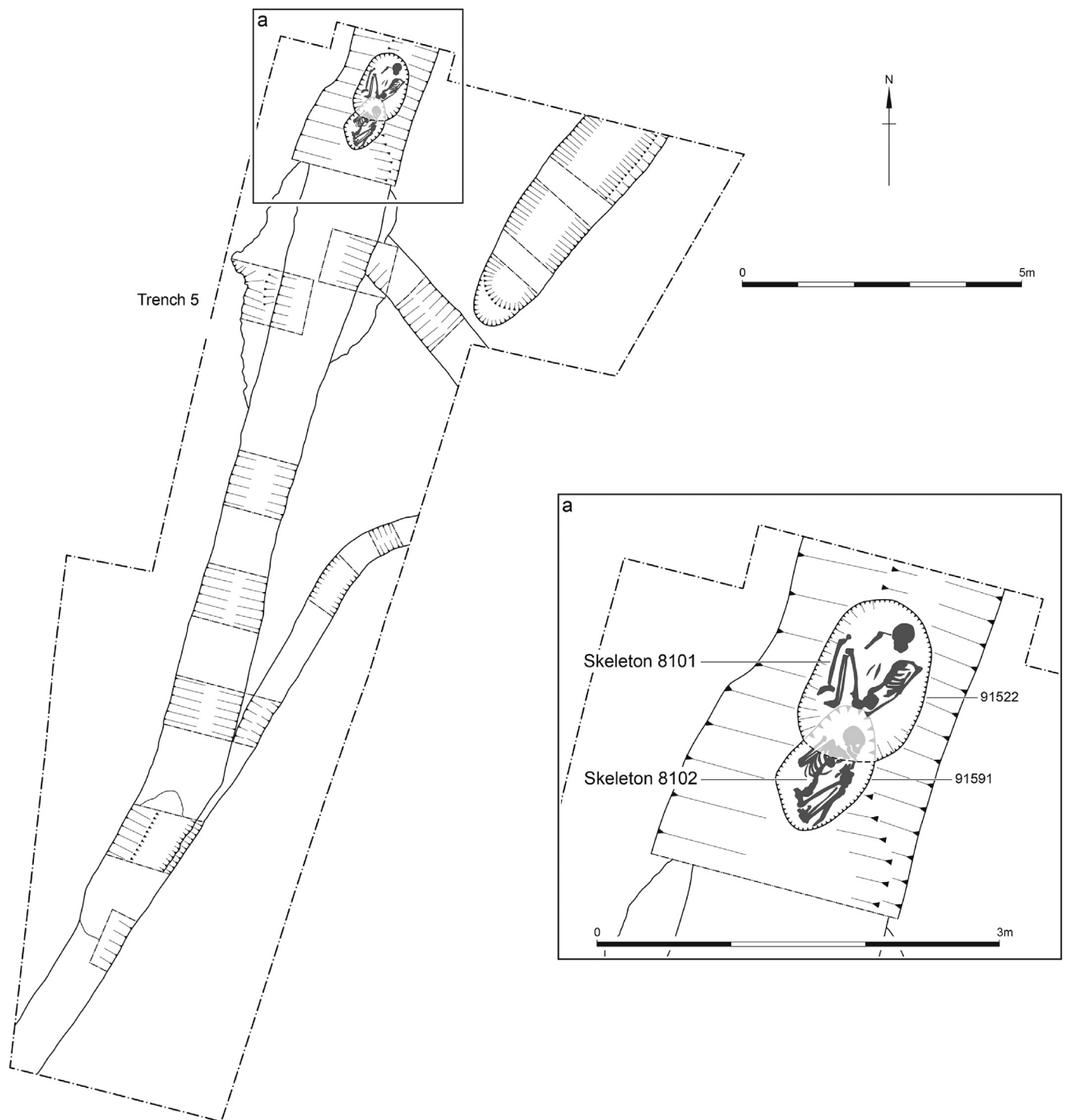
Fig. 3. Location of Skeletons 8101 and 8102, West Amesbury Farm.

dated by AMS (Bronk Ramsey et al., 2004). All three laboratories maintain a continual programme of quality assurance procedures, in addition to participation in international inter-comparisons (Scott et al., 2010). These tests indicate no laboratory offsets and demonstrate the reproducibility and accuracy of these measurements. Carbon and nitrogen stable isotope analysis was undertaken on the samples. This is because of the potential for a diet-induced radiocarbon offset if the individuals had taken up carbon from a reservoir not in equilibrium with the terrestrial biosphere (Lanting and Van Der Plicht, 1998).

3.3.2. Osteological study

Sex was determined in adult remains using dimorphic aspects of pelvis and skull (Brothwell, 1981: 59–63). In adults, age at death was estimated using dental wear (Brothwell, 1981: Fig. 3.9), the morphology of the pubic symphyses (Brooks and Suchey, 1990) and auricular surfaces (Falys et al., 2006), and the state of closure of the cranial sutures (Perizonius, 1984). In the perinatal burial, age was estimated from fusion of the tympanic ring (García-Mancuso et al., 2016), and measurement of cranial and post-cranial elements (Scheuer and Black, 2000).

In adults, skeletal measurements were recorded following Brothwell

Fig. 4. Skeletons 8101 and 8102, West Amesbury Farm. Composite figure derived from photogrammetry.

(1981), Howells (1973), and Raxter et al. (2006). To study biodistance, cranial morphology for the Middle Bronze Age burials was compared to other British Neolithic and Bronze Age material using the data of Brodie (1994). Data were subject to principal components analysis. Most researchers regard shape as more important than size for osteometric biodistance studies (Pietrusewsky, 2008), so it is usual to remove the size-based component of variation from the data prior to analysis. The

geometric mean is an established indicator of size (Mosimann, 1970; Gallagher, 2015). To eliminate size effects, each of the 20 measurements used in this part of the work were normalised by the geometric mean of all measurements for that individual, an approach that has been used by others in craniometric analyses (e.g. McKeown and Jantz, 2005; Allen and von Cramon-Taubadel, 2017). Stature was estimated using the methods of Raxter et al. (Raxter et al., 2006; Raxter and Ruff, 2010) and Trotter and Gleser (1952). Body weight was estimated from stature and bi-iliac breadth using the method described by Ruff (2000: Table 1).

3.3.3. Stable isotope measurements on dental remains

The Middle Bronze Age infant lacked dental remains. Seven permanent molar teeth from the other three individuals were sampled: M1 and M3 from Middle Bronze Age burials 8101 and 8102 and M1, M2 and M3 from Middle Neolithic burial 8301. For strontium isotope analysis, the teeth were carefully removed from the jaw and longitudinal sections of approximately 1 mm thick enamel and some incidental dentine were removed using a hand drill and diamond cutting disk. The samples represent a section of the complete available length of the enamel from the crown to the cervix. Samples were cleaned in an ultrasonic bath in 18 MΩ H_2O for 10 min and dried overnight in an oven at 60 °C. For oxygen isotope analysis, a second and similar section was taken from each tooth. Surface dirt and any dentine were removed using a dental burr. The sample was ground to a fine powder in an agate mortar under acetone. The powder was leached for 10 min in 10% acetic acid to remove diagenetic carbonate, then centrifuged and washed in 18 MΩ H_2O five times and dried. Two 5 μg aliquots were weighed for analysis.

For carbon and nitrogen stable isotope analysis ca. 50 mg of dentine was cut from the apex of the root of each tooth, cleaned in an ultrasonic bath in 18 MΩ H_2O for 10 min and dried overnight in an oven at 60 °C. The dentine was demineralized over ca. 48 h in 0.5 M HCl at room temperature, centrifuged and rinsed. To remove contamination, the sample was treated with 0.1 M NaOH for 30 min, rinsed and treated with 0.5 M HCl for 15 min and further rinsed. The samples were then gelatinized in pH 3 HCl at 70 °C for 24 h. Insoluble residue was subsequently removed by centrifuging and filtering, and the soluble fraction containing the collagen was freeze dried.

Strontium isotope analysis was conducted using laser ablation. The enamel samples were mounted in the laser cell by pressing into bluetack. Sr isotopic analysis was performed on a Finnegan Neptune multi collector ICP-MS with a New Wave Research ArF excimer homogenised-beam 193 nm laser (NWR193), using the oxide reduction technique of
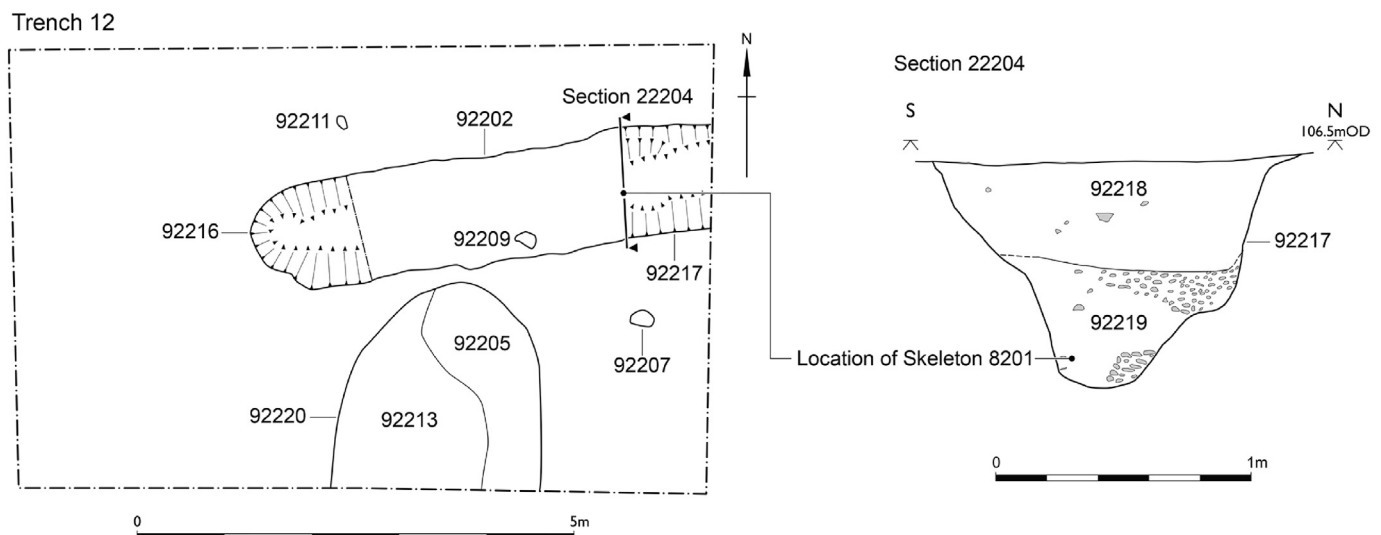

Fig. 5. Location of skeleton 8201, Druid's Lodge.

