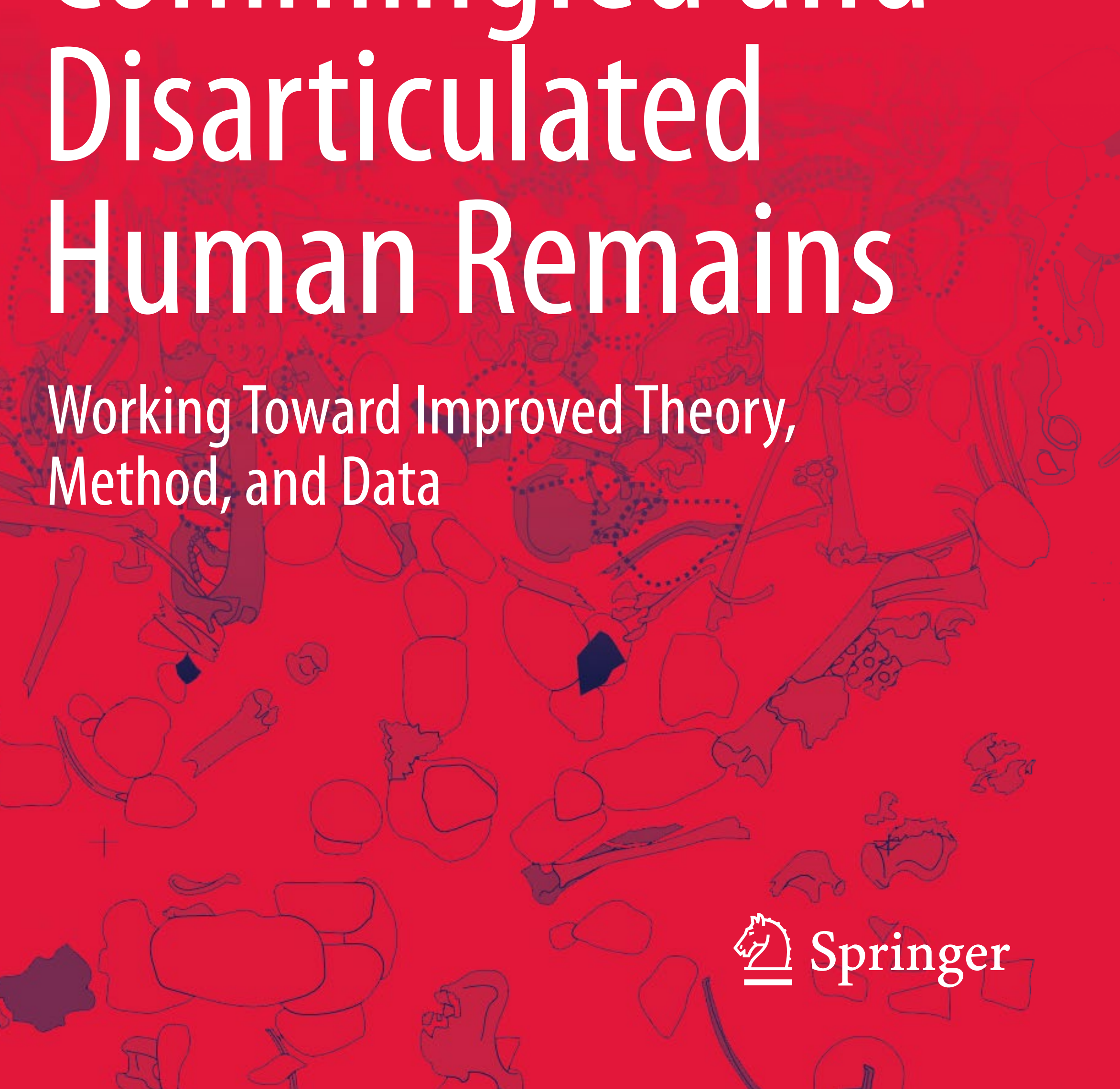
Anna J. Osterholtz
Kathryn M. Baustian
Debra L. Martin *Editors*

Commingled and Disarticulated Human Remains

Working Toward Improved Theory, Method, and Data



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ISBN 978-1-4614-7559-0 ISBN 978-1-4614-7560-6 (eBook)
DOI 10.1007/978-1-4614-7560-6
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013943277

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Cover Illustration: Cover art courtesy of Robert Turner, Office of Archaeological Studies, Department of Cultural Affairs, Santa Fe, NM

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To my parents (and forces of nature),
Roger and Janet Osterholtz. (AJO)

To my large family assemblage.
Thanks for your continual support. (KMB)

To all my commingled and disarticulated
grad students. (DLM)

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Introduction

Anna J. Osterholtz, Kathryn M. Baustian, and Debra L. Martin

Introduction

This volume provides new analytical procedures and theoretical models that can be applied to human remains that are neither complete nor undisturbed. The focus on commingled, disarticulated, disturbed, and/or collective burials is important because often these kinds of assemblages languish in museums and repositories due to challenges in analysis. Starting out as an organized podium session at the Society for American Archaeology annual meeting in 2012, these studies provide valuable theory, methods, and data to the interpretation of commingled and disarticulated human remains.

The primary goal of each study in this volume is to address innovation and applicability in the treatment of commingled and fragmentary assemblages. The individual contributions present a wide variety of methodologies and theoretical viewpoints for the analysis and interpretation of commingled assemblages. These case studies provide a template adaptable enough to meet the variable needs of any commingled analysis, whether it is the commingling of three individuals or three hundred. There is no *right* way to analyze a commingled assemblage. This set of studies provides what can be considered *best practices* for the analysis of commingled and disarticulated human remains.

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_1,

Types of Commingled, Disarticulated, or Fragmentary Assemblages

There are three main types of commingled assemblages that are covered in this volume (Fig. 1). Though many different actions can lead to commingling and fragmentation, similar methodologies can be used in their analyses.

Long-Term Usage Commingled Assemblages

The first type of commingled assemblage results from long-term usage. These assemblages are the result of primary and/or secondary interments from community groups. Long-term usage of a tomb will inadvertently lead to greater commingling and fragmentation due to movement of the extant elements with the placement of new remains (whether they be secondary or primary in nature). Demography within the assemblage will reflect mortuary programs within the society. Or, if all individuals from a community are buried together, the demography will reflect this. If, for example, it is culturally sanctioned for children to be interred separately from adults,

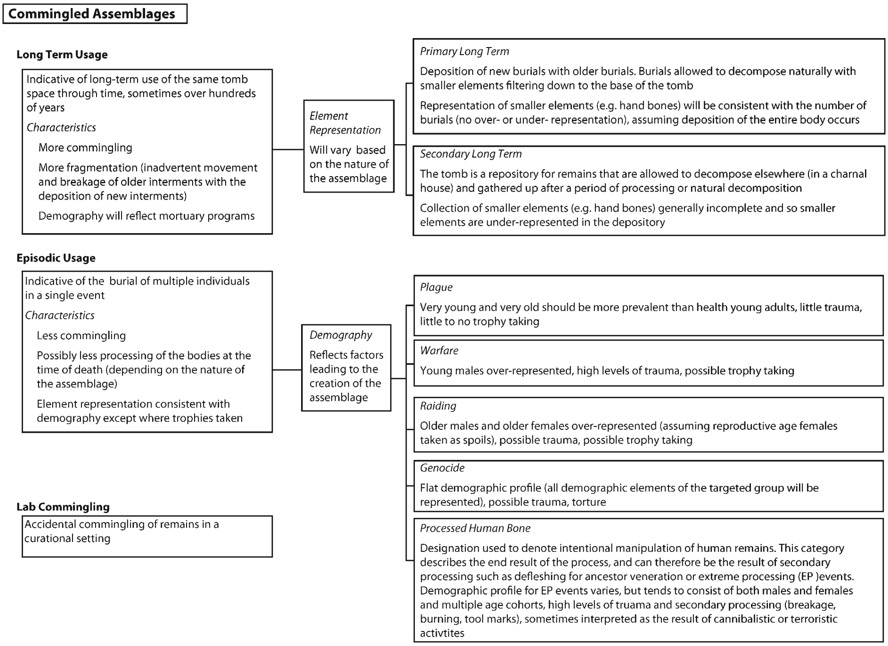

Fig. 1 Types of commingled and fragmentary assemblages

the ossuary containing adult remains would not be expected to contain juvenile remains. Within ossuaries exhibiting long-term usage, a further distinction can be drawn between primary and secondary assemblages. These will be the result of different depositional histories and present different elemental distributions of remains.

Primary long-term usage commingled assemblages are those where the deposition of new burials occurs on top of prior interments. Burials decompose naturally and the smaller elements (such as hand and foot phalanges) will filter down to the bottom of the tomb. All other things being equal (e.g., rodent predation is low and elements are not removed for secondary purposes), the representation of the smaller bones will be consistent with those for the larger elements. Secondary long-term usage assemblages are those where the assemblage represents the end of a multistage process. Bodies are processed in one location (such as a charnel house), and then remains are gathered together for disposal within the secondary structure. Typically, the collection of smaller elements such as hand and foot phalanges is less thorough and will lead to an underrepresentation of these elements in proportion to larger bones. Often, there is a mixture of primary and secondary deposits in community tombs. For example, the Tell Abraq assemblage (Osterholtz et al. 2013) consists of a mixture of both primary and secondary interments, as suggested by the degree of representation of the smaller bones of the hands and feet. While there is an underrepresentation of these elements, they are present in significant numbers to suggest at least some primary depositions (Osterholtz, Baustian, & Martin, 2012).

Episodic-Usage Commingled Assemblages

Another major category of commingled assemblages results from episodes of mass burial. These include burials that result from plague or warfare, and they are indicative of the death of multiple individuals at a single time. Hence they are episodic in nature, versus more chronic or long term as discussed in the prior section. Characteristics of these assemblages may include minimal commingling, less handling of the body at the time of death (i.e., little to no processing), and little fragmentation. Element representation is expected to be consistent with the demography of the burial population. Demography itself will reflect the processes leading to the creation of the deposit. Primarily, there are five main categories of human or cultural activities that create an episodic assemblage.

Assemblages relating to plague or epidemic disease will present the demographic signature of the disease that created them. Normally, epidemic disease will disproportionately affect the very old and very young within society. These are the individuals expected to be overly represented in plague pits. Because disease on such a grand scale often leads to fears of contamination (particularly prior to an understanding of disease processes), interference with the body after death is expected to be kept to a minimum. In their analysis of burials associated with a typhoid outbreak in South Africa, L'Abbe, Henderson, and Loots (2003) note that for 36 burials, the overall impression is of "rudimentary burial methods" (2003, p. 315). Also of interest with this burial assemblage is that an existing structure (in this case an active mine shaft) was co-opted as a place of burial. Burials following natural disasters also follow this pattern (e.g., Perera, 2005) but will exhibit a demographic profile consistent with all individuals exposed to the disaster.

The burial of warriors or soldiers is known from battles worldwide and across time periods and often presents to the archaeologist as a commingled assemblage. Examples of this type of burial can be seen in battlefields such as the Battle of the Little Bighorn (Phillips, 1987) and the Battle of Towton (Fiorato, Boylston, & Knüsel, 2007). Assemblages resulting from raiding are expected to contain an overabundance of older males and older females if young females are taken as spoils or captives. The taking of women and children and killing the men is a strong pattern in raiding activities and is well established in the ethnographic literature (e.g., Cameron, 2011; Maschner & Reedy-Maschner, 1998). Among the Inupiaq, Burch (2005) noted that raids tended to occur when young males were not in the community, and so demographic profiles resulting from raiding activity would be expected to show low frequencies of young males if, and only if, the absence of males in the community was a precursor to raiding activity. If males were present at the time of the raid, they can be expected to be overrepresented as the focus of raiding would have been the capture of young females (who would be underrepresented). In either case, older females would be expected to be overrepresented in relation to younger females, the goal of raiding activities. Little commingling or fragmentation is expected, unless bodies left exposed after raiding were not recovered or buried until after significant time had lapsed. Partial exposure and animal predation may be responsible for differential preservation and element representation of some sets of remains within these mass graves (Willey, 1990). The Crow Creek site provides an excellent example of this type of commingled assemblage (Kendell & Willey, 2013).

Assemblages resulting from genocide present a demographic profile consistent with the living population that is targeted which may be all the males and boys (as was seen in the Serbian-Croation conflict of the 1990s), or it may be men, women, and children (as was the case with the Rwandan-Tutsi genocide of 1994). The term "genocide" is generally attributed to lawyer Raphael Lemkin in 1944 with respect to the 1915 mass killing of Armenians. The United Nations General Assembly codified genocide as a legal concept in 1948 providing the definition as intentional destruction of a specific group based on national, ethnic, racial, or religious affiliation (Schabas, 2008). Integral to the definition is the intent to completely destroy a group, and from an archaeological perspective, the demography will reflect if part or all of the group was targeted. Kimmerle and Baraybar (2008) provide numerous examples of mass graves fitting this description. Komar (2008) states that there are no identified examples of genocide in the archaeological record, likely due to the importance of intent for the identification of a genocidal assemblage. These assemblages are expected to have traumatic injury on the majority of remains and may be directly related the cause of death (e.g., Hougen, 2008). Assemblages of this type are thoroughly explored by Adams and Byrd (2008) and are not covered in this volume.

The episodic assemblages of Sacred Ridge (Osterholtz, 2013; Osterholtz & Stodder, 2010; Stodder & Osterholtz, 2010; Stodder, Osterholtz, Mowrer, & Chuipka, 2010), La Plata (Martin, Akins, & Toll, 2013), and Op. 1000 (Duncan & Schwarz, 2013) present interesting analytical challenges as the degree and patterning of processing as well as taphonomy must be taken into account in the overall interpretation. Processed human remains with cut marks and signs of defleshing and dismembering among other things are also present in episodic assemblages. In the case of Sacred Ridge, the assemblage appears to be the result of a massacre of a clan or extended family with extensive processing, possible trophy taking, and interment shortly after death. This site is one of several in the Southwest exhibiting “extreme processing” (Kuckelman, Lightfoot, & Martin, 2000). These assemblages, interpreted by Turner and Turner (1999) as cannibalistic, exhibit episodic deposition and commingling, burning, fracturing, possible scalping, and mutilations. Interpretations abound regarding these assemblages, including cannibalism (e.g., Turner & Turner, 1999; White, 1992), terrorism (Turner & Morris, 1970; Turner & Turner, 1999), witchcraft executions (Darling, 1999), and politically motivated massacres with social overtones (e.g., Osterholtz, 2010; Stodder, Osterholtz, & Mowrer, 2010).

Martin et al. (2013), on the other hand, describe an assemblage (La Plata) where intentional manipulation of the remains is present, but the degree of processing is less intensive and represents a different intention, likely related to secondary mortuary processing. Alternatively, the Op. 1000 site is interpreted as representing the desecration of land by immigrants. In this way, Duncan and Schwarz (2013) argue for land tenure and co-optation of space by manipulation of the bodies. This could be seen as a form of extreme processing, as the bodies are used as symbols to convey a message to the living witnesses. In essence, this designation of processed human bone describes the appearance of the assemblage when discovered, not the activities that create it. Careful analysis of these assemblages is necessary to infer activities and motivations surrounding the creation of the deposit.

Lab Commingling

Lab commingling is an artificial process that can occur at any stage of analysis or curation. Zejdlik (2013) details the use of excavation photos to sort out issues of lab commingling for the ultimate analysis of the remains. The presence of lab commingling can complicate analysis for numerous reasons. Primary among them is the loss of information and context. When commingling occurs in the course of the creation of a deposit archaeologically (such as at Tell Abraq), there is a significant amount of information that can be inferred based on the presence of that commingling. We can analyze these remains within a heuristic framework informed though ethnographic analogy (see Baustian, Osterholtz, & Cook, 2013) with groups where similar practices still exist. When lab commingling occurs, however, no such allusions can be drawn. Zejdlik’s use of photos was a simple but effective way to combat lab commingling and return the burials to a state where they could be productively analyzed.

Volume Focus and Organization

This volume began with a symposium organized at the 77th Annual Meetings of the Society for American Archaeology entitled "Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data." Participants were asked to provide case studies relating their experiences with commingled and/or fragmentary assemblages with an eye toward theory and innovation. Additional chapters were added to provide geographical, methodological, and temporal coverage.

Innovation

Methodological innovations such as the use of photos to assist in conjoining exercises (Zejdlik, 2013), the adaptation of a feature-based approach for the determination of MNI (Osterholtz, Baustian, Martin, & Potts, 2013), and the application of taphonomic techniques from zooarchaeology (Atici, 2013) are but a few of the innovative methodologies detailed in this volume. Statistical techniques (Duncan and Schwarz 2013) can help to bring to the surface hidden relationships. How these innovations are used to answer social questions is explored by Baustian and colleagues (2013).

Applicability

A second goal of the organized session and this volume is to provide archaeologists and bioarchaeologists with a multitude of techniques for the analysis of commingled and fragmentary remains. By showcasing different time frames and geographic regions (as the authors of these chapter have done), it is clear that no matter what period or location in which an archaeologist is working, the analytical challenges of commingled remains are often present and instead of leaving these unanalyzed, this volume shows that they can be identified, quantified, and part of a research strategy.

As with most archaeological puzzles, there are multiple solutions to the analytical challenges of commingled assemblages. There is no *right* way of attacking the analysis of fragmented and commingled remains. There are multiple ways of analyzing and presenting these data. It falls to the analyst to determine what is appropriate for the research goals of the project. Different methodologies will be appropriate for different situations. This volume provides numerous case studies that highlight the tremendous data potential along with the limitations of a commingled assemblage.

Terminology

The study of commingled remains is fraught with acronyms and jargon. For students of bioarchaeology and archaeology, Table 1 provides an overview of some of the more often used terms in the volume. Working definitions are provided here.

