Histotaphonomy Report

Scott D. Haddow

Introduction

The diversity of mortuary treatments observed in the archaeological record of the Neolithic Near East, including primary and secondary intra- and extramural interments, has long been recognised as a distinctive feature of these early sedentary communities. The practice of 'skull retrieval' is the most well-known example of the phenomenon, which is observed archaeologically as deposits of disarticulated crania (and sometimes mandibles) in 'caches' or as accompaniments to primary burials (*e.g.*, Bienert 1991; Bocquentin *et al.* 2016; Gresky *et al.* 2017; Haddow and Knüsel 2017). Secondary treatments involving elements of the infracranial skeleton are also known, although they often receive less attention. Early research on this subject linked such practices with the emergence of 'ancestor cults' and the need to control access to local resources as a result of increasing sedentism (Kenyon 1956; Cauvin 1978, 1994; Bienert 1991; Goren *et al.* 2001). However, with the emergence of new data from a wider range of sites and regions, many researchers have since called this narrative into question (*e.g.,* Verhoeven 2002; Bonogofsky 2003, 2004, 2005, 2006; Croucher 2006; Özbek 2009; Benz 2010). More recently, the interpretation of such secondary mortuary practices has tended to centre on the role of the dead in establishing and maintaining social continuity, as well as reducing intra-communal tensions (*e.g.*, Goring-Morris 2000; Kuijt 2000, 2001, 2008; Benz 2012).

Given the enormous range of regional and chronological variability, it is becoming increasingly clear that a simple, one-size-fits-all interpretative model is no longer sustainable (Bocquentin *et al.* 2016; Haddow and Knüsel 2017). An increased attentiveness to the subtle patterns and particularities of individual sites and regions is required in order to build a more comprehensive and multifaceted understanding of Neolithic mortuary practices. For example, recent research at Çatalhöyük suggests that mortuary practices at the site were far more complex than previously conceived, likely involving extended, multi-stage mortuary treatments (Haddow and Knüsel 2017; Haddow *et al.* 2021). Based on observations such as extreme skeletal hyperflexion, missing bones or unusual patterns of disarticulation, many primary skeletons at the site appear to show signs of an extended interval between death and final interment. Whether these variable treatments reflect changes in ideology, increasing social differentiation or more pragmatic concerns such as off-site deaths and/ or seasonal burial cycles, the ability to discern such subtle patterning is important to our understanding of the ways in which Neolithic societies were organised and evolved over time.

In order to disentangle the diverse patterning observed in Near Eastern Neolithic mortuary practices, an attentiveness to the taphonomy of the burial environment and the bones themselves is required. In particular, histotaphonomic analyses of human bone have the potential to reveal important information about the period immediately following death, especially with regard to environmental conditions and/ or human interventions. One of the most common factors affecting the preservation of archaeological bone is the alterations caused by microorganisms such as bacteria, fungi, and algae. Successive researchers have demonstrated that each of these types of microorganisms leaves a distinctive signature in the microstructure of bone. Studies of these bioerosive features, including their presence/ absence and severity, have been utilised to characterise taphonomic changes associated with the burial of fleshed and unfleshed bodies (Turner-Walker and Jans 2008; Bell 2012;

Benz M., Gresky J., Purschwitz C. and Gebel H.G.K. (eds.), *Death in Ba`ja. Sepulchral Identity and Symbolism in an Early Neolithic Community of the Transjordanian Highlands. Household and Death in Ba`ja* 2.
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DOI: https://doi.org/10.11588/propylaeum.1224.c16952

Hollund *et al.* 2012; Brönnimann *et al.* 2018; Tjelldén *et al.* 2018). Several studies have suggested that the bacteria responsible for specific patterns of bioerosion derive from the gut and are released during the early stages of decomposition (Jans *et al.* 2004; White and Booth 2014; Booth 2016). Low levels of bacterial degradation in bone may indicate an anthropogenic intervention to reduce or halt the decomposition process, through the removal (*i.e.*, excarnation) or reduction (*i.e*., desiccation) of soft tissue body mass. Other histotaphonomic indicators that can be employed to infer patterns of body treatment and characterise burial environments include collagen preservation (birefringence), microfissures, staining and the presence of foreign inclusions within bone pores and cracks (Hollund *et al.* 2012; Brönnimann *et al.* 2018).

Initial results from the histotaphonomic analysis of Neolithic burials from Çatalhöyük and two other Anatolian sites (Boncuklu and Barcın Höyük) reveal a great deal of intra- and inter-site variability in terms of microstructural bone preservation, as well as demographic and spatial patterning (Haddow *et al.* 2021; Haddow in prep.). As part of a Marie Skłodowska-Curie research fellowship (GAP-837781), this histotaphonomic study was expanded to include Neolithic sites from southern Jordan, including Ba`ja, Shkārat Msaied, Basta and Beidha. Unfortunately, only the samples from Ba`ja could be acquired before travel restrictions associated with the COVID-19 pandemic were put in place.

Recent excavations at the Late Pre-Pottery Neolithic B (PPNB) site of Ba`ja in the framework of the *Household and Death Project* have added new evidence on the diversity of burial rituals. Besides collective burials, many subadults were buried in single and double burials (Benz *et al.* this volume). With two exceptions, adults were exclusively buried in the four collective burials (Gebel and Hermansen 2001; Gebel *et al.* 2006, 2020; Benz *et al.* 2019). Most of the subadult corpses seemed to be well articulated and, at first glance, were considered primary burials (Gebel *et al.* 2019, 2020). However, several aspects of these burials remain enigmatic and require further investigations. First, the preservation of the human bones is unexpectedly poor (Gresky this volume; Lösch and Arenz this volume; Skourtanioti and Feldman this volume). As geochemical analyses of the sandy burial fill show (Gerlitzki written comm. 30.8.2019), this cannot be explained by the surrounding sediment. Despite carbonate coatings observed on some stones, the sand of the burial filling is neither acid (pH 7.32), nor does it contain unusual trace elements which may have affected the bones (Table 1). The loam content of the paleosol in which most of the burial pits were dug may have caused periodic standing water if the burial place was not roofed. Second, the grave fill of four primary child burials (CG2, CG5, CG8, CG9) were found to contain well-articulated or isolated infant bones, while in the multiple/ collective Burial CG9, two pairs of subadults were interred (Gebel *et al.* 2020; Benz *et al.* this volume). Lastly, despite the sediment infilling of the adult Burial CG10 (Benz *et al.* 2019), the collapsed position of the cranium and mandible suggests the existence of a void around the skeleton for a period of time before the grave cut was eventually filled. Similar observations were made for the collective Burial CG1 (Benz *et al.* this volume).

