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Recovery of Human Skeletal Elements from a Recent UK Murder Inquiry: Preservational Signatures*

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ABSTRACT: Factors that control bone preservation are not fully understood but generally include those that reflect "natural" taphonomic or diagenetic processes and also those reflecting anthropogenic activity. The aim of this paper is to examine whether the survival of skeletal elements from a recent UK serial murder investigation ($n = 12$) and three archaeological cemetery sites from England ($n = 112$, 95, 182; Roman to early-medieval), share a similar recovery signature. Examination of this data demonstrates that even when clear evidence of traumatic and perimortem dismemberment exists within an assemblage, the distribution of missing elements can be almost identical to archaeological material buried in normal attrition cemeteries.

Given that these preservational signatures are so similar, it is concluded that careful observation of bone surfaces is necessary to confidently interpret bone loss, particularly where dismemberment and/or element excision is suggested by the non-anatomical position of the skeleton within the grave. Where postmortem excision of bone is suspected, careful examination of contiguous bone surfaces, both macroscopic and microscopic, is suggested to detect fine cutmark lesions indicative of anthropogenic excision. Without this evidence other preservational factors must be considered both taphonomic and diagenetic.

KEYWORDS: forensic science, skeletal element preservation, bone diagenesis, preservational signatures, taphonomy

This paper aims to examine whether the survival of skeletal elements recovered from recent and archaeological subsurface contexts share a common or similar preservation signature at the point of exhumation. This became an issue of interest during, and subsequent to, the investigation of a high profile serial murder enquiry, where many of the peripheral, anterior and highly cancellous elements of individual skeletons, recovered from three different locations, were found to be missing. This paper discusses this phenomenon in the context of this case, and in comparison to three British archaeological cemetery sites representing deliberate burial. The preservational profile for the forensic case has been constructed from secondary data, both written and communicated orally, provided by the Senior Investigating Officer (SIO) and the Home Office (HO) pathologists, whilst the archaeological data have been extracted from both published and unpublished peer-reviewed reports.

Background to Bone Preservation

The factors that control bone preservation are not fully understood. Much taphonomic work has been conducted at the macroscopic level and has concerned itself primarily with identifying agencies which effect skeletal element survival and would modify bone surfaces in exposural contexts (1–3). These types of studies help piece together what has occurred to an individual at the point of death, and for a period of time thereafter. Little is understood of the preservational fate of bone once it has entered a depositional matrix. It is known, however, that post mortem microstructural change can occur to bone and to teeth prior to skeletonization both above and below ground (4). In some instances, where the depositional environment is aggressive towards skeletal material, e.g., very acid or very alkaline, then bone is less likely to survive in the longer term (5). Most often, the depositional matrix is not so clearly aggressive, and yet the preservational status of bone both at a macroscopic and microscopic level remains unpredictable. This unpredictability can be thought of as a direct function of our current lack of understanding of preservational processes. Forensic data have the potential to contribute to our understanding of these processes, where other possible causes for the same taphonomic signature should be considered.

The case discussed below concerns the absence of postcranial elements at the point of exhumation from three separate and distinct burial contexts. Commonly, the carpals and tarsals, metacarpals and tarsals, phalanges, sternum/manubrium and patellae were missing. This pattern of differential survival is common in cemetery sites where there has been active burial over a period of years (6,7). Studies by Waldron (8), Henderson (9), and Mays (10,11) have demonstrated that the peripheral small bones of the hands and feet, bones with a high proportion of trabecular bone, particularly carpals and tarsals, and those positioned anteriorly such as the patellae, the manubrium and sternum, are regularly preferentially absent.

