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New evidence for diverse secondary burial practices in Iron Age Britain: A histological case study

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ABSTRACT

Iron Age (c. 700 BC–43AD) funerary practice has long been a focus of debate in British archaeology. Formal cemeteries are rare and in central-southern Britain human remains are often unearthed in unusual configurations. They are frequently recovered as isolated fragments, partially articulated body parts or complete skeletons in atypical contexts, often storage pits. In recent years, taphonomic analysis of remains has been more frequently employed to elucidate depositional practice (e.g. Madgwick, 2008, 2010; Redfern, 2008). This has enhanced our understanding of modes of treatment and has contributed much-needed primary data to the discussion. However, only macroscopic taphonomic analysis has been undertaken and equifinality (i.e. different processes producing the same end result) remains a substantial obstacle to interpretation. This research explores the potential of novel microscopic (histological) methods of taphonomic analysis for providing greater detail on the treatment of human remains in Iron Age Britain. Twenty human bones from two Iron Age sites: Danebury and Suddern Farm, in Hampshire, central-southern Britain were examined and assessed using thin section light microscopy combined with the Oxford Histological Index (OHI). Results suggest that diverse mortuary rites were practised and that different configurations of remains were subject to prescribed, varied treatment, rather than resulting from different stages of the same process. Practices that may be responsible for these patterns include exhumation followed by selective removal of elements and sheltered exposure prior to final burial. Only one sample provided evidence for excarnation, a practice that has been widely cited as a potential majority rite in Iron Age Britain.

1. Introduction

Variation in the character of human remains recovered from British Iron Age sites suggests that the dead were subject to a diverse range of mortuary rites (Whimster, 1977, 1981; Wait, 1985; Cunliffe, 1988; Stead, 1991; Darvill, 2010). Unburnt human bones are most often recovered in varying states of articulation from storage pits and other non-funerary features within settlements and hillforts and rarely from discrete burial grounds (Whimster, 1981; Wait, 1985; Stead, 1991; Darvill, 2010). Formal cemeteries are largely absent from central-southern Britain, an area that clearly sustained a substantial population, with widespread settlement and relatively intensive agricultural production during the Iron Age (Sharples, 2010). The numbers of human remains can only account for a fraction of the individuals that occupied these sites, and it is likely that the practices represented do not reflect the rites afforded to the majority of the dead, which may not have left an archaeological record (Wait, 1985; Bradbury et al., 2016). Wait (1985: 90) suggested that an archaeologically visible rite was practised for only 6% of individuals in the early/middle Iron Age. The diverse, fragmentary and limited evidence for funerary ritual in Iron Age Britain has led to considerable debate on the majority rite and the modes of treatment for the minority that are represented archaeologically (Ellison and Drewett, 1971; Wilson, 1981; Wait, 1985; Hill, 1995; Carr and Knüsel, 1997; Craig et al., 2005; Carr, 2007; Madgwick, 2008; Tracey, 2012).

Excarnation through sub-aerial exposure, followed by disturbance and selective retrieval of skeletal elements represents the dominant interpretation of disarticulated and partially-articulated human bones (Stead, 1991; Carr and Knüsel, 1997; Craig et al., 2005; Knüsel and Outram, 2006; Redfern, 2008; Darvill, 2010). In strict terminology, excarnation refers to flesh removal (by any

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means) but throughout this article it refers specifically to flesh removal through sub-aerial exposure, as is generally the case in archaeological literature. Excarnation might account for the dearth of human bones and may therefore have been the majority rite, as the weathering promoted by prolonged exposure would eventually destroy all physical remains (Redfern, 2008). Disposal in aqueous environments has been suggested as an alternative explanation for the majority rite (Madgwick, 2008; Sharples, 2010: 272). Analysis of surface modifications in Iron Age human bones from Danebury hillfort and Winnall Down enclosure in Hampshire indicates that the human assemblage was unlikely to have been produced by sub-aerial exposure (Madgwick, 2008). The sparse surface modification of the human bones suggests that they had not been exposed for long periods. However, small numbers of modified bones at Gussage-all-Saints and Maiden Castle, Dorset, have been taken as evidence for excarnation (Redfern, 2008). In both cases there is evidence that bodies decomposed in a primary depositional environment before selected skeletal elements or body parts were moved to a new context (secondary deposition). Whether excarnated or not, there is clear evidence for formalized treatment of human remains, as part of a suite of prescribed depositional practices (Hill, 1995; Madgwick, 2010; Sharples, 2010).

Labile skeletal elements, such as those of the hands and feet, disarticulate rapidly during bodily decomposition. Therefore, most skeletons recovered in complete anatomical articulation, can be assumed to represent bodies that were buried soon after death and not subject to post-depositional disturbance (Duday, 2006). A far broader range of processes may have been involved in the production of disarticulated or partially articulated human bone assemblages (e.g. excarnation, exhumation, disturbance, cannibalism). Specific taphonomic methods of analysis such as bone surface modification and skeletal part representation have been used to discriminate between different formation mechanisms, but they provide only a limited suite of information (see Carr and Knüsel, 1997; Craig et al., 2005; Knüsel and Outram, 2006; Redfern, 2008; Madgwick, 2008, 2010). Therefore there is still considerable uncertainty regarding the specific funerary rites practised by British Iron Age populations, as well as the degree of variability in practices within and between sites.

Understanding of Iron Age burial practices has been complicated by issues of equifinality. Therefore new lines of enquiry are required to improve interpretative resolution.

1.1. Taphonomic analysis of bone microstructure

Microscopic analysis of taphonomic modifications of bone microstructure has substantial potential for providing greater detail on the depositional treatment of remains and no research on British Iron Age populations has yet been published. Microscopic bioerosion, consisting of ‘micro-foci of destruction’ (MFD), is the most common form of diagenesis found in archaeological bone (Hackett, 1981; Turner-Walker et al., 2002). Three types of MFD (linear longitudinal, budded and lamellate) are associated with bacteria and represent the predominant form of bioerosion (Hackett, 1981; Balzer et al., 1997; Jackes et al., 2001; Turner-Walker et al., 2002). A fourth type of MFD, Wedl tunneling, relates to fungal attack from external sources in the depositional environment (Marchiafava et al., 1974; Hackett, 1981; Fernández-Jalvo et al., 2010).