Furthermore, the manipulation of corpses/ handling of bones was attested – in addition to the collective burials and isolated human bones in room fillings – by the infant Burial CG6, in which disarticulated adult and infant bones were found in association with the corpse of a neonate. The isolated adult and infant bones may represent the remnants of an older burial in the same location that was disturbed by the construction of Burial CG6, or the bones may have been intentionally placed slightly beneath and around the infant as a sort of 'grave good'. A row of ten bone beads next to the isolated adult ulna speaks in favour of the first option (Benz *et al.* this volume). Many of these *in field* observations might be explained by the corpses having been desiccated or kept above ground for a period of time, perhaps tightly wrapped in some organic material, before being interred simultaneously. The initial results of the histotaphonomic analyses suggest diverse pre-burial treatments of the individuals sampled. An evaluation of possible differences due to different household affiliations must await further systematic investigations and above all analyses of human bones from other areas of the site.[1]

Material and Methods

In February 2019, bone samples from eleven Ba`ja individuals were taken for histotaphonomic analysis at the University of

[1] Except for the infant Burial DG2 in Area D, DR19, no human remains were available from Areas A, B, D, and G for analyses within the *Household and Death Project*.

Table 1 Geochemical analyses of the burial filling sand (Loc. CR6:43) of Burial CG6 and some concretions in the grave filling (Loc. CR6:38/39). (Analyses: M. Gerlitzki)

ID	Sediment F.no. 117700, Loc. CR6:43	Concretion F.no. 117844; burial filling Loc. CR6:38 above infant Loc. CR6:40	Concretion F.no. 117815, next to the isolated bones Loc. CR6:41a
SiO_2	65.29	54.00	77.93
Al_2O_3	14.22	20.07	17.04
Fe_2O_3	6.74	12.17	2.51
MgO	1.22	2.96	0.25
CaO	3.23	0.90	0.22
Na_2O	0.41	0.34	0.21
K_2O	2.70	7.87	0.66
P_2O_5	0.42	0.18	0.36
SO_3	4.21	0.05	0.09
Minerals	quartz, kaolinite	quartz, illite, goethite	quartz, kaolinite
Comment	quartz sand (SiO2) coated with haematite (red colour); kaolinite (Al content) is a weathering product of feldspar	concretion in the soil predominantly of quartz and goethite	quartz concretion from the soil, kaolinite content presumably due to adherence

Loc. CR6:38	red-brown loose silty sand 10 YR 5/6; 7.5 YR 5/6, with few flitters of charcoal and animal bones.
Loc. CR6:39	grave filling, around Loc. CR6:40, similar to Loc. CR6:38, but with more humous dark brown soil, possibly from decay of the corps
Loc. CR6:43	sediment at the bottom of the infant Burial CG6, Loc. CR6:40, also the isolated bones Loc. CR6:41a/b were in this sediment.

Copenhagen. Samples were taken primarily from the femur or tibia for most individuals, with a few samples taken from the lower arm in the absence of lower limb bones.

Thin sections ranging between 40 and 125 micrometres in thickness were produced for each bone sample. Each thin section was analysed under plane-polarised and cross-polarised light with a *Leica DMR HC* fluorescence microscope at 5x, 10x and 20x magnification. The analysis took place at the Center for Advanced Bioimaging (CAB) at the University of Copenhagen. The samples were also analysed using backscatter scanning electron microscopic (BSEM) imaging techniques. The SEM analyses took place at the Danish Technical University Nanolab using a *QFEG 200 Cryo ESEM*. Both types of microscopy were employed in order to provide the maximum amount of information for each sample. Backscatter SEM is especially well suited for confirming the presence of bacterial modification of bone, as this type of bioerosion is characterised by an electron-dense hypermineralised rim (Hackett 1981; Fernández-Jalvo and Andrews 2016: 144).

Based on observations of bone sample microstructure using standard light and SEM microscopy, each sample was scored for a series of common taphonomic indices, including bacterial attack (BAI), Wedl Type I (WT1) and Type II (WT2) tunnelling (Wedl 1864), cracking (CRI), collagen preservation (COI) and inclusions (INC) (Table 2). Bacterial attack (BAI) results in a patterning of tunnelling that tend to follow the lamellar structure of individual osteons. Hackett (1981) describes bacterial tunnels as either budded, lamellar or linear longitudinal in form. While earlier research has suggested that the bacteria responsible for these bioerosive features originate from the soil, more recent studies indicate that they derive from the gut and are released during the early stages of decomposition (Jans *et al.* 2004; White and Booth 2014; Booth 2016). However, there is still some debate on this subject (*e.g.*, Turner-Walker 2019). Wedl Type I tunnelling

Table 2 Description of microbial indicators, their causes, and interpretations.

Microbial indicators	Description	Cause	Presence/ absence indicates?
BAI	Linear longitudinal, lamellar and budded tunnels with hypermineralised rims	Bacteria (from gut or soil)	Presence expected in fleshed bodies buried immediately after death Absence suggests accelerated decomposition process, *e.g.*, exposure, desiccation, removal of soft tissue
WT1	Thin, dendritic tunnels initiating from the outer bone surface	Fungus	Presence suggests surface exposure of corpse/ bones
WT2	'Spider web' pattern of enlarged canaliculi	Moss/ lichen/ algae or acidic soils	Presence suggests surface exposure of corpse/ bones