Fig. 6. Burial 8102. Detail view from the north, showing dislocation of right sacro-iliac joint. Note that the sacrum is flat on the grave floor.

De Jong (De Jong et al., 2010; De Jong, 2013; Lewis et al., 2014). Time series of strontium isotopes are obtained as continuous data by moving the tooth along the growth axis of the enamel (at 2.5 or 5 μms^{-1}) as the laser pulses with a repetition rate of 20 Hz and spot size 110 μm. Repeat analysis of an in-house ashed bovine pellet standard (BP1) bracketing the analyses of the archaeological samples, showed an offset of $+75 \pm 118$ ppm (1σ) for the laser ablation analyses over TIMS values, which is similar to values reported by other laboratories using a similar methodology (Willmes et al., 2016). This is within the precision of individual measurements of 200–600 ppm and the total variation between the teeth of 2000 ppm, and is therefore considered insignificant to our interpretation of the isotopes. The strontium isotopic range local to the site was estimated from published values of archaeological bones and dentine, and modern flora for archaeological sites nearby on the same chalk geology (Viner et al., 2010; Evans et al., 2006a, 2006b).

The oxygen isotopes in the carbonate fraction of tooth enamel were measured on a Thermo KEIL IV Carbonate Device using 105% phosphoric acid at 90 °C to evolve the CO_2 before transfer to a Thermo Finnegan MAT 253 isotope ratio mass spectrometer. For comparison with published measurements on enamel phosphate oxygen isotopes and estimations of drinking water $\delta^{18}O$, structural carbonate values were converted to phosphate values using Chenery et al. (2012). Equivalent drinking water values were estimated using Longinelli (1984).

The carbon and nitrogen isotope analyses were performed on 0.65 mg aliquots of the retentate collagen using an Elementar Vario MICRO Cube elemental analyser linked to an IsoPrime100 isotope ratio mass spectrometer. Results are quoted as δ values relative to VPDB and AIR for carbon and nitrogen respectively. International calibration standards (USGS 40 and USGS 41) were used for normalisation of values. Measurement uncertainty was monitored using an in-house protein standard with well-characterised isotopic compositions ($\delta^{15}N = 6.08 \pm 0.15‰$, $\delta^{13}C = -27.29 \pm 0.06‰$). Within-run precision was determined to be $\pm 0.21‰$ for $\delta^{15}N$ and $\pm 0.13‰$ for $\delta^{13}C$ on the basis of repeated measurements of in-house protein and acetanilide standards. The C:N atomic ratio was monitored as a control for contamination, and all samples fell within the acceptable limits of 2.9–3.6 (DeNiro, 1985).

3.3.4. Dental calculus

Microscopic analysis of dental calculus recovered from the three individuals with dentitions preserved was applied to investigate ingested or inhaled microdebris, while metaproteomic analysis of dental calculus was applied to investigate entrapped dietary proteins, particularly the milk protein beta-lactoglobulin (Warinner et al., 2014a). For microscopic analysis laboratory procedures followed established protocols (e.g. Radini et al., 2016a; Warinner et al., 2014b), slightly

adapted for the small size of the samples (see Supplementary Report 5 for details). The identification of the micro-fossils retrieved was based on anatomical and optical properties, followed by visual comparisons with a modern reference collection and published material (e.g. Petraco and Kubic, 2003; Torrence and Barton, 2006; Warinner et al., 2014b). For metaproteomic analysis, proteins were extracted using a Gel-Aided Sample Preparation (GASP) protocol based on Fischer and Kessler (2015) and modified for ancient mineralized samples. Extracted peptides were analysed using a nanoLC interfaced to an Orbitrap Fusion hybrid mass spectrometer.

4. Results

4.1. Burial practice

In Middle Bronze Age burials 8101 and 8102, close study of the site photographs indicated that the torso, including pelvic and pectoral girdles, lay flat on the grave floor. The lower limbs were flexed to the side, with the long-bones approximately parallel with the grave floor (Fig. 4). The range of motion at the hip joints means that this lower limb posture cannot be attained in a fresh cadaver, so it is unlikely to have been the original posture of the bodies. This appears to be confirmed from the site photographs. In 8102, where the lower limbs are flexed to the left of the torso, there is dislocation of the right sacro-iliac and hip joints (Figs. 6 & 7). In 8101, where the lower limbs lay to the right side, there is dislocation of the left hip and sacro-iliac joints. It seems likely that in each case the lower limbs may originally have been positioned with the knees fully flexed in front of the body so that the heels were in contact with the buttocks. This position was probably maintained by perishable bindings or wrappings. The original placement of the corpse in the grave cannot be determined unambiguously, but the positioning of the torso, including pelvic and pectoral girdles, flat on the grave floor may indicate that it is most likely that the body was, in each case, originally positioned on its back. As soil was placed on top of the bodies at burial, the flexed lower limbs may have been pushed to one or other side, creating a poorly filled void space beneath them. As they decayed, the ligaments at the hip and sacroiliac joints would have gradually become less able to resist the weight of the settling overburden, so the lower limbs slumped further to the side. The skulls of 8101 and 8102 face in opposite directions, but it should be recalled that, in a corpse placed on its back, the head may tend to roll to the side as the body is placed in the grave.

Given the above discussion, it may be that the posture of the two Middle Bronze Age adults at deposition was more similar than the skeletal positions as excavated suggest. The only difference that seems unlikely to be post-depositional in origin is in the positions of the left

Fig. 7. Burial 8102. Detail view from the south showing dislocation of right hip joint.
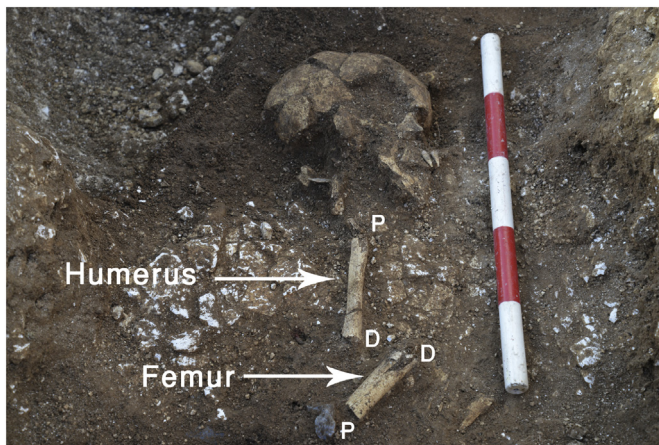
Fig. 8. Burial 8301. P = proximal end of bone, D = distal end of bone.

upper limb. In 8102 both upper limbs are flexed, but in 8101, the stratigraphically later interment, the left upper limb is extended toward the location of the earlier burial. However, even in this case the possibility of inadvertent movement of a flexed upper limb as the corpse was placed in the grave (especially if the body was shrouded) cannot be definitively excluded.

Middle Neolithic burial 8301 is poorly preserved and heavily truncated, so identifying the original posture of the body is problematic. The only two long-bones that could be identified were part of a left humerus, which lay on the base of the grave, and part of the right femur, which lay at an approximately 45 degree angle to the humerus (Fig. 8). If these two bones have remained in situ, their location and orientation, together with the position of the skull, would be consistent with a crouched body placed on its left side.

4.2. Radiocarbon dating

The results (Table 1, Fig. 9) are conventional radiocarbon ages (Stuiver and Polach, 1977), and are quoted in accordance with the Trondheim convention (Stuiver and Kras, 1986). Radiocarbon determinations on the three Middle Bronze Age individuals are statistically consistent (T' = 0.9; T'(5%) = 6.0; ν = 2; Ward and Wilson, 1978) meaning that they could have all died at the same time. But as the two individuals from West Amesbury Farm are included in a chronological model as having a stratigraphic relationship (Roberts et al., 2017: Fig. S1) it is more likely they could all have died within a very short period of time. Middle Neolithic individual 8301 buried in grave [93240] is estimated to have died in 3330–3315 cal BC (1% probability; 8301; Fig. 9) or 3295–3280 cal BC (4% probability) or 3245–3110 cal BC (90% probability). Technical details of the calibration and modelling of these results (Fig. 9) can be found in Roberts et al. (2017; in preparation).The sample C:N values (Table 1) are within the range normally used to indicate good collagen preservation (2.9–3.6; DeNiro, 1985). The stable isotope results (Table 1) indicate that the individuals consumed a diet predominantly based upon temperate terrestrial C3 foods (Katzenberg and Krouse, 1989; Schoeninger and DeNiro, 1984). The radiocarbon ages are therefore unlikely to be affected by any significant reservoir effects (Bayliss et al., 2004).