The preservation of the internal bone microstructure does not correspond with the external condition of the bone and represents a distinct source of taphonomic information (Hedges et al., 1995; Hedges, 2002; Jans et al., 2004). Experimental studies of bacterial bioerosion in bone have suggested that it is an early taphonomic process, mostly confined to the first decade after death (Bell et al., 1996; Boaks et al., 2014; White and Booth, 2014). The extent of bacterial tunneling is unrelated to the chronological age of an archaeological bone and the diagenetic signature of early post-mortem bioerosion persists through deep time in environments where bone preserves (Hedges et al., 1995; Hedges, 2002; Jans et al., 2004; Turner-Walker, 2012). Microscopic analyses of ancient bone diagenesis have proven useful in discriminating between bones with variable taphonomic histories (Turner-Walker and Jans, 2008; Hollund et al., 2012; van der Sluis et al., 2014). However, microscopic methods have rarely been used to address questions surrounding funerary treatment (Parker Pearson et al., 2005).

Efforts to determine the specific processes that control bioerosion have been hampered by inexplicable variation in bacterial attack, particularly within and between skeletal elements (Hanson and Buikstra, 1987; Nicholson, 1996; Nielsen-Marsh and Hedges, 2000; Jans et al., 2004). This variation is still not properly understood, but evidence suggests it relates to differences in ratios of cortical and trabecular bone within and between skeletal elements (Hanson and Buikstra, 1987; Jans et al., 2004; Booth, 2014). Variation in bioerosion within archaeological bones from burial contexts that inhibit bacterial activity (e.g. anoxic or waterlogged sediments) will reflect environmental fluctuations rather than specific mortuary events (Turner-Walker and Jans, 2008; Hollund et al., 2012; van der Sluis et al., 2014). However, outside of these specific environments, the appearance and severity of bacterial bioerosion in archaeological and modern bone has been broadly linked to early taphonomic events. For instance, butchered archaeological bone is often free from bacterial bioerosion, whereas bone from complete articulated skeletons has usually been extensively tunneled by bacteria (Jans et al., 2004; Nielsen-Marsh et al., 2007; White and Booth, 2014; Booth, 2015). Several large-scale studies focused mainly on archaeological long bone shafts have replicated these results, suggesting that there is usually no significant variation in bioerosion within compact diaphyseal bone of the same element (Jans et al., 2004; Nielsen-Marsh et al., 2007; Booth, 2014, 2015). Micro-CT scans of archaeological infant human remains produced by one of the authors (Booth, in prep) show that the extent of bacterial bioerosion does not vary significantly across femoral diaphyses.

Bones from modern excarnated corpses exhibit limited or no bacterial tunneling (Bell et al., 1996; Fernández-Jalvo et al., 2010; White and Booth, 2014). These findings indicate that bacterial attack in archaeological bone will reflect processes that affect the degree of early bacterial soft tissue decomposition. Butchered bones would have been exposed to little, if any, soft tissue decomposition. Excarnated bodies are rapidly skeletonised by vertebrate and invertebrate scavengers within a few months, limiting bone exposure to soft tissue putrefaction. Burial protects the body from rapid skeletonisation, ensuring the bones are subject to prolonged bacterial attack over a number of years (Rodriguez and Bass, 1983, 1985; Bell et al., 1996; Campobasso et al., 2001; Dent et al., 2004; Vass, 2011).

This link between bone bioerosion and soft tissue decomposition provides strong evidence that non-Wedl MFD are produced by an organism's enteric gut microbiota. These bacteria transmigrate around a cadaver in the first few days after death and go on to permeate the bone microstructure (Child, 1995a, 1995b; Gill-King, 1997; White and Booth, 2014). They are largely responsible for the early putrefaction stage of soft tissue decomposition (Child, 1995b; Bell et al., 1996; Gill-King, 1997). Recent studies of modern and archaeological bone have established that putrefactive bacteria are a principal cause of non-Wedl MFD (Jans et al., 2004; Nielsen-Marsh et al., 2007; Boaks et al., 2014; White and Booth, 2014). There is still debate on the role of soil bacteria, which may produce similar patterns of bioerosion (Turner-Walker, 2012), but a growing body of evidence supports the dominant impact of endogenous gut bacteria (Bell et al., 1996; Jans et al., 2004; Guarino et al., 2006; Nielsen-Marsh et al., 2007; Boaks et al., 2014; White and Booth, 2014).

Most European archaeological bones retrieved as part of complete inhumed skeletons demonstrate extensive bacterial bioerosion, as the majority rite of immediate burial over the last two millennia (Jans et al., 2004; Nielsen-Marsh et al., 2007; White and Booth, 2014; Booth, 2015). Although climate and seasonality impact on soft tissue decomposition, evidence indicates that they do not substantially affect bone bioerosion in temperate environments (Campobasso et al., 2001; Vass, 2011; Booth, 2015). Variation in bacterial attack is therefore generally best explained by different modes of pre-depositional treatment and consequently histological preservation is useful for detecting divergent taphonomic trajectories related to early bodily decomposition (Nielsen-Marsh et al., 2007; Hollund et al., 2012; van der Sluis et al., 2014; Booth, 2015). This study explores the potential of assessing microscopic diagenesis of human bone alongside macroscopic taphonomic evidence to reconstruct mortuary practice in a sample of individuals from the British Iron Age sites of Danebury and Suddern Farm, Hampshire, UK. This study was designed to address the following questions:

Can variation in bone bioerosion be observed that is best explained by differential post-mortem treatment?

How many separate mortuary practices appear to be represented when the results are combined with accompanying taphonomic information?

Is it possible to interpret the results alongside other taphonomic analyses to make inferences about specific treatment of the dead at these sites?

2. Materials and methods

2.1. The sites

The Danebury assemblage was an ideal choice for the current study as the configurations and contexts of the human remains were typical of southern British Iron Age settlement sites and have been suggested to reflect variable forms of mortuary treatment (Cunliffe, 1984). In addition, one of the authors (RM) had previously performed extensive macroscopic taphonomic analysis of this assemblage, providing a useful complementary dataset. Human remains from Suddern Farm were included in the study, as they formed part of the same collection and might add to the potential variation in post-mortem treatment. These burials may represent a different funerary practice from individuals from Danebury, as they were recovered from a more formal inhumation cemetery (Cunliffe and Poole, 2000).

Danebury is the most comprehensively excavated hillfort in Britain and is located near Nether Wallop, Hampshire (Fig. 1). The main excavations were conducted by Cunliffe (1984, 1991) between 1969 and 1988. The hillfort consisted of a 5 ha settlement surrounded by ramparts and ditches. It was occupied from approximately 550 BC. and largely abandoned around 100 BC.

Over 300 deposits of human remains have been recovered from Danebury (see Walker, 1984; Cunliffe and Poole, 2000; Sharples, 2010; after Cunliffe, 1995). These were recovered in various states of articulation as part of single and multiple burials from various features dispersed around the settlement (Walker, 1984: 443). Human remains were associated with all phases of activity, although most dated to the later periods of occupation (Walker, 1984: 457). Much of the human bone had been deposited on top of a mixture of domestic refuse and chalk silt. Some of the bones were covered by a layer of natural silt, which suggested that pits had been left open whilst bodies decomposed (Walker, 1984: 448). The frequency of discrete depositions of crania and the common absence of the cranium from partially-articulated skeletons suggests selective retrieval and redeposition of this element (Walker, 1984: 164). The absence of cut mark evidence indicates that crania are likely to have been disarticulated through natural decomposition.