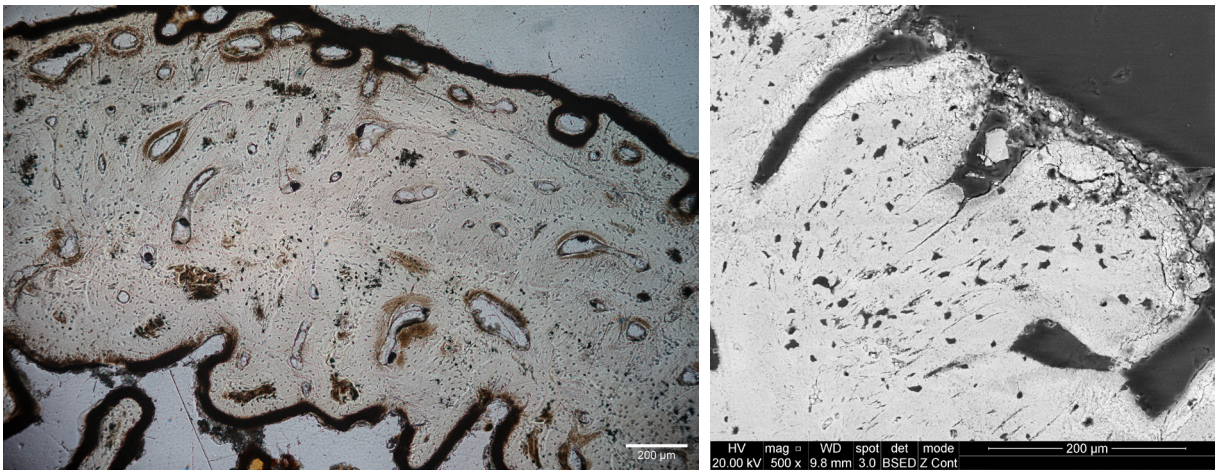
(WT1) is typically associated with exogenous fungal attack and characterised by very thin tunnels (5-10µm in diameter) originating from the outer bone surfaces (Machiafava *et al.* 1974; Hackett 1981; Trueman and Martill 2002). Wedl Type II tunnelling (WT2), characterised by enlarged canaliculi emanating from osteon lacunae, sometimes creating a broad spider-web pattern, has been documented in a number of studies but its aetiology is not fully understood (Trueman and Martill 2002); some researchers have attributed it to soil acidity or the corrosive action of moss, lichen, and algae cover (Fernández-Jalvo *et al.* 2010; Fernández-Jalvo and Andrews 2016). Cracking (CRI) refers to micro-fissures that occur within the bone tissue as a result of, *e.g.,* wet/ drying cycles, soil chemistry, *etc.* Collagen preservation (COI) is assessed by observing the intensity of collagen fibre birefringence within osteon lamellae under cross-polarised light microscopy. The scoring of BAI, WT1, WT2, CRI and COI is based on the Oxford Histology Index (OHI), which records the percentage of intact bone microstructure on an ordinal scale of 0 to 5 (0 representing 0% preservation and 5 representing 100% preservation) (Hedges *et al.* 1995; Millard 2001). Inclusions (INC) refer to the presence of foreign material such as mineral precipitations, soil particles, *etc.* within bone pores and cracks. Inclusions (INC) were recorded on a scale of 0 to 3, with 0 representing no inclusions, and 3 representing frequent inclusions.

Results

Table 3 presents the age, sex and taphonomic scoring for each individual. Each sample is discussed in further detail below

Sample a1 from Burial DG2, Loc. DR19:110

Sample a1 derives from the left femur of a neonate (0mths ± 2mths) recovered from a primary burial context (DG2) in Room DR19. There are no signs of bacterial attack, but fungal tunnelling



A B

Fig. 1 Sample a1 from Burial DG2: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)

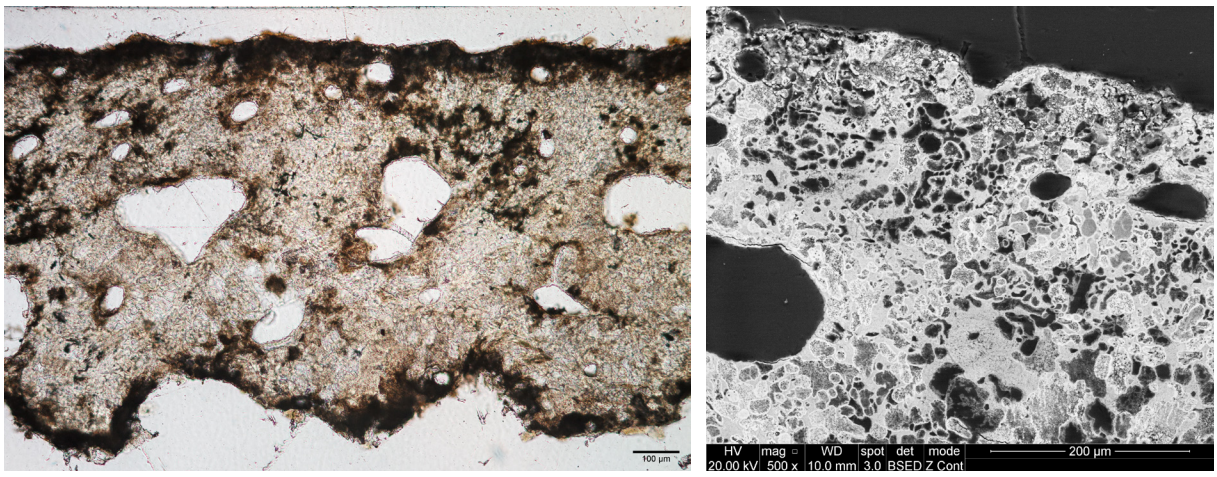
Table 3 Taphonomic scoring for each sample from Ba`ja, ID=sample ID, Unit=burial number and loci, OHI=Oxford Histology Index, BAI=Bacterial Attack Index, WT2=Wedl Type I, WT1=Wedl Type II, CRI=Cracking Index, COI=Collagen Preservation Index, INC=Inclusions, mths=months, yrs=years, frgm./ frgms.=fragment/ fragments, indet.=not identified;
*1 from to the same individual as b2
*2 from the double Burial CG8 as b1 but from another individual.
*3 from the double Burial CG5 as b4 but from another individual.

ID	Unit	Age	Sex	OHI	BAI	WT1	WT2	CRI	COI	INC	Bone	Notes
a1	DG2, Loc. DR19:110	0yrs ± 2mths	too young	4	5	3	5	5	1	1	left femur	
a3*1	CG6, Loc. CR6:41	young adult	indet.	4	5	5	4	3	1	0	right radius	
b2	CG6, Loc. CR6:41	young adult	indet.	5	5	5	5	3	1	2	right ulna	gypsum ($CaS0_4$) crystals
a4	CG4, Loc. CR6:48	7yrs ± 24 mths	too young	4	5	5	3	3	1	0	right femur	
a5	CG3, Loc. CR5:49a	1.5-2yrs	too young	3	5	5	3	4	1	1	left femur	barite ($BaSO_4$) crystals
a2*2	CG8, Loc. C10:405 Ind I	6-9mths	female (aDNA)	1	1	5	5	5	1	0	left femur	double burial
b1	CG8, Loc. C10:405 Ind II	3/4 yrs	too young	3	3	5	4	4	1	1	long bone frmg.	double burial
b3*3	CG5, Loc. CR6:23b Ind II	1.5-2yrs	too young	4	5	5	3	4	2	0	right femur	double burial
b4	CG5, Loc. CR6:23a Ind I	3yrs ± 1yr	too young	3	5	?	?	4	1	0	left femur	double burial
b5	CG7, Loc. C1:46	8yrs ± 2yrs	female?	4	5	5?	3	4	1	0	left femur	
b6	CG10, Loc. C10:408.8	young adult	male	4	5	5	5	3	1	0	shaft frmgs.	

(or possible root activity) near the outer surface of the bone is observable (OHI = 4) (Fig. 1). The infill of the grave pit consists of room fill and – unlike other burials – the grave pit was not sealed by stone slabs.