Factors other than the depositional matrix can affect the distribution of skeletal preservation and these include post depositional disturbance by roots, rodents and insects, where skeletal elements may be physically moved (12). Anthropogenic inter-cutting of the depositional matrix during the lifetime a cemetery site is another

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dominant factor. The physical act of the excavation of human remains can result in the smaller elements being overlooked and therefore not recovered (10,13). Another factor which might pertain to both forensic and archaeological inhumations, but which is less frequently considered by archaeologists, is that the body parts which are missing never actually entered the depositional matrix in the first place. This last aspect, is a central taphonomic concern when reconstructing fossil faunal assemblages, where predator behavior creates a bias in the representation of certain skeletal elements (14). This was explored in various forensic contexts by Haglund (Haglund WD. Applications of Taphonomic models to forensic investigations. Unpublished PhD thesis. University of Washington, 1991) and later by Haglund and Sorg (15). Early hominid behavior and later archaeological husbandry techniques are no different in this regard, being evidenced by missing body parts in association with cut-marks (1,16). Establishing the murder profile can be thought of as analogous to these latter taphonomic concerns.

Method and Material

The Forensic Material

In the early 1990s, twelve graves were located, at three scenes of crime, by police and scene of crime officers investigating the activities of suspected serial murderers. They were located using information received from one of the accused, and standard investigation and search techniques. Each grave was excavated by the Home Office Pathologist acting for the county police force. Where possible, grave cuts were identified. The graves were usually square pits (*c*. one meter) at the base of which were the lower limbs, upon which was placed the axial skeleton and arms, with the cranium and mandible on top. The grave fill and all peripheral and surrounding material was sieved to recover smaller skeletal elements and artefacts not located in the initial excavation. Passing the residue over a fine membrane and sluicing it with water to recover any remaining material followed this process. Using such methods, the investigating authority recovered the smallest of elements including finger and toenails and foetal material.

Twelve female skeletons were recovered from three sites, each with a different burial environment. These were examined and recorded by Home Office pathologists acting for the Crown and the defence. Nine were buried in site A (one with a foetus); two in Site B (one with a foetus), and one in Site C. Four victims were juveniles aged 8, 15, 16, 17, and the remainder were young adults ranging in age from 18 to 21, with one 28-year-old. Six of the burials had a postmortem interval (PMI) of 20 to 26 years, five between 14 and 19 years and one only six years (Table 1). The victim buried at site C was believed to have been buried some weeks after death (SIO personal communication).

Sites A and B both share common drift geology of esturine alluvium, being situated adjacent to the tidal reach of the estuary of a river with an extreme tidal range. This resulted in the area being subject to seasonal water logging and a rapidly and dramatically fluctuating water table—a hydrological recharge situation. Soil samples were taken as a part of the scene of crime investigation (at 6 in. intervals within the graves), but were not required as evidence by the Court and were subsequently disposed of. Consequently, they were not available for this study.

Site A included the cellar (with a concrete floor) and paved rear garden of a terraced house, with six and three burials respectively. At this site, the substrate was affected by the fact that work carried out on the sewage outlet from the house was inadequate resulting in raw sewage leaking into the burial environment. This combined with the waterlogged nature of the soil and the fact that nine cadavers had been interred therein over a 20 year period resulted in a waterlogged, malodorous and glutinous substrate which is likely to have been bacterially active. Comments on the substrate (SIO personal communication) included that blue particles identified as vivianite (ferrous orthophosphate octahydrate) were found near Burials 5, 7, 8, 9, 11, and 12. This can be formed in anoxic conditions by the action of orthophosphate acid on an iron bearing material. It has also been observed in clay and recent sedimentary deposits associated with animal and human remains (17). Vivianite is colorless but turns blue when oxidized, however, whether this indicates free oxygen in the burial environment or oxidation during recovery is not known. Analysis showed that other gardens nearby also had vivianite in the soil. Of the individuals buried at Site A, only Burial 4 was not subject to this environment and was interred within an inspection pit in the former garage, which was relatively dry.

TABLE 1—*Age at death and postmortem interval for each burial.*

ID	Site	Age at Death Years	PMI Years
01	B	18.3	26.11
02	B	28.0	22.0
03	C	8.2	23.0
04	A	19.11	20.11
05	A	15.7	20.4
06	A	21.9	20.4
07	A	21.5	19.11
08	A	15.7	19.8
09	A	18.1	18.11
10	A	18.7	15.9
11	A	17.0	14.5
12	A	16.8	06.8
Range		8.2–28	6.8–26.11

Site B was a green field site from where two victims were recovered. The soil associated with Burial 2 was noted as being heavy red clay which had greenish veins, and that with Burial 1, as heavy clay soil. Adipocere was associated with Burial 2 which was recovered from a wet area.