Individual Chapters

Long-Term-Usage Assemblages

Boz and Hager (chapter "Making Sense of Social Behavior from Disturbed and Commingled Skeletons: A Case Study from Çatalhöyük, Turkey") examine the relationship between the living and the dead at Çatalhöyük, Turkey, through an analysis of the location of the burials within intramural spaces. They compare two distinct methods for the determination of MNI, highlighting the benefits of each method. Through careful examination of the locations of the burials as well as their designation as *primary* versus *secondary*, the authors present a complex picture highlighting the importance of the manipulation of the dead through the replacement of elements by contemporary inhabitants.

Likewise, Osterholtz, Baustian, Martin, & Potts (2013) provide a methodology for the determination of MNI based on feature count for the Tell Abraq assemblage. In assemblages with high degrees of fragmentation, the use of anatomical features to determine MNI will allow for an identification of the differential representation of elements. In this way, mortuary behavior can be discussed with respect to over- and underrepresentation of various elements. In this assemblage, for example, male crania are underrepresented, suggesting that these were retained and disposed of in an alternate mortuary context or taken as trophies. Without the intensive methodology described by the authors, though, this relationship would be unclear and not quantifiable.

Herrmann, Devlin, and Stanton (2013) examine the mortuary patterns at the Walker-Noe site in southern Kentucky Bluegrass in their analysis of a fragmentary and cremated assemblage. This chapter provides an excellent example of the use of high-tech methodology in the analysis of commingled assemblages in that they examined the representation of individual landmarks, standardized color mapping (using a spectrophotometer), and spatial patterning. They were able to show that color (degree of burning) and cranial representation varied with respect to the distance from the central platform at which a fragment was recovered, suggesting that distribution of elements after cremation was not random, but instead shows the complexity of Adena mortuary activity.

Finally, Glencross (2013) examines commingled assemblages from southern Ontario that date from the Woodland period. She argues that commingled remains

Table 1 Terminology used throughout the volume

Term	Definition
Ancestor veneration	The act of using human remains in religious or cultic worship. Elements or fragments to be used as venerated remains (or relics) are taken from either primary or secondary contexts (see below), modified (or used without any modification), and disposed of in an alternate fashion from the rest of the burial.
Bone mineral density (BMD)	Degree of mineralization present within an element (or individual). BMD is dependent upon age, sex, diet, health, and other social and genetic factors. BMD plays a large role in survivorship (see below), fragmentation (see below), and the composition of any assemblage.
Bonebed	"A single sedimentary stratum with a bone concentration that is unusually dense (often but not necessarily exceeding 5 % bone by volume), relative to adjacent lateral and vertical deposits." (Behrensmeyer, 2007, p. 66). This definition is not based on species identification, and can be applied to both human and nonhuman assemblages.
Commingled remains	Human (or faunal, or a mixture of both) remains that have become indistinguishable as individuals due to mixing of elements, either intentionally or unintentionally. Fragmentation (see below) is not necessary for commingled assemblages, but typically accompanies this type of mixing.
Compound mortuary program	Mortuary program consisting of multiple stages, with a *reduction process* and a *secondary or final disposal* (Sprague, 2005, p. 63). Essentially, with a compound (or, secondary disposal), it is expected that the body will be less complete at the final stage of disposal than it was at the beginning of the process.
Cremated remains	Bones where a primary portion of the mortuary program involved the systematic burning of the body. Degrees of burning vary, from charring to calcination. Key to the identification of remains as "cremated" is that the burning is an end in itself. A goal of the mortuary activity is to produce burned remains (as opposed to part of a mortuary process preparatory to breaking the bones for another purpose, see EP assemblages below).
Extreme processing events (EP)	Term typically used to describe processed assemblages from the American Southwest dating to the Pueblo II and Pueblo III (AD 900–1300) periods (Kuckelman et al., 2000). These assemblages, like PHR (see below), contain intentionally modified human bone. EP assemblages, though, have a suite of characteristics: good preservation, highly fragmented, burning, perimortem fracturing, tool marks, and (possibly) pot polish. These assemblages have typically been identified by Turner and Turner (1999) as resulting from cannibalistic activity. Others have posited witch disposal (Darling, 1999; Walker, 1998) and ritual massacre (Stodder et al., 2010).
Fragmentary remains/ fragmentation	Remains that are no longer complete. Fragmentation is by definition breaking a bone into more than one part. In some cases, such as EP assemblages (see above), fragmentation is severe, resulting in difficulties in identification of elements as well as the development of baseline data (MNI, MNE, etc.—see below). Fragmentation may be the result of natural taphonomic processes (such as natural filtration or trampling) or intentional processes (such as EP events or as part of ancestor veneration).

(continued)

Table 1 (continued)

Term	Definition
MNE	"Minimum Number of Elements." This measure is the number of total elements represented, regardless of side. This is the "minimum number of skeletal units required to account for all of the fragments in an assemblage that are identifiable as each skeletal category or skeletal portion" (Atici, 2013). This may be determined in multiple ways, but involves the identification of specific elements or element features.
MNI	"Minimum Number of Individuals." This measure may be determined through a variety of methods, but all involve replication. A single individual can only have one left femur, and so if 14 left femora (or features found on the left femora, if using a feature-based approach) are present, a minimum of 14 individuals are present in an assemblage.
NISP	"Number of Identified Specimens." This is a measure of the number of fragments that can be identified to at least general taxonomic or size categories (e.g. "large mammal"). Typically, NISP is used in conjunction with MNI or MNE to describe the amount of fragmentation (see above). Generally with increased NISP, MNI decreases (due to increased fragmentation).
Ossuary burial	Commingled assemblage that "involves the periodic and collective secondary burial of individuals previously interred separately elsewhere" (Glencross, 2013). Ossuary burials are the result of a compound disposal program (see above).
Primary depositions/ inhumations	Depositions (burials) of individuals in a complete stage. The body is interred (or otherwise disposed of) and then not disinterred, moved, or otherwise manipulated.
Processed human remains (PHR)	A broad term used in this volume to describe intentionally modified human bone. This may entail defleshing as part of a mortuary program, modifying remains for ancestor veneration, or otherwise intentionally changing their depositional outcome (i.e., where/how they are discarded). No statement about the cultural meaning of the processing is given; this designation is merely used as a recognition of the intentionality of the processing of the remains. EP events (see above) are one form of PHR.
Ripley's *K* function	A statistic used to explore whether an assemblage exhibits special randomness. This statistic is used by Duncan and Schwarz (2013) to show intentionality in fragmentation on the basis of side and element.
Secondary depositions	Disposal of remains at the conclusion of a compound mortuary program (see above). Element representativeness is expected to be different for assemblages arising from secondary disposals in that smaller bones are less likely to be present.
Survivorship	Potential for preservation of various skeletal elements. This will vary based on BMD (see above), age at death of the individual, morphology, age of the deposit, size of the fragment (and general size of the animal), or intentional modification/destruction.
Taphonomic filters	"Complex interacting factors including human activities, non-human animal ravaging, and diagenetic processes" that "do not necessarily operate simultaneously and may affect an assemblage differentially, increasing the preservation potential of some bones while destroying others." (Atici, 2013).
Unmingling	The act of reassociating individuals from commingled and/or fragmentary isolated bones, typically through the examination of field photographs (Zejdlik, 2013).
Zooarchaeology	The study of nonhuman bony remains in an archaeological context.

present an excellent vehicle for the discussion of the population versus the individual and how these two topics are inextricably linked. The individual in commingled assemblages cannot be completely removed from the discussion of the population, but the population cannot be discussed without respect to the individuals contained within the assemblage.

Episodic Commingled Assemblages

Kendell and Willey (2013) provide in their analysis of the Crow Creek bone bed a discussion of the factors that impact skeletal preservation based on bone mineral density. They show that age at death impacts bone mineral density and that this should be acknowledged when discussing MNI measures. In a different kind of commingled assemblage from Post-Classic Maya site Op. 1000, Duncan and Schwarz (2013) explore the concept of embodiment through statistical analysis of the relationships between elements. Using Ripley's *K* function, they were able to show that the distribution of elements within the mass grave is not random and use this to argue that the grave was intentionally created to co-opt ritual space by newcomers to the area through manipulation of the bodies of the previous inhabitants. Both of these chapters use methodological innovation to provide data on the demographic nature of the assemblages.

Finally, Osterholtz (2013) provides a comparison of the extreme processing evident at Sacred Ridge with that from Mancos Canyon. The Mancos Canyon study (White, 1992) was one of the first studies of disarticulated human remains that provided a detailed taphonomic methodology. Building on this, Osterholtz presents a detailed analysis, on an element-by-element basis, which allowed for a discussion of processing techniques. By carefully examining fracture patterning, tool mark presence and distribution, and burning patterns, different patterns in the treatment of the individuals could be identified between the two sites. These differences in processing may be indications of different motivations for the massacres of individuals. Using a similar methodology, Martin and colleagues (2013) demonstrate the importance of careful taphonomic and locational (stratigraphic detail) data to make sure that disarticulated remains with processing are not always relegated automatically to cannibalism. Very different natural and cultural processes can result in bones that have cut marks and that are disarticulated.

Contributions from Other Disciplines, Caveats, and Future Directions

Zejdlik (2013) provides a case study of the importance of excavation records and particularly photographs in her analysis of the Aztalan site assemblage. Commingling of these remains occurred post-excavation, and photographs and excavation records were used to unmingle individuals. Once unmingled, skeletal analysis could be accomplished using standard techniques. This chapter shows that sometimes the simplest techniques are the most effective ones.

Fox and Marklein (2013) present four assemblages with varying degrees of commingling from the eastern Mediterranean. The assemblages from Helenistic Kalavasos-*Kopetra* site and Roman sites of Paphos, Cyprus, and Corinth, Greece, present commingling as part of a secondary burial practice. The late Byzantine site of Thebes in Greece, on the other hand, has burials that were comingled during excavation. Using both of these types of assemblages, Fox and Marklein propose a methodology for the purpose of maximizing data potential from commingled assemblages focused on comparison of elements between spatial locations. This methodology facilitates analysis regardless of when the commingling occurred (in antiquity or during excavation).

In an important study, Atici (2013) provides examples of how zooarchaeological theory, particularly in the determination of MNI and MNE, can be used in the analysis of any commingled assemblage, whether it consists of human or nonhuman bone. Zooarchaeology has developed a wide range of techniques for the analysis of such assemblages, and understanding the theoretical underpinnings of these methods is important for the most robust interpretation possible of commingled assemblages. This chapter makes clear the great partnership that zooarchaeologists and bioarchaeologists can have.

Cook (2013) highlights the need for cross-disciplinary training through her reanalysis of the Franchthi Cave cranial fragments. Angel originally examined these remains and determined them to be pathological human remains, but during reanalysis, Cook properly identified them as normal caprid cranial vault fragments. This case study shows the importance of breadth and depth in an analyst's experience as well as the importance of cross-species identification.

Opening and concluding chapters serve in this collection of studies as "book ends" to provide an overview of the major themes that run throughout. The concluding chapter suggests where the gaps still reside within the study of commingled remains. Theoretical approaches are highlighted in the final chapter as a means towards showing how important they are for interpreting meaning and explaining human behavior. Future directions are suggested so that this volume, although one of the first of its kind, will not remain so.

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Part I
Long Term Usage Assemblages

Making Sense of Social Behavior from Disturbed and Commingled Skeletons: A Case Study from Çatalhöyük, Turkey

Başak Boz and Lori D. Hager

The Neolithic site of Çatalhöyük in Anatolia, Turkey, is well known for its size (~13 ha), long occupation (~1,400 years), mud-brick architecture with plastered house walls and floors, decorated buildings (painted walls, elaborate installations), figurines, and intramural burial practices. Dated from 6000 to 7400 B.C.E., Çatalhöyük was once a thriving Neolithic village of 3,500–8,000 people who lived in houses built atop older ones, creating a human-made mound physically linking one house to another through time (Cessford, 2005; Hodder, 2007). The dead were kept close to the living at Çatalhöyük by burying them within the houses. The occupants of the houses continued their daily activities above the floors while the dead occupied the space under the floors. The two worlds of life and death coexisted in Çatalhöyük houses, and through their burial customs and social rituals, the living continued to interact with the dead post-interment.

The burial customs of the Çatalhöyük people have been the focus of attention since the late James Mellaart (1967) famously, but erroneously, suggested that skeletal excarnation occurred prior to the interment of the secondary skeletons under the house floors of Çatalhöyük. In fact, the excavations at Çatalhöyük since 1995 demonstrate that the majority of the human remains found in the houses were primary interments, albeit often disturbed, and fewer were secondary depositions. Less commonly, individuals were interred in foundation deposits, middens, and the external areas near the buildings. Many loose and disarticulated bones have been found in both grave and non-grave contexts throughout the site.

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_2,

Intramural burial customs were commonly practiced at other contemporary Neolithic sites around the region, such as Çayönü, Bademağacı, Aşıklı Höyük, Körtiktepe, and Nevali Çori (Duru, 2005; Esin & Harmankaya, 2007; Hauptmann, 1999, 2007; Özdoğan, 2007a; Özkaya et al., 2008; Özkaya & San, 2007),with a few exceptions including PPNA Hallan Çemi (Rosenberg, 2007). However, at Çayönü and Abu Hureyra (Moore & Molleson, 2000; Özbek, 1986; Özdoğan, 2007b; Özdoğan & Özdoğan, 1998; Talalay, 2004), nonresidential buildings were used to bury people. At other sites such as Ilıpınar and Menteşe, the graves were in a large, nonresidential space that lacked the regularity and organization of a cemetery (Roodenberg & Roodenberg, 2007a, 2007b; Roodenberg-Alpaslan, 2008). The burial preferences at many Anatolian sites have resulted in a great deal of commingled bones, making the issue of mixed assemblages a general problem for this region during this time period.

Çatalhöyük contains an abundance of commingled remains in large measure because of their intramural burial customs. For instance, the Çatalhöyük people reused the same space in the houses for interment on a continual basis, often encountering previously interred skeletons as they dug the graves. In addition, as part of their burial customs, they routinely engaged in dismemberment and bone retrieval, actively collecting bones and body parts, and later intentionally depositing some of these partial skeletons or elements as secondary interments. Some burials were disturbed at a maximum level while others were left alone or only mildly displaced. By deciphering the flow of bones in and out of the grave during the life of the house, the interactions of the Çatalhöyük people with their dead before and after interment can be traced. One goal of this chapter is to untangle the commingled human remains in order to understand the social responses of the Çatalhöyük community to death and to the dead in various states of decomposition which they routinely confronted post-interment.

Neolithic activities are one source of disturbance to the burials at Çatalhöyük, but other factors contribute to the large amount of scattered and mixed bones on the site. The upper layers of the east mound at Çatalhöyük have been altered by considerable erosion, particularly on its slopes, and by the use of the mound as a cemetery by post-Neolithic people, including Roman, Byzantine, and early Selçuks (Cottica, Hager, & Boz, 2012). Burrowing animals have had a negative impact on the mound, especially at its core.

Tracing the Movement of Bones

The intramural interment of the deceased at Çatalhöyük did not end the interaction of the living with their dead. Many locations in the house were used for interment, but some areas were more heavily used than others. The platforms and central floors in many buildings, for instance, were opened and closed several times for multiple burial events over the life of the house. When other dead people were encountered in the same grave area, those digging the grave had to make choices. Once confronted with a body, did they avoid a skeleton or did they disturb it? Did they leave some or all of the bones in the grave pit or did they take them outside the grave? Did they put more bones in the open grave, adding secondary skeletal elements, or did they close the grave immediately after the last interment?

Table 1 Depositional categories at Çatalhöyük

Primary	A complete or nearly complete articulated skeleton found in its original place of interment
Secondary	A partial or complete skeleton moved from its original interment location, then redeposited in a different location
Tertiary	Loose, scattered, disarticulated human bones unrelated to burial contexts
Primary disturbed	A complete or partially articulated skeleton found in its primary location but disturbed from its original position during another interment or during bone retrieval event(s)
Primary disturbed loose	Loose, scattered, and disarticulated human bone that is found in contexts related to interment
Unknown	Inadequate contextual data for determination of deposition

The complicated movement of human bones post-interment by the people at Çatalhöyük dictated the use of customized depositional categories for the skeletal remains.[1] Starting with the three depositional categories used by Andrews, Molleson, and Boz (2005) for Çatalhöyük burials (primary, primary disturbed, and secondary), three additional categories were recognized: primary disturbed loose, tertiary, and an unknown category (Table 1) (Boz & Hager, in press). Primary burials are skeletons found undisturbed in situ, primary disturbed burials are found partially in situ and partially disturbed, and secondary interments are skeletons or skeletal elements that were intentionally redeposited into a grave after having been originally buried or curated elsewhere. The primary disturbed loose bone category was created to identify the bones stemming from the in situ disturbance to primary individuals. The post-excavation analysis clearly demonstrated that many, if not all, of the loose bones in the grave fill could be refitted to the primary disturbed skeleton(s) lying partially articulated in the grave. Large and complicated burial pits with a considerable number of loose bones proved more difficult to refit due to time and lab space constraints. The primary disturbed loose bone category was added to specifically address issues related to the minimum number of individuals in each burial pit.

Tertiary bones are unassigned bones found mainly outside of the grave, mostly in isolated contexts, buried without intention. This category includes loose bones and, less frequently, articulated parts of bodies. These bones are scattered in non-burial contexts including midden deposits, building fill deposits, and in-construction materials. Some of the loose bones in grave fills may have reentered the grave pit as tertiary bones. An unknown was also included for the small number of bones without contextual data, mainly due to issues of erosion or Post-Neolithic disturbance.

The archaeological context and post-excavation analysis of the human remains clarify the flow of the human bones in and out of the graves during the life of the typical Çatalhöyük house (Fig. 1). When a primary interment was disturbed, the body/skeleton or its parts were moved and/or taken, but the partial skeleton, still articulated, often stayed in the grave, becoming a primary disturbed interment. The skeletal elements disarticulated from the body or skeleton moved in two directions

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[1] Recovered from 1999 to 2010.