4.3. Osteology

4.3.1. Summary of results

The partial remains of Middle Neolithic burial 8301 are from a male adult. Middle Bronze Age burials 8101 and 8102 are also male adults. Middle Bronze Age burial 8201 was an approximately full-term infant of unknown sex. The skeletal survival, and demographic and basic osteometric data for each individual are summarised in Table 2.

Table 1

Radiocarbon dating and bone stable isotope results from West Amesbury Farm and Druid's Lodge. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward & Wilson (1978); T'(5%) = 3.8, ν = 1 for all). The posterior density estimates for West Amesbury Farm are derived from the models described in Roberts et al. (in prep. Fig. RC1) and Roberts et al. (2017, Fig. S1).

| Laboratory code	Sample ref	Material & context	δ13C (‰) - IRMS	δ15N (‰) - IRMS	C:N	Radiocarbon age (BP)	Calibrated date (2σ) cal BC	Posterior Density Estimate, (95% probability) cal BC
West Amesbury Farm								
SUERC-66775	(8301)	Human bone, cranial fragment from grave [93240] that cuts Pit [93208] and is cut by a second pit[93233]	−21.7 ± 0.2	11.2 ± 0.3	3.3	4341 ± 30		3330–3315 (1%) or 3295–3280 (4%) or 3245–3110 (90%)
SUERC-75184	SK8301.D	Human bone, cranial fragment from the same context as SUERC-66775	−21.5 ± 0.2	11.5 ± 0.3	3.2	4396 ± 30		
OxA-,35714	SK8301.B	Human bone, cranial fragment from the same context as SUERC-66775	−21.8 ± 0.2	11.0 ± 0.3	3.2	4507 ± 34		
SUERC-76338	SK8301.B2	Replicate of OxA,35714	−21.8 ± 0.2	11.3 ± 0.3	3.3	4535 ± 34		
14C: 4545 ± 25 BP, δ13C: −21.8 ± 0.2; δ13C: −21.8 ± 0.15‰, T' = 0.1; δ15N: 11.2 ± 0.21‰, T' = 0.5								
OxA,35715	SK8301.C	Human bone, right femur from the same context as SUERC-66775	−21.9 ± 0.2	11.0 ± 0.3	3.2	4554 ± 34		
SUERC-76339	SK8301.C2	Replicate of OxA,35715	−21.6 ± 0.2	11.3 ± 0.3	3.3	4509 ± 34		
14C: 4508 ± 25 BP, δ13C: −21.8 ± 0.15‰, T' = 0.0; δ13C: −21.8 ± 0.15‰, T' = 0.0; δ15N: 11.2 ± 0.21‰, T' = 0.5								
SUERC-66321	SK8102	Human bone, left femur from Skel 8102	−20.5 ± 0.2	9.2 ± 0.3	3.3	3124 ± 30		1495–1475 (5%) or 1460–1370 (77%) or 1355–1310 (13%)
UBA-31357	SK8101	Human bone, left femur from Skel 8101	−20.5 ± 0.22	9.3 ± 0.15	3.2	3153 ± 45		1450–1285
Druid's Lodge								
SUERC-66780	SK8201	Human bone, four long bone fragments from Skel 8201	−20.3 ± 0.2	10.4 ± 0.3	3.2	3102 ± 31	1440–1270	
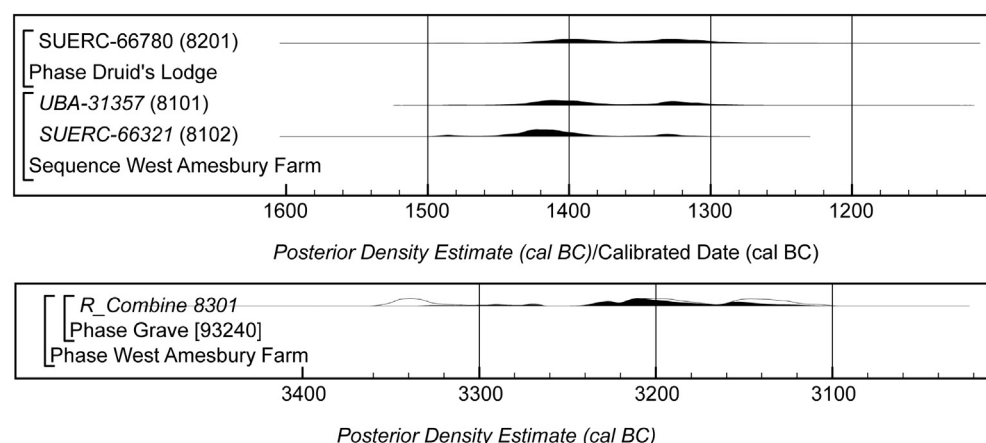
Fig. 9. Probability distributions of dates from human remains. Each distribution represents the relative probability that an event occurred at a particular time. Above: The distributions from West Amesbury Farm have been taken from the model described in detail in Roberts et al., 2017, Fig. S1 and the distribution for Druid's Lodge by simple radiocarbon calibration (Stuiver and Reimer, 1993). Below: The distribution from West Amesbury Farm has been taken from the model described in detail in Roberts et al. (Roberts et al., in preparation: Fig. RC1).

4.3.2. Pathologies and anomalies

4.3.2.1. Burial 8301.
There is dental calculus (grade II–III, according to the scheme of Dobney and Brothwell, 1987). The anterior dentition shows heavy wear, especially in the maxilla, with significant tertiary dentine formation.

4.3.2.2. Burial 8101.
There is dental calculus (grade II, according to the scheme of Dobney and Brothwell, 1987).

There are six rather than the more usual five sacral vertebrae, the sixth being an extra vertebral segment rather than sacralisation of the fifth lumbar vertebra. Numerical variations in the vertebral column appear to have a genetic component in their causation (Wong et al., 2015).

The fifth lumbar vertebra shows bilateral clefts in its neural arch at the *partes interarticulares*. This condition is termed spondylolysis, and is thought to represent fatigue fracture of the neural arch (Standaert and Herring, 2000). Spondylolysis may lead to forward slippage of the anterior part of the affected vertebra upon the one below it, a condition termed spondylolisthesis. In the current individual there are osteophytes at the margins of the bodies of the fifth lumbar and first sacral segments. The upper surface of the body of the first sacral segment shows a domed or convex profile (Supplementary Report 3: Figs. 1 & 2). There is some new bone formation upon the anterior surface of the body of the first sacral segment. These are indications of spondylolisthesis (Mays, 2006).

In modern populations, spondylolysis generally occurs during childhood and adolescence (Fredrickson et al., 1984; Beutler et al., 2003; refs in Ward et al., 2010), but in archaeological groups it appears mainly to form in late adolescence or early adulthood (Mays, 2007), and high frequencies have been associated with strenuous lifestyles (Mays, 2006). When forward slippage of the affected vertebra occurs, it mainly happens soon after the fracture occurs during the growth period. The mechanism appears to be slippage between the bony centrum and the unfused growth plate, so that continued slippage once skeletal maturity is reached is usually minimal (Ikata et al., 1996; Sairyo et al., 1998, 2001; Leone et al., 2011). The 'doming', observed to S1 in this case, is due to increased mechanical pressure on the anterior part of the unfused growth plate (Hagashino et al., 2007; Terai et al., 2011). This means that, in 8101, the forward slippage, and the original injury, happened before fusion of the annular epiphysis of S1. In recent populations this generally occurs by about 14–18 years of age in males (Cardoso et al., 2014), but given that poor nutrition in the growth period retards skeletal development (Mays, 2010: 58–59) this may have been somewhat later in ancient times.

Spondylolitic defects generally cause lower back pain when they form, but in adulthood, fibrous union across the *partes interarticulares* generally results in a pain-free stable joint, even in the presence of olisthesis. However, enhanced disc degeneration may occur so that lower back pain from this source may become a problem in later life (Haun and Kettner, 2005).

4.3.2.3. Burial 8102.
There is dental calculus (grade II–III, according to the scheme of Dobney and Brothwell, 1987).

There is faint pitting in the orbital roofs. The morphology of lesions (Supplementary Report 3: Fig. 3) is consistent with marrow hyperplasia, perhaps due to past episode(s) of anaemia (Mays, in press). In the growing skeleton, the bone marrow, including the trabecular bone (diploe) of the cranial bones is a site of red blood cell production. In anaemia the diploe may show hyperplasia as the body attempts to combat anaemia by raising erythrocyte production. At birth, bone marrow is almost entirely haemopoietic red marrow but by adulthood this has been largely converted to non-haemopoietic fatty, yellow marrow. In adults, a need to increase erythrocyte production is met by a conversion of fatty marrow to erythropoietic marrow usually without hyperplasia of the diploe, so bone lesions do not form. Porotic hyperostosis seen in adult skeletons is normally considered a relic of childhood disease. The timing of the conversion of red to yellow marrow is different in different bones, but in the frontal bone the process is essentially complete by about 7–10 years (Simonson and Kao, 1992; Taccone et al., 1995). Cranial lesions are most likely to form in response

Table 2
Selected osteological results.