Site C was also a domestic setting and a single victim was recovered from a grave beneath the floor in the site of a dry cellar. The substrate here was a dry mixture of coal-dust and soil.

The presence of non-human organics and polymers, including the human bones missing from all burial contexts are given in Table 2. In brief, the burials in the drier sites had no hair surviving. Finger and toe-nails were recovered at Site A but only in the burial with the relatively short PMI of six years. Foetal remains survived equally well in the green field Site B and Site A, despite the varied PMIs (26 and 15 years respectively). All of the victims were believed to have been interred unclothed.

The percentage of skeletal elements recovered from each victim is given in Table 3. The number of bones in the average adult skeleton is 206 and the youngest individual in the group would be expected to have surviving ossification centers for elements of each of these bones. Grouping of elements is according to the criteria used by the investigating officers. In immature individuals, epiphyses are included in the count for the bone to which they pertain. Where an element is not listed, they were all recovered. Data for the foetal material are not available. Only 44% of carpals, tarsals, metacarpals/tarsals, and phalanges were recovered. Forty-two percent of patellae were recovered and all but four individuals had one or

TABLE 2—*Burial environment and additional information from the forensic case.*

ID	Site	Soil	Wet/Dry	Associated Materials	Depth cms	Hair	Number of Bones Missing (of 206)
01	B	Clay	Wet	Textile Foetus	60–95		042
02	B	Clay	Wet	Textile Adipocene	60–95		041
03	C	Coal/soil	Dry		61		071
04	A	Inspection pit	Dry-moderate	Textile	80	Yes	113
05	A	gl/al/cell	Wet	Vivianite Rope	80	Yes	049
06	A	gl/al/cell	Wet		55	Yes	072
07	A	gl/al/cell	Wet	Vivianite Textile Rope	70	Yes	039
08	A	gl/al/cell	Wet	Vivianite Plastic	64	Yes	040
09	A	gl/al/cell	Wet	Vivianite Textile Plastic	53	Yes	088
10	A	gl/al/pat	Wet	Foetus	0–106	Yes	077
11	A	gl/al/pat	Wet	Vivianite Textile Plastic Metal	0–110	Yes	096
12	A	gl/al/pat	Wet	Vivianite Textile Plastic Nails	96–140	Yes	038

* Key: gl/al/cell = glutinous alluvial soil beneath cellar: plastic = plastics, nylon, tubing, acetate: gl/al/pat = glutinous alluvial soil beneath the patio: nails = finger/toenails: textile = textiles including silk, wool, and cotton.

TABLE 3—*Skeletal elements recovered from the forensic case.**

ID	Site	c/t %	h/f %	pat	st	ri %	sc %	fi %	cv	tv	lv	cl
01	B	87	53	✓	✓	✓	✓	60	7	12	5	2
02	B	93	54	1	✓	✓	✓	✓	7	12	5	2
03	C	30	38	0	0	✓	✓	✓	7	12	5	2
04	A	17	15	0	0	71	✓	✓	2	5	3	2
05	A	60	54	✓	0	✓	✓	✓	6	12	5	2
06	A	53	30	1	✓	88	0	✓	6	12	5	2
07	A	53	68	✓	✓	✓	✓	✓	7	12	5	1
08	A	76	59	✓	✓	✓	✓	✓	6	11	5	2
09	A	30	24	0	0	96	✓	✓	4	11	4	2
10	A	7	45	0	✓	92	✓	✓	6	10	5	2
11	A	10	17	0	0	92	✓	✓	7	11	5	2
12	A	50	71	1	✓	✓	✓	✓	7	12	5	2
Mean %		44	44	42	58	95	92	97	86	92	97	96

* Key:
ID = identifying number.
site = as described above.
c/t = carpals and tarsals including the talus and calcaneus.
h/f = all metatarsals, metacarpals, and phalanges.
pat = patella.
st = includes the manubrium.
ri = ribs.
sc = scapula.
fi = fibula.
cv = cervical vertebrae.
tv = thoracic vertebrae.
lv = lumber vertebrae.
cl = clavicles.
✓ = all present.
0, 1 or more = number of elements recovered.

more patellae missing. One individual had a complete scapula missing. Five individuals had all or part of the sternum/manubrium missing. Seven had one or more vertebrae missing, usually from the cervical (six individuals) or thoracic regions (five), and one or more ribs were not recovered in five cases. These were usually the smaller elements, ribs 11 or 12. Only one bone (proximal fibula) partially survived (Burials 1).