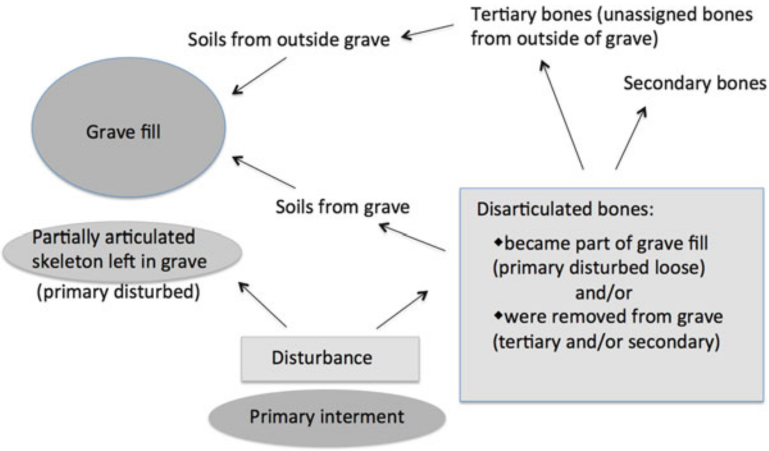

Fig. 1 Flow of human bones in and out of the grave during the life of the Çatalhöyük house

that were not necessarily mutually exclusive. First, some or all of the loose bones joined the soils from the grave and became part of the grave fill surrounding the partial skeleton and any other skeletons still in the grave pit. These bones were identified as "primary disturbed loose bones." Secondly, some or all of the disarticulated bones from the primary burial were removed from the grave pit to be used as secondary context elements. Less care was afforded to other bones coming out of the grave pit, many subsequently dropped or discarded, ultimately becoming tertiary bones. Tertiary bones might reenter the grave pit when soils from outside the grave were brought in by human actions as grave fill and/or by the activities of burrowing animals. Secondary elements could also reenter the grave pit through human deliberate action.

The intramural burials at Çatalhöyük generally reveal a high level of disturbance to the primary interments where many, but not all, of the skeletons were impacted, some several times. With multiple disturbances, the grave fill became increasingly mixed and churned over time, containing many primary disturbed loose bones and some tertiary bones from outside soils. Ultimately the integrity of the grave fill for each individual was lost. The customized depositional categories used in the study take into account the specific conditions of past human interaction that resulted in the commingled remains at Çatalhöyük.

Determining MNI

Observed MNI

The complicated deposition and redeposition of the human remains at Çatalhöyük presented a challenge to the determination of the minimum number of individuals (MNI) from the site. The Çatalhöyük Human Remains Database (access-based) was designed to code information for a number of variables for each bone and/or skeleton. The variables include a bone inventory where bones are marked present or absent, fragmented, or complete, and the bone preservation and bone condition are noted. Age and sex information are recorded as codes whenever sex determination was possible (Hillson et al., in press). The bone inventory has a link to all of the context information from the excavation and specialist databases. The 2,017 entries in the Çatalhöyük Human Remains Database range from complete skeletons to single loose bones, and therefore, they do not correspond to 2,017 discrete individuals.[2] The first task was to determine how many of these entries represent separate interred individuals and how many entries represent the disarticulated, scattered bones of disturbed individuals.

During excavation and at lifting, the depositional categories of the skeletons and loose bones were documented. On post-excavation analysis, the MNI was calculated and the depositional category confirmed by examination of the bones for the duplication of elements, and of the age, sex, and size criteria that discriminate between individuals. The six depositional categories were separated in two subgroups: (1) primary, primary disturbed, and secondary skeletons which represent the number of individuals that were observed to be interred on the site and (2) tertiary and primary disturbed loose bones which represents the disarticulated bones recovered from Çatalhöyük. The tertiary category was excluded from the first subgroup because it represents unprovenienced bones, occupying soils without intention, from skeletons potentially counted already in the MNI calculation. The primary disturbed loose bone category was excluded from the first subgroup because these bones are from individuals who have already been counted as primary disturbed skeletons. The exclusion of the primary disturbed loose bones from subgroup 1 was a cornerstone of the MNI calculation as an explicit attempt to avoid inflation of the primary disturbed individuals in the sample. All bones in the category of unknown contexts were excluded from the study.

The primary, primary disturbed, and secondary depositional data (subgroup 1), combined with the post-excavation analysis of the skeletons, produce an MNI of 384 Neolithic individuals recovered from the east mound of Çatalhöyük. The tertiary bones and primary disturbed loose bones (subgroup 2) were found in high absolute numbers ($n=1{,}633$), aptly demonstrating the considerable movement of bones throughout the site.

Computerized MNI

A computerized determination of the MNI based on the entries into the Çatalhöyük Human Remains Database was attempted as a means to simplify the process of MNI calculation when large numbers of commingled bones were found, a situation common to the large, substantial burial pits that have been excavated at Çatalhöyük.

Diagnostic zones (DZs) are a way of standardizing the counts of bones for the MNI that has been used for faunal assemblages (Russell & Martin, 2005; Watson,

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[2] All data are based on queries completed August 2010.

1979). The principle of the DZ technique is to count only recognizable parts or zones of a particular bone. These zones were counted when more than half of the zone was present. In fragmentary collections, the use of the DZ prevents counting the same bone more than once. For this study, three zones exist for the long bones: proximal, shaft, and distal. These zones were recorded in the Çatalhöyük Human Remains Database as complete, fragmented, or absent but without further comment on the state of fragmentation. Due to the constraints of the database on this last issue and to avoid potential counting errors resulting from the duplication of elements, the computerized MNI only counted the bone(s) when the diagnostic zone was complete. Loose teeth, ribs, and small finger bones of the hands and feet were also excluded from the query.

In most instances, the computerized MNI and the observed MNI resulted in the same MNI determination. A few differences in the MNI from each technique proved to be instructive because they point to the strengths and weaknesses of the two MNI calculations. For example, in Building 1, a large house in the North Area of the site, the computerized MNI is 34 while the observed MNI yields 58, representing the greatest level of discrepancy between the two MNI techniques in the sample. Since the number of burials observed in the field was more closely aligned with the higher number (58), the underrepresentation of individuals in the computerized MNI (34) is inaccurate in this building. Upon examination, the computerized MNI missed several individuals due to the level of fragmentation of the commingled remains that characterized the complicated burials in Building 1. The computerized MNI should be helpful when studying large and commingled samples because the technique takes into account all the bones that are recovered from the site whether they were found in a burial context or not. However, for this study, the computerized MNI was not able to adequately calculate fragmented bones in all instances, and therefore, the current configuration of the MNI calculation from the database needs improvement to accurately count fragmentary skeletons, focusing first on recording the level of fragmentation of the diagnostic zones.

By contrast, in Buildings 3 and 44, the computerized MNI exceeded the observed MNI by one individual, suggesting that the observed MNI based on the archaeological context and laboratory analysis was incorrect. When the skeletal samples in each house were scrutinized, it was plausible that another individual had been interred without any in situ evidence in the grave pit due to a high level of disturbance. On the other hand, the known flow of tertiary bones into the grave pit through the introduction of new grave fill means that the bones from the "extra" individual in Buildings 3 and 44 could be tertiary bones from the imported soils. In most instances, the observed MNI gives the number of skeletons accurately when field and laboratory information are combined and the skeletons are fully contextualized. Underestimation due to the exclusion of isolated bones or tertiary bones is the main weakness of the observed MNI technique.

Deposition, Age, and Sex

Recent work at Çatalhöyük confirms that the majority of depositions were primary single interments (Andrews et al., 2005; Boz & Hager, in press), although many of these same interments were partially disturbed post-interment. Loose human bones

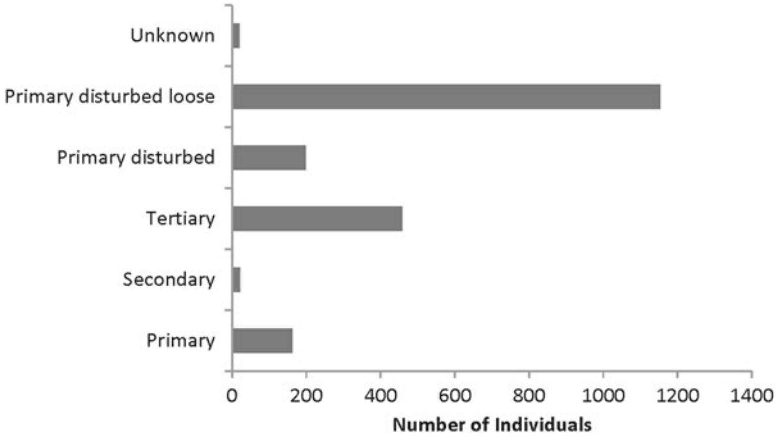

Fig. 2 Distribution of Çatalhöyük human bones by depositional categories

in primary disturbed contexts account for the majority of disarticulated human skeletons found at the site (57 %, $n=2{,}017$) (Fig. 2). The large number of loose bones from grave contexts reflects the numerous times previously interred individuals were disturbed as a result of multiple burials events in the same location, a common and regular burial practice at Çatalhöyük. Burials containing multiple individuals interred in a single burial event occurred rarely. Tertiary bones are the next highest category of recovered bones (23 %), indicating how much of the human bone on the site has been moved from primary interments to non-burial contexts by humans, Neolithic and post-Neolithic, and animals over the course of 1,400 years.

The primary disturbed individuals (52 %) comprise the majority of the three depositions in subgroup 1 (MNI = 384), followed by primary deposition individuals (42 %). Secondary interments, while often striking and memorable, account for a minority of the individuals (6 %) recovered thus far.

When age categories from all depositions are examined ($n=1{,}894$), the adults are represented in higher percentages than other age groups (67 %) (Fig. 3). The “adult” category, that is, individuals of adult status (post-20 years) who could not be further designated, were found predominantly in tertiary, unknown, and primary disturbed contexts. A different pattern is seen when only primary, secondary, and primary disturbed deposition age categories are viewed ($n=384$). In these three depositions, subadults represent a higher percentage (56 %) of the sample relative to the adults (46 %). Many of these juveniles were neonates, infants, and children (90 % of juveniles, $n=214$). Adults of all ages were dying and surviving in nearly equal numbers although middle adults are more common in the sample than younger and older adults. In secondary depositions, adults (mainly middle adults) and juveniles (mainly children) have been recovered in nearly equal numbers.

Sex was difficult to determine for many of the adults, and an assessment was not attempted for the juveniles who were too young for accurate sex determination. When all depositions are included ($n=1{,}598$), the adults for whom sex could not be determined dominate the sample (51 %), and there are a large number of youths in the

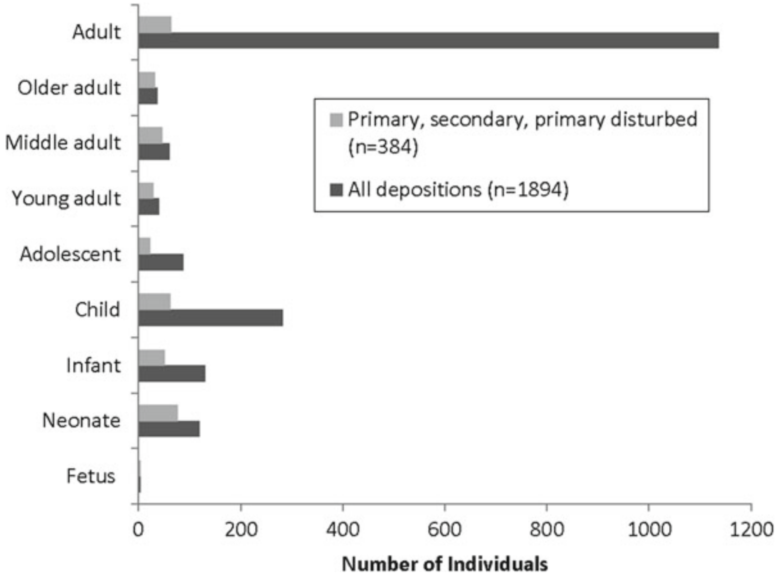

Fig. 3 Age categories by deposition

sample (38 %). Examination of only primary, primary disturbed, and secondary skeletons (*n*=384) for sex reduces the amount of indeterminate adults in the sample (14 %) while maintaining a relative large number of juveniles of unknown sex (54 %). Adult females (17 %) slightly outnumber the adult males (15 %) in the sample.

Locations of Graves in the Houses

The analysis of the MNI by buildings reveals an interesting aspect of Çatalhöyük intramural burials: the number of interments in the houses varies significantly. Not surprisingly, the houses with the largest number of interments demonstrated the most pronounced amount of disturbance to the previously interred human skeletons, resulting in sizeable areas of commingled remains. In the North Area, Building 1 contained the largest number of individuals (*n*=58) while the adjacent Building 3, also a relatively large building, had eight (*n*=8) individuals interred within it. Additionally, two skulls were deposited secondarily, likely at the time of house abandonment (Hager & Boz, 2012). By contrast, Building 49, a relatively small house by Çatalhöyük standards, had 15 individuals buried within it, most in two northern platforms. In the South Area, Building 50 yielded the largest number of interments (*n*=15), followed by Building 65 (*n*=13), and Buildings 6 and 44 (*n*=10). Yet, other buildings had no burials (Building 2) or a relatively low number of interments (Building 79). These MNI data from the North and South Areas indicate that residence in the house did not guarantee interment in the house. Some houses, like

Building 1 with its large number of interments and Building 2 with no interments, clearly show that other factors were involved in the interment decisions within specific houses. Pilloud and Larsen (2011) found that the dead in a single house may or may not have been kin-related ancestors based on metric and non-metric dental traits. They found that the occurrence of specific dental morphologies did not correlate with the choice of building in which the individuals were interred and that based on phenotypic similarities, there was no evidence of any clustering of dental traits in individuals buried in houses which were spatially close. Pilloud and Larsen conclude that the social structure at Çatalhöyük may have been centered on the house as a unifying structure as opposed to biological relatedness. Additional work needs to be done on the biological relatedness of the residents of Çatalhöyük to corroborate these results.

Since the use and reuse of the same space for interment in the houses contributed greatly to the displacement of the human bones, a closer look at the locational data was undertaken. Çatalhöyük is strikingly uniform in the layout of the Neolithic house and in the similarity of the functional divisions of the house. While conformity was the rule, both vertically and horizontally, some important variations did exist relative to building size, decorative elaboration, interior installations, and other interior factors (Hodder, 2007). Given that the houses conformed to a similar pattern, not only in structure but also in function, the distribution of the Çatalhöyük interments was examined in the different areas of the house.

The typical Çatalhöyük house was comprised of a main room that was functionally divided into specific areas. A rooftop entrance incorporated a ladder located at the southeast corner of the main room. In the south, under the roof opening, were the ovens and hearths that were associated with cooking and the preparation of foods and other resources. Raised platforms characterized the houses, and they were frequently located in the north and east of the central room. Many houses, but not all, had side rooms with thresholds open to the main room. These smaller rooms served primarily as food storage areas, having yielded numerous paleobotanical samples during excavation (Twiss et al., 2009). The external areas, the side yards and open spaces immediately around the buildings, had a small number of interred individuals. Foundation deposits, also containing intentionally interred individuals, refer to the base construction layers of the building.

The intramural burials have been found in all areas of the house although the greatest number of individuals was interred in the central room of the building, including both males and females, and all age groups (Fig. 4). Within the central room, the raised platforms were often used for interment and, in many instances, repeatedly opened and closed for multiple burial events, resulting in a large quantity of commingled remains over time. The northern and eastern platforms were favored for burial of the dead over the other platforms. In addition to the platforms, the central floors were used for interment. Infants and neonates were the most varied in their burial localities. Found in the platforms and central floors like the adults, neonates and infants were also interred in less common areas near ovens and other southern localities where few adults have been found.

Two locations are of particular interest because the interments are dominated by the presence of neonates: side rooms and the foundation layers of buildings. These

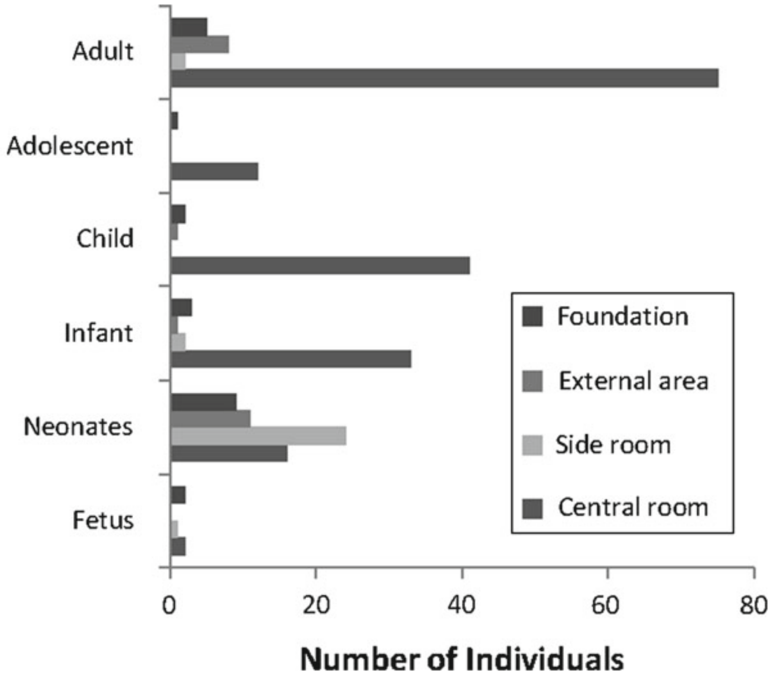

Fig. 4 Location of interments in or near Çatalhöyük buildings by age

locations are also similar because, for the most part, the burials were not disturbed post-interment and thus lack commingled remains and because no males have been found interred in the side rooms or foundation layers.