Burial	Period	Skel. compl.	Sex	Age	Stature	Body weight	Bi-iliac br.	Crn Indx	Meric indx	Pilast. indx	Cnemic indx
8301	Middle Neolithic	< 20%	M	30–50	–	–	–	73.3	–	–	–
8101	Middle Bronze Age	> 90%	M	35–45	164.6 (168.2)	60.5	264	77.4	71.6	112.8	57.5
8102	Middle Bronze Age	> 90%	M	25–35	162.1 (163.2)	52.3	240	72.3	89.9	109.6	53.4
8201	Middle Bronze Age	ca. 30%	–	Perinatal 38-41wiu	–	–	–	–	–	–	–

Key: Skel. Compl., approximate skeletal completeness; Sex, M = male; Age, approximate age at death, in years, except wiu = weeks gestation; Stature, in cm, estimated according to Raxter et al. (2006), figure in parentheses is estimate from femur length using Trotter and Gleser (1952) white male formula; Body weight, in kg, estimated from stature and bi-iliac breadth using Ruff (2000): Table 1; Bi-iliac br., skeletal bi-iliac breadth in mm taken following Tague (1989); Crn Indx, cranial index; Meric indx, meric index = $100 \times FeD_1/FeD_2$; Pilast. indx, pilasteric index = $100 \times$ midshaft a-p/midshaft m-l; Cnemic indx, cnemic index = $100 \times TiD_2/TiD_1$.

to anaemia in individuals under about ten years old. Growth in the bones of the cranial vault is very rapid in infants and young children (Humphrey, 1998), so perhaps early lesions would be removed during bone modelling. Lesions forming in middle and later childhood probably stand a greater chance of remaining on the skeleton into adulthood.

4.3.3. Analysis of cranial morphology

Due to its fragmentary and poorly preserved nature, only maximum length and width could be taken for the cranium of Middle Neolithic burial 8301. It is well established that there was a change in cranial form in Britain around the Neolithic–Bronze Age transition, Early Bronze Age skulls having a higher cranial index (100 × maximum cranial breadth/maximum cranial length) than their Neolithic counterparts. Cranial index for Neolithic material averages about 71, for Early Bronze Age skulls it is about 78 (Mays, 2010: Table 4.2). The value for 8301 (73.3) is fairly typical of Neolithic crania. The cranial index of Middle Bronze Age burial 8101 (77.4) is close to the mean reported for Early Bronze Age material, but 8102 (72.3) is less so.

The crania from Middle Bronze Age burials 8101 and 8102 were largely intact, permitting more detailed analysis. Cranial morphology, analysed using the methods of Giles and Elliot (1962) and Bass (1987: 83), classifies the ancestry of both individuals as European. Results of the principle components analysis of these crania together with the Neolithic and Early Bronze Age crania recorded by Brodie (1994), are shown in Table 3 and Fig. 10.

Analysis is limited to components with Eigenvalues > 1 (Shennan, 1988: 264). Seven components satisfy this condition, but the first two account for 35% of the variance. The only component upon which Neolithic and Early Bronze Age crania differ in their scores is component 1 ($t = 7.81$, 55df, $p < .001$). The scores of Neolithic and Early Bronze Age crania, together with Middle Bronze Age individuals 8101 and 8102, on components 1 and 2 are shown in Fig. 10. There is little overlap in the Neolithic and Early Bronze Age point clouds along PC1 (the vertical axis of the graph). This emphasises the morphological distinction between crania of these two periods. Table 3 indicates that vault measurements taken in the sagittal plane tend to have positive loadings on PC1, whereas maximum vault breadth has a negative
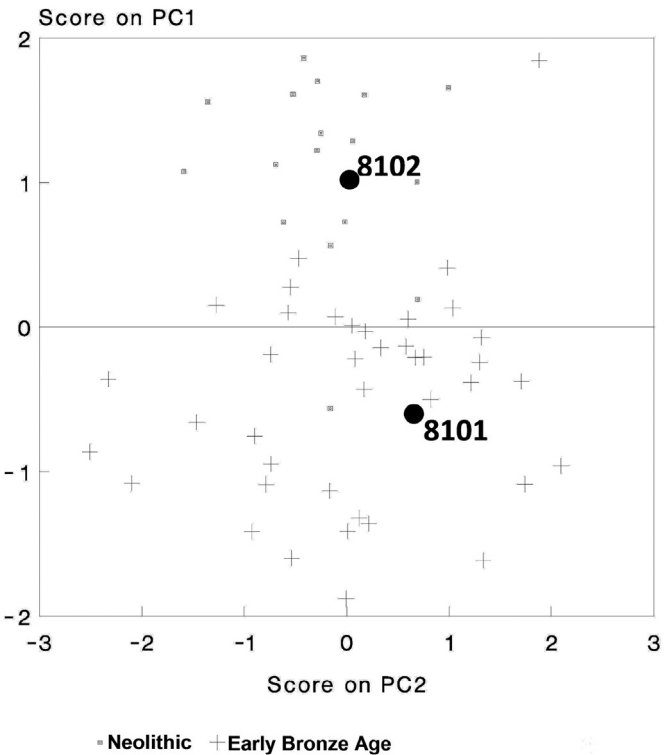

Fig. 10. Principle components analysis of cranial morphology of Neolithic and early Bronze Age crania using size corrected variables. Scatterplot of first and second principle components, with Middle Bronze Age crania of 8101 and 8102 superimposed.

loading as do most measurements of the facial skeleton. The Early Bronze Age crania tend to have lower scores on PC1 than Neolithic crania (Fig. 10). This indicates that they tend to have shorter, broader cranial vaults and larger facial skeletons. The results confirm that Neolithic and Bronze Age crania differ morphologically. Given the high degree of genetic control over cranial morphology, this is consistent with British Early Bronze Age people having a different genetic background to the Neolithic population. This interpretation appears to be supported by recent aDNA data (Olalde et al., 2018).

The cranium of burial 8101 sits quite comfortably in the Early Bronze Age point cloud (Fig. 10); 8102 differs from the British Early Bronze Age material. The separation between the crania of 8101 and 8102 on their scores on PC1 (1.63) is no less than that between the mean scores of the Neolithic and Early Bronze Age crania studied by Brodie (1.58). In sum, the cranial morphological studies suggest that individuals 8101 and 8102 are both of European origin, but their degree of morphological separation is consistent with them having had ancestries from different parts of Europe.

4.3.4. Stature and physique

Modern mean young adult male stature in Britain is 177.8 cm (Health Survey for England, 2013). Middle Bronze Age individuals 8101 and 8102 would have been rather short by modern standards (Table 2); they are also rather short compared to average stature (estimated using the Trotter and Gleser (1952, 1958) regression formulae) for male (presumably mainly Early) Bronze Age burials of 172 cm (Roberts and Cox, 2003: Table 8.1). They differ from one another in physique, 8101 being rather taller and of heavier build (Table 2).

4.3.5. Longbone cross-sectional geometry

In contrast to cranial morphology, genetic control over long-bone cross sectional geometry is weak, the most important influence probably being biomechanical loading (Mays, 2010: 141). Living bone tends

Table 3

Principle components analysis using size-corrected variables (($N = 59$ crania): eigenvalues, percent variance accounted for, and component loadings for the first two components.

	PC1	PC2
Eigenvalue	4.16	2.78
% variance accounted for	20.8	13.9
Variable	Component loading	
Maximum cranial length	0.83	−0.22
Maximum breadth	−0.46	0.63
Minimum frontal breadth	−0.35	0.14
Biasterionic breadth	0.18	0.48
Basi-bregmatic height	0.08	−0.37
Frontal arc	0.32	0.48
Parietal arc	0.57	0.33
Occipital arc	0.60	−0.34
Frontal chord	0.48	0.36
Parietal chord	0.70	0.29
Occipital chord	0.62	−0.39
Upper facial height	−0.49	0.03
Basi-nasal length	−0.17	−0.72
Basi-alveolar length	−0.13	−0.70
Orbital height	−0.09	0.17
Orbital breadth	−0.21	0.10
Nasal height	−0.53	0.19
Nasal breadth	−0.47	−0.02
Palatal length	−0.36	−0.14
Palatal breadth	−0.48	−0.16

to adapt to resist the mechanical forces placed upon it, increased mechanical forces tend to lead to bone being thickened at the sites affected. This means that the distribution of bone in the cross-section tends, to some extent, to reflect the orientation of the bending forces placed upon it in life (Mays, 2010: 140–142). Although plasticity in response to biomechanical loading is retained throughout life, this capacity is greater in adolescence than in adulthood. Long-bone cross-sections have widely been used to investigate activity patterns in skeletal populations (Larsen, 2015: 222–255). In the current study, the meric, pilasteric and cnemic indices are used to express the relative mediolateral versus anteroposterior widths at the subtrochanteric area of the femur, the femur midshaft and the nutrient foramen of the tibia respectively (Table 2). Although not conveying such precise loading information as analysis of CT scans, which allow modelling of internal and external cortical contours, because the periosteal dimensions are the more critical to bone rigidity, external width indices such as these still convey useful information (Pearson, 2000; Wescott, 2006). In addition they have long been taken in osteoarchaeology, so there are background data to place results in context.

Comparison of the long-bone shaft indices for Middle Bronze Age individuals 8101 and 8102 shows that they differ quite markedly in meric index. The lower index for 8101 suggests that the subtrochanteric area of the femur was subject to greater mediolateral bending forces than was the case for 8102. Proximal femoral cross-sections are influenced by body shape; specifically a wider pelvis increases mediolateral bending forces on the proximal femur shaft (Ruff, 1995). Individual 8101 has a wider pelvis than 8102, both in absolute terms and in relation to stature (Table 2), so this may be a reason for the difference. The effects of pelvic width on shaft cross-section become less more distally in the lower limb, and consistent with this, the pilasteric indices in the two individuals are similar.