Suddern Farm is an Iron Age settlement located around 5 km to the west of Danebury. The site consisted of a medium-sized double or treble-ditched enclosure of 2.2 ha (Cunliffe and Poole, 2000). It was excavated in 1991 and 1996 as part of the Danebury Environs Project. Ceramic evidence indicated that the site was contemporaneous with Danebury. Excavation of a three-ditch linear earthwork identified to the southwest of the enclosure located a quarry that had been used as a cemetery from the Early to Middle Iron Age (c.700–100 BC). Human remains representing a minimum of 60 individuals were recovered (Hooper, 1984), but it is estimated that several hundred further burials are present in the quarry (Cunliffe and Poole, 2000). In contrast to Danebury, these remains were recovered from graves (or quarry pits) dug directly into the chalk rubble and silt, rather than from storage pits and ditches. This represents a rare example of something analogous to a formal cemetery in Wessex (outside of the Durotrigian cemeteries of Dorset, Fitzpatrick, 1997).

The skeletons from the Suddern Farm cemetery were recovered in various stages of articulation and were often accompanied by partial remains of several individuals (Cunliffe and Poole, 2000: 166). Excavation showed that grave cuts did not respect previous interments and the absence of crania indicated selective removal post-decomposition. Accumulations of natural silts within some graves suggest that they had been left open whilst bodies decomposed. Cunliffe and Poole (2000: 168) proposed that the individuals recovered from Suddern Farm had been buried complete and, subsequently, some had become partially disarticulated through disturbance by later grave-digging. By contrast, human remains from Danebury were interpreted as having been excarnated in open pits before body parts were selectively removed and buried. However, these interpretations are based on limited evidence and comparison of bacterial bioerosion has the potential to improve resolution.

2.2. Samples

Twenty human bones were sampled at Hampshire Museums Service collections in Winchester, UK. Skeletal element was controlled where possible. The femur is the most commonly-sampled element in studies of archaeological bone diagenesis as it survives well, is mostly composed of compact bone and is the closest long bone to the gut, which may mean that it is more sensitive to the activity of putrefactive bacteria (Jans et al. 2004). Femoral midshafts were sampled preferentially for the current study for these reasons and in order to produce comparable results (Nielsen-Marsh and Hedges, 2000; Jans et al., 2004; Hollund et al., 2012). The extent of bacterial bioerosion is usually consistent along femoral shafts (Booth, in prep). Sampling targeted remains that exhibited variable patterns of anatomical articulation on recovery (e.g. disarticulated elements, complete articulated skeletons, partially articulated parts of skeletons). These configurations of bones potentially signified diverse post-mortem processes and sampling across these categories represented an attempt to capture variation in post-mortem treatment. Danebury human bone deposits were classified into three categories: complete articulated skeletons, partially articulated deposits and discrete disarticulated bones.

Six bones from each category were chosen for sampling. One of the disarticulated bones could not be located and no equivalent remains were available, therefore a bone from an additional

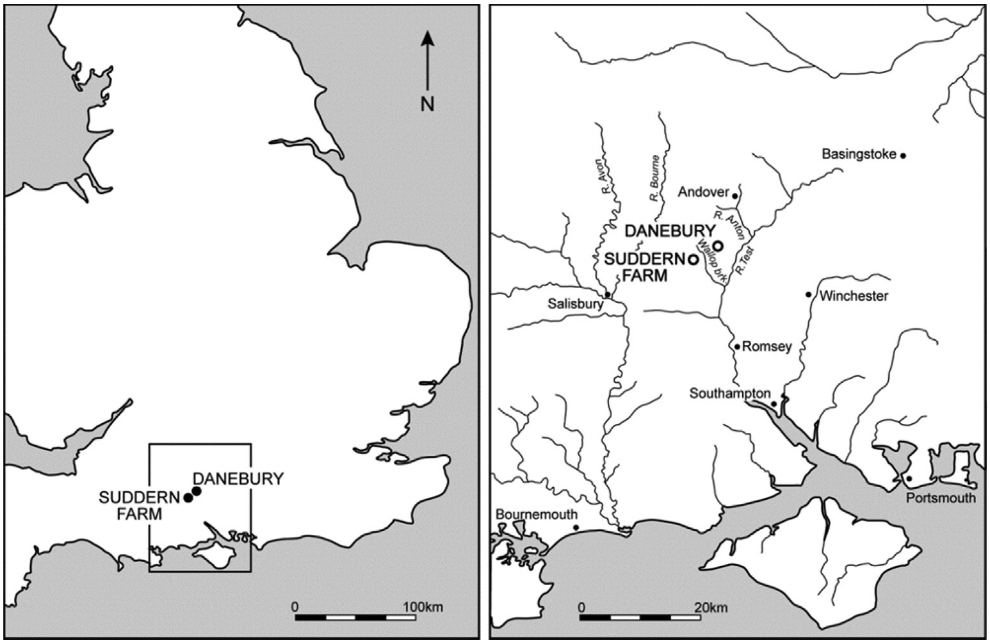

Fig. 1. Location map of the two sampled sites.

partially articulated skeleton was taken instead. The Suddern Farm skeletons were considered as a discrete category of post-mortem treatment. Two partially articulated skeletons were sampled from Suddern Farm. Sampling only two skeletons from the site cannot be considered representative and provides a very limited window into practices and potential variation with the Danebury deposits. However, histological data can at least hint at the potential for further research.

Left femoral midshafts were sampled preferentially to ensure that each sample represented a discrete individual. Right femora were occasionally sampled (e.g. when they had already been drilled for isotope analysis) but only from complete individuals or partially articulated remains when the antimere was present, with one exception. This disarticulated femur was checked against other selected left femora to ensure that none of the individuals had been sampled more than once. In addition, femora were unexpectedly absent from one deposit and therefore the left tibia was sampled and patterns of modification were carefully scrutinized to ensure results did not relate to inter-element variation. Long bone midshafts were sampled in all cases. It was beyond the scope of this study to address chronological variation in histological results. The majority of sampled bones dated to the middle and later ceramic phases (>5; the Middle and Late Iron Age). Details of the samples are provided in Table 1.