The majority of the side room burials (83 %) were neonates. The interment of the newborns in these small rooms, mainly without disturbance, suggests that the small spaces played an important role in the life of Çatalhöyük parents, possibly the women above all, when a newborn died. Why bury the youngest of the dead in the side rooms? Certainly, the newborn's grave would be near the central room but not in it, away from busiest areas of the house but close by. The lack of disturbance and any subsequent commingling of the neonatal bones suggest a specific memory of the graves. In addition, the small side rooms may have afforded privacy to the parents in the event of the death of a newborn, perhaps becoming a place of solace or refuge. The side rooms mainly contained food items, and domestic activities were clearly focused in these rooms. Patton and Hager (in press) and Gifford-Gonzalez (2007) suggest that there may be a link between the storage areas, a viewpoint that food is life, and the unrealized life potential of the newborns. Interment of the newborn within the domestic sphere of the houses might be related to the transformation of foodstuffs into life, just as newborns transform into adults.

The high proportion of juveniles (73 %) in foundation layers ($n=22$) in the upper levels of Çatalhöyük compared to other age groups, and newborns (41 %) especially, supports the viewpoint that newborns might represent the potentiality of the life, both for the house and for those who occupied it. As in the side rooms, all of the adult foundation burials were females or possible females, perhaps reflecting a link to house construction and new life. Practicality and a convenient place to bury the newborns with a minimum of grave digging may explain the interment of neonates in foundation deposits over other age groups. The death of a newborn might have coincided with the construction of a new house, although conversely, it could also be argued that the construction of the house may have begun with the death of a neonate.

The external areas and middens have also yielded several neonates and fewer adults, mainly older ones. In these extramural areas near the buildings, adult males but no adult females have been found. The disposal of the body extramurally rather than in the house indicates differential treatment of the dead at the site. While it is clear that some individuals were given much care and attention and that others appear to have been discarded, perhaps carelessly in some instances, especially in these external areas, it remains unclear what discriminating factors contributed to the interment decisions. Social factors, issues of health, cause of death, and/or group membership outside of the community could have come into play in the decisions surrounding death and the disposal of the body.

The locational data from the Çatalhöyük houses demonstrate how interment decisions impacted the integrity of the dead body or skeleton over time for adults and juveniles and males and females. Intramural burial practices at Çatalhöyük offered limited amounts of space in concert with a preference for certain areas of the house for interment. With repeated disturbances and interactions with the deceased, the burial practices contributed substantially to the dispersal of human bones on the site.

Dismemberment

Another major source of human bone dispersal at Çatalhöyük was the practice of dismemberment. Numerous examples of fully articulated arms, hands, legs, and feet have been found dispersed in various grave and non-grave contexts. Skeletons with the heads removed post-interment and solitary skulls have been found at Çatalhöyük, but in the majority of cases, the skulls and headless bodies could not be matched. An analysis of the sample of headless bodies shows no preference for age although there is no evidence for taking the skulls of neonatal or preterm skeletons. However, more adults than juveniles had their heads taken. By sex, more males have been found headless than females. When the solitary skulls are examined, there was no particular preference for any age, although the skulls of neonates have not been found in isolated contexts. Solitary skulls, where sex is based solely on cranial and mandibular traits, suggest that more males than females had their heads taken.

Evidence for cut marks on the human bones is relatively rare at Çatalhöyük given the amount of human bones taken from the bodies (Andrews et al., 2005; Human Remains Archive Reports from Çatalhöyük, 1999–2009). The lack of cut marks and the presence of fully disarticulated elements suggest that many of the loose body

Fig. 5 An example of dismemberment at Çatalhöyük: the secondary interment of a partial older woman from Building 49. Photo courtesy of the Çatalhöyük Research Project

parts were separated after complete decomposition of soft tissues had occurred. Even so, there are examples from Çatalhöyük where articulated body parts were separated from the rest of the body in a manner that demonstrate deftness in their bone retrieval abilities. A striking example of their surgical skill during dismemberment was the last burial of Building 49, an older woman buried in the central floor where it abutted the northwest platform containing the interred remains of nine individuals (Fig. 5). For this last house burial, all that was present in the well-defined grave was the articulated head, mandible, and torso of the older woman. The grave was devoid of extraneous, loose human bones, including those missing from the woman. Her grave indicated that dismemberment took place at a different locale when her body was partially decomposed and that she was secondarily deposited under the floor of the house, already dismembered. The bones of her shoulders (scapulae and clavicles), arms, and legs had been cleanly removed, leaving no cut marks on the articulated bones of the torso, head, or mandible. This individual represents an example of intentional dismemberment prior to interment, rather than a disturbance to an intact primary burial, and demonstrates an intimate knowledge of human anatomy.

In another example, the skillful removal of an adult man's skull (F. 492) from his body did result in cut marks on the first cervical vertebra (C1) that remained in articulation with the base of the skull (Andrews et al., 2005). At the time of skull removal, at least some soft tissues were holding the skull and vertebrae in articulation. The person taking the skull clearly knew how to take it between C1 and C2 with a minimum disturbance to the rest of the body.

Fig. 6 Figurine from Istanbul Area of East Mound of Çatalhöyük, side view. Photo courtesy of the Çatalhöyük Research Project

Other similar examples exist in the Çatalhöyük burial sample demonstrating not only familiarity with the skeleton but also the relative importance of human skeletal elements in the Çatalhöyük culture more broadly. In their material culture, the skeleton can also be found, such as a figurine carved with images conjuring up themes of birth and death on opposing sides of a headless figure (Fig. 6). On the back of this figurine, skeletal parts were precisely carved: ribs connected to vertebrae, scapulae correctly floating on the upper back, and individual pelvic bones holding the weight of the torso. The front of the figurine is highly suggestive of a late-term pregnant female, raising questions on how the Çatalhöyük people may have viewed birth and death, perhaps understanding that they lie on the same continuum.

Bone retrieval was an integral part of Çatalhöyük burial customs. When and why did they reclaim the bones? The archaeological context of the burials indicates that bone retrieval was always intentional but not always planned. At the interment of a newly deceased person, the removal of the skull or bony elements from the previously interred may have occurred without the specific intention of opening the grave for those bones. On the other hand, the Neolithic people might have anticipated doing both once the grave cut was made. In other cases, the removal of the body parts was clearly intentional and planned as evidenced by the specificity of their actions and of the bones taken from the grave.

The repeated opening of the graves and the fact that the typical Çatalhöyük house was occupied for ~75–80 years (Cessford, 2005) strongly suggest that a social memory of the burial locations existed. Evidence to support the memory of specific graves includes not only the neonates in the side rooms but also crowded platforms where disturbance had not occurred. In Building 49, for instance, the northeast platform had five juveniles sequentially buried in close proximity to each other, some in tightly constrained graves and with none disturbing the other; this was a surprising finding given the relatively small size of the platform. Moreover, the movement of specific bones between houses clearly demonstrates a social memory of some of the individuals beneath the floors. In two related buildings, for instance, there is evidence that the Neolithic people removed body parts from one house to specifically add to the deposits of the house built directly above it. At the abandonment of Building 65, an older building, the Neolithic people retrieved bones from two individuals and then later placed these bones into the new house, Building 56, thus creating a physical and ancestral link between the houses.

Kuijt (2008) suggests that individuals could lose their named individuality after two to three generations, the living having little connection to the previously dead as specific individuals where their memory did not persist. In this case, the dry bones may have meant less to the living as they had before and may account for the apparent random disposal of some bones which may represent the forgotten dead (Boz & Hager, in press). By contrast, great care was taken regarding the bones of many individuals at Çatalhöyük, perhaps those with specific named personae.

Secondary skeletons provide information on what happened to some of retrieved bones. In some cases, the removed body parts were used as artifacts. In one such example, a plastered skull reddened with pigment was curated, re-plastered, and repainted several times before it was buried in the arms of an older female in the foundation layers of a house. In another case, the skull of a woman was found in a post-retrieval pit, possibly as a foundation offering. In Building 3, the intentional placement of two skulls with their foreheads touching at the time of house abandonment represents retrieved, possibly curated skulls, from other individuals whose specific identity may have been known. In Building 60, a secondary deposition of a partial male skeleton consisting of his skull, arms, hands, legs, and feet had been placed into the grave in a simulated flexed position above a woman who had died in childbirth (Patton & Hager, in press). The woman's skull was taken after her interment, possibly up to a year later, and the placement of the male's skull replicated the missing skull of the female. The close proximity of the two individuals indicates a potentially significant relationship between the woman who died first and the man who was placed near her later, likely when her head was removed.

In other cases, there is no indication of what the Çatalhöyük did with body parts they had removed with such care. For example, there is no indication of where the removed arms and legs of the older female from Building 49 were deposited. As the last interment in that house, this woman's dismemberment could have been related to the formation of a new, as yet undiscovered house, in a manner similar to what has been documented in Buildings 56 and 65.

Conclusions

The large number of commingled remains at Çatalhöyük raised the issue of how to deal with them in a meaningful way. In order to understand the factors leading to the commingling of the human remains and to discern the minimum number of individuals in the sample, six depositional categories were applied to the collection. There were distinct advantages to customizing the depositional categories to the site-specific conditions at Çatalhöyük where commingled remains are the norm and bones loosened and transported during grave disturbance and/or pre-interment dismemberment pose particular challenges. Two techniques for the determination of MNI were done, each technique is predicated on observations of the depositional category in the calculation. The computerized MNI needs modifications to the database to better incorporate fragmentary bones into the analysis. In particular, recording the degree of fragmentation for the diagnostic zones would aid in achieving solid results. The observed MNI relied heavily on information from the field that proved valuable in our determinations. Followed by rigorous laboratory analysis, the calculation of the observed MNI produced reliable results but with some underrepresentation in the multiple event burials where earlier interred individuals were fully disturbed and where isolated bones were not counted.

For Çatalhöyük, this study found that social factors of the Neolithic people lead to the broad dispersal of the commingled remains, in concert with disturbance by post-Neolithic people and erosion and disruption through normal taphonomic processes over time. The intramural burial practices of the Çatalhöyük people, likely the same community of people as the deceased, accounted for a considerable amount of the commingling of the Çatalhöyük human remains recovered from the new excavations since 1995. The reuse of the same space in the houses for interment was common, the custom of dismemberment and bone retrieval was pervasive, and secondary deposits of the specific bones were noted, at times in provocative contexts. All of these funerary activities impacted the integrity of the Çatalhöyük human remains.

Clearly, an intense and complex relationship existed between the living people of Çatalhöyük and their dead. They shared space in their houses, above and below, and the dead were routinely encountered with each new death. They managed, handled, and disrupted the dead bodies before and after interment, at times on partially defleshed skeletons. Once a grave pit was open, they sometimes took bones, possibly of specific individuals, while placing other ones into the grave. With their constant interaction with the deceased, the inhabitants of Çatalhöyük undeniably became familiar with the dead body in its various states of decomposition at a very high level. Their link to the dead lay in the reality of the skeletons that occupied the space below them and in their interactions with their dead throughout the life of the house.

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Commingled Human Skeletal Assemblages: Integrative Techniques in Determination of the MNI/MNE

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Introduction

This chapter addresses methods for the determination of the MNI and demographic breakdown of the human skeletal assemblage from the Bronze Age site of Tell Abraq. Baseline data such as MNI are important in the process of investigating osteobiographical information such as health status, disease profiles, and mortuary practices of the community.

The site of Tell Abraq is located in the northern United Arab Emirates (UAE) on the border of Sharjah and Umm al-Quwain, about an hour's drive north of Dubai. The site is located approximately 100 m from the edge of a salt flat but likely bordered a lagoon during its occupation. The site should therefore be considered coastal. Occupation at Tell Abraq began around 2200–2100 BCE and lasted until approximately 400–300 BCE with slight traces extending into the first century AD (Potts, 1994, 2000a, 2000b, 2009, 2012). Though first noted in 1973 by an Iraqi survey crew, excavations did not begin until 1989 (under the aegis of the University of Copenhagen). Subsequent excavations occurred in the 1990s through the University of Sydney (Potts, 1994, 2000a, 2000b, 2009, 2012) and in recent years under the direction of excavators from Bryn Mawr College and Eberhard Karls University in Tübingen, Germany (Magee et al., 2009). The tomb is located approximately 10 m

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_3,

west of a fortification tower; the tower and tomb appear to both date to the early occupation of the site. The use of the tomb appears to be limited to a relatively short time during the early use of the site, approximately 2100–2000 BCE.

Like other Umm an-Nar tombs, the Tell Abraq tomb consists of local stone construction (in this case, conglomerate slabs gathered from the floor of the lagoon) with ashlar facings. The tomb measures approximately 6 m in diameter and was entered through a trapezoidal opening approximately 50 cm above the floor. This opening served as the sole entry to the two chambers within the tomb. Preservation of the tomb was generally good with the exception of missing portions on the northwest and southeast. At the conclusion of the tomb's use, it appears that it was covered relatively quickly with settlement debris and sand which protected it from looting later in time (Potts, 2000a, 2000b).

Umm an-Nar Mortuary Patterns

The Umm an-Nar period (late Early Bronze Age) is typified by circular, aboveground tombs throughout the UAE and Oman. Tombs are constructed of local stone and faced with ashlar stones. One or more internal chambers are typically present. The number of chambers depends on the overall size of the tomb, which ranges from 4 to 14 m in diameter (Al-Tikriti, 1989; Blau, 2001; Cleuziou, Méry, & Vogt, 2011; Frifelt, 1975; Potts, 1990). Tombs were roofed by large, flat slabs of stone supported by the internal partitions. Their floors were formed by unworked stone slabs. Most currently known Umm an-Nar tombs were looted in antiquity; however, a few preserved tombs exist (Potts, 2009).

Umm an-Nar tomb construction is variable in many ways. Tombs demonstrate differences in size, location, association with settlements, and orientation of entrances, among other things (Blau, 2001; Potts, 1990). This variability suggests that either mortuary practices were not consistent or poor preservation has obscured overarching patterns.

As discussed in Chap. 1, there are two categories of collective burial. Umm an-Nar tombs qualify as long-term usage tombs. The presence of large numbers of hand bones suggests a primary context, but a combination of primary and secondary contexts is always possible and may be impossible to distinguish. A single intact burial discovered during excavation may indicate the final deposition in the tomb (Martin & Potts, 2012).

A variety of grave goods have been found in Umm an-Nar tombs, including ceramics, stone vessels, lamps, jewelry, ivory combs, bronze weaponry, cylinder, and stamp seals. Textiles are suggested based on impressions found on corroded bronze objects. Potts (1994, 2000a, 2000b) notes that locally manufactured goods such as ceramics and stone vessels are typical of the period and that the wide range of grave goods (both in origin and quality) suggest all social and economic groups of the community are represented. The presence of numerous nonlocal goods may indicate the importance of trade as much as relative social status of individuals to each other in the tomb itself. Based on grave goods found in the Tell Abraq tomb, it is believed that both fishing and trading were important economic activities for the inhabitants of the associated settlement (Potts, 1994, 2000a, 2000b, 2003a, 2003b). Gregoricka (2011) examined elemental isotope ratios for the Tell Abraq assemblage and found that almost all individuals lived in the area around the tomb during dental development except for an individual whose values are consistent with either Bahrain or Iraq. So, while trade is important to the populace as a whole (based on the presence of nonlocal items as grave goods), the tomb itself acted as more of a community cemetery.

In addition to grave goods deposited with the burials as commemorative items, some items may have been included with the burials as a mechanism for ensuring the rest of the deceased. Potts (1997) notes that the primary reason for burial was to protect the living from the restless dead. Ostrich eggs, ceramic vessels, and other food containers may have been included in the tomb as a mechanism for the nutritional provisioning of the dead. Spiritual provisioning may be indicated by the presence of small flecks of charcoal found with the remains. Aromatics may have been burned as part of the burial rituals. This is suggested by the presence of frankincense at the site of Ras al-Jinz 2 in the Sultanate of Oman, another Umm an-Nar site (Cleuziou & Tosi, 2007).

Baseline Data and the Tell Abraq Assemblage

Baseline data include biological information, such as age and sex, which inform an analyst about the demographic profile of a community. Using these data to understand who is interred is imperative in any bioarchaeological analysis but is especially necessary for commingled and fragmentary skeletal assemblages. Through careful sorting and a meticulous analytical technique for every fragment, baseline data and the minimum number of individuals (MNI) can be obtained. For determining the MNI of an assemblage, Buikstra and Ubelaker (1994) have set guidelines that count elements based on their relative completeness. Knüsel and Outram, in contrast, argue for a zonal method where individual features of the bones are scored as present and MNI is determined using the highest counts of features (Knüsel & Outram, 2004).

The project discussed in this chapter uses a feature-based method for the determination of MNI. This technique differentiates skeletal features by bone density. The method was adapted from analysis completed on a large commingled and fragmented collection from the American Southwest at a site called Sacred Ridge (Osterholtz & Stodder, 2010, 2011; Stodder & Osterholtz, 2010; Stodder, Osterholtz, Mowrer, & Chuipka, 2010). In that assemblage, the degree of fragmentation was extreme (long bone shaft fragments often less than 5 cm in length), and so the methodology was slightly different from that presented here. Having exposure to multiple commingled assemblages has shown that each will be slightly different, as different formation processes (both accretional and taphonomic) will necessitate a modification of the methodology employed. Sacred Ridge was a deposit that formed in a single action and the research questions focused on violent interaction, so the features chosen to score for MNI included elements likely to be intentionally fractured in violent interaction or during body processing. For the Tell Abraq assemblage, we seek to know the degree of accidental damage to bone caused by repeated use of the tomb for approximately 150 years. With this research intent, features were chosen based on bone type and degree of density. It is through the choice of these features that we are able to examine not only what has preserved but also what has *not* preserved. This provides insight into the formation processes of the tomb itself.