The tibia is more mediolaterally centred under the body's centre of gravity than the femur (Ruff et al., 2006), which means it may provide better insights into activity patterns (Davies and Stock, 2014). During locomotion (walking, running), biomechanical forces on the tibial shaft are concentrated in an approximately antero-posterior direction. So, for example, increased disposition of bone in the antero-posterior plane in the tibial shaft has been found in track athletes, and this variable has been used as an indicator of lifestyle mobility in past populations (Shaw and Stock, 2009). In Europe there appears to have been a change in the shape of the tibial shaft cross-section over time since the Neolithic, with greater disposition of bone in the antero-posterior plane in earlier compared with more recent populations (Macintosh et al., 2015). The cnemic indices for 8101 and 8102 (53.4, 57.5) are similar to one another and are at least two standard deviations below a mean calculated for other adult Bronze Age burials from the Stonehenge area ($N = 27$, mean = 67.1, see Supplementary Report 3: Table 1), indicating greater resistance to antero-posterior bending. Only one individual in that comparative data set (also dating from the Middle Bronze Age) has a similar value. These results may suggest unusually mobile lifestyles for 8101 and 8102.

4.4. Stable isotopes

4.4.1. Dietary stable isotopes: $\delta^{13}C$ and $\delta^{15}N$

Table 4 presents the results of the C and N isotopic analyses of the dentine of the West Amesbury Farm individuals, and the results from the M3 root tips are depicted in Figs. 11a and b. The $\delta^{13}C$ value of the M3 root tip collagen of Middle Neolithic burial 8301 (-22.02‰) is consistent with a predominantly C3 diet, and is somewhat more depleted in ^{13}C than bone collagen values of other Neolithic individuals in southern Britain (Fig. 11a). The slight depletion in ^{13}C compared to 8101 and 8102 may be a result of a phenomenon known as the 'canopy effect', brought about by the consumption of forest-dwelling fauna (see Bonafini et al., 2013). In 8301, the M3 root tip exhibits a $\delta^{15}N$ value of 11.98‰; approximately 7.4‰ higher than the average $\delta^{15}N$ value for the West Amesbury cattle (4.6 ± 0.3‰). This is one of the highest $\delta^{15}N$ values observed in a Neolithic individual in the region (see Fig. 11a).

It has been demonstrated (Schulting and Borić, 2017) that there are regional variations in $\delta^{13}C$ and $\delta^{15}N$ within the British Isles in the Neolithic. On the bivariate plot (Schulting and Borić, 2017: Fig. 7.7, $N = 377$ mainly Early and Middle Neolithic humans) the rather enriched $\delta^{15}N$ and depleted $\delta^{13}C$ place the dental values for 8301 outside the point-cloud for England or Wales and, although the values lie on the fringes of the point-cloud for Scotland, they appear most typical of Ireland. Ireland typically shows lower $\delta^{13}C$ than other regions and rather variable $\delta^{15}N$ with some very high and low values. The reasons for the regional differences are unclear, but Schulting and Borić (2017) argue that the lower $\delta^{13}C$ reflects an environmental rather than a dietary signal, presumably a canopy effect. However, without systematic study of faunal values, this interpretation remains tentative.

The M3 root tip $\delta^{13}C$ values of Middle Bronze Age individuals 8101 and 8102 are also consistent with terrestrial C3 diets. Comparative data are available from the Beaker People Project (BPP) (Jay and Richards, 2007; Jay et al., 2012; Parker Pearson et al., 2016). The BPP isotope values presented in Fig. 11b are average values for 264 individuals excavated from sites spread between Scotland and Wessex, and dated to between 2500 and 1500 cal BC (Parker Pearson et al., 2016). The $\delta^{13}C$ and $\delta^{15}N$ values of 8102 fall within the range of those of the BPP individuals, whose isotopic values are suggested to be indicative of high-protein terrestrial diets with little or no marine input and no apparent dietary variation between regions across Britain (Parker Pearson et al., 2016). The $\delta^{13}C$ value of the M3 root tip of 8101 falls outside the range of the BPP $\delta^{13}C$ values, and is approximately 0.7‰ more enriched in ^{13}C than the highest $\delta^{13}C$ value observed in the BPP individuals. Without a greater range of contemporary faunal isotopic values from the site, however, it is difficult to identify the cause of this enrichment.

The gestational age of Middle Bronze Age individual 8201 (ca. 38–41 weeks) corresponds to an approximately full term infant (Tanner, 1989: 43), but it is unclear whether it was stillborn or died in the immediate post-natal period. Breastfeeding elevates $\delta^{15}N$ by about 2–3‰ compared with adults (Fuller et al., 2006). The burial lacked dentition, but bone yielded $\delta^{13}C$ and $\delta^{15}N$ of -20.3‰ and 10.4‰ respectively (Table 1). These values closely resemble the M3 root tip values of the two contemporaneous adults. As an infant begins to suckle, breastmilk signals are rapidly incorporated into its bone collagen – for example, in the large Mediaeval cemetery at Wharram Percy, individuals consistently showed elevated $\delta^{15}N$ from a gestational age of about 40 weeks (i.e. perhaps within about two weeks of birth) (Richards et al., 2002), and in the Post-Mediaeval burials from London Spitalfields, a breastfeeding signal could be demonstrated from about five weeks post-natal (Nitsch et al., 2011). The lack of elevation in $\delta^{15}N$ in 8201 does not resolve the question of whether this individual was born alive or not. It is consistent with either stillbirth, that the infant failed to suckle or that it did so too briefly for the breastfeeding signal to be evident, or that the mother had a diet with an unusually low $\delta^{15}N$.

4.4.2. Mobility isotopes: $\delta^{18}O$ and $^{87}Sr/^{86}Sr$

Fig. 12 shows the variation in strontium isotopes along the enamel section from cusp to cervix compared to an estimate of the 'local' strontium range. The $^{87}Sr/^{86}Sr$ isotopic range of the Upper Cretaceous chalk that makes up the upland chalk of Salisbury plain is well constrained by the strontium isotope seawater curve to 0.7074–0.7077 (Jones et al., 1994), but bioavailable strontium will contain a mix of the chalk strontium and rainwater strontium (with an isotopic value of 0.7092). Since it is unlikely that the local value would reflect 100% rainwater, we use the local $^{87}Sr/^{86}Sr$ range of 0.7078–0.7090 given by Viner et al. (2010) which is based on strontium isotopic values of modern plants collected from around Durrington Walls (about 2.5 km NE of West Amesbury Farm) and published dentine and bone values from archaeological fauna and humans from the southern chalklands

Table 4
δ13C and δ15N in dentine.

Skeleton	Tooth	Approximate age of mineralization of apical root dentine sample[a]	δ^{15}N$_{AIR}$ (‰)	δ^{13}C$_{VPDB}$ (‰)	C:N
8102	Right mandibular M1	ca. 7–10 years	9.91	−20.40	3.15
8102	Right mandibular M3	ca. 18–23 years	10.66	−20.79	3.17
8101	Left mandibular M1	ca. 7–10 years	9.92	−20.84	3.11
8101	Right mandibular M3	ca. 18–23 years	10.57	−20.01	3.13
8301	Left maxillary M1	ca. 7–10 years	11.79	−21.63	3.21
8301	Right maxillary M2	ca. 12–16 years	12.33	−21.90	3.26
8301	Right mandibular M3	ca. 18–23 years	11.98	−22.02	3.38

[a] Apical root formation times taken as timing of R¾ and Ac from AlQahtani et al. (2010).

(Evans et al., 2006a, 2006b).

The ^{87}Sr/^{86}Sr from the teeth of Middle Bronze Age skeletons 8102 and 8101 and M1 and M2 of Middle Neolithic burial 8301 are all consistent with chalk geology. However, sometime after initiation of enamel formation (i.e. after about 8.5 years of age) the strontium isotopic values for M3 of 8301 of between 0.7100 and 0.7105, indicate a move to a more radiogenic geology. Such values are present in the Palaeozoic and Mesozoic geologies around Gloucester (Chenery et al., 2010), the Palaeozoic of south Wales, the Devonian deposits in west Devon, the Ordovician geologies of Wales (Evans et al., 2010 and Supplementary Report 4: Fig. 4), and in various parts of Ireland (Snoeck et al., 2016), though with strontium isotopic analyses we cannot rule out similar geologies further afield.