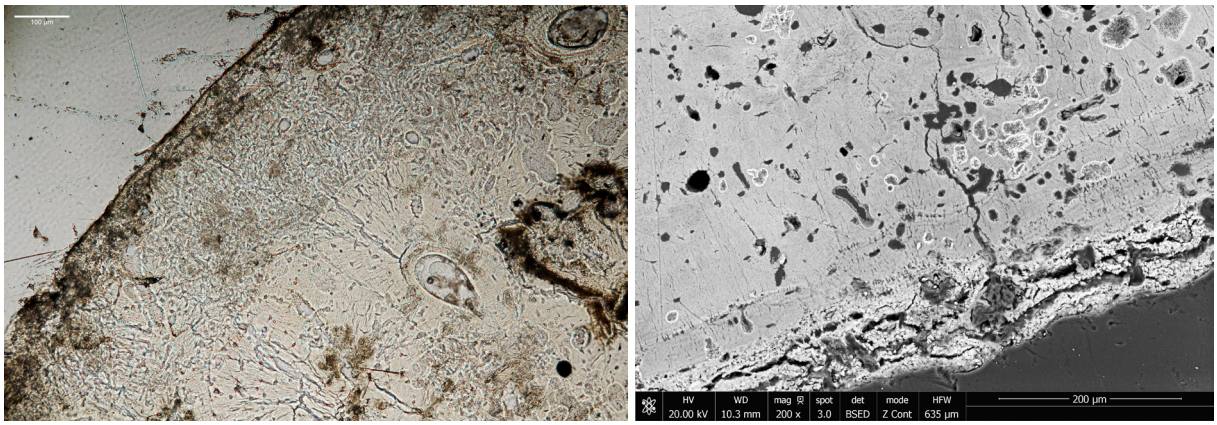
Samples a2-b1 from Burial CG8, Loc. C10:405 Individual I and Individual II

Sample a2 is from the left femur of an infant (6-9mths old, female, see Skourtanioti and



A B

Fig. 2 Sample a2 from Burial CG8, Individual I: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)



A B

Fig. 3 Sample b1 from Burial CG8, Individual II: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)

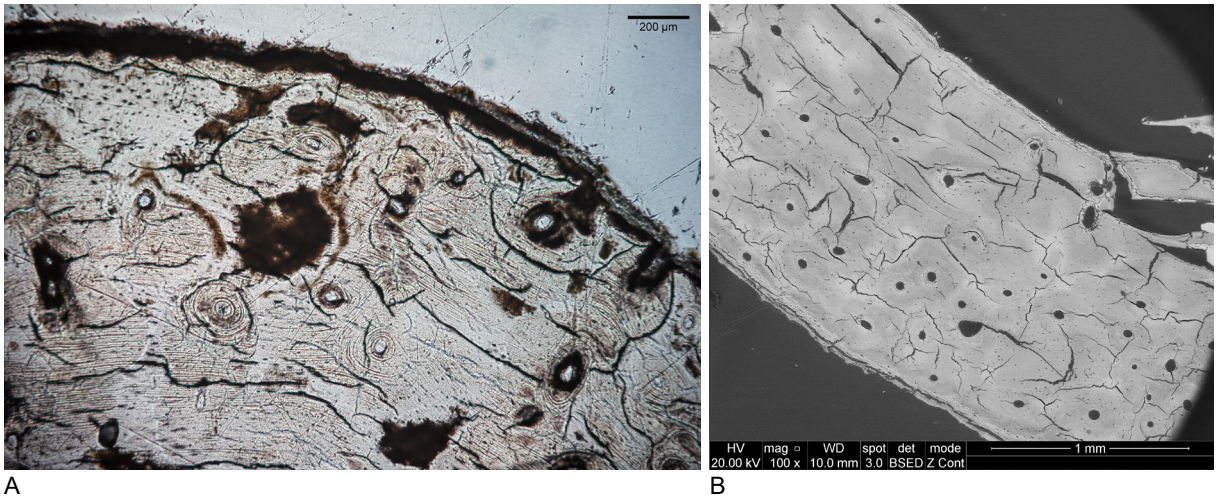
Feldman this volume: Table 2) in a double primary burial (CG8) in Room CR35. The bone has very poor microstructural preservation as a result of intensive bacterial bioerosion (OHI = 1) (Fig. 2). Individual I appears to have been buried simultaneously with Individual II (see below) in a subfloor grave cut and filled with sterile red sand. The grave pit was sealed with a stone slab.

Sample b1 derives from a long bone fragment of a child (3-4yrs old) from the double primary burial (CG8) in Room CR35. Unlike Individual I (see above), light and scanning electron microscopy reveal low levels of bacterial bioerosion affecting the bone microstructure (OHI = 3) (Fig. 3). EDX analysis reveals that inclusions within some bone pores derive from silicon (Si) as well as degraded bone mineral: calcium (Ca), phosphorus (P). Such inclusions were not observed in Individual I.

Sample a3 (Right Radius) and b2 (Right Ulna) from Burial CG6, Loc. CR6:41a

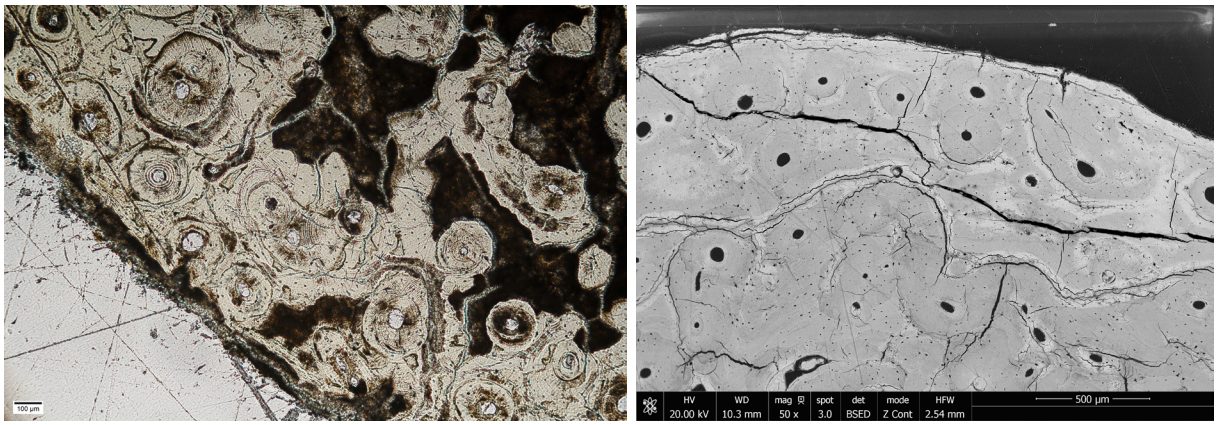
Sample a3 and b2 derive from the right radius and ulna (respectively) of a young adult recovered in the burial pit from the primary infant inhumation (CG6, Loc. CR6:40) in Room CR6. The disarticulated remains of this individual, consisting of a right lower arm and hand, were recovered from the grave infill, which consisted of sterile red sand (for the geochemical analyses see Table 1).