Developing a good baseline is necessary for any project utilizing the Tell Abraq tomb assemblage. To date, most research has examined paleoepidemiological questions. This type of inquiry requires the development of a life table which is completed using baseline data. While life tables are not completely feasible for all commingled assemblages, baseline data can provide enough information to mediate issues with some interpretation. Data from one element can be used to extrapolate information for other elements in the assemblage. Age-at-death estimations of the os coxae were used in an analysis of the patella to argue that the higher rates of osteoarthritis among males may be a result of an older average age at death than females and may not be indicative of harder workloads. We have been incredibly conservative in applications such as this.

Baseline data are incredibly important for the most informed interpretation of the tomb in that they will show what is *not* present. Discrepancies in element representation suggest that some elements may have been removed from the tomb, possibly for ancestor veneration. In determining the MNI using multiple features and different bone types (i.e., cortical, spongy, and so on), we may be able to see, through its absence, how a body part was used ritually. In the case of Tell Abraq, the crania (particularly of males) are underrepresented. We suggest that these were ultimately removed for secondary disposal elsewhere.

Methodology

Tell Abraq and Sacred Ridge

The approach to analysis of the Tell Abraq assemblage was based on methodology developed for the Sacred Ridge assemblage (Osterholtz & Stodder, 2010; Stodder & Osterholtz, 2010). In developing that methodology, the work of both bioarchaeologists (e.g., White, 1992) and faunal analysts (e.g., Knüsel & Outram, 2004) were consulted. Based on the high degree of fragmentation observed at Sacred Ridge, it was determined that standard techniques based on element completion (as outlined in Buikstra & Ubelaker, 1994) for recording commingled MNI would be inadequate. Knüsel and Outram (2004) used a zonal system based on muscle attachment sites in order to compare processing of animal and human bone. Stodder and

Osterholtz (2010) adapted this system to look at specific features that would be involved in disarticulation and dismemberment of human bone specifically. As an example, the femur was scored for multiple features including the greater trochanter, lesser trochanter, and neck. All of these features are integral to analysis of the hip articulation and dismemberment: the neck had to be circumferentially cut to loosen the tendonous attachment of the os coxae to the proximal femur, while the trochanters providing muscle attachment sites for hip stabilizing muscles would need to be cut in order to disarticulate this joint. The Sacred Ridge assemblage consists of intentionally fragmented and commingled bone, and so the identification of small and distinct features was integral for the identification of biological information such as age, sex, and health status.

The nature of the Tell Abraq tomb is significantly different from Sacred Ridge. Whereas Sacred Ridge was a unique assemblage probably created over a short period of time, the Tell Abraq tomb represents at least 100 years (and probably as many as 200 years) of continual use by a community. The fragmentation is much less extreme than that seen at Sacred Ridge. But because the methodology used on the Tell Abraq assemblage is based on that used on a more complex deposition, the recording is very rigorous and conservative. The goal with the Sacred Ridge methodology was to preserve as much data as possible since the collection was set for repatriation (which has occurred). While the Tell Abraq assemblage is not under a similar time constriction for analysis, the data collection has benefited from the very strict data collection protocols that were developed for the Sacred Ridge assemblage.

Sorting

The determination of MNI for Tell Abraq was a multiphase process, beginning with a sorting of elements. Initially, a rough-sort/fine-sort approach was taken, where analysts roughly sorted elements into boxes so that all of the scapulae fragments would be boxed together. These boxes have since been fine sorted into age and side categories. All unfused epiphyses were boxed as subadults except for late-fusing elements such as medial clavicles. Unfused clavicles that had attained adult morphology and relatively substantial robusticity were boxed with other adults. Given the fragmentation of the assemblage and the incredibly large number of fragments that needed sorting, this process has taken over a year to complete despite a robust contingent of analysts and significant lab time devoted to the project.

Data Management

While the assemblage was being sorted, the database was being built by Anna Osterholtz. Though based on the Sacred Ridge database developed by SWCA

Environmental Consultants (Reeder & Horton, 2007), this simplified version uses primarily a visual recording form to ensure that whomever records the individual element also records the feature in the same location as any other recorder. Also, a single individual is performing data entry for each element, interobserver error is minimized in the identification of features. Features were marked as present which could then be tabulated and compared with other features from the same bone (with additional comparisons by sex, side, and age). Using a visual form increased the speed of data entry as well. Individual elements were examined by a single analyst to provide consistency in the recordation of age and sex criteria and the identification of features present. As of October, 2012, over 12,000 fragments have been examined and recorded, leading to a final MNI of 276 adults based on the right talus. The methodology used in this analysis leads to a tremendous amount of data. Baseline data can be broken down by sexes, age groups, or type of bone (i.e., cortical vs. spongy bone). These data can then be used in subsequent analyses.

Accession Numbers

Given that these remains were excavated approximately 20 years ago in the UAE, were shipped to the USA, and have been used as a teaching collection at two different universities, we expected a moderate amount of lab taphonomy; however, there is very little. During excavation, bones were identified and assigned accession numbers which were kept in a logbook. These books were curated with the bones and were often consulted during data entry to make sure that the correct bone was entered under the correct accession number. This will ensure that an accurate depositional map is produced in the future. When these numbers could not be read due to lab taphonomy (either partially or completely missing or obscured in some other way), an accession number was assigned and permanently written on the bone. A repeating sequence of four digits was used to denote a lab-assigned number. In some cases, this was done even when the accession number was perfectly legible. For some bones in the field, a single accession number was assigned for multiple fragments or whole bones (this is particularly true for carpals or tarsals). When this occurred, the repeating sequence of numbers was added to the end of the original accession number, usually with another number at the end to signify the order it was examined. For example, in the analysis of hand bones, the accession number "495" was given to seven scaphoids. We wanted to retain the locational information encoded in the accession number but needed to record each individual scaphoid for demographic purposes, so a unique identifier needed to be assigned for each one. For example, the second scaphoid examined with the accession number "495" was entered in the database under the lab-assigned accession number "49500001," the four 0's denoting the lab-assigned nature of the accession number and the 1 indicating the second bone found with that accession number. The lab-assigned number was written on the bone before it was boxed with the other scaphoids. Also, in this way, if pathological processes were recorded as present on a bone that had a common accession number, it could be easily identified for subsequent analysis.

Demographic Standards

The estimation of age at death and sex were made using standard osteological techniques, as outlined in Buikstra and Ubelaker (1994). For the estimation of sex, morphological characteristics of the pelvis are considered to be the most accurate (Phenice, 1969), but metric analyses were also used. We set a minimum accuracy level of 70 % for these analyses and attempted to use standards developed on geographically similar populations where possible (e.g., Introna, di Vella, & Campobasso, 1998; Kemkes-Grottenthaler, 2005). Where this was not possible, the use of modern forensic standards (e.g., Spradley & Jantz, 2011) were employed. Sex was estimated as "male" or "female" where traits associated with those sexes were found, "ambiguous" when a combination of both male and female traits were visible, and "undetermined" where a lack of dimorphic features were present. Age at death is very difficult to estimate for many of the isolated elements. For example, the patellae could only be estimated as "adult" or "subadult"[1] based on general size and morphology. For the os coxae, we were able to estimate age finely using methodologies developed for the pubic symphysis (Brooks & Suchey, 1990) and the auricular surface (Lovejoy, Meindl, Pryzbeck, & Mensforth, 1985). For elements/features such as femoral shafts, however, the estimation of age is necessarily more general. This lack of fine detail is a serious limitation of commingled remains and requires that questions be asked using diagnostic elements in the body (such as long bones with known epiphyseal fusion times). On the Sacred Ridge project, a series of overlapping age categories was employed so that the finest possible age-at-death estimation could be given. In the final analysis, however, the majority of these categories were ultimately reduced to "adult." While we maintained the ability to record individuals as "young adult," "middle adult," and "old adult," for most elements, only the use of "adult" is really possible. We have no way of knowing the typical age of onset for osteoarthritic change for this population and no way of ascertaining primary versus secondary osteoarthritic change or differentiating normal age-related changes from increased entheseal development due to activity; these general indicators can therefore not be used to narrow age-at-death estimation. All finely detailed age-at-death estimations are based solely on the os coxae.

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[1] "Subadult" includes all individuals who have not attained adult morphology, indicating age at death of <18 years.

Results

Element Representativeness

The MNI of 276 is based on the right talus. Figures 1 and 2 show the MNI for elements from all parts of the body. Of note are the higher counts for dense, round bones (such as the talus and patella). These bones are large enough to have been found despite a lack of screening at the excavation and relatively dense, and so better preserved. Thin bone, such as the blade of the scapula, was highly fragmented. Individual fragments could still be identified as scapula, but these could not contribute to the MNI due to overall small size of the fragments. Among long bones, the proximal and distal ends are better represented than shafts. This suggests fragmentation with the subsequent shaft fragments being unidentified as specific elements (and therefore stored simply as "long bone shaft fragments"). This representation of elements is consistent with bony preservation found at Crow Creek in South Dakota, indicating that taphonomic changes are related at least in large part to the density of the individual bones (Willey, Galloway, & Snyder, 1997).

There is no bias in the representation based on side (Fig. 3). If there had been far fewer right side elements present, for example, it would have suggested that these

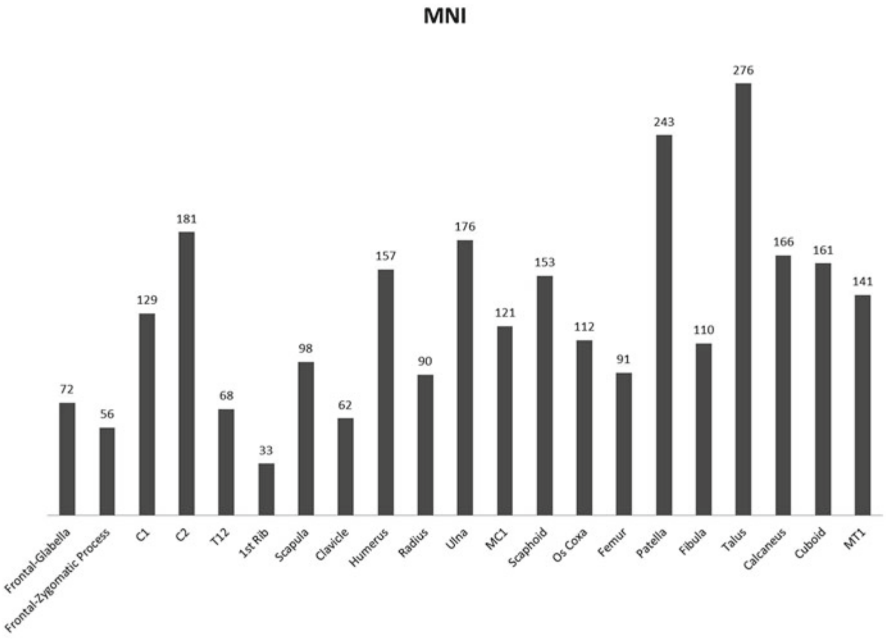

Fig. 1 Overall MNI, without regard to sex or side

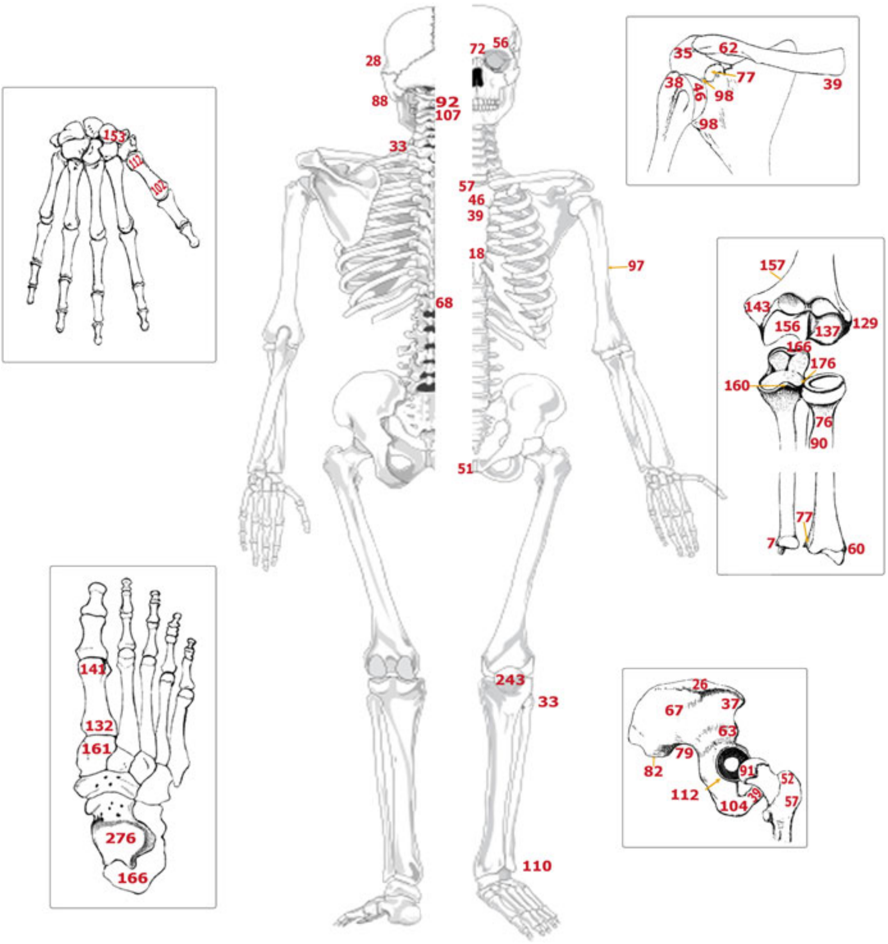

Fig. 2 Detailed MNI diagram, without regard to sex or side

elements were removed for some form of secondary processing or veneration purposes. But for some elements, there are more rights and, for others, more lefts, indicating that the entire body (with the exception of the crania, discussed in greater detail below) was placed in the tomb and allowed to decompose within that structure. The overall MNI of cranial elements is lower than would be expected. Other flat bones, such as scapulae and os coxae, are well represented, so the underrepresentation of the crania suggests that some of the crania were removed as part of the mortuary ritual. The high number of small hand and foot elements indicates that these portions of the body were present when the body was placed in the tomb itself. This argues against solely secondary deposition of the remains within the tomb.

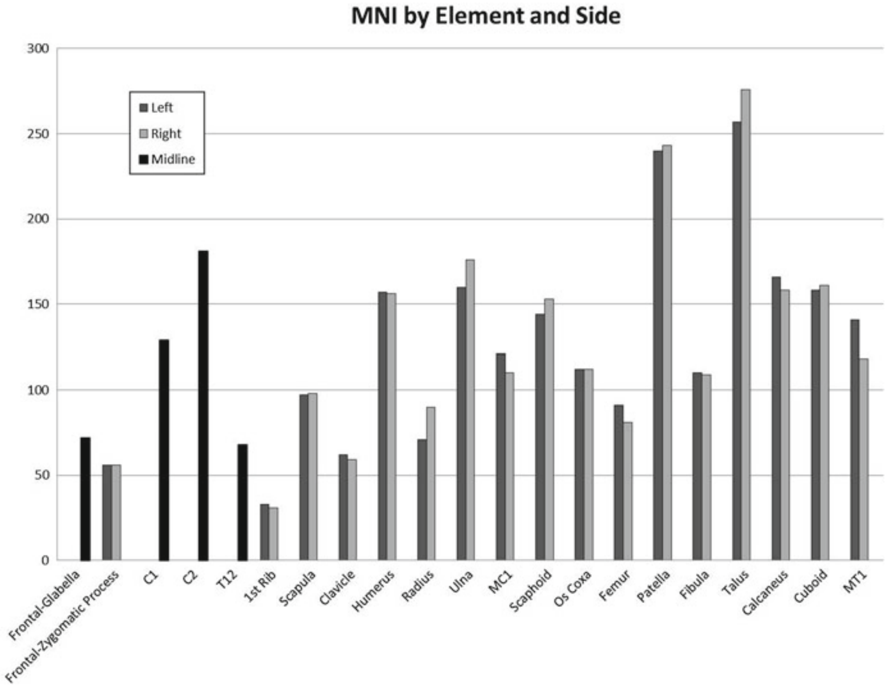

Fig. 3 Overall MNI by element and side

Table 1 Sex ratios by element

	Sex estimates					Sex ratios	
Element	Total	Female	Ambiguous	Male	Undetermined	% Female	% Male
Frontal-Glabella	72	30	4	34	4	47	53
Frontal-Zygomatic Process	56	24	8	21	3	53	47
Temporal	88	37	6	39	11	55	45
Humerus	158	31	2	64	61	33	67
Os Coxa	112	26	1	36	80	42	58
Femur	176	24	0	61	91	39	61
Patella	240	45	25	132	38	25	75
Talus	278	50	6	101	103	33	67
Calcaneus	166	13	1	45	107	22	78

Demography

Demography is considered on an element by element basis. Each postcranial element for which sex could be estimated (either morphologically such as the os coxae or metrically such as the talus and calcaneus) was examined. These consistently provided a roughly 65:35 male to female sex ratio (Table 1, Fig. 4). The sex

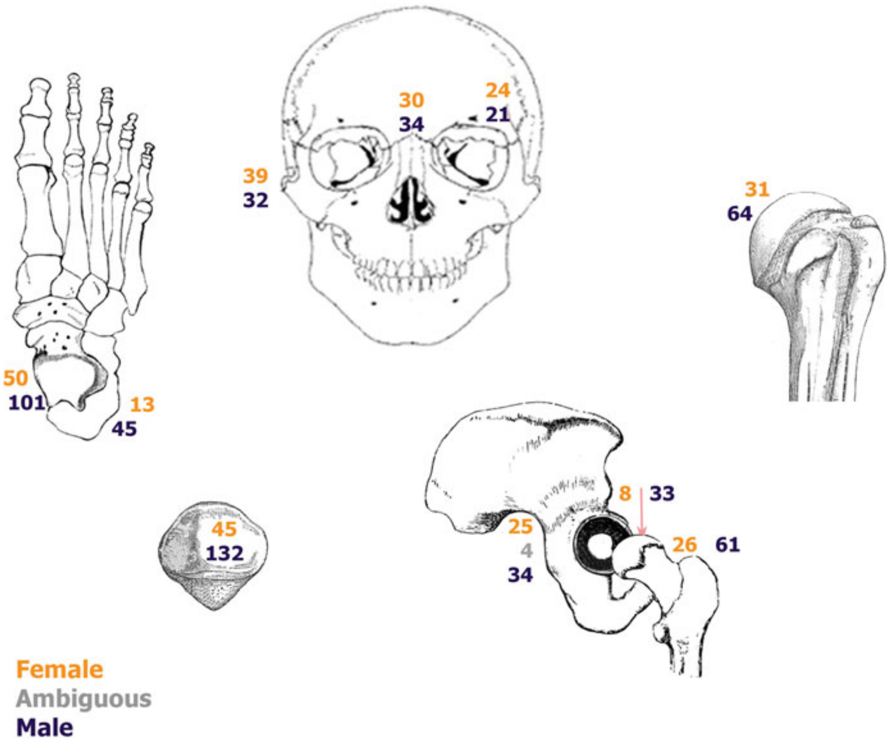

Fig. 4 Sex ratios by element

breakdown for cranial elements is very different, with roughly equal numbers of identified males and females. This may indicate that the skulls of males were retained outside of the tomb for some purpose, possibly ancestor veneration or other funerary rituals. At this point, it is unclear what this observation actually means. As Andrews and Bello note, body parts may be selected for retention based on biological criteria such as age, sex, family associations, or social criteria (Andrews & Bello, 2006, p. 14).