The measured carbonate and their phosphate equivalent oxygen isotope results are given in Table 5. For comparison with drinking water, regression equations of both Longinelli (1984) and Daux et al. (2008) have been used, though these values must be used with caution since the conversion can introduce large (> 1‰) uncertainties. Nevertheless, a comparison of the data with predicted local oxygen isotope (i.e. phosphate equivalents of −6.0 to −7.5‰ values in drinking water (Supplementary Report 4: Fig. 5)) and local strontium values reveals some interesting patterns (Fig. 13). Both the strontium and oxygen isotopic values for 8101 are consistent with a local origin (or at least somewhere on the chalkland of southern Britain). The δ^{18}O$_P$
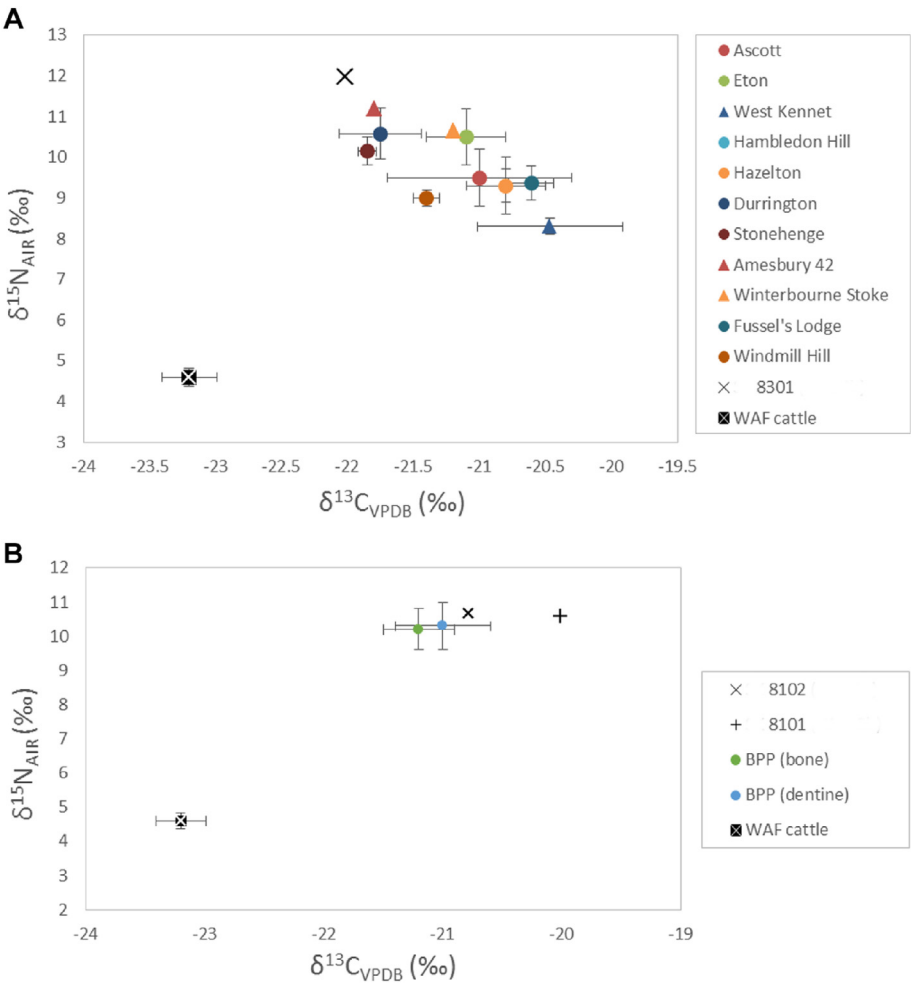

Fig. 11. (a) δ^{13}C and δ^{15}N values for M3 root tip collagen of Middle Neolithic skeleton 8301 and bone collagen values for individuals from other Neolithic sites in southern Britain. Triangles denote barrow inhumations. References for data from published works can be found in Supplementary Report 4. (b) δ^{13}C and δ^{15}N values for M3 root tip collagen of Middle Bronze Age individuals 8101 and 8102, with average bone and dentine collagen values for individuals from the Beaker People Project (data from Parker Pearson et al., 2016).
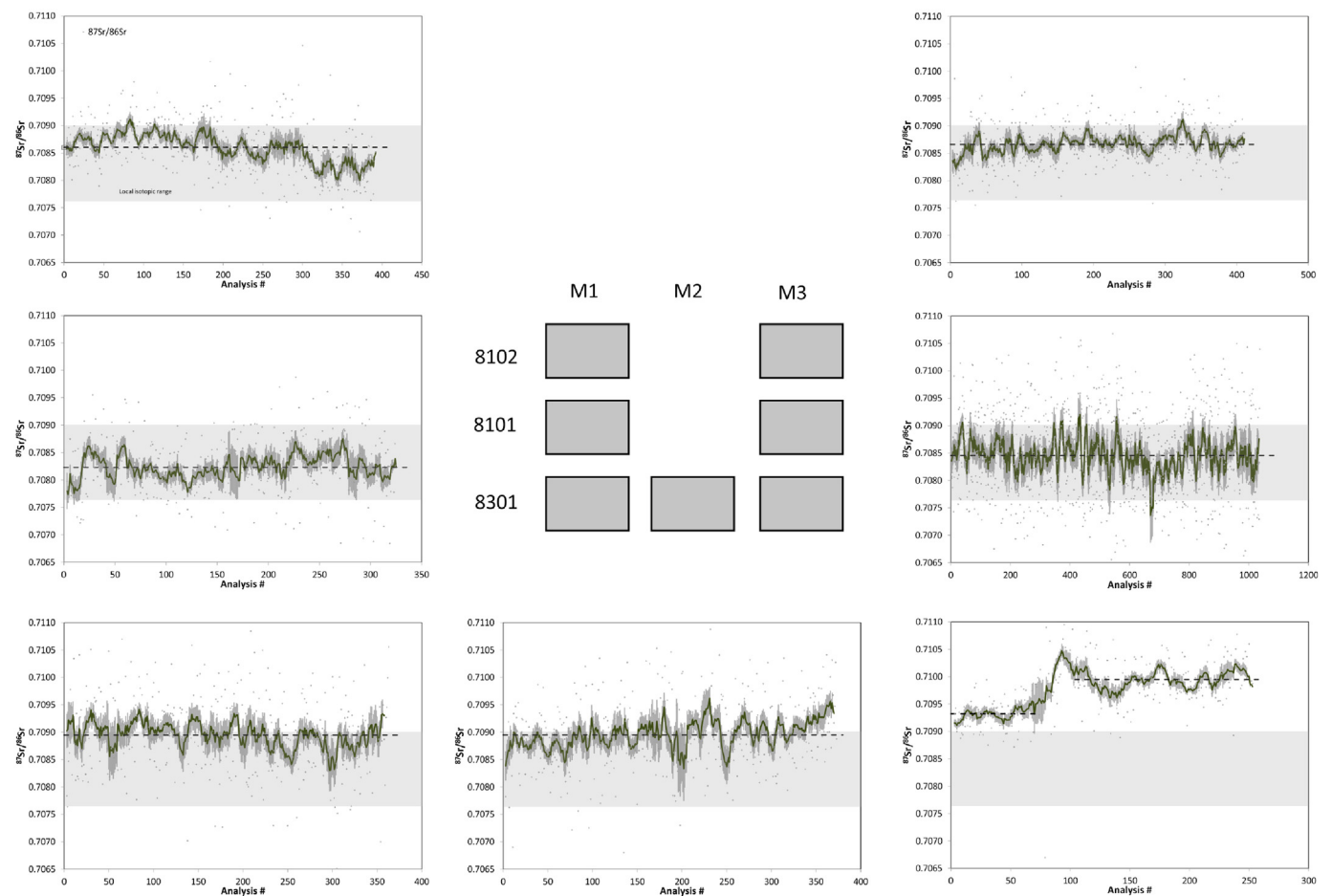
Fig. 12. Strontium isotopic profiles (10 point average) along the growth axis of molars from West Amesbury Farm. The ages at which the enamel begins to mineralize are given in Table 5, though there is some uncertainty as to the rate at which mineralization proceeds. The timescales represented by the Sr profiles are therefore uncertain, though they must obviously commence after the initiation of the crown formation. The grey area represents the estimated local Sr isotopic range and the broken line represents the mean Sr isotopic value of the enamel.

Table 5
Measured $\delta^{18}O$ in dental enamel carbonate (c) with the equivalent phosphate (p) and drinking water (dw) values. Typical measurement uncertainty $\pm$ 0.2‰.

Skeleton	Tooth	Approx. age of enamel mineralization (years)[a]	$\delta^{18}O_{c, \text{ VMSOW}}$ ‰	$\delta^{18}O_{p, \text{ VMSOW}}$ ‰	$\delta^{18}O_{dw,}$ ‰ (Longinelli, 1984)	$\delta^{18}O_{dw,}$ ‰ (Daux et al., 2008)
8102	Right mandibular M1	0.33–3.5	25.19	16.32	−9.34	−9.02
8102	Right mandibular M3	8.5–13.5	26.15	17.31	−7.81	−7.30
8101	Left mandibular M1	0.33–3.5	26.38	17.55	−7.46	−6.90
8101	Right mandibular M3	8.5–13.5	26.40	17.56	−7.43	−6.87
8301	Left maxillary M1	0.33–3.5	27.49	18.69	−5.70	−4.91
8301	Right maxillary M2	2.5–8.5	26.82	18.00	−6.76	−6.11
8301	Right mandibular M3	8.5–13.5	26.20	17.36	−7.74	−7.22

[a] Taken from AlQahtani et al. (2010).