2.3. Thin section light microscopy

Samples (*c.* 1 cm by 1 cm) were cut from the mid-section of each long bone diaphysis using a Foredom K.1070 rotary saw. Transverse thin sections 50–120 microns thick were cut from these samples, without the application of an embedding agent, using a Leica 1600 diamond saw microtome. Each undecalcified and unstained thin section was mounted onto a glass slide using Entellan mounting medium and glass cover slip (Merck Chemicals). All thin sections were analyzed under normal and polarized light at 25, 40 and 100 times magnification using transmitted light binocular microscopes fitted with polarizing filters. All digital micrographs of bone thin sections were produced using an eye-piece mounted Lumera infinity digital microscopy camera in conjunction with Lumera Infinity Capture and Analyze software. Samples were also viewed using a polarizing filter to assess birefringence of adjacent lamellae, as an indicator of collagen loss (Hackett, 1981).

Bioerosion was assessed using the Oxford Histological Index (OHI) (Hedges et al., 1995; Millard, 2001). The OHI translates the percentage of remaining unaltered bone microstructure into an ordinal grade from 0 to 5, representing the worst and best preserved microstructure respectively. The OHI is subjective but has proven effective in numerous previous studies of bioerosion. Interobserver testing of the OHI by Hedges et al. (1995: 203) found that deviations in OHI score were insignificant and repeat assessments never differed by more than one unit. Microstructural studies of archaeological bone which have utilized several diagenetic parameters have consistently found that the OHI correlates with quantitative parameters of decomposition such as collagen content and preservation of DNA (Ottoni et al., 2009; Deviѐse et al., 2010; Sosa et al., 2013). The deposit number was written on each slide to identify the thin section, but other information, such as level of articulation, was not made available during histological assessment.

3. Results

Results of the histological analysis are presented in Fig. 2 and Table 2 and selected micrographs are presented in Figs. 3 and 4. All of the bone samples from Danebury and Suddern Farm exhibited destructive tunneling consistent with non-Wedl MFD (Table 2). This tunneling accounted for all significant variation in OHI scores. Histological preservation across the whole sample set was quite poor, but the extent of bacterial bioerosion was variable amongst lower OHI scores (Fig. 2). Four partially-articulated/articulated samples exhibited minor Wedl-type tunneling in areas of microstructure that were unaffected by bacterial attack. Wedl tunneling had never progressed to an extent where it affected OHI scores. The modal OHI score of the assemblage was 2, although there was also a notable peak at 0 (Fig. 4). A single anomalously well-preserved sample (sample 107, OHI = 5) exhibited only limited bacterial

Table 1
Details of human remains from Danebury and Suddern Farm sampled for thin section analysis. Modification information relates to the skeleton/part skeleton rather than the analysed element. Ceramic phases are best treated as an ordinal rather than absolute chronological scale. Absolute dates were originally suggested as: cp 1-3- 550–450BC, cp 4–5: 450–400BC, cp 6: 400–300BC and cp 7: 300–100/50BC (Cunliffe, 1984: 242; see Haselgrove, 1986: 364 for critique of absolute chronology and Cunliffe, 2013 for revised chronology).

Sample number	Feature	Layer	Deposit	Ceramic phase	Deposit type	Element	Modification	Age	Sex
101	10	–	72	6	Disarticulated	R. Femur	None	Adult	–
102	26	6	BG14	7	Disarticulated	L. Femur	Weathered (Behrensmeyer , 1978 stage 1)	Adult	–
103	120	5	7	8	Partially Articulated	L. Femur	Gnawed	~8	??
104	266	1	10	3	Partially Articulated	L. Tibia	None	20–30	F?
105	374	5	13	3	Articulated	R. Femur	None	~3	??
106	699	1	127	6	Disarticulated	L. Femur	Eroded (other modifications may be obscured)	Adult	–
107	761	2	130	8	Disarticulated	L. Femur	Weathered (Behrensmeyer, 1978 stage 2) & gnawed. Possibly burnt	Adult	–
108	829	2	29	6	Articulated	L. Femur	None	25–35	M
109	829	2	28	6	Articulated	R. Femur	None	25–35	M
110	923	6	40	7	Partially Articulated	L. Femur	None	25–30	F
111	923	6	37	7	Partially Articulated	R. Femur	None	16–20	F?
112	1015	6	46	7	Articulated	R. Femur	None	20–25	M
113	1078	6	162	7	Partially Articulated	R. Femur	None	Adult	M
114	1993	6	214	7	Incomplete skeleton	R. Femur	None	25–30	F
115	2044	2	275	6	Disarticulated	L. Femur	Gnawed	Adult	–
116	2100	2	248	3	Articulated	R. Femur	None	~35	F?
117	2447	5	239	7	Partially Articulated	L. Femur	None	18–22	M
118	2605	7	259	7	Articulated	R. Femur	None	>50	F
201	Suddern Farm	–	C19	–	Partially Articulated	L. Femur	None	~16	F
202	Suddern Farm	–	C20	–	Partially Articulated	L. Femur	None	~30	M

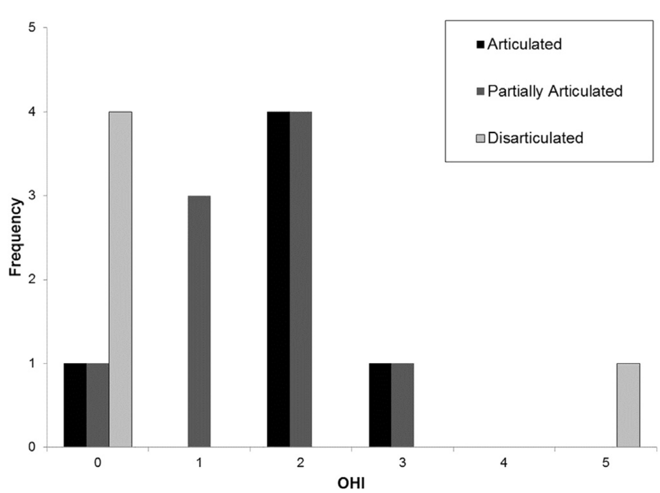

Fig. 2. Distribution of OHI scores in samples from Danebury and Suddern Farm separated by level of articulation.

tunneling.

Excluding sample 107, the histological preservation of the disarticulated bones was consistently very poor (Fig. 5). Macroscopic preservation was also poor, with one bone gnawed, one weathered and one both gnawed and weathered. In addition, one of the samples had suffered substantial subterranean erosion and therefore other modifications may have been overprinted. The two peaks at OHI scores of 2 and 0 were differentiated by articulation pattern, with most samples scoring 0 being disarticulated and all those scoring 2 being articulated/partially articulated (Fig. 2). Sample 107 was exceptional in the presence of severe cortical weathering (Behrensmeyer (1978) stage 2), and its unusually high OHI score further differentiated it from the rest of the sample set. The difference in OHI scores between the articulated/partially articulated and disarticulated bones was significant at 90% confidence ($n = 20$, Mann–Whitney $U = 19.00$, $p = 0.090$) and became significant at 95% confidence when the anomalous sample 107 was excluded ($n = 19$, Mann–Whitney $U = 4.000$, $p = 0.006$).