Future Research

Mapping the Tomb

Because each accession number has embedded location data, it is possible to develop a two- or three-dimensional map of the tomb deposit, a project that we are anxious to begin. Mapping the tomb will give us tremendous insight into how the deposition was created as well as help us to understand how individuals were placed within the tomb. Given Schiffer's concepts of superpositioning and site formation processes (1987), smaller bones like the carpals and tarsals should filter down to the bottom of the tomb when the soft tissue decomposes. These bones should therefore be plentiful and well preserved since they won't have been subjected to rough handling at the top of the tomb. The mapping of the tomb will also allow us to see if there is any intentional movement of body parts within the tomb. A comprehensive map will also illustrate the nature of the relationship of those few complete interments within the tomb itself. Only three complete interments have been identified in situ, named in the field as "Daphne," "Lesley," and "Parker". These individuals may represent the final three interments. Their bodies may not have become commingled with the other tomb inhabitants because there were no subsequent interments causing an unintentional disarticulation and commingling of all the previous burials. But these individuals may also have been special or unique in some way. A thorough map will help to illuminate their spatial relationship to the rest of the assemblage. The distribution of both burning and mineral staining will also be elucidated through a high-resolution map of the remains within the tomb.

Subadult MNI

To date, the subadult portion of the Tell Abraq assemblage has been understudied. Due to a lack of research concerning the younger members of this Bronze Age community, little analysis has been accomplished using subadult skeletal remains. Our knowledge of the subadult assemblage is therefore inadequate.

Curation of the subadult skeletal remains is identical to the adult skeletal remains: bones are stored by element and side. Previous analysis by Baustian (2010) selected left and right tibiae and femora for an assessment of health and maintenance of growth. These elements were selected for numerous reasons. First, these elements were among the most numerous elements in the subadult assemblage. Second, these leg bones were relatively more complete and better preserved than other skeletal elements. Lastly, the nature of the research to be accomplished required bones that could reveal substantial information regarding growth, development, and overall health. Femora and tibiae display much higher frequencies of infectious reactions than any other area of the skeleton (Mensforth, Lovejoy, Lallo, & Armelagos, 1978; Ortner, 2003, p. 182). The femur is also excellent for analysis because its growth and development patterns are well understood and deviations from those patterns can be measured (Anderson, Messner, & Green, 1964; Fazekas & Kosa, 1978; Garn, 1970; Gindhart, 1973; Jeanty, 1983; Scheuer, Musgrave, & Evans, 1980).

These two long bones were selected for determination of the MNI for subadults. Careful sorting and siding of the femora and tibiae resulted in the selection of the right femur for establishment of the MNI and further analysis. Like adult skeletal elements, the goal in this process was to prevent duplication of individuals while using fragmented bones. Although less precise than the strict technique used among adult remains, features were scored as present or absent with simple visual sorting.

Better preservation of the proximal ends of femora permitted more of this element to be counted. Using proximal ends of right femora, a preliminary MNI of 127 was determined for the Tell Abraq subadult assemblage.

The MNI for subadults from Tell Abraq is preliminary until the techniques applied to the adult assemblage can be utilized. Moving forward with the subadult analysis will require more detailed sorting and analysis. The subadult MNI produced by Baustian (2010) was one of the earliest studies completed for the whole skeletal assemblage. It was completed prior to the majority of fine sorting of elements, and some additional subadult remains have been discovered with adult remains. Most of these have been older subadults whose size was comparable to adult counterparts, thus leading to admixture. These elements have since been placed in the appropriate storage boxes.

As analysis continues among subadult remains, age is an integral factor. The timing of epiphyseal union for different elements and patterns in growth and development permit more specific age estimation for each bone/fragment. The method for determining the final subadult MNI will likely involve multiple skeletal elements and age groups. Counts of every element in every phase of epiphyseal union will be assembled and compared. Those elements that demonstrate active fusing will be able to represent very specific age groups.

It is anticipated that our final subadult MNI will be more than 127 because of the more detailed sorting and analysis. The original MNI included high representation of preterm babies, neonates, and infants (67.6 %, $n=86$) and underrepresentation of subadults over the age of 6 years (7.1 %, $n=9$). Juvenile and adolescent age groups are expected to increase in number. Subadults currently represent approximately one third of the total Tell Abraq assemblage. This is also expected to increase with a more precise subadult MNI. When completed, this may have interesting implications for research concerning the Tell Abraq community. Specifically, issues addressing health and mortuary patterns among subadults could be investigated further with these data.

Conclusion

The MNI methodology for the Tell Abraq assemblage was specifically designed to perform several functions. First and foremost, baseline data needed to be recorded for individual elements using methodologies that did not require the presence of more than one element. For example, to estimate sex of the talus, Steele's (1976) discriminant functions were used because they don't rely on the presence of more than a single element. While this approach has its own problems (including reference sample mismatch and degree of accuracy), it is the best way to approach the issue with current data. Primarily at issue here is the use of multiple samples in the original studies that are both biologically and temporally distinct from the Tell Abraq assemblage. As Spradley and Jantz (2011) note, accuracy of sex estimation techniques varies by the reference sample used as well as the element examined.

To again use the example of Steele's (1976) analysis of foot bones, the analysis was conducted on historic American samples and so is not directly comparable to the Tell Abraq assemblage. In order to minimize this issue, we chose methodologies with at least 70 % accuracy rates for the estimation of sex. We understand that this does not completely resolve the issue, but without the use of these various analyses, developing baseline data for the assemblage would be impossible. Second, the methodology, including the identification of features and the use of visual recording forms, was designed to maintain a level of consistency in recording features and elements. Another mechanism to ensure consistency is the use of a single analyst to complete analysis of a single element (e.g., the analyst who began recording the scapulae finished recording the scapulae). Third, by recording a variety of features on both dense and spongy bone, we can examine the breakage and representation of elements within the tomb assemblage. We can see if the denser bone is more prevalent than less dense bone. If elements were recorded as present based solely on their degree of completeness, this level of detail would not be possible. Finally, the methodology was designed to facilitate future research such as the development of a high-resolution map of the elements by linking accession numbers digitally to individual elements and their associated baseline data.

The Tell Abraq assemblage demonstrates the utility of commingled human skeletal remains and offers a great deal of information about the Bronze Age population. Furthermore, the methods employed during analysis are illustrated as applicable to commingled remains from a variety of time periods and geographies. With some modification for each assemblage, these techniques will prove useful for additional bioarchaeological researchers. Commingled assemblages, while they present significant analytical challenges, can provide a wealth of information about mortuary practices, health, and demography that may not be possible to access without their careful analysis. Although they require extensive planning and organization in methodologies, they can be just as fruitful as collections comprised of individual burials.

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Bioarchaeological Spatial Analysis of the Walker-Noe Crematory (15GD56)

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Introduction

Documenting the distribution of fragmentary human remains from an archaeological context is critical to understanding mortuary patterns and site formation processes. The Walker-Noe site (15Gd56), a Middle Woodland crematory in the southern Kentucky Bluegrass offers a unique opportunity to examine a highly fragmentary and cremated human burial sample. Using osteological data from each excavation unit including traditional bone weight, color values assessed with a spectrophotometer, and MNE/MNI estimates based on landmark counts and summary geographic information system (GIS) grids, we examine the spatial pattern of human remains across the crematory. Prior work on Walker-Noe by two of the authors (Devlin & Herrmann, 2008; Herrmann & Devlin, 2008) focused on the quantification of the sample using a novel GIS-based approached initially developed in zooarchaeological studies (see Marean, Abe, Nilssen, & Stone, 2001) combined with semiautomated documentation (using a spectrophotometer) of bone colors across the burial deposit. In this chapter, these lines of evidence are spatially synthesized within a GIS platform in an effort to visualize and analyze patterns in the data, providing an innovative approach for revealing clues to the mortuary behaviors of the people who constructed, burned, and ultimately abandoned the Walker-Noe site. The application of GIS technology and spatial assessment of burials or human remains is not new to bioarchaeology (for example see Duncan & Schwarz, 2013; Herrmann, 2002).

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_4,

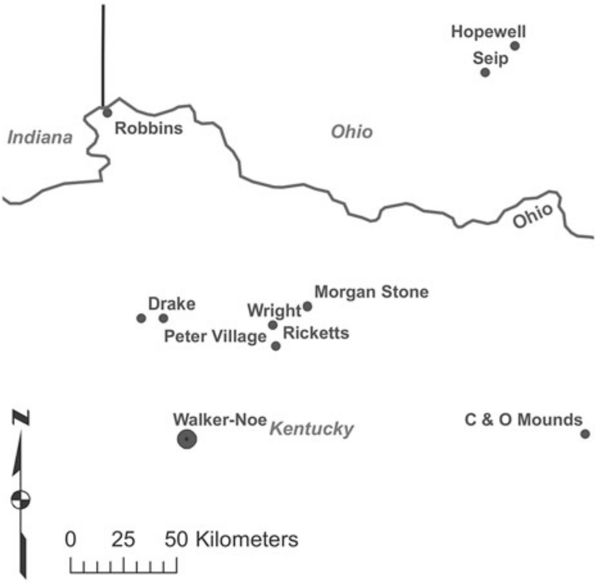

Fig. 1 Location of Walker-Noe and other Middle Woodland mortuary facilities in the central Ohio River Valley (modified from Pollack, Schlarb, Sharp, & Tune, 2005)

However, this study does provide a means to use highly fragmented but identifiable human remains to assess issues of quantification and burning. The key to this approach is the systematic recording of identifiable fragments beyond traditional inventory methods and automation of data collection such as digitizing fragments or digital color assessments. By combining color and quantification data, we have attempted to gain a better understanding of this enigmatic Middle Woodland mortuary facility and present an approach applicable to the analysis of other commingled sites.

Walker-Noe (15Gd56)

The Walker-Noe site is located in the southern Bluegrass physiographic zone in central Kentucky (Fig. 1). The Kentucky Archaeological Survey excavated the crematory in 2000. Two radiocarbon assays on wood charcoal date the crematory to cal 166 BC to AD 129 ($p=0.95$; Pollack et al., 2005). The burial sample has been the focus of analyses to assess burning patterns (Devlin & Herrmann, 2008) and quantify the minimum number of individuals present (Herrmann & Devlin, 2008). Numerous other Middle Woodland mound and mortuary facilities are present in the Ohio River drainage (Fig. 1). Human cremations are a typical feature of these sites, and these burned remains have been the focus of numerous bioarchaeological studies (see Baby, 1954; Konigsberg, 1985; Webb & Baby, 1957; Webb & Snow, 1945).

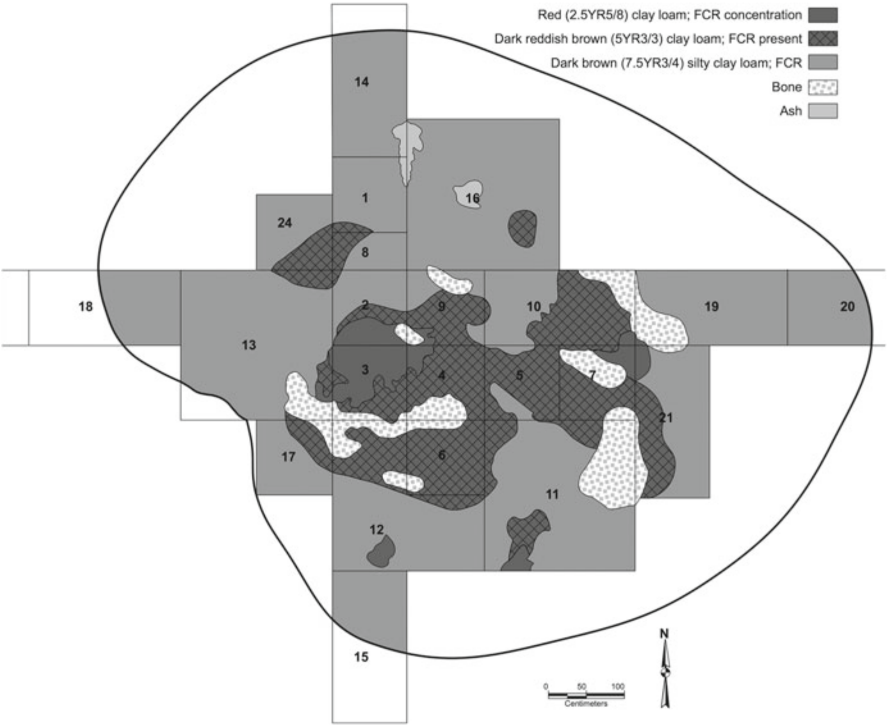

Fig. 2 Site plan map with the excavation units and cremated bone distribution depicted

Archaeological fieldwork conducted during the fall of 2000 yielded over 18 kg of charred and calcined human bone. Ceramic and lithic artifacts associate activity at the mound with the Adena culture, and excavations revealed evidence of in situ cremations indicated by substantial burned soils and burned black walnuts suggesting use of the mound as a crematory (Pollack et al., 2005; Sharp, Pollack, Schlarb, & Tune, 2003). In total, the mound excavation yielded more than 61,000 pieces of debitage, primarily Boyle chert. Several recovered projectile points demonstrate attributes that indicate contextual association with the cremation practices at the mound. Further, six points do not exhibit any use wear, and two additional points demonstrate heat alteration, suggesting their preparation and use as ceremonial objects during cremation activities (Pollack et al., 2005).

Initial excavation involved removal of the plow zone, which exposed a 1.25 m^2 area of burned red clay loam to a depth of 5 cm (see Fig. 2). This central region is surrounded by a region of dark reddish brown clay loam ranging in depth from 5 to 10 cm. A third region of dark-brown silty clay loam expanded the mound area. Concentrations of cremated bone were identified directly above and around the central burned area. In addition, aggregations of burned bone were present in regions peripheral to the central burned zone. All skeletal material was located in association with wood charcoal, burned walnuts, ash, and burned soil. Excavation indicates that a central region served as the crematory platform with remains deposited in adjacent regions surrounding the central zone. Analyses of skeletal material were directed at illuminating particulars of crematory activities (i.e., number of individuals present, differential burning, and whether the site was used repeatedly).

Quantification and Spatial Analysis Methods

The bone fragments examined in this study represent the commingled remains of an unknown number of individuals (Bennett Devlin, Herrmann, & Pollack, 2006). Based on the excavator's notes and field descriptions, it is apparent that no articulated elements were observed during excavation. Overall, the bone assemblage is characterized by extreme fragmentation and coloration commonly associated with significant thermal alteration. The majority of fragments are less than 4 cm in diameter, with numerous specimens significantly smaller in size. The condition of the skeletal material from the Walker-Noe site reflects a thorough incineration process with all bone surfaces demonstrating evidence of advanced heat exposure. Surface colors associated with incomplete combustion of the organic components (i.e., brown and black tones) were infrequently observed with nearly all specimens exhibiting gray and white tones, evidence of calcination. In addition, fragments display extreme shrinkage and moderate degrees of warping, though the latter do vary across the assemblage. Based on comparison to pooled-sex average mandibular measurements for Kentucky Adena collections as reported by Webb and Snow (1945), bone shrinkage exceeds 13 % for the Walker-Noe mandibular specimens examined (Bennett Devlin et al., 2006). Surface cracking and fracturing is visible on the majority of specimens, including both endocranial and ectocranial surfaces.

Quantification Estimation Methods

A key to the Walker-Noe project is the estimation of MNE of the cranial elements and teeth. The MNE values for various elements can then be compared to determine MNI. Lyman (1994, p. 102) defines MNE as "minimum number of a *particular skeletal element* or portion of a taxon" (emphasis added to stress that it is a measure that is element based). Lyman (1994) stresses that it is typically determined based on a particular section of the bone (proximal, distal, or midshaft). MNI, on the other hand, is traditionally defined as the "minimum number of individual animals necessary to account for all the kinds of skeletal elements found" (Lyman, 1994, p. 100). Therefore, our prior work at Walker-Noe (Herrmann & Devlin, 2008) focused on the calculation of MNE for the various elements of the splanchnocranium. The derived maximum MNE value from the elements examined was used to determine MNI. Data presented in the current study extend this examination to the cranial base and focus on the temporal bone, which is the most frequently identified element of the cranium. We determined the MNE for the temporal bone and compared it to the other cranial elements. Quantification of the postcranial material was not possible at the level of the cranial material. Postcranial bone fragments were typically less than 2 cm in length or diameter, and these fragments could not be specified to element or side or placed within the GIS templates. As a result, postcranial remains were quantified, but the derived numbers are not discussed here because they are considerably lower than the cranial numbers (typically less than a quarter of the cranial MNI). Proportions of bone weight (cranial bone weight/total bone weight) are presented to assess the amount of postcranial remains.