Sample a3 has good overall microstructural preservation (Fig. 4A-B), with no signs of bacterial or fungal (WT1) bioerosion (OHI = 4),



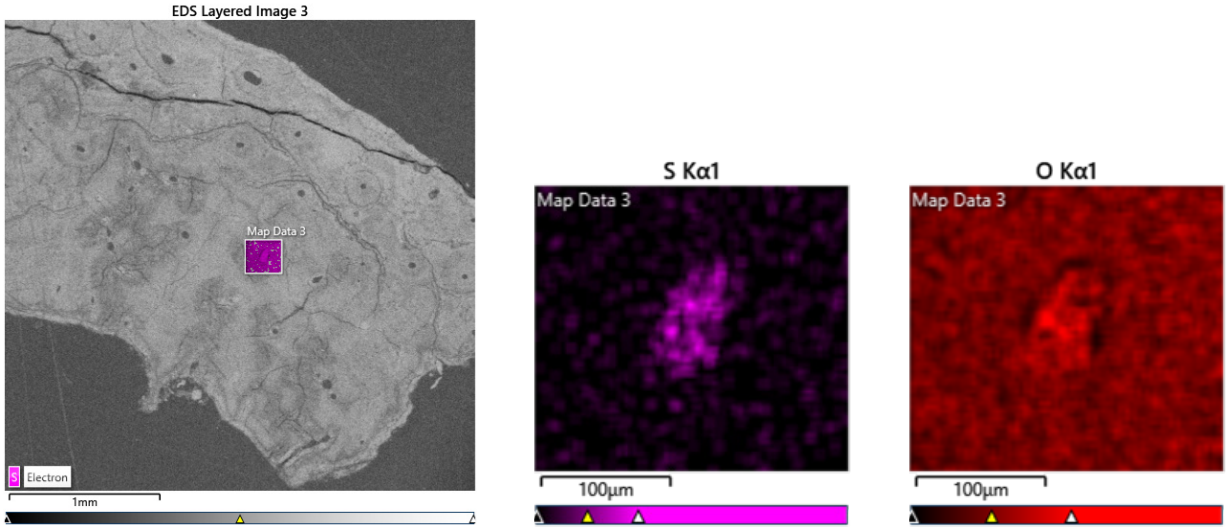
A B

Fig. 4 Sample a3 from Burial CG6, Loc. CR6:41a: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)



A B

Fig. 5 Sample b2, Loc. CR6:41a: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)



A B C

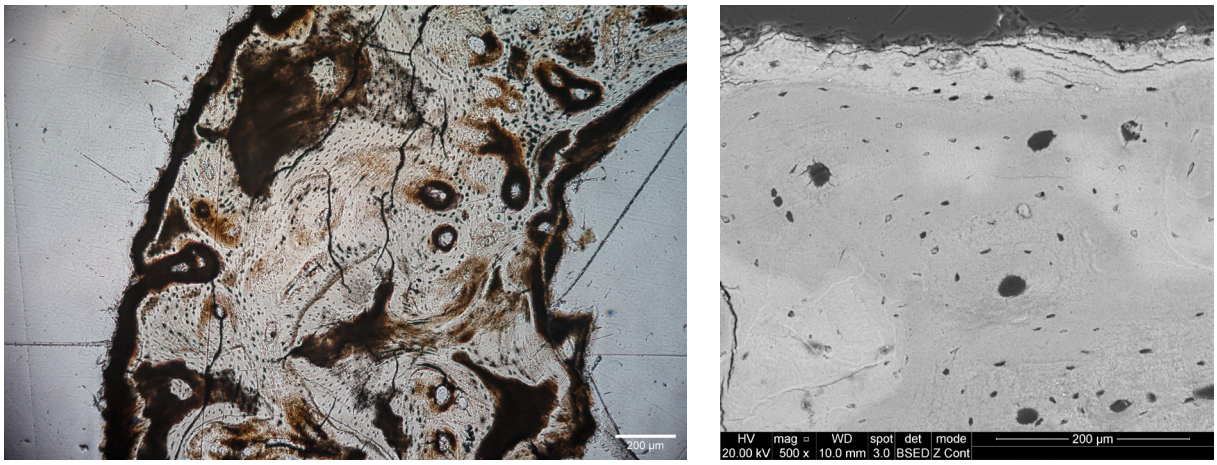
Fig. 6 *A* Mineralised inclusions in Sample b2: *B* of sulphate and *C* oxygen. (Photos: S.D. Haddow)

although some very limited WT2 is visible on the thin section (Fig. 4A). Moderate cracking (CRI) is also observable. Sample b2 also has good overall microstructural preservation (OHI = 5) (Fig. 5A-B).

An interesting observation here is the presence of crystalline structures within the bone pores of sample b2. EDX analysis demonstrates that these crystalline inclusions (visible in the SEM images) consist of gypsum ($CaSO_4$; Fig. 6). As with the barite crystals seen within the bone pores of Loc. CR5:49a, these inclusions represent diagenetic processes, but it is unclear why they only occur in this particular sample and none of the others. It is also unusual that they are present in sample b2 but not a3.

Sample a4 from Burial CG4, Loc. CR6:48

Sample a4 derives from the right femur of a child (7yrs ± 24mths) from a primary single subfloor burial (CG4) in Room CR6. The bone has good overall microstructural preservation, with no signs of bacterial or fungal (WT1) bioerosion (OHI = 4) (Fig. 7A, B). Enlarged canalicular networks associated with Wedl Type II tunnelling (WT2) are observable on the thin section (Fig. 7A). The excavators note that the skeleton was rather well articulated, although some elements, *e.g.,* cervical, and thoracic vertebrae and right pelvis were missing. The grave pit was filled with almost sterile red sand including some charcoals and sealed by a large stone slab.



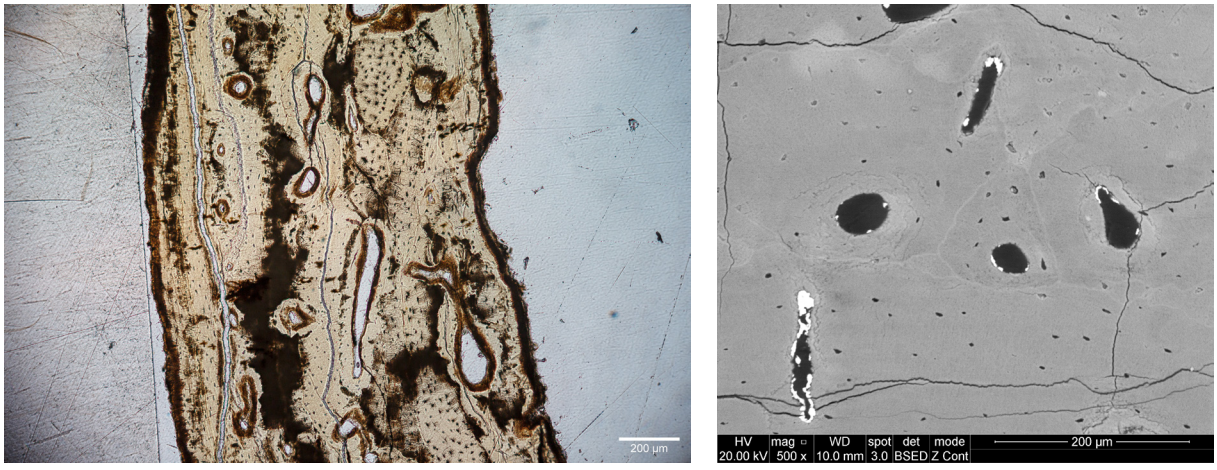
A B

Fig. 7 Sample a4 from Burial CG4, Loc. CR6:48: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)