Looking at the number of missing elements at different sites, it is interesting to note that the number of missing carpals and tarsals at Site B (the green field site) is significantly lower. At Site B the number of missing metacarpals, metatarsals, and phalanges is at the lower end of the range found at Site A. Figures for the individual buried at Site C show it fitting well within the range for Site A, despite this individual being the youngest (8 years) of the group (mean 18). The individual (Burial 4) with the greatest number and diversity of missing elements (113) was recovered from within the inspection pit within the garage, the driest area at Site A, where the mean was 68 missing bones.

It is notable that unlike archaeological material, where completely missing skeletal elements are usually accompanied by a large number of partial bones, only one bone from the forensic group was noted as being partially present, a proximal fibula. Two of the burials with large numbers of missing bones were recovered from the drier sites, neither of which were "natural" soil types. However, sample sizes were very small.

The postmortem examination revealed a range of cut-marks on the skeletal material of most victims. The cut-marks fell broadly into three groups (HO pathologist personal communication): cut-marked smashed bone, sharp short and deep cut-marks, and very fine shallow cut-marks (observed using a strong hand lens). Respectively, this suggests a heavy blunt instrument used with some force, a cleaver-type tool and a sharp scalpel-like blade. The first two types of cut-marks were found in association with complete bisection of bone, whilst the third type was located on or close to the area of the joint capsule and/or margins. This range of cut-marks, along with other indicators, was interpreted as evidence of dismemberment and decapitation. No cut-marks were observed on bones contiguous to missing elements.

The Archaeological Data Sets

Given all the victims from the forensic case had been deliberately buried it was decided to choose cemetery sites for comparison. The three sites chosen are: West Tenter Street; London (third and fourth centuries AD); School Street, Ipswich (tenth and eleventh centuries AD); and Ancaster, Lincolnshire (third and fourth centuries AD). These sites were chosen because the reports contained a high level of information on the survival of skeletal elements. The archaeological data for each site are presented as comparative summations of skeletal elements present or absent (see Tables 4 to 6). At present recording the completeness and condition of skeletal remains is not standardized in the UK (6–8).

TABLE 4—*Skeletal elements recovered at less than 30% of expected at West Tenter Street, London (*n = 112*).**

Skeletal Element	% Recovered	Skeletal Element	% Recovered
Scapula body	11.4/18.4	Manubrium	23.9
Sternum body	22.7	Proximal fibula	20.5/18.2
Patellae	25.0/28.4	Carpals	18.0/15.6
Medial phalanges	22.7/22.7	Distal phalanges	8.4/5.7
Left tarsals†	29.6	Proximal phalanges	1.4/12.5
Medial phalanges	3.1/3.1	Distal phalanges	1.4/1.4

*Key: left/right †31.1% of right tarsals were recovered.

TABLE 5—*Survival of early-medieval skeletal elements at School Street, Ipswich, Suffolk (*n = 95*).**

Skeletal Element	% Recovered	Skeletal Element	% Recovered
Sternum	43.2	Patellae	29.7/31.1
Carpals	20.1/22.1	Metacarpals	41.9/44.6
Hand phalanges	15.6/16.0	Tarsals	30.5/28.6
Metatarsals	41.1/34.3	Foot phalanges	5.1/5.0

* Key: left/right.

TABLE 6—*Skeletal element recovery from Roman Ancaster, Lincolnshire (*n = 182*).**

Skeletal Element	% Recovered	Skeletal Element	% Recovered
Carpals	51.5/55.7	Metacarpals	63.6/61.9
Phalanges	55.0	Tarsals	67.4/66.5
Metatarsals	64.0/64.4	Phalanges	45.5
Patellae	46.4/48.1	Sternum	51.0

* Key: left/right.