Bone fragments were initially sorted into skeletal division categories of cranial, dental, appendicular, axial, and unidentifiable (UNID). When possible, fragments were identified to a particular skeletal element. In addition, fragments were macroscopically assessed in terms of surface colors, level of distortion, apparent degree of shrinkage, and overall fracture and cracking patterns [see Devlin and Herrmann (2008) and Herrmann and Devlin (2008) for additional analysis and discussion of the Walker-Noe cremains]. Quantification of the sorted material required the adoption of innovative techniques given that coding systems such as *Standards for Data Collection* (Buikstra & Ubelaker, 1994) or *Osteoware* (Osteoware, 2011) would be ineffective in capturing the fragment diversity and anatomical positions of the fragments. As a result, two quantification methods were adapted to document the Walker-Noe cremated remains. One approach is based on bone landmarks, while the other employs the analysis of fragment shapes within a GIS.

In the first approach, discrete traditional and nontraditional anatomical landmarks are tallied to determine the element frequency. Giovas (2009) employed a similar approach to examine shellfish remains from archaeological contexts. Skeletal elements were recorded within the database by anatomical location. Additionally, fracture pattern, external and internal color, and presence of other traditional human skeletal characteristics (pathology and discrete variants) were assessed and recorded.

The second approach is an extension of the Marean et al.'s (2001) ESRI ArcView approach developed for the quantification of fragmentary faunal remains. Within the GIS approach, MNE estimates are derived from fragment overlaps. While the original method developed by Marean et al. (2001) employed a customized ArcView 3.x interface entitled *Bone Entry GIS*, our study employed a similar approach though the method was updated to ESRI's ArcMap 10 platform in which several of the steps of the *Bone Entry GIS* program (such as raster addition) are part of the ArcMap toolbox and data and layer management is performed within ESRI ArcCatalog.

The two quantification methods are highly correlated, and undoubtedly either approach is more appropriate for analyses of fragmented remains especially when compared to traditional bone coding systems. Fig. 3 illustrates the MNE summation using the GIS-based approach application for the left and right temporal bones recovered from Walker-Noe. The resulting summation raster provides a localized MNE count based on fragment overlaps.

A critical aspect of the Walker-Noe analysis (or the examination of any burned bone assemblage) must include assessment of heat-generated attributes such as

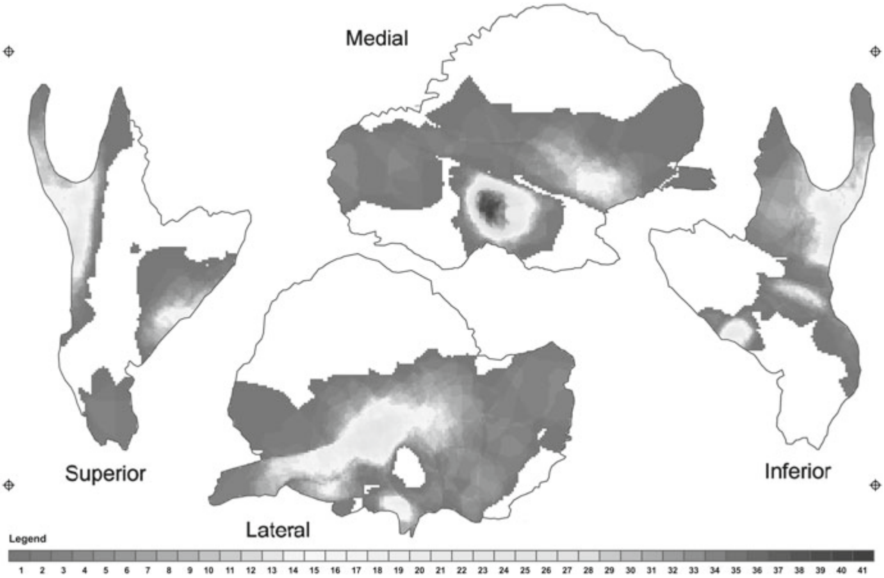

Fig. 3 GIS-based MNE summary raster for the left temporal bone

shrinkage and bone color. In the present study, supplementing our GIS-based fragment analysis, bone specimens were subjected to color assessment and interpretation by skeletal division and archaeological context. Surface colors were assessed on all specimens using an X-Rite CA22 spectrophotometer. This handheld tethered instrument systematizes color evaluation within the *L*a*b** color space under D65 illumination (daylight). The color value is sent to a host computer running *MatchRite Color Designer* software, which allows the direct input into the Microsoft Access interface. A second software utility, Munsell Conversion Program (available at http://WalkillColor.com), translates Munsell and RGB color values into *L*a*b** colors. This transformation enables comparison of the experimentally derived colors reported by Shipman, Foster, and Schoeninger (1984) and Walker, Miller, and Richman (2008) with the Walker-Noe specimens. A total of 3,843 fragments were assessed for primary surface color. The values for the specific axes of the *L*a*b** color space were averaged across excavation units and divided and averaged by skeletal divisions. For a specific discussion of the color evaluation of the Walker-Noe burial sample, please refer to Devlin and Herrmann (2008).

Spatial Analysis Method

Excavators collected human skeletal material from arbitrary levels within the excavation units, and though bone was found in discrete locations within each unit,

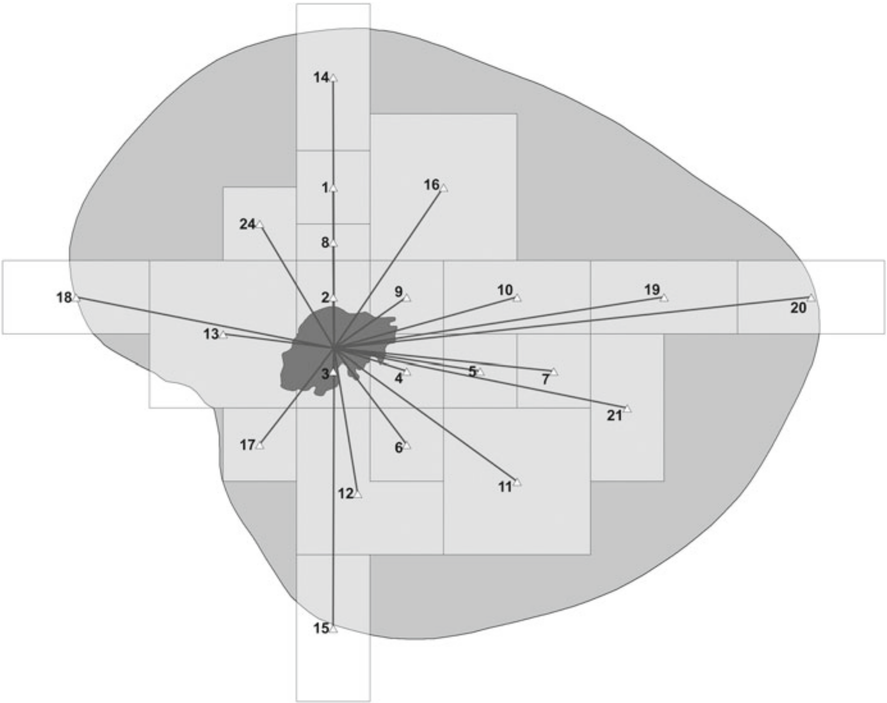

Fig. 4 Site plan with the platform and unit centroids and straight-line distances plotted

we use the excavation unit as the spatial reference for this investigation. To facilitate the analysis of the units relative to the prepared clay platform, the site plan was digitized into ArcGIS and the centroid of each excavation unit and the prepared clay platform was calculated. Based on these coordinates, distance measures from each unit to the platform centroid were calculated (Fig. 4). The resulting data set consists of a total of 14 variables including bone and tooth weights, MNI values (derived from the temporal MNE), dental counts, and color scores. Weight values by excavation unit include total bone weight, cranial bone weight, total tooth weight, and postcranial element weight. Based on these measures, two derived values were calculated which include a standardized measure of weight (total weight divided by unit area) and the cranial weight ratio (cranial weight divided by total bone weight). Total tooth counts per unit were also calculated and summarized by single and multi-rooted teeth. In addition, the total number of alveolar sockets was counted for each unit. Next, a series of MNI counts were determined by unit including the temporal MNI (total, left, and right) and a dental MNI based on specific tooth sockets. Finally, various color means were calculated for all bones, all teeth, cranial elements, and postcranial remains. This data set was incorporated into R (R Development Core Team, 2011) and various analyses performed.

Results

These analyses yielded insightful information on the Walker-Noe crematory site. The methods described herein resulted in greater, and arguably more precise, MNI estimates than previously calculated for this assemblage. Clearly this influences the interpretation of site formation processes and our understanding of the cremation practices during the Middle Woodland period. Both results of the quantification component and the spatial analyses are presented below.

Quantification

The MNI estimate of the entire collection is 41 individuals based on the summed temporal bone ArcGIS rasters (Fig. 3 and Table 1). The database landmark analysis produces a maximum of 40 individuals (Table 1). Both values are significantly higher than the previous MNI determination of 21 individuals based on examination of the bones of the facial skeleton (Herrmann & Devlin, 2008). Interestingly, the MNI based on alveolar tooth socket data is 22, which is consistent with the previously reported MNI for the facial skeleton. The dramatic increase in the MNI determination using temporal bones is indicative of several potential factors influencing the minimum number of individuals at Walker-Noe. It is likely that various taphonomic factors have influenced the estimate. First, portions of the temporal bone are denser than the thin bones of the facial skeleton and temporal bone sections often preserve better than splanchnocrania. Second, the marked increase in the number of individuals may suggest that cranial vaults and basiocrania were preferentially burned compared to splanchnocrania.

Spatial Analysis

To assess the relationship of the various measures of color, bone weight, and skeletal distribution across the crematory, pair-wise Pearson correlations were performed for all 14 variables relative to unit distance from the prepared clay platform. The linear distances from the center of each excavation unit to the centroid of the burned clay area were then linked to the excavation unit-based summary variables

Table 1 MNI estimates for various cranial elements

Element	Frontal	Malar	Maxillae (*R*/*L*)	Mandible	Temporal (*R*/*L*)	Total
Placed	112	45	59/58	122	153/141	690
MNI (GIS)	26	17	20/21	21	38/41	41
MNI (DB)	–	–	–	–	40/39	40

Table 2 Correlation statistics and probabilities of skeletal and dental attributes with distance from central platform

Variable	Correlation with distance	t^a	p-Value
Total weight	−0.566	−3.071	0.006
Cranial weight	−0.570	−3.099	0.006
Tooth weight	−0.443	−2.153	0.044
Postcranial weight	−0.531	−2.804	0.011
Ratio of cranial material	−0.710	−4.507	0.000
Temporal MNI	−0.645	−3.775	0.001
Alveolar MNI	−0.602	−3.376	0.003
Tooth count	−0.451	−2.262	0.035
Single rooted tooth count	−0.421	−2.078	0.051
Multiple rooted tooth count	−0.480	−2.450	0.024
Alveolar socket count	−0.531	−2.800	0.011
Mean *L*	−0.435	−2.163	0.043
Mean *a*	−0.167	−0.758	0.457
Mean *b*	−0.413	−2.029	0.056

[a] All test have 20 degrees of freedom (df)

derived from the osteological analysis. These numbers represent either summed bone weights or element counts or average measures for color.

The results of the correlation analysis are presented in Table 2. As expected, all 11 of the weight and count variables are negatively correlated with distance. Excavation units farther away from the prepared clay platform yielded less volume of skeletal material. These correlations are all significant and this relationship is quite evident in the bone weight plot shown in Fig. 5 where total bone weight has been adjusted by unit size. Clearly a large quantity of bone was placed on the platform for the final burn at the crematory, and then the low mound was covered over. While the overall pattern is lower total bone weights for the peripheral excavation units, there is evidence that some bone material from prior burn events was redistributed away from the platform. This is illustrated by the height of the bars associated with Units 8 and 6 located to the north and south, respectively, of the platform. Most notably, however, is the amount of bone relative to unit area for Unit 8 as it is extremely high and its temporal bone MNI differs from that of the central platform and Unit 6. This unit has a considerably higher amount of bone relative to the surrounding units, and it is located off of the prepared platform.

Color

The distance analysis of mean $L^*a^*b^*$ color values by unit is consistent with Devlin and Herrmann's (2008) conclusions concerning core versus periphery color variation. The $L^*a^*b^*$ color space model and the plots of each color axis relative to the excavation unit's distance to the clay platform is shown in Fig. 6. All three

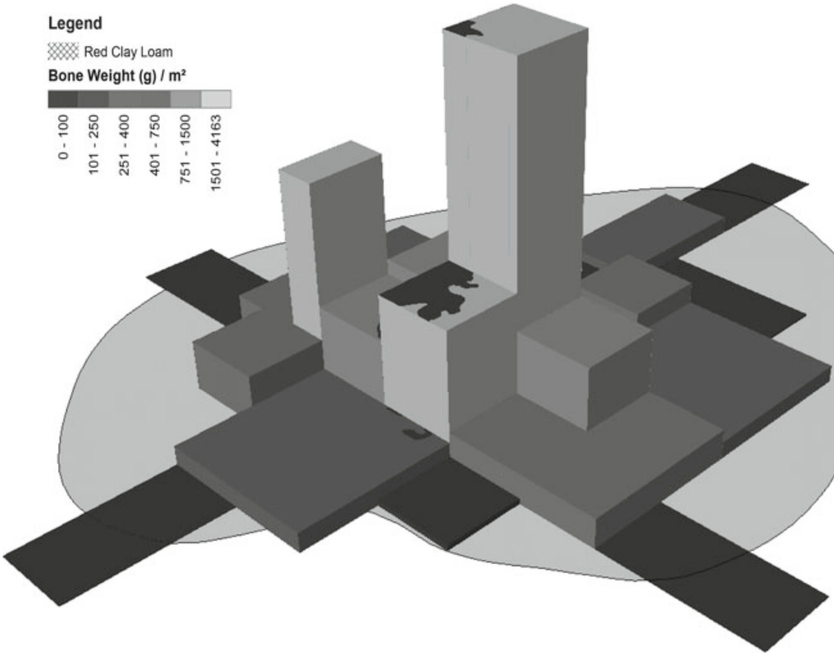

Fig. 5 Three-dimensional representation of cremated bone weight standardized by unit size

independent color axes variables are negatively correlated with distance (Table 2). However, only axes *L* and *b* are remarkable with *p*-values of 0.045 ($t = -2.163$, $df = 20$) and 0.056 ($t = -2.021$, $df = 20$), respectively. These two axes are important in that the *L* axis represents the transition from black (smoked bone) to white (calcined bone) and the *b* axis represents the color transition from blue to yellow, as such it relates to the color transition associated with higher temperature burns. Walker and colleagues' (2008) color plot of burn temperatures relative to color for both exposed and "buried" bone shows a transition from bluish hues to more yellow colors in the high-temperature exposed (greater than 600 °C) and likely calcined specimens. At Walker-Noe, bone fragments become increasingly black and blue in color with distance from the clay platform. If the extreme distance (Unit 20) is removed where the lowest amount of bone was recovered (0.81 g), the relationship of *L* and *b* values with distance becomes stronger with both relationships being statistically significant.