Loss of collagen birefringence in the majority of samples was associated with bioerosion. Sample 107 demonstrated reduced levels of collagen birefringence that was not associated with bacterial tunneling (Fig. 6). This sample alone also demonstrated consistent yellow discoloration. Intense microstructural staining can obscure bone microstructure and reduce collagen birefringence (Garland, 1987; Grupe and Dreses-Werringloer, 1993). However, the staining in the thin section of sample 107 was too weak to be responsible for the loss of birefringence. Collagen must have been lost from this bone via a non-biological mechanism for low levels of birefringence to be associated with well-preserved microstructure

Table 2
Results from the histological analysis of the Danebury and Suddern Farm human bone thin sections.'OHI' refers to Oxford Histological Index scores.

Sample number	Articulation	OHI	Wedl MFD	Collagen birefringence
101	Disarticulated	0	Absent	None
102	Disarticulated	0	Absent	None
103	Partially Articulated	2	Absent	Reduced/obliterated at sites of bioerosion
104	Partially Articulated	1	Absent	Reduced/obliterated at sites of bioerosion
105	Articulated	0	Absent	None
106	Disarticulated	0	Absent	None
107	Disarticulated	5	Absent	Reduced throughout section, even within unbioeroded areas
108	Articulated	2	Absent	Reduced/obliterated at sites of bioerosion
109	Articulated	2	Present	Reduced/obliterated at sites of bioerosion
110	Partially Articulated	2	Present	Reduced/obliterated at sites of bioerosion
111	Partially Articulated	2	Present	Reduced/obliterated at sites of bioerosion
112	Articulated	2	Present	Reduced/obliterated at sites of bioerosion
113	Partially Articulated	1	Absent	Reduced/obliterated at sites of bioerosion
114	Partially Articulated	1	Absent	Reduced/obliterated at sites of bioerosion
115	Disarticulated	0	Absent	None
116	Articulated	2	Absent	Reduced/obliterated at sites of bioerosion
117	Partially Articulated	0	Absent	None
118	Articulated	3	Absent	Reduced/obliterated at sites of bioerosion
201	Partially Articulated	3	Present	Reduced/obliterated at sites of bioerosion
202	Partially Articulated	2	Absent	Reduced/obliterated at sites of bioerosion

(see Smith et al., 2002, 2007).

4. Discussion

Environmental conditions that inhibit bodily decomposition (e.g. waterlogging, anoxic or arid contexts) can influence bacterial bioerosion (Turner and Wiltshire, 1999; Turner-Walker and Jans, 2008; Hollund et al., 2012; Booth, 2015), but there was no evidence for these conditions in the free-draining Hampshire chalkland. Considerable variation in bacterial attack was observed in the Danebury and Suddern Farm samples, despite all having originated from similar sedimentary matrices and some having come from the same context (Cunliffe, 1984; Cunliffe and Poole, 2000, Table 2). In common with previous studies, there was no evidence that variation in bacterial bioerosion was dictated by specific environmental factors (Jans et al., 2004; Nielsen-Marsh et al., 2007). Therefore variation is interpreted as resulting from patterns of mortuary treatment.

The OHI scores of the Danebury and Suddern Farm bone samples suggest that they had been exposed to variable levels of decomposition relating to their extent of articulation. At least three taphonomic trajectories are represented by articulated/partially articulated remains, isolated disarticulated skeletal elements and sample 107. Results suggest that each sub-sample represents a different form of funerary treatment, rather than all bones deriving from disturbed partially articulated/articulated deposits, as has been previously suggested (see Stanford, 1974: 220; Dunning, 1976: 116–117; Carr and Knüsel, 1997: 170). The exclusive appearance of Wedl tunneling in articulated/partially articulated bone and the non-biotic loss of collagen from sample 107 is also consistent in these sub-samples having divergent taphonomic histories. At a basic level therefore, the results of the histological analysis, considered alongside the accompanying taphonomic information suggest that the human remains deposited at Danebury had been subject to diverse funerary practices which produced distinctive patterns of articulation and microstructural bioerosion.

The associations between bacterial bioerosion and early post-mortem treatment represent central tendencies rather than absolutes. Therefore interpretations of processes responsible for the variation in bioerosion and skeletal articulation will be coupled with a degree of uncertainty. However, combining histological analysis with other taphonomic indices has the potential to disentangle some issues of equifinality in light of models of how bodies decompose under different circumstances. In discussing possible mortuary scenarios, equifinality remains a problem and consequently multiple interpretations must be considered. In short, whilst precise practices are very difficult to reconstruct with confidence, possible rites can be identified and others can be eliminated, thus improving the resolution with which Iron Age funerary practice is understood.

Histological preservation of disarticulated bone, with the exception of sample 107, was poor. This is somewhat surprising, as such poorly preserved histology is most often characteristic of fully articulated inhumed burials (Jans et al., 2004; Nielsen-Marsh et al., 2007). Partially articulated and disarticulated remains have previously been interpreted as evidence for excarnation (Ellison and Drewett, 1971; Carr and Knüsel, 1997; Cunliffe et al., 2015) and protected decomposition in either mortuary houses or subterranean environments (Madgwick, 2008). Excarnation is an unlikely scenario, as the rapid soft tissue degradation associated with this treatment substantially inhibits bacterial attack and seasonal variation in insect-mediated soft tissue loss could not account for differences (see Rodriguez and Bass, 1983, 1985; Campobasso et al., 2001; Fernández-Jalvo et al., 2010; Vass, 2011). This result is consistent with previous macroscopic analyses, which revealed only sparse modification evidence on disarticulated remains, also inconsistent with excarnation (Madgwick, 2008). However, some samples showed evidence of gnawing and weathering, indicative of some sub-aerial exposure, but this could have occurred at any point in the bones' taphonomic histories. Decomposition in mortuary houses is an unlikely explanation, as whilst structures can delay rapid soft tissue loss mediated by invertebrates, rates of skeletonisation in these types of environments are still more similar to those promoted by excarnation and would probably still be too rapid for putrefactive bacteria to completely degrade the histological bone structure (see Goff, 1991; Anderson, 2011). Bacterial bioerosion in the disarticulated samples is most consistent with primary burial of fleshed individuals and disinterment after the body had decomposed (see Nielsen-Marsh et al., 2007; Booth, 2015). For such poor preservation of the histological structure to be observed, the bodies must have been buried for several years prior to re-opening for the extraction of specific elements. Some remains may have then become accessible to scavengers and agents of weathering prior to incorporation into their final depositional