of the M1 of 8102 (16.32‰) is more depleted than the M3 (17.31‰), and falls outside the range expected for southern Britain. If we take the drinking water equivalents as accurate, this value (< −9‰) is not represented in Britain (Supplementary Report 4: Fig. 5). The $\delta^{18}O_p$ is closer to the values found in the Early Bronze Age Amesbury Archer ($\delta^{18}O_p = 16.2$‰) where a central European origin was proposed (Fitzpatrick, 2013). While the phosphate equivalent M1 value of individual 8102 still falls at the extreme of those reported for a large dataset of UK individuals (16.3–19.1‰ at 95% confidence, Evans et al., 2012), statistical treatment of a second dataset of 261 Chalcolithic and EBA individuals suggest $\delta^{18}O_p$ values < 16.6‰ reflect an origin outside Britain (Pellegrini et al., 2016). Therefore, a Continental origin for this individual is highly probable. Interestingly, the M3 of 8102 shows

oxygen and strontium consistent with the southern British chalk, so this individual had moved by the time of M3 enamel mineralization (i.e. approximately 8.5–13.5 years). The M1 of Middle Neolithic burial 8301 is the most enriched in ^{18}O, with drinking water equivalents between about −5 and −6‰. These enriched values must be to the west, in either Cornwall, Devon, south Wales or Ireland (Supplementary Report 4: Fig. 5) though the strontium isotopes suggest relatively non-radiogenic geology which rules out most of Cornwall and north and central Wales. Intriguingly, the dentine carbon and nitrogen stable isotope ratios of 8301 were atypical for England, but consistent with Irish values. Although $\delta^{15}N$ and $\delta^{13}C$ bear a much less direct relationship to location than do $^{87}Sr/^{86}Sr$ or $\delta^{18}O$, it is possible that this individual spent at least some of his childhood and early adult life in Ireland (the
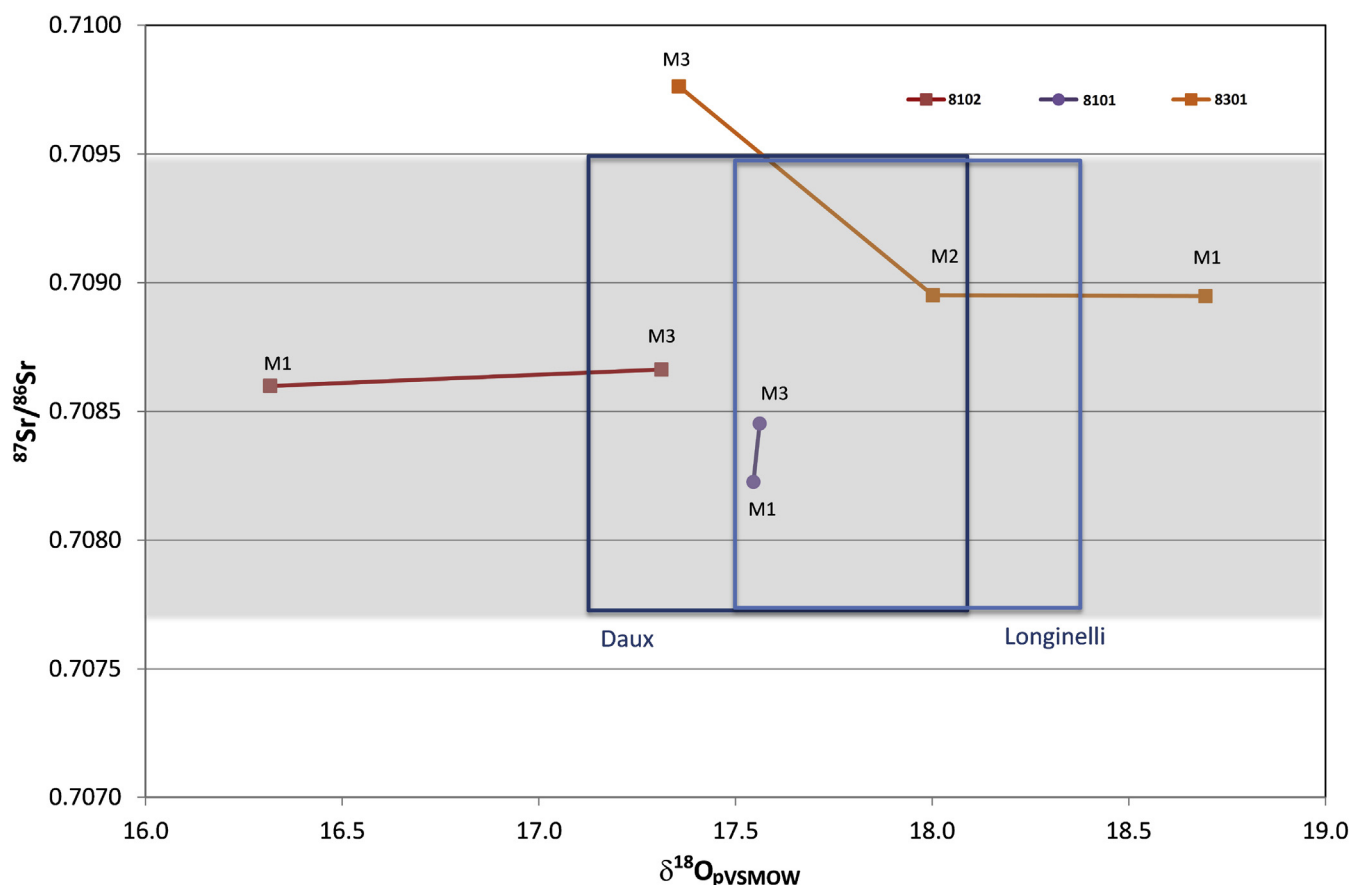
Fig. 13. Measured strontium (mean values of profiles) and oxygen isotopes in the teeth from West Amesbury Farm compared to 'local' values for the Wiltshire chalk (boxed). Local oxygen values are calculated as the phosphate equivalent values of −6.0 to −7.5‰ drinking water.

dental enamel $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values are both consistent with a childhood in Ireland (Supplementary Report 4: Fig. 5; Snoeck et al., 2016)).

The overall picture therefore is of individuals with very different origins, one from the east, possibly as far as central Europe (8102) one from the chalk of southern Britain (8101) and another (8301) from further west, possibly Ireland. Middle Bronze Age individuals 8102 and 8101 had terrestrial C_3 diets, and $\delta^{13}C$ and $\delta^{15}N$ values similar to individuals analysed for the Beaker People Project (Parker Pearson et al., 2016). The Middle Neolithic individual (8301) also appears to have had a predominantly C_3 diet, though with some evidence of a canopy effect. The elevated $\delta^{15}N$ suggest that pigs or freshwater fish may have been important protein sources.

4.5. Dental calculus

Metaproteomic analysis of dental calculus revealed the presence of oral bacteria, and human and dietary proteins (Supplementary Report 5). All three individuals analysed displayed the presence of the milk whey protein beta-lactoglobulin, a robust biomarker for dairy consumption (Warinner et al., 2014a). The identified beta-lactoglobulin peptides for the Middle Neolithic individual 8301 could be taxonomically assigned to the sub-family Bovinae (including cattle and water-buffalo) milk. In the Middle Bronze Age individuals, the beta-lactoglobulin peptides could be taxonomically assigned as sheep milk (*Ovis* sp.) in 8101, while in 8102 distinct peptides were consistent with both sheep milk (*Ovis* sp.) and the sub-family Bovinae milk, indicating the consumption of milk from two different species by this individual. In 8101 and 8301, dietary micro debris retrieved from the calculus points to the presence of carbohydrate foods in the form of starch

granules, potentially belonging to the tribe Triticeae (cereals) and Fabeae (legumes). It must be stressed, however, that such tribes of important food plants, mainly known for their domesticated crops, also have a number of wild species native to Britain (e.g. Stace, 2010: 1053) as well as continental Europe, and secure identification as either wild or domestic form was not possible. In the case of the Tribe Fabeae, vetches (*Vicia* spp.) could be a possibility due to their known presence in British Flora (Stace, 2010: 157–163). Nevertheless, as individuals may be highly mobile, it is not possible to establish where such plants were consumed, and thus narrow down their area of origin. Individual 8102 also yielded starch granules, but their condition precluded identification. In 8301, evidence for the consumption of hazelnuts was found in the form of plant tissues from the nut. Individual 8301 also provided evidence for bast fibres, with nettles being the most likely origin. Nettles provide useful fibres, so these remains may be a result of fibre processing. Other micro-particles of environmental origin were also retrieved from all three individuals, in the form of low amounts of birch pollen, micro-charcoal and soot. These latter may reflect exposure to smoke/soot and/or the ingestion of burnt food particles (Radini et al., 2017).

5. The osteobiographies

Middle Bronze Age individuals 8101 and 8102 may have been contemporaries who knew one another. **8102** may have spent his early years in central Europe, but had moved to an area isotopically consistent with the chalkland of southern England by late childhood. Sometime during his childhood, probably before coming to the Stonehenge area, he suffered from anaemia sufficiently severe to have left a mark on his bones. The cause is unclear, but in premodern

populations, chronic blood loss due to heavy intestinal parasite burden is a common cause. Neither childhood nor adult diet showed any evidence for a marine protein source. His adult diet included both sheep and cow's milk, as well as unidentified plant foods. He probably died at around 30 years of age, having lived in the chalkland of southern England for up to about a decade and a half.

In contrast to 8102, individual **8101** was probably of local origin, and may have lived in southern England all his life. He suffered a fracture in his lower back, probably sometime in adolescence. It is unlikely that this injury troubled him during the prime of life, but it may have been a source of pain in his later years. Like 8102, there is no evidence for a significant marine protein source in his diet. In adulthood, he consumed cow's milk, likely together with some carbohydrate from species of cereals and legumes, although it is not possible to determine if these were cultigens, gathered or traded plant foods. As an adult, he was noticeably taller and of heavier build than 8102. He died when he was perhaps about 40 years old and was buried closely adjacent to 8102 who had shortly predeceased him.

Middle Bronze Age individual **8201** was an infant of unknown sex, who was either stillborn or who died immediately after birth. He or she was a close contemporary of 8101 and 8102 and was buried about 3 km away.