West Tenter Street, London

Relevant aspects of the results reported by Waldron (8) are summarized in Table 4 ($n = 112$). At the time of excavation the burial environment was dry, with brick-earth overlying sand and gravel. The graves were sealed with a plough-soil and were recovered from a depth of between 0.25 m and 1.7 m below the modern ground surface (Conheeney personal communication).

Examination of Waldron's postcranial data (8) revealed that the pattern of bone loss closest to that evident in the forensic case was where less than 30% of the skeleton was recovered. Table 4 shows that missing elements in this category included the scapula, manubrium, sternum, proximal fibula, patellae, carpals and (left) tarsals, and phalanges. Generally, the metacarpals and metatarsals survived better at over 40%.

School Street, Ipswich

Data for skeletal element recovery ($n = 95$) from the early medieval site at School Street, Ipswich (Mays S. The Anglo-Saxon bone from School Street, Ipswich. Unpublished English Heritage Report 115/1989) was presented similarly to that of Waldron (8) though elements were not sub-divided in the same way. These data are presented in Table 5. As far as is possible, the percentages are shown for the same elements as in Table 4. No other elements were represented at less than 30% of the expected figure.

Ancaster, Lincolnshire

Skeletal element recovery from the Roman cemetery ($n = 182$) at Ancaster, Lincolnshire (Cox MJ. The human bones from Roman Ancaster. Unpublished Ancient Monuments Laboratory Report 93/1989) shows a similar trend to those discussed above i.e. the most poorly represented elements were the smaller bones of the hands and feet, and the patellae, but generally the percentage recovered was higher. Table 6 shows the data for the bones in question; poorest recovery rates were for the smaller bones of the feet (intermediate phalanges, 21.3%; distal phalanges, 29.7%).

Results

In order to examine whether the forensic and archaeological data are exhibiting the same trend it was useful to break the data down into three groups of element. These are:

- anterior—patellae and sternum / manubrium
- distal—metacarpals and tarsal and all phalanges
- spongy or highly cancellous bones—tarsals and carpals including the calcaneus and talus

Table 7 shows the data from all the sites discussed above. However, sites B and C can be ignored as they are too small as samples to be meaningful. In respect of anterior bones, Site A, with 44% recovery falls within the range of 25 to 49% suggested by the archaeological data. The same is apparent for the distal elements recovered at 43% and falling within a range of 26 to 53%, and the "spongy" elements at 40% within a range of 35 to 60%. Figure 1 shows the percentage of different types of bone for each of the four sites and Fig. 2, the percentage of surviving bone types.

TABLE 7—*Summary statistics of % elements recovered for all sites.*

Site	PMI (Mean -Years)	n	Anterior Elements %	Distal Elements %	"Spongy" Elements %
A	18.5	9	44	43	40
B	25	2	88	54	90
C	23	1	84	38	30
London	c1600	112	25	40	35
Suffolk	c900	95	35	26	60
Lincolnshire	c1600	182	49	53	60