Sample a5 from Burial CG3, Loc. CR5:49a

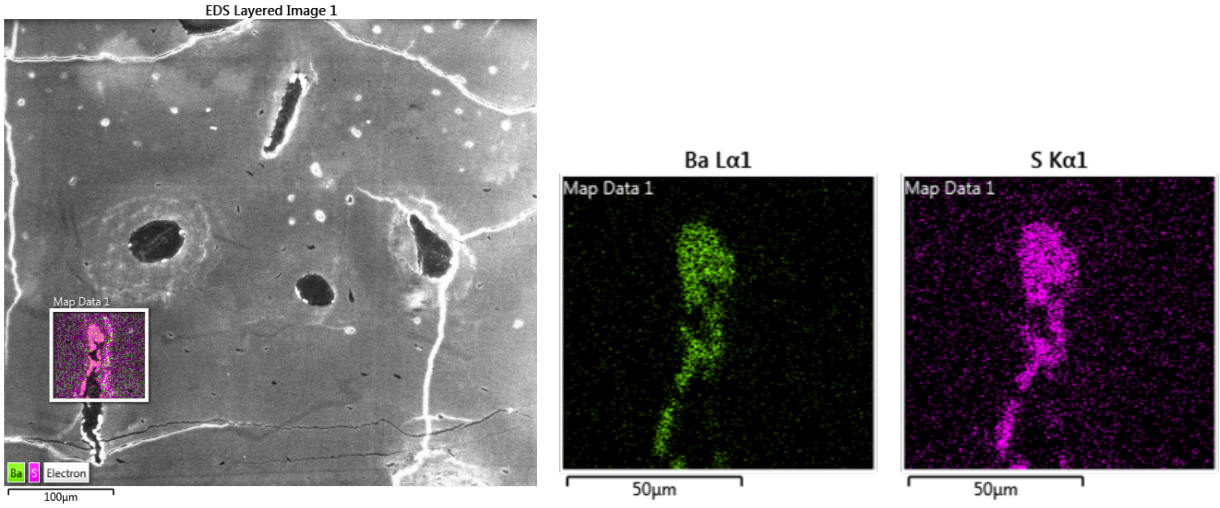
Sample a5 is from the left femur of an infant (1.5-2yrs old). This individual was recovered from a primary burial (CG3) in Room CR5. The bone has relatively good microstructural preservation (OHI = 3), with no signs of bacterial attack or Wedl Type I tunnelling. However, a moderate amount of Wedl Type II (WT2 = 2) is observable on the thin section (Fig. 8A). The cranium and mandible of this individual was not found in the grave pit (although it may have originally been in the grave). Furthermore, traces of red and black pigment were observed on some of the bones. The grave fill consisted of dirty sand and the pit does not appear to have been sealed by a stone slab.

Moderate amounts of birefringent inclusions were observed within some of the bone pores of this sample (Fig. 9A). EDX analysis revealed that these inclusions contain high levels of barium (Ba, Fig. 9B) and sulphur (S, Fig. 9C). This likely represents the mineral barite ($BaSO_4$), which occurs naturally within sandstones of the Kurnub Sandstone Formation in southern Jordan. These barite crystals likely formed via diagenetic transfer from soil/ groundwater to the bones. However, no other bone samples in this study contained observable barite crystals.



A B

Fig. 8 Sample a5 from Burial CG3, Loc. CR5:49a: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)



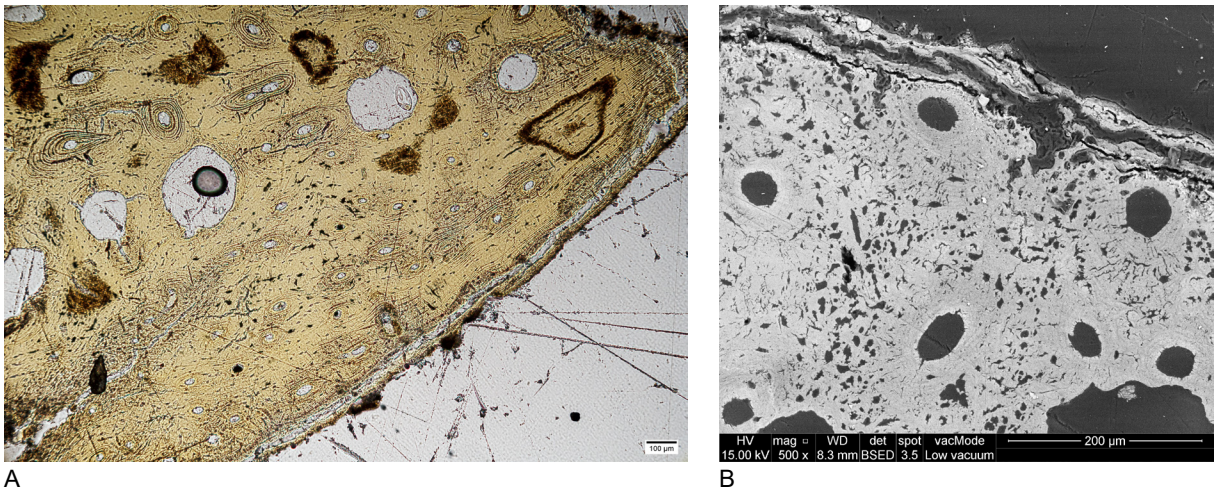
A B C

Fig. 9 Sample a5: *A* mineralised inclusions of *B* barium and *C* sulphur. (Photos: S.D. Haddow)