Temporal Bone Distribution

Given that the temporal bone provides the MNI estimate for Walker-Noe samples, the distribution of this element should also be a good proxy for the distribution of individuals across the small mound. The maximum MNI for left and right elements

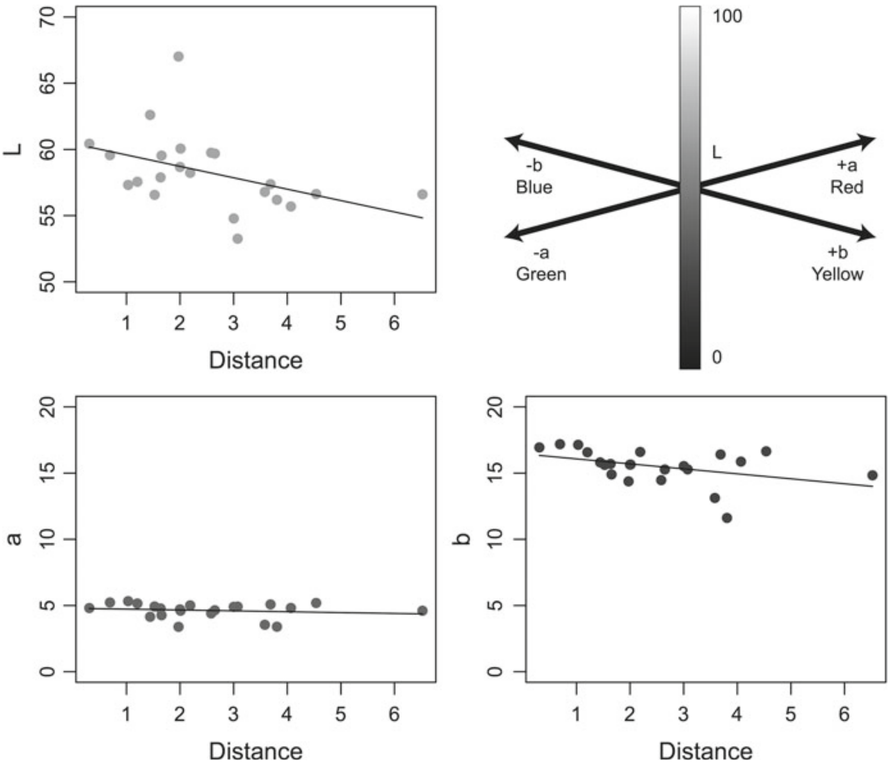

Fig. 6 Biplots depicting the relationship of the three axes of the *L**a*b** color space to distance from the platform. A least squares fit line is placed in each biplot. The *L**a*b** color model is shown in the *upper right* quadrant of the figure

was summarized by excavation units, and these counts are visualized on the site map (Fig. 7). The pattern is consistent for both sides with a larger proportion of the individuals defined by temporal bone portions coming from units that overlap the prepared clay area. The distribution of individuals based on temporal bone portions is consistent with the total bone weight pattern. Excavation Unit 8, previously noted as having a higher than expected total bone weight given its location off the prepared platform, also exhibits higher than expected MNI values. Four left and seven right temporal bones were identified in Unit 8, higher than any other excavation units not located on the platform. In fact, with the exception of Unit 8, the counts for temporal bones that contribute to the side-based MNI are considerably lower (<3) for all units not associated with the platform. As is evident in Fig. 7, individuals are concentrated close to the clay platform and rapidly decline in number with increasing distance from the center; fewer identified temporal bone fragments contribute to the overall side-based MNI counts. This relationship is also shown in the far right plot in Fig. 8. This figure depicts the unit-based temporal bone MNI estimates plotted by side with a loess fit line for each side. Loess fit is locally weighted (or estimated)

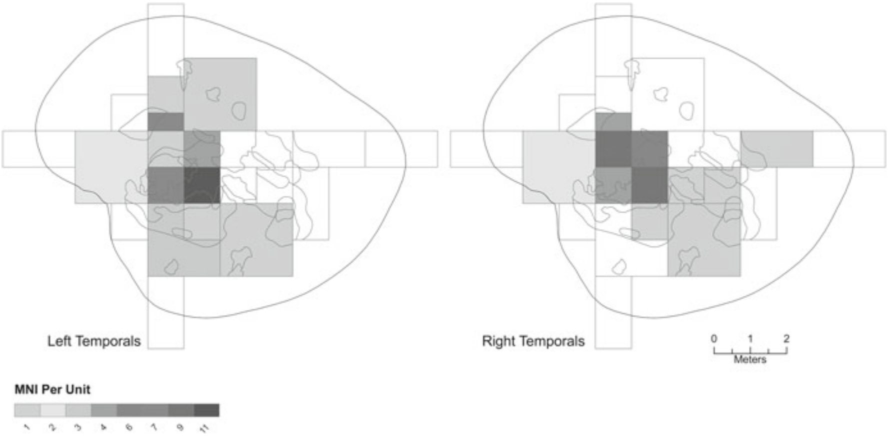

Fig. 7 Distribution of temporal bones MNI values by excavation unit and element side

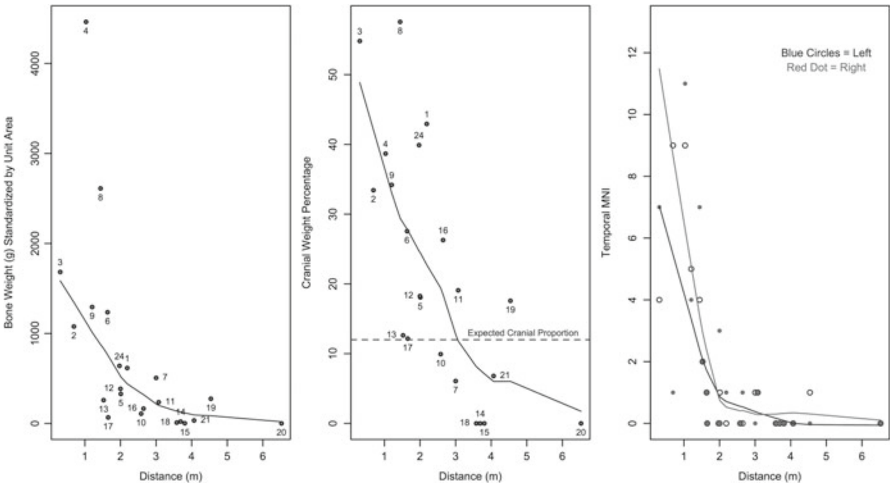

Fig. 8 Three plots showing the relationship of bone weight adjusted for unit size (*left*), cranial bone weight percentage (*center*), and MNI (*right*). In each plot, loess fit lines are added to highlight the relationships and common trends in these variables

scatterplot smoothing (R Development Core Team, 2011), and the resulting regression line is a line through the central tendencies of the point scatter. The temporal bone MNI plot shows a clear break at 2 m distance from the clay platform centroid and the temporal bone MNI values flatten off at that distance. Based on the distribution map of skeletal material and the MNI distribution, numerous crania were placed and burned on the clay platform. Similar trophy caches have been identified at large Adena and Hopewell mounds and earthworks. Interestingly, the mortuary behaviors practiced at the large ceremonial sites such as Wright and Ricketts in Kentucky are being transferred to the local communities and hamlets.

Bone Weight and Cranial Bone Distribution

Standardized bone weight by unit area and the ratio of cranial bone weight to total bone weight exhibit similar patterns at Walker-Noe (Fig. 8). Generally speaking, both measures decrease with distance from the center of the prepared platform (Fig. 8—left and center plots). This pattern is not surprising given that the site is limited in size and it is expected that bone amounts would diminish towards the edges of the site. The left plot in Fig. 8 is consistent with our model of site use. It is worth noting that the inflection point of the loess fit line of the scatterplot is at approximately 2.5 m in distance from the clay platform centroid; this is consistent with shift at 2 m for temporal bone MNI distance. Similar to Devlin and Herrmann's (2008) core/periphery model for color differences, the 2 m region around the platform represents the primary activity area for the site. Devlin and Herrmann (2008) defined a much larger area as core as compared to what the bone weight plot represents, which would restrict the core to the platform and to areas directly adjacent to the platform.

Perhaps more interesting than the expected bone weight distribution pattern is the distribution of identified cranial bone at Walker-Noe. The proportion of cranial bone in the central units far exceeds the expected pattern based on examination of three donated commercial cremations curated in the William M. Bass donated skeletal collection housed at the University of Tennessee, Knoxville. Assessment of modern cremations indicated that cranial bone represents approximately 12 % of total weight. For the purposes of this study, the burned bone powder which is collected as part of the commercial cremation was not included in the total weight because the collection method at Walker-Noe would have missed the bone powder (or it was missing due to site formation processes) given the bone and soil were collected together and the soil was processed by flotation. Numerous researchers have considered relationships between cremation weight, body mass, and sex in forensic contexts, but none have sorted the resulting cremains to look at the proportions of various skeletal divisions (i.e., cranial and postcranial elements) (Jantz & Bass, 2004; May, 2011; Van Deest, Murad, & Bartelink, 2011; Warren & Maples, 1997). Obviously a larger sample of modern cremations would help clarify this value, and age, sex, and pathology probably significantly influence the proportion. It is unlikely, however, that these confounding factors would increase the proportion beyond 15–20 % and certainly not to 40 % of total weight, as is evident in several excavation units at Walker-Noe. As apparent in the central plot in Fig. 8, the proportion of identified cranial remains relative to total bone weight is substantially higher in the central units as compared to the peripheral areas of the mound with cranial weight accounting for approximately 50 % of the total bone weight in the central area. The higher than expected cranial percentage exists for the area extending up to 3 m from the central platform. If whole bodies were cremated on a regular basis, this pattern would be expected to be more consistent across the mound area. The distribution of cranial fragments may indicate that the final cremation event included numerous isolated crania, more specifically calvaria and basiocrania, as compared to complete skeletons. Such a pattern is consistent with other Adena mortuary and mound sites (Fenton, 1991; Webb & Baby, 1957; Webb & Snow, 1945) as well as regional Early to Middle Woodland practices in the Copena (Goad, 1980) and Hopewell cultures (Baby, 1954).

Discussion

Assessment of the spatial distribution of fragmentary elements across the Walker-Noe crematory yields informative patterns of site formation and use. These data on the distribution and condition of the bone fragments reflect the use of Walker-Noe as a crematory with a prepared low platform burn area. The quantification patterns documented here and the color pattern present in an earlier publication (Devlin & Herrmann, 2008) suggest that lower temperature or shorter duration cremations were redistributed away from the prepared platform or at least these fragments were moved away from the heat source. The colors of bone fragments recovered from excavation units located at greater distances from the platform reflect this pattern when compared to the bone fragment colors from more centrally located excavation units. It is likely that elements remaining near the prepared clay platform would have been subjected to reheating and greater thermal alteration and trauma.

The comparison of quantification methods indicates that the approaches described herein are productive when confronted with highly commingled and fragmentary remains. In addition, examination of the temporal elements demonstrates that the MNI is much higher than previously thought; greater than values revealed using traditional MNI measures. Moreover, element counts from the central platform indicate a higher than expected concentration of cranial elements, possibly suggesting dismemberment or selective inclusion of crania. Such practices are consistent with the Adena culture (Dragoo, 1963; Fenton, 1991; Webb & Snow, 1945) and other woodland mortuary programs in Kentucky and across the Ohio River valley (Baby, 1954; Goad, 1980).

Acknowledgements We would like to thank David Pollack at the Kentucky Archaeological Survey and George Crothers at the William S. Webb Museum of Anthropology for access to the Walker-Noe skeletal material. We would also like to thank the William M. Bass Endowment at the University of Tennessee Forensic Anthropology Center for funding the X-Rite CA22 spectrophotometer. Finally, we thank Brittany Dunn and Dorothy Damm for their assistance with the analysis and inventory of the collection.

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Into the Kettle: The Analysis of Commingled Remains from Southern Ontario

Bonnie Glencross

Introduction

Human remains from archaeological contexts are frequently commingled. One form of commingling is observed in skeletons recovered from secondary deposits—the end result of multiple stages of funerary treatment or subject to natural post-depositional disturbances. Commingling can also occur when archaeological sites are looted and during the curation phase if skeletal remains are not well documented. Assemblages of commingled skeletons are highly variable in their nature and composition presenting problems specific to each collection. Methodology employed by bioarchaeologists and biological anthropologists in dealing with commingled skeletons is highly variable. Indeed, there is no one best approach that applies to all cases of commingled remains. For this reason, practitioners must be aware that several techniques are available.

Commingled remains from archaeological sites in Ontario provide good case studies and illustrate their value in broadening interpretations of past human behaviors. Most of the commingled remains are recovered from ossuaries that date to the Late Woodland, particularly the later part (AD 1300–1650). In Ontario, ossuary burials are defined on the basis of specific characteristics. Foremost, an ossuary burial involves the periodic and collective secondary burial of individuals previously interred separately elsewhere. The reburial takes place after a culturally prescribed event and/or period of time (Spence, 1994) and the elements of individual skeletons

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_5,

are mixed together (Jackes, 1988). A large proportion of skeletal assemblages in Ontario are made up of ossuary deposits; Ontario is cited as having the highest number of reported investigations involving commingled remains (Ullinger, 2012).

An appreciable history of theoretical and methodological approaches has resulted from bioarchaeological and anthropological studies of Ontario's ossuaries. By examining the history of the treatment of commingled human remains, practitioners have the opportunity to learn from different techniques and develop a hybrid of applicable methodology. Of initial interest are essential data on mortuary practices derived from ethnographic and archaeological investigations in Ontario. After framing investigations of these commingled remains, the various approaches taken in osteological analyses and problems encountered over the last century are examined. Hybrid methods are subsequently developed based on the suggestion that commingled remains, particularly those from southern Ontario that benefit from a rich ethnohistoric record, have the potential to liberate aspects of individual identity that relate to age, life course, and community.

Despite the fact that individual skeletons may not be available, it is still possible to tease out aspects of individual experience in the context of larger social issues. Very early on in the history of osteological investigations in southern Ontario, samples of commingled human remains were characterized as only suited to aggregate-level studies because individuals are no longer present. The historical approach is responsible for the dichotomization of studies into population level versus individual level. Because of Ontario's rich ethnohistoric record, the two levels of analyses can be viewed as inextricably linked and essential to comprehensive analyses.

The Ethnography and Archaeology of Commingled Human Remains in Southern Ontario

Iroquoian speakers broadly referred to as Iroquois occupied southern Ontario during the Late Woodland period. Amongst the Ontario Iroquois, the Wendat (Huron), Attawandaron (Neutral), Tionnontaté (Petun), and St. Lawrence Iroquois are the main distinct nations and confederacies that existed. Each occupied neighboring areas found between the south shore of Lake Simcoe and the north shores of Lake Erie and Lake Ontario and along the St. Lawrence River (Fig. 1). The Iroquois peoples experienced dramatic social, political, and economic transformations (e.g., adoption of agriculture) during the early centuries of their southern Ontario occupation. Tumultuous conditions resulting from European trade and warfare characterize the later centuries. The cultural adaptations of the Iroquois certainly had important biological consequences which are the main focus of bioarchaeological investigations. Practitioners investigating the Iroquois are often confronted with commingled human skeletons. The skeletons mainly originate from two different archaeological contexts, mortuary sites and what is recognized as "scattered" human remains. Yandatsa and Yandasqua associated with the Wendat are examples of these two disparate archaeological contexts.

Fig. 1 Historically documented locations of Iroquois occupations in southern Ontario

Yandatsa: The Kettle

Aboriginal mortuary practices evolved into socially complex and ideologically driven forms of manipulation of the dead during the Late Woodland. Among the Wendat, the Feast of the Dead was held to coincide with the periodic relocation of a village (Sutton, 1988). The dead were disinterred from the village cemetery and their bones were washed and bundled for transport to "Yandatsa" (Fig. 2). Yandatsa is the Wendat term for "the Kettle," a common ossuary in the form of a large pit (Trigger, 2000, p. 85).

Rich ethnohistoric accounts provide important information about the Feast of the Dead and Yandatsa. French Jesuit priest Jean de Brébeuf who lived and worked among the Wendat was responsible for a detailed eyewitness account. In May of 1636, Brébeuf attended the feast at Ossossané, the capital of the Attignawantan Nation of the Wendat. Brébeuf describes an ossuary pit over 3 m deep with a diameter of approximately 9 m being tended by over 2,000 participants from surrounding villages (Thwaites, 1896–1901). The pit was surrounded by a scaffold approximately 3 m high and 15 m in diameter. Poles and cross poles of the scaffold were used to suspend the bundles of bones over the pit (Fig. 3; Thwaites, 1896–1901). The remains of the dead were dropped into the pit at the height of the feast. Despite lineage or clan autonomy in a village, all of the human remains were intentionally "stirred" and mixed in the kettle to signal membership in and solidarity amongst the community.

Archaeologists have since pieced together a substantial record supporting the ceremonially created ossuary as a primary feature of Wendat burial practices. The locations of many ossuaries were rediscovered in the early 1800s. Anderson (1964) suggests as many as 216 ossuaries are documented by colonial sources. However, few were the subject of controlled excavations or recording until the middle of the twentieth century. A number of large scientific investigations took place between 1940 and

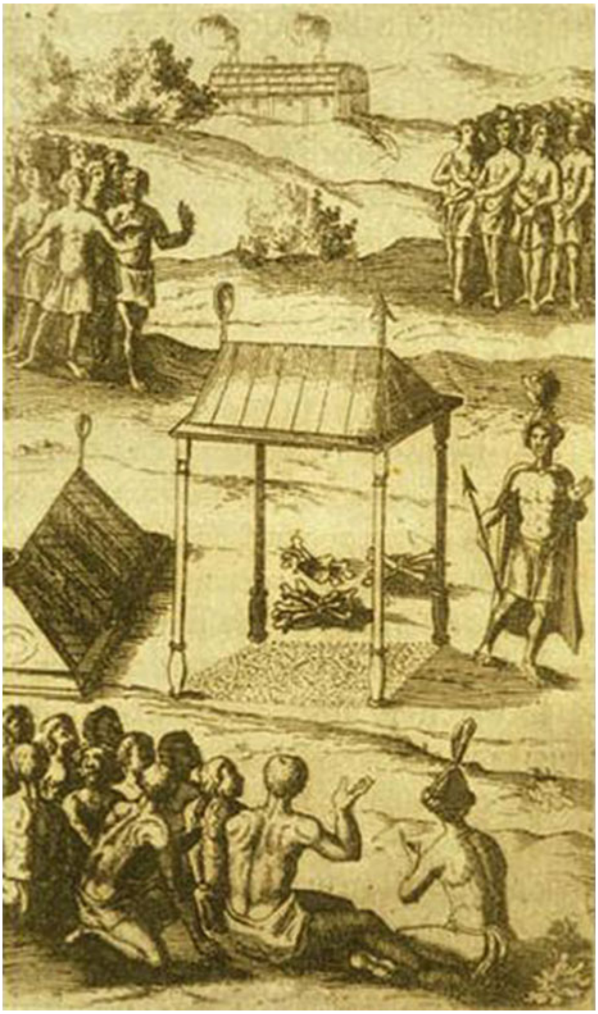

Fig. 2 Wendat primary interment, where human remains are held until the Feast of the Dead. From Samuel de Champlain's, Voyages et descouvertures, 1619

1970 including the excavation of Ossossané. Archaeologist Kenneth E. Kidd (1953) confirmed many of the descriptive details of Brébeuf's account particularly those concerned with the size of the ossuary pit and the structure surrounding it.

More recently, some archaeologists suggest that too much emphasis has been placed on the Wendat mode of ossuary burial (see, e.g., Jackes, 1996; Ramsden, 1990). For example, broad cultural similarities between the Attawandaron and Wendat have generally led archaeologists to interpret remains from both groups in the same way. Jackes (1996) cautions that this is likely not justified while noting that individuation and separation of skeletal remains with minimal or no commingling occur in the large burial pits at the Grimsby site. Ethnographic accounts also indicate age and cause of death dictated the mode of burial among the Wendat and