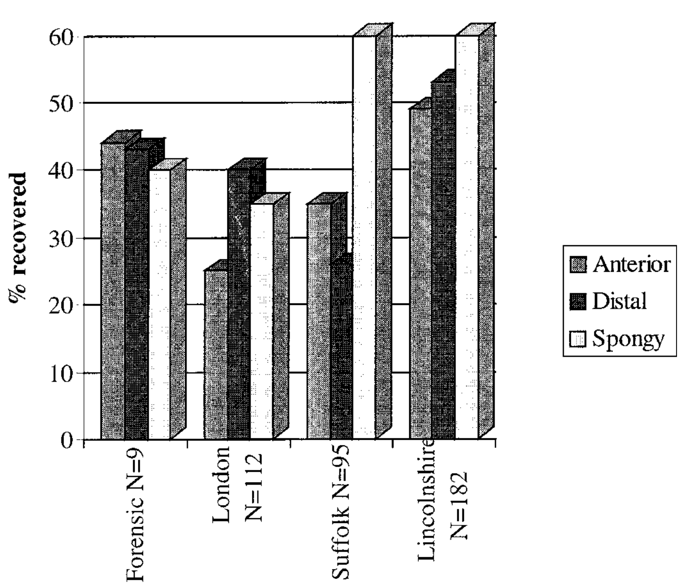

FIG. 1—*Percentage survival of different bone type from four sites.*

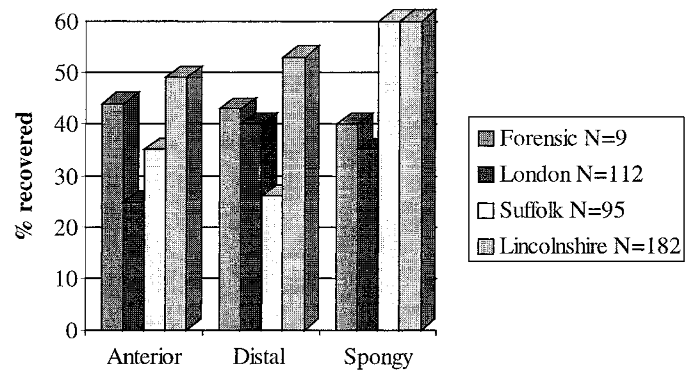

FIG. 2—*Percentage survival of different bone type.*

TABLE 8—*Variables which can affect buried bone preservation and survival.*

Variables	
Recovery: excavation and retrieval	Digestion
Pre-depositional dispersion	Gnawing
Abrasion	Insect damage
Exfoliation	Rootlet damage
Microstructural diagenesis	Soil depth, type and hydrology

Discussion

It is, arguably, self evident from the location and type of cut-marks found on the forensic remains that deliberate dismemberment did occur and that this is the most obvious explanation for the non-recovery of at least some of the observed missing elements. This interpretation is further supported by the differential preservation of associated organic remains recovered at all three sites (Table 2). What remains perplexing, is the absence of cut-marks on bones contiguous to the majority of the missing elements. However, for the interpretation of future cases it is not without value and some caution to consider other reasons for the loss peripheral elements, since Figs. 1 and 2 clearly demonstrate that the pattern of preservation, or bone loss (putting cut-marks aside), is enclosed within the pattern observed in the three archaeological cemetery sites (where bodies are assumed to have been interred whole). It is therefore, important to be able to deduce what is clearly anthropogenic and what is not.

There are a number of reasons why skeletal material may not be recovered from a depositional matrix intact and complete. These are listed in Table 8. The recovery of human remains as an act of excavation and retrieval is perhaps the most difficult variable to consider, since one cannot know if the failure to recover an element was due to the recovery technique, taphonomic factors, soil co-factors or that the element was never originally interred. These methodological aspects of excavation have been a burdensome subject of discussion amongst archaeologists for many years (8,10,13,18–20). Other primary non-anthropogenic agencies of change, can be detected with careful macroscopic examination of bone surfaces and/or with the use of microscopy, particularly for microstructural change (4). All of the changes listed above will reduce overall bone integrity and result eventually in the partial or total loss of skeletal elements.

Conclusion

The aim of this paper was to examine whether the survival of skeletal elements from a recent serial murder investigation and three archaeological cemetery sites shared a similar recovery signature. It has been shown that even when clear evidence of traumatic and perimortem dismemberment exists within an assemblage, the distribution of missing elements can be almost identical to archaeological material buried in normal attrition cemeteries. Given that these preservational signatures are so similar, caution and careful observation of bone surfaces is necessary to confidently interpret bone loss where dismemberment is suggested by the non-anatomical position of the skeleton within the grave. Where peri/postmortem excision of bone is suspected, careful examination of contiguous bone surfaces, both macroscopic and microscopic, is suggested to detect fine cut-mark lesions indicative of anthropogenic excision. Without this evidence other preservational factors must be considered both taphonomic and diagenetic.

Subject to the availability of modern material of similar PMIs for analysis, future work by anthropologists should include examination of element survival patterns in modern buried material where foul play is not suspected. This will help elucidate the complex picture presented in this case and, if non-predated element loss is occurring within the PMIs indicated in this sample, provide some indication of one aspect of the temporal range involved in this complex process.

Acknowledgments

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