Samples b3-b4 from Burial CG5, Loc. CR6:23a/ b, Individuals I-II

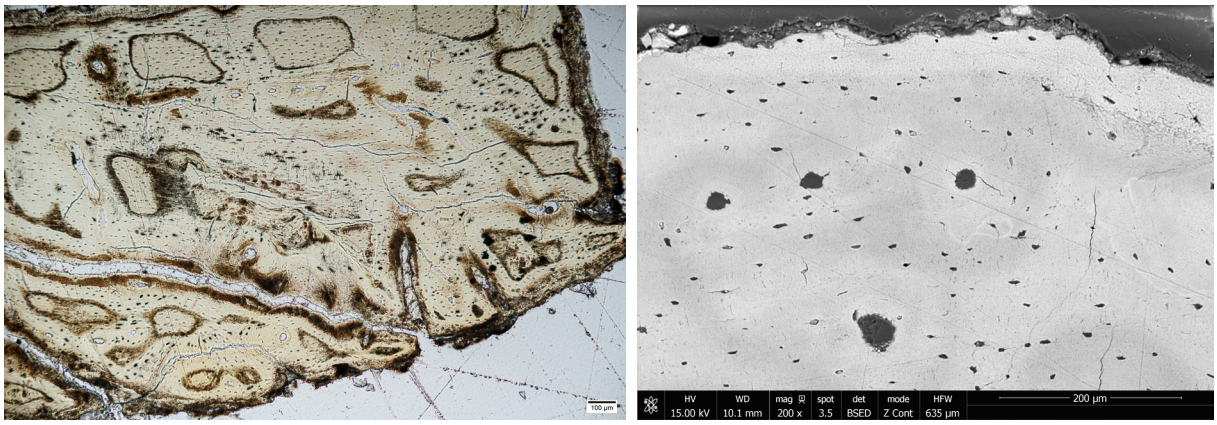
Sample b4 was taken from the left femur of a child (3yrs ± 1yr, Individual I, Loc. CR6:23a) recovered from a double burial (CG5) in Room CR6. This sample has an unusual taphonomic signature (OHI = 3), with enlarged canaliculi (WT2) and ragged-edged tunnelling near the outer bone surface that lack the hypermineralised rim typically associated with bacterial bioerosion (Fig. 10A). Dal Sasso *et al*. (2014: 39, Fig. 9) describe nearly identical features in a series of Meroitic period bone samples from Sudan. Fernández-Jalvo *et al.* (2010) attribute these features to acid soils and the corrosive effects of moss, algae, and lichen exposure. If this is correct, it would suggest that these bones remained in an aerobic environment long enough for such vegetation to form. The grave, which was not sealed by a stone slab, was infilled with dirty sand.

Sample b3 is from the right femur of an infant (1.5-2yrs old, Individual II, Loc. CR6:23b) that was recovered from the same double Burial CG5 in Room CR6 as Sample b4. The bone retains good overall microstructural preservation (OHI = 4), with no signs of bacterial erosion or Wedl Type I tunnelling (Fig. 11). However, low amounts of Wedl Type II (WT2) tunnelling are observable on the thin section (Fig. 11A). Despite being placed within the same grave, the two individuals within CG5 have divergent taphonomic signatures; in particular, the bone sample from Individual II



A B

Fig. 10 Sample b4 from Burial CG5, Loc. CR6:23a: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)



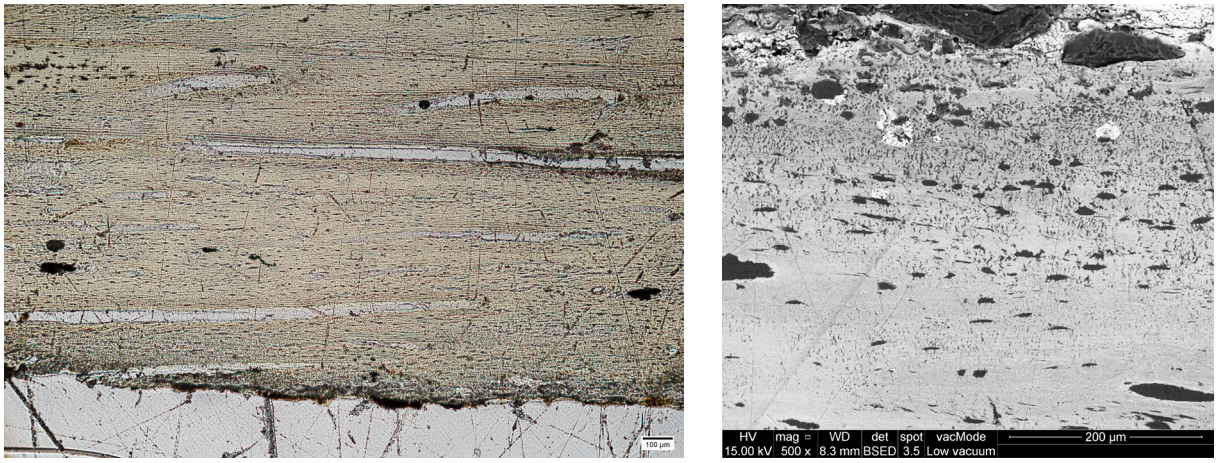
A B

Fig. 11 Sample b3 from Burial CG5, Loc. CR6:23b: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)

lacks the unusual ragged-edged tunnelling observed in the sample from Individual I. As with the two individuals from double-burial CG8, the disparate taphonomic signatures observed here suggest divergent treatments prior to interment.

Sample b5 from Burial CG7, Loc. C1:46

Sample b5 is from the left femur of a child (8yrs ± 2yrs old) found within the unusually elaborate primary subfloor Burial CG7 in Room CR36.1. The bone has good overall microstructural preservation (OHI = 4) with no bacterial or fungal (WT1) bioerosion (Fig. 12A). However, there are areas of dense Wedl Type II (WT2) activity near the surface that are visible in the thin section and SEM scan (Fig. 12B). As in the case with Sample b4 described above, Fernández-Jalvo *et al*. (2010) attribute such features to soil acidity and/ or vegetation cover. The bones were extensively stained with red pigment. The stone-lined cist grave was infilled with sterile red sand and sealed with a large stone slab.

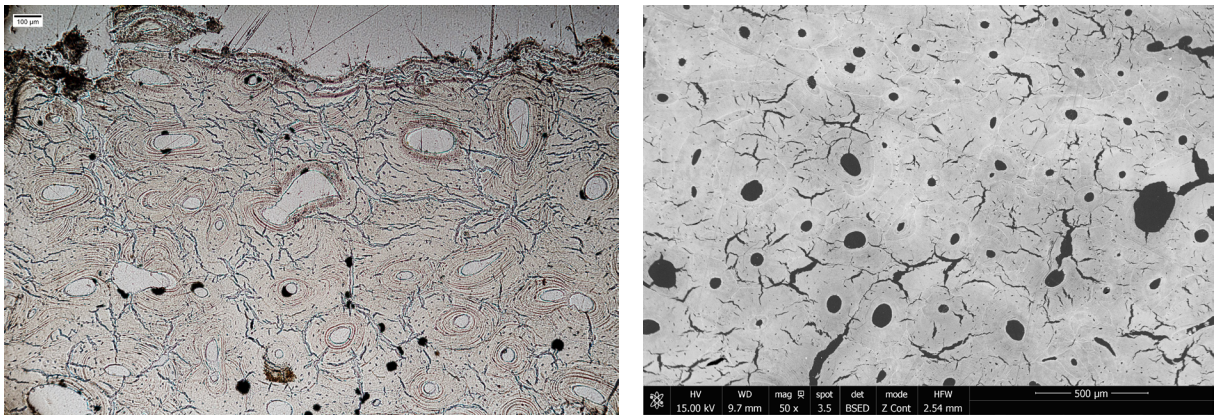


A B

Fig. 12 Sample b5 from Burial CG7: *A* thin Section, *B* SEM photo. (Photos: S.D. Haddow)