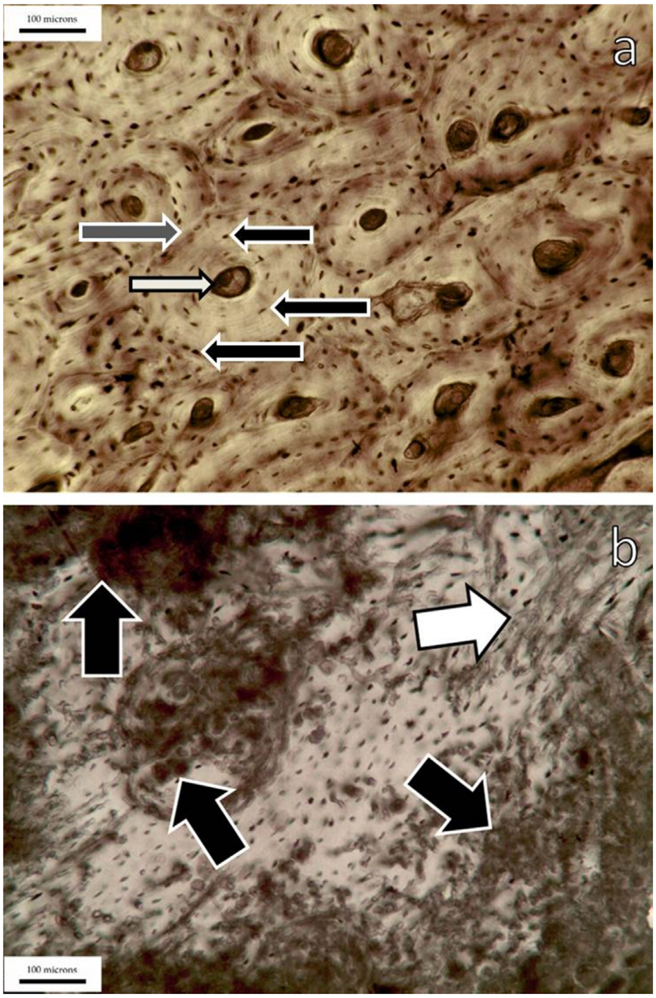

Fig. 3. a) Transverse micrograph of a fresh human femoral thin section from the collections of the University of Sheffield Department of Medicine and Biomedical Science under normal transmitted light exhibiting perfect histological preservation. Haversian canals (white arrow) and osteocyte lacunae (black arrows) can be observed within osteons (circular structures) defined by the cement or reversal line (grey arrow). b) Longitudinally-orientated non-Wedl tunneling (black arrows) and subtle, branched transverse-orientated Wedl-type attack (white arrow) in a transverse thin section under normal transmitted light from sample 109. Tunnels have a dark mottled appearance and obliterate osteocyte lacunae.

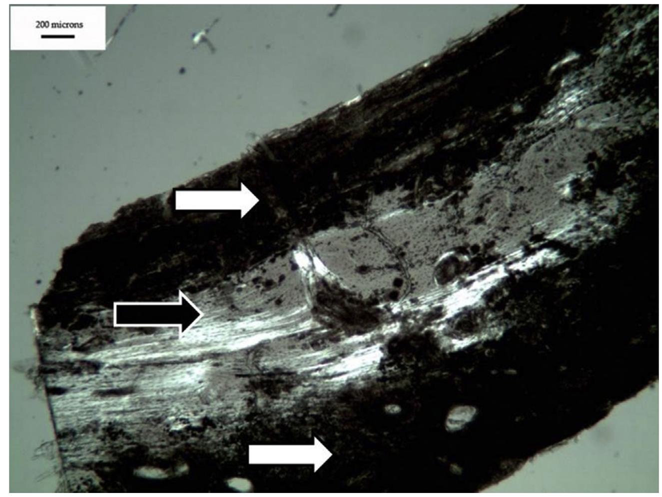

Fig. 4. Transverse thin section from sample 111 viewed under polarized light. A substantial fraction of the microstructure remains intact and birefringent (black arrow), whilst the rest of the section has been heavily bioeroded at the periosteal and endosteal surfaces (white arrows), leaving only Haversian canals. The thin section was allocated an OHI score of two, the modal score for the sample set.

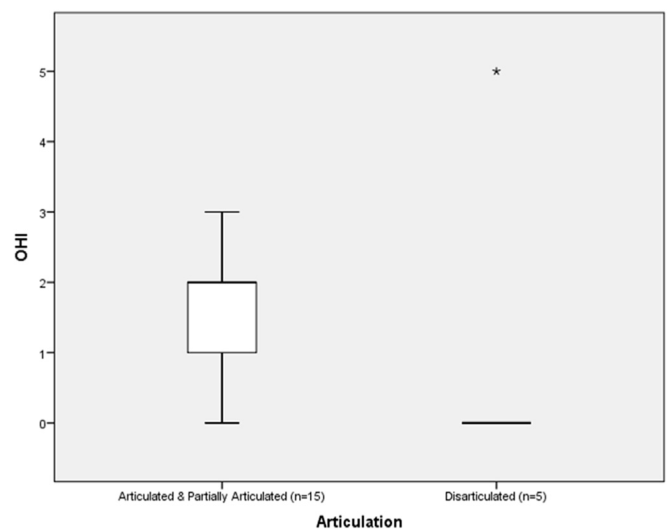

Fig. 5. Distributions of OHI scores in samples from Danebury and Suddern Farm grouped by extent of articulation. The outlying asterisk represents Sample 107.

setting.

The modal OHI score for the partially articulated/articulated samples was 2. This is atypical for archaeological human bone and inconsistent with exposure to extensive putrefaction associated with immediate burial (Jans et al., 2004; Nielsen-Marsh et al., 2007; White and Booth, 2014). This result is also inconsistent with minor levels of bioerosion associated with excarnation (Bell et al., 1996; Fernández-Jalvo et al., 2010; White and Booth, 2014). Results suggest more gradual exogenous degradation of soft tissue than would occur during excarnation, but more rapid than would occur if immediately buried. Although extensive experimental research has been undertaken on histological modification, none of the studies provides the range of scenarios of mortuary treatment that may have been employed in the Iron Age. However, the corpus of experimental data means that suggestions can be made concerning pre-depositional practices, which may be responsible for this pattern of evidence.