The Middle Neolithic individual **8301**, like his Middle Bronze Age successors, had a diet lacking significant marine foods. The foods he did consume may have come from a more heavily wooded environment than was the case for his Middle Bronze Age counterparts. By the Middle Neolithic, the Stonehenge landscape was already fairly open (Parker Pearson, 2012: 163–4, Hazell and Allen, 2013), but he may not have spent his younger years in this location – we make the tentative suggestion that he may have moved from Ireland, perhaps during his adult life. There is evidence that as an adult he consumed cow's milk, and this is consistent with faunal remains from West Amesbury Farm that suggest dairying (Worley et al., in preparation). However, the stable isotope data from 8301 suggest cattle and their secondary products are unlikely to have been his main protein sources – pigs or freshwater fish may have been more important. In adulthood, he also likely consumed hazelnuts and wild or cultivated cereals and legumes. He was probably in his 40s when he died.

6. Discussion

Mortuary practices form an arena for the expression of the identities of the deceased (Fowler, 2013). Middle Bronze Age individuals 8101 and 8102 were accorded inhumation burial at a time when cremation was the predominant archaeologically visible funerary practice (Brück, 2006), the main period of inhumation in round barrows having ended a century or two earlier (Bowden et al., 2015, 55). This may mean that aspects of the social identities of 8101 and 8102 were considered by those who buried them to have been sufficiently removed from most others in Middle Bronze Age society that they merited this fundamental difference in mortuary treatment. The location of the burials in a field boundary may also be significant. It has been suggested (Roberts et al., 2017) that field boundaries in this area during the Middle Bronze Age may have been a place of deposition for those whose social identities led to them being regarded as occupying liminal positions in society. There is an infrequent but repeated pattern of similar inhumation burials in field boundaries in the south Wiltshire area during the Middle Bronze Age (Ellis and Powell, 2008, 184–6; Wessex Archaeology, 2015; Andrews and Thompson, 2016).

Although different from normative Middle Bronze Age practice, 8101 and 8102 were buried in very similar ways to one another. Their bodily positions in their graves were similar, the graves lay close together, and the later burial has one upper limb extended toward the earlier one. This similarity in funerary treatment is despite the likely differences in ancestry and geographic origin (key components of ethnicity) of these two individuals. It should be recalled that interment is

merely the final episode in what may have been a complex series of ritual acts that comprised funerary treatment, and that the differences in ethnicity may have been marked by differences in those ceremonies. Nevertheless, it would seem that aspects of identity that 8101 and 8102 shared in common rather than what separated them, were held to be more important in determining the manner of deposition of their bodies. What were these aspects of identity that separated 8101 and 8102 from others, and which they shared? Given the myriad factors that determine social identities, it is of course impossible to provide a definitive answer. However, the osteological study does raise one possibility. These two individuals resembled one another in cross-sectional morphology of the tibiae, morphologies that suggested a more mobile lifestyle than is likely in other prehistoric individuals from the area (although the paucity of Middle Bronze Age inhumations makes closely controlled chronological comparison difficult). Because the tibial cross-sectional data from both burials were similar, this mobility does not seem to be a function of 8102's migration from Continental Europe to Britain. Mobility may have occurred mainly within the chalklands of southern Britain, although because dental enamel only records childhood/adolescent and not adult location, this is not certain. The Middle Bronze Age has recently been characterised as a time of transition back to arable farming, with the development of relatively more permanent, sedentary communities that this implies (Stevens and Fuller, 2012, 2015; Bowden et al., 2015; Pelling et al., 2015). However, this generalisation does not exclude the possibility that there was a diversity of subsistence at that time, with some groups, or some members of some communities, continuing to pursue a more mobile lifestyle. The presence of plant remains in the dental calculus from 8101 and 8102 (identified as cereal and legumes in the case of the former) does not necessarily contradict this interpretation; these remains may be gathered rather than cultivated foods, and even if the latter, more itinerant groups may have obtained cultivated foodstuffs via trade with more settled arable farming communities.

Burial 8201, the Middle Bronze Age perinatal infant, was also inhumed rather than cremated and was interred in a boundary ditch. Ethnographic evidence (Ucko, 1969; Woodburn, 1982) shows that the very young often receive differential burial treatment from that normally accorded to older individuals - in many societies infants occupy a liminal social position, yet to be fully incorporated into human society. Although it may not have been very unusual in this part of Wessex to place infants in boundary features during the Middle Bronze Age (Roberts et al., 2017), given the numbers found, it is unlikely that this was the normative mortuary treatment for them. It therefore seems unlikely that the place and manner of burial simply reflect 8201's identity as a very young individual. Its seems likely that the disposal of the body in this way was at least in part because he/she was considered to hold social identities more in common with 8101 and 8102 than with infants accorded cremation or other means of disposal. The burial treatment of this infant may reflect the marginal position of his immediate family or of the wider kin or social group to which he belonged.

A recent study (Neil et al., 2016) used isotopic data to argue for the existence of residentially mobile populations in the Early Neolithic of southern Britain. Those authors proposed a 'tethered mobility' model, in which people moved between favoured occupation sites within a fairly restricted geographic area. If we are correct that 8301 spent large part of his life in Ireland, then this implies a rather greater degree of mobility for him. He died a century or two (75–305 years (95% probability) probably 130–240 years (68% probability); distribution not shown) earlier than the individuals whose cremated remains were deposited in the Aubrey Holes as part of the earliest phase of activity on the site of Stonehenge (Willis et al., 2016). Whilst the chronology is not certain, evidence from the re-excavation of Aubrey Hole 7 suggests it may have held a bluestone (Pitts, 2008), and 'bluestonehenge' beside the Avon at West Amesbury may also have been constructed during the first centuries of the 3rd millennium cal BC (Allen et al., 2016). These

suggest early contact with southern Wales given the origin of the bluestones (Parker Pearson et al., 2015b), but if we are correct that individual 8301 spent a large part of his life in Ireland this demonstrates earlier mobility from the west of the British Isles to the Stonehenge landscape.

Isotopic analysis of 68 individuals with Early Bronze Age Beaker associations, dating to ca. 2500–1500 cal BC, recovered from the southern English chalklands (mainly Wiltshire), showed that at least 23 (34%) had non-local origins (Parker Pearson et al., 2016: Table 1). There are indications that some individuals in that dataset, including those buried in the Stonehenge area, may have originated from beyond Britain (discussed in Mays, 2013). The importance of the current results is that they suggest that people were drawn to this landscape from far afield, and were selected for burial here, not only during the phases of monumentalisation, but both before Stonehenge's construction and after it ceased to be structurally modified. A monument undergoing active construction or alteration may not have been the only 'pull' factor drawing people to this landscape in later prehistory.

7. Conclusions

Physiologically, bones and teeth respond to disease and other environmental variables in limited ways. Skeletal morphology is a result of a complex array of genetic and non-genetic factors. Isotopic composition of bones and teeth is under-determined by geographic location and diet. This means that a range of scenarios may be consistent with any one particular set of results. This makes constructing narratives of individual lives very difficult. In this work we have tried to build narratives that seem plausible, but we are aware that the interpretations presented here are not the only ones that are possible.

A role of osteobiography within a biocultural approach to burial archaeology is to help provide narratives for individual lives, which can shed light on social identities of past people. To be most effective, osteobiography often requires combining different types of skeletal evidence. Typically these comprise osteological and isotopic data (e.g. papers in Stodder and Palkovich, 2012), but the current study demonstrates the value of incorporating dental calculus analyses that can yield complementary information on ancient diets and living environments. Osteobiographical evidence can usefully be integrated with analysis of mortuary practices, which form an arena in which social identities of the deceased may be displayed and manipulated by those that buried them. In the current study, two closely contemporaneous Middle Bronze Age burials, of adults who probably differed in ancestry, geographic origin and appearance, were nevertheless buried in similar ways. Why they were treated in a way that resembled one another but was very different from the normative archaeologically visible funerary treatment of cremation is uncertain, but the osteobiographical approach did at least suggest one possibility: that they shared a rather mobile lifestyle which differentiated them and their social group from more settled arable farming communities.

The relationship between osteobiographic and population-based skeletal studies is synergistic. In order to aid interpretation of data for individuals, and construct plausible osteobiographies, it is usually necessary to set the results for the individuals of interest in the context of data from broader, population-based studies. Conversely, osteobiography can aid population-based studies by helping us to guard against unwarranted assumptions concerning the integrity of pooled data. Because of the nature of the burial record, population-based studies in British prehistory inevitably require the combining of data from temporally and geographically separated skeletons in order to build up workable numbers. This runs the risk of combining groups who may have had rather diverse origins, diets and lifestyles. An osteobiographical approach may help to bring out differences in individual lived experience, and may help to make us more aware of the potential in our data sets for heterogeneity and diversity.

Since the advent of isotopic studies of residential mobility about

20 years ago, we are getting used to the idea that, even after the introduction of farming, prehistoric populations were rather mobile in the landscape. We are now beginning to progress toward testing hypotheses concerning which particular models of residential mobility may be most appropriate at different times and in different places (e.g. Neil et al., 2016; Parker Pearson et al., 2016). The current work suggested a different pattern of residential mobility for one Middle Neolithic individual than that recently inferred for an Early Neolithic southern British population. It would be interesting to investigate whether this is a temporal pattern that applies more generally. We made the case here that these two Middle Bronze Age adults may have had more mobile lifestyles than has been envisaged as being typical at that time. This suggests the possibility of a diversity of lifestyles during that period, but this is clearly a hypothesis that requires further analysis of skeletal data (perhaps including study of cross-sectional properties of longbones) to evaluate it. These observations illustrate that although it is not suited to hypothesis testing, the osteobiographic approach is potentially useful in the formulation of hypotheses that can then be tested in more synthetic, population-based studies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2018.06.008.

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