Sample b6 from Burial CG10, Loc. C10:408.8

Sample b6 is from the indeterminate long bone shaft fragments of a young, probably male adult from a primary subfloor burial (CG10) in Room CR35. The bone has good overall microstructural preservation (OHI = 4) with no bacterial bioerosion, WT1 or WT2 (Fig. 13A-B). However, moderate cracking is visible throughout the bone section (Fig. 13A-B). The grave was infilled with sterile red sand and sealed by three sandstone slabs.



A B

Fig. 13 Sample b6 from Burial CG10: *A* thin section, *B* SEM photo. (Photos: S.D. Haddow)

Discussion

While collagen preservation is poor across all samples (as reflected in low levels of collagen birefringence [COI]), there is a high degree of variability in terms of the other taphonomic variables recorded (Table 3). This is despite each individual having been buried intramurally, within largely similar burial conditions.

The presence of Wedl Type I (WT1) tunnelling (associated with fungal activity) near the outer bone surface of Sample a1 (Loc. DR19:110) from Grave DG2 suggests that the body of this neonate remained in an aerobic (unburied) environment long enough to attract fungal spores. No other samples showed signs of WT1 tunnelling. Samples b4 and b5 show signs of advanced Wedl Type II (WT2) tunnelling near the outer bone surface that have been linked with the corrosive action of moss, lichen and algae (Fernández-Jalvo *et al.* 2010; Fernández-Jalvo and Andrews 2016), which also suggests a period of aerobic exposure. While acidic soils are also thought to contribute to WT2 tunnelling, such soils have not been demonstrated at Ba`ja.

The presence of bacterial attack (BAI) is rare, with only two samples, Loc. C10:405 Individuals I and II from double Burial CG8, showing signs of bacterial tunnelling, with Individual I displaying substantially more tunnelling than Individual II. If the extent of bacterial bioerosion reflects the duration of the postmortem decomposition process (as argued by White and Booth 2014), the decomposition process appears to have lasted longer for the infant (Individual I) than for the 3-4 year-old child (Individual II), whose bone sample shows only incipient bacterial tunnelling.

The individuals (Loci CR6:23a [Individual I] and CR6:23b [Individual II]) recovered from the other double burial (CG5) also reveal clear taphonomic differences. While both individuals lack signs of bacterial bioerosion, Individual I has a pattern of tunnelling near the outer bone surface that is associated with corrosive soils, moss, and lichen. On some bones, remains of plaster were observed macroscopically within cracked bones, corroborating the idea of pre-interment treatments (see Reifarth this volume). Individual II, on the other hand, is free of such tunnelling and has good microstructural preservation overall.

Taken together, these observations suggest that each pair of individuals was treated differently prior to interment together as the result of either (1) intentional postmortem mortuary treatments, (*e.g.,* defleshing, desiccation, *etc.*) or (2) differences in the timing of their deaths, such that the first individual to die was kept elsewhere until the second individual died.

Another interesting observation is the occurrence of unusual mineral inclusions (gypsum and barite) within the bone pore of two individuals. Their presence is likely the result of natural diagenetic processes, but why do they only occur in these two individuals? There is nothing particularly distinctive about their burial locations. Again, this suggests pre-interment environments or treatments that differ from the other burials. Seasonality in the timing of subfloor interments may also play a role. Alternatively, microenvironmental variation within the Ba`ja graves might also account for such differential taphonomic signatures, *e.g.*, in the case of the two bone samples from individual Loc. CR6:41a, where one sample revealed gypsum crystals within the bone pores

and the other did not. Could such phenomena be explained if some parts of the skeleton were in contact with specific materials, *e.g*., covered in pigment, wrapped in matting, *etc*. while other parts were not (see Reifarth this volume)? It is clear that more analysis is required in order to fully understand these processes.

The observation that some grave pits were not immediately infilled suggests an extended mortuary ritual in which the body remained accessible for a period of time. Perhaps the superficial bioerosive features observed in some of the bone samples can be linked to this phase of the mortuary ritual. This is all the more intriguing when taken together with signs of fire activity observed near some grave structures; were these fires used to desiccate the body, or to repel insects and reduce the smell of decomposition? Given that desiccation is known to reduce the occurrence of bacterial bioerosion, could smoke and fire be an explanation for the lack of bacterial tunnelling observed in the majority of the study sample?

Conclusions

While small in scale, this initial histotaphonomic study at Ba`ja has revealed some intriguing variability within the burial assemblage. While the interments are largely consistent in terms of grave architecture and location (*i.e.*, intramural), each bone sample is relatively distinct in terms of taphonomy, which suggests that the postmortem histories of these individuals were equally diverse. Whether these histories reflect intentional mortuary treatments such as defleshing or desiccation, microenvironmental variation, or variability in terms of the interval between death and final burial remains unclear for now, although the taphonomic signatures observed on the samples from Loci CR6:23a (Individual I) and Loc. C1:46 suggest that these individuals were exposed to the elements for a period of time prior to being interred.

The initial histotaphonomic study presented here has shown that meticulous excavation methods and systematic macroscopic analyses of the skeletal material are only the first stage in the study of Neolithic Near Eastern funerary practices. Much more information can be revealed at the microscopic level. Histotaphonomic studies have the potential to confirm what some researchers have previously observed (*e.g*., Haddow *et al.* 2016; Haddow and Knüsel 2017): that Neolithic Near Eastern funerary practices were far more complex than conceived previously, likely involving extended, multi-stage treatments. For example, a grave containing an articulated skeleton may not always be a true primary burial or that the person had been buried immediately after death; and multiple individuals buried simultaneously may not have died at the same time. Moreover, the chemical signature of mineralised inclusions in the bone may provide important clues to the environmental conditions or even to vanished organic materials that were in close associations with the dead and may even indicate microenvironmental variation within individual grave features. In the future, it is hoped that a comprehensive histotaphonomic analysis of the entire Ba`ja skeletal assemblage will shed more light on these issues.

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Scott D. Haddow
Department of Cross-Cultural and Regional Studies
University of Copenhagen
scott.haddow@hum.ku.dk

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