The histological preservation combined with lack of evidence for cut marks suggests partial disarticulation occurred through bodies being left to decompose within depositional environments, which reduced, but did not wholly prevent rapid soft tissue loss through insect activity. Depositional environments which promote this approximate pattern of decomposition include sheltered contexts such as structures or caves (Goff, 1991; Terrell-Nield and MacDonald, 1997; Anderson, 2011). Similar patterns of bioerosion were observed within Neolithic human remains that were most likely deposited as fleshed corpses in caves and megalithic monuments (Booth, 2015). The diagenetic signature of the articulated/partially articulated remains is therefore potentially consistent with primary deposition in a mortuary house. However, the completeness of some of these skeletons precludes secondary deposition, as this would cause considerable disarticulation.

As most of the partially articulated/articulated remains were in a good state of completeness, it is likely that they were recovered from their primary depositional context and therefore the best explanation is that bodies degraded in a state of partial exposure,

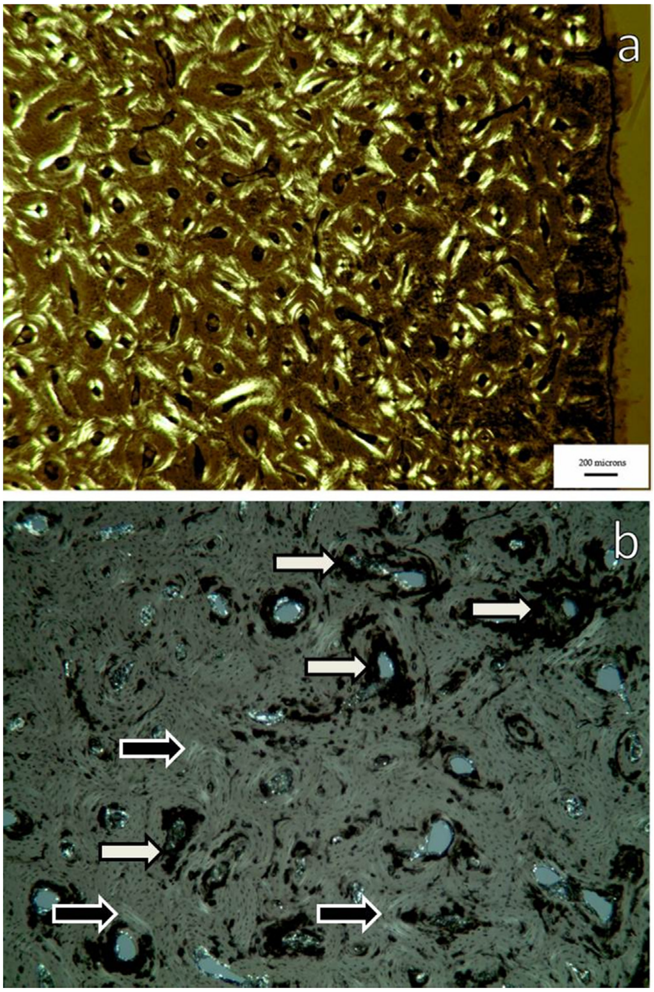

Fig. 6. a) Transverse femoral thin section taken from a fresh cadaver from the collections of the University of Sheffield Department of Medicine and Biomedical Science viewed under polarized light. Birefringence of circumferential lamellar bone surrounding Haversian canals is clearly visible as bright white striations. b) transverse femoral thin section from sample 107 viewed under polarized light. Minor bacterial tunneling can be observed around Haversian canals, which is accompanied by a loss of collagen birefringence (white arrows). However, collagen birefringence is also entirely absent or reduced (black arrows) in unbioeroded areas of bone where osteocyte lacunae are clearly visible, indicating non-biotic loss of collagen.

potentially in open, silting pits. This scenario is consistent with evidence for silt accumulation on burials at both sites (Cunliffe, 1984; Cunliffe and Poole, 2000) and *in situ* exposure has also been suggested by Tracey (2012). Bodies exposed in pits would still have been subject to relatively rapid skeletonisation by insects but the increased protection of a deep, steep-sided silting pit (Fig. 7) would reduce the speed of soft tissue loss, allowing bioerosion to commence, but not progress to completion. Exposure in a silting pit might also explain the very low levels of modification on the sampled remains and those that have been observed on a wider sample of human remains from Danebury (Madgwick, 2008, 2010), as weathering would be slow to progress and the bones would not be accessible to scavengers. Only a single partially articulated sample exhibited minor evidence of gnawing. Sub-aerial exposure of bodies in pits, followed in some cases by selective retrieval of body parts and burial before complete decomposition, provides a plausible explanation for the patterns of microscopic and macroscopic preservation observed in the articulated/partially articulated samples.

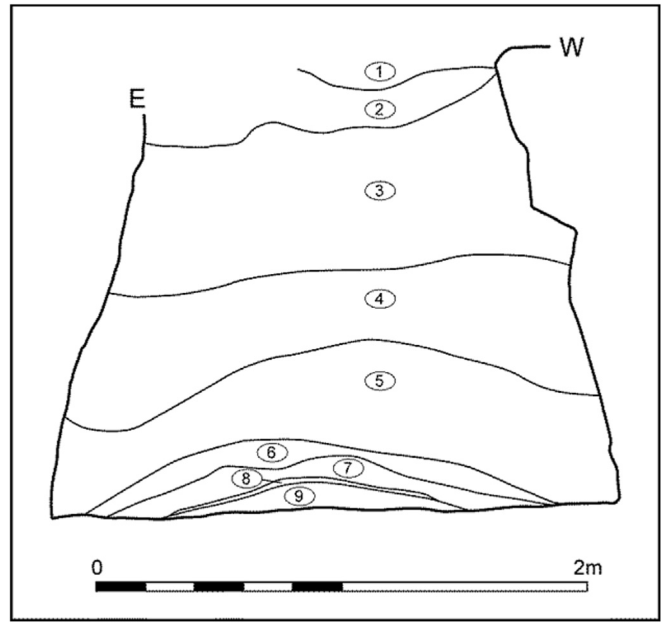

Fig. 7. Section drawing of pit 878, a typical storage pit, from Danebury (adapted from Cunliffe, 1984: 142). Note the depth and undercut sides, which would afford deposits a certain degree of protection from the elements.

The degree of shelter required to promote considerable, but not complete levels of bacterial attack, is open to debate. Although silting pits would prevent scavenger disturbance and reduce the degrading effects of full exposure to the elements, remains would still be subject to attack from skeletonising insects. Therefore for bacterial attack to progress to OHI scores centering on 2, pits may have been prepared in a way that afforded remains some level of protection from insects, causing more prolonged bacterial soft tissue decomposition. For patterns of relatively extensive bacterial bioerosion, it may have been necessary for pits to have been covered, perhaps with textile or leather whilst the bodies decomposed. The severity of bacterial bioerosion would have been controlled by the efficacy of the coverings in reducing invertebrate access (see Bell et al., 1996; Terrell-Nield and MacDonald, 1997; Jans et al., 2004; Simmons et al., 2010). Heavy wrapping of bodies in clothing or textiles may present an alternative possible scenario, however in forensic examples the effect of clothing and wrapping on bodily decomposition is often variable and contradictory (Goff, 1991; Vass, 2011; Campobasso et al. 2001; Ferreira and Cunha, 2013). In the absence of directly relevant experimental research, it is not possible to establish whether deposition in covered pits or exposed, silting pits is most likely to be responsible for patterns of bioerosion. Equifinality remains a substantial hurdle to interpretation and determining precise practices is beyond the limits of the data. However, both practices have clear similarities in terms of mortuary treatment.

Wedl MFD, which was common on partially articulated/articulated remains has been linked to invasion by exogenous saprophytic fungi. A large-scale study of European archaeological human bone (N = 250) found that 8% of human samples were affected by Wedl tunneling (Jans et al., 2004). The rate of Wedl tunneling amongst the samples (25%) used in the current study is comparatively high. Fungal bioerosion has been observed to be more common in faunal remains (42% rate) and may be linked with the deposition of partially-fleshed bone in a well-aerated environment (Marchiafava et al., 1974; Jans et al., 2004). The high rate of Wedl tunneling amongst the articulated/partially articulated samples from Danebury and Suddern Farm is inconsistent with immediate burial and emphasizes their taphonomic divergence from the disarticulated bones (Jans et al., 2004). Deposition in rapidly-silting pits would have maintained an accessible, aerated environment more conducive to fungal growth than a standard grave (Marchiafava et al., 1974; Terrell-Nield and MacDonald, 1997). However, the conditions that promote fungal bioerosion are poorly understood, and the extent to which Wedl tunneling can support interpretations of early post-mortem treatment is questionable.

The minimal bacterial bioerosion observed in sample 107 contrasted with the extensive tunneling recorded in the rest of the sample set. The accompanying evidence for unique discoloration and non-biotic loss of collagen within sample 107 provided further evidence for its divergent taphonomic history. This histological signature is consistent with sub-aerial exposure (see Bell et al., 1996; Turner-Walker and Jans, 2008; Fernández-Jalvo et al., 2010; White and Booth, 2014). This would also explain the disarticulated state of the remains and the heavily weathered and carnivore-gnawed cortex. The extensive weathering of the femur (to stage 2, following Behrensmeyer, 1978) suggests that the bone had remained above ground for a substantial length of time prior to final deposition.

The Danebury skeletal catalogue stated that sample 107 demonstrated macroscopic signs of burning (Cunliffe, 1984). Reassessment of this femoral fragment found that the evidence for burning was ambiguous and that discoloration could have been caused by mould staining and/or mineral infiltration. The extent and regularity of the microscopic discoloration in this sample is inconsistent with infiltration by extraneous elements from the soil and resembles changes associated with low-level heat treatment (cf. Shahack-Gross et al., 1997; Hanson and Cain, 2007; Squires et al., 2011). The loss of birefringence in this thin section indicated non-biotic collagen loss, which is most often attributed to circumstances that accelerate hydrolytic reactions (Smith et al., 2002, 2007). Loss of collagen via accelerated hydrolysis is consistent with low level heating (Hackett, 1981; Smith et al., 2002, 2007; Abdel-Maksoud, 2010). However, accelerated hydrolysis and discoloration of the bone microstructure could have also been caused by extreme weathering promoted by prolonged sub-aerial exposure (Smith et al., 2002, 2007).

These results suggest that the individual represented by sample 107 had been afforded a different form of post-mortem treatment from other sampled individuals. This bone had most likely been weathered substantially after the body was excarnated, although the application of some form of heat treatment to smoke or dry the bone cannot be entirely ruled out. Previous suggestions that a predominant Iron Age practice of excarnation was responsible for the dearth of human remains suggests that sample 107 may represent a rare survivor of a major funerary process that usually left no physical trace (Wait, 1985; Redfern, 2008). However, there is ample evidence for variable treatment of the dead in the British Iron Age and this bone could embody an alternative funerary process afforded for a small minority of Danebury's inhabitants. It cannot be entirely excluded that sample 107 represents a more common pattern of practice that is not widely evidenced in the limited sample in this study.

The results of these analyses suggest a high degree of regulation in practice, with distinct rites being adhered to for remains that were finally deposited in a partially or fully articulated state and those that are deposited as disarticulated fragments. Further research is required on more people buried in the Danebury environs and from a broader range of Iron Age sites in order to characterize variation in funerary practice across Britain. The results of this study challenge the assertion that disarticulated remains recovered from British Iron Age sites invariably result from the process of excarnation.

This study highlights the potential of integrating microscopic analyses of bone diagenesis with other taphonomic evidence to improve the resolution with which funerary treatment can be reconstructed. Microscopic techniques can reveal discrete taphonomic information that cannot be discerned through macroscopic examination alone and which can help to discriminate between diverse taphonomic histories of bone samples. Comparison of diagenetic signatures with previous studies of bioerosion and bodily decomposition can provide specific interpretations of early post-mortem processes when used alongside macroscopic taphonomic analyses. However, equifinality remains a problem, and there are persistent uncertainties regarding the types of processes responsible for particular diagenetic signatures. Further experimental and archaeological research into bone bioerosion will help to resolve these problems.

5. Conclusion

The human bones sampled from Danebury and Suddern Farm demonstrated extensive but variable levels of bacterial bioerosion, indicative of diversity in mortuary practice. The patterns of bacterial bioerosion suggested that three different funerary processes were represented. Regulated, discrete rites appeared to have been adhered to for remains finally deposited in a partially or fully articulated state and those deposited as disarticulated fragments.

The poor histological preservation of the discrete disarticulated elements (except sample 107) suggests that they originated from bodies that had been buried immediately after death. These bones are consistent with a distinct practice of primary burial followed by exhumation and re-deposition after skeletonisation. Partially and fully articulated remains exhibited an unusual pattern of extensive but incomplete histological destruction. The lack of experimental research means it is impossible to provide a confident interpretation of funerary treatment, but the most parsimonious explanation for these patterns is that bodies had been left to decompose in covered or rapidly silting pits before being selectively manipulated and buried. The anomalous histological and cortical preservation of a single disarticulated bone provided evidence for excarnation. It is likely that this bone represents another minority funerary rite, but it could plausibly be a rare survivor of a process afforded to the majority of the Iron Age dead which usually left no archaeological trace. Overall, these results challenge the implication that disarticulated human remains from British Iron Age sites invariably represent excarnation practices. The study of bone diagenesis – and bacterial bioerosion in particular – can contribute positively to interpretations of funerary processes as part of a suite of taphonomic evidence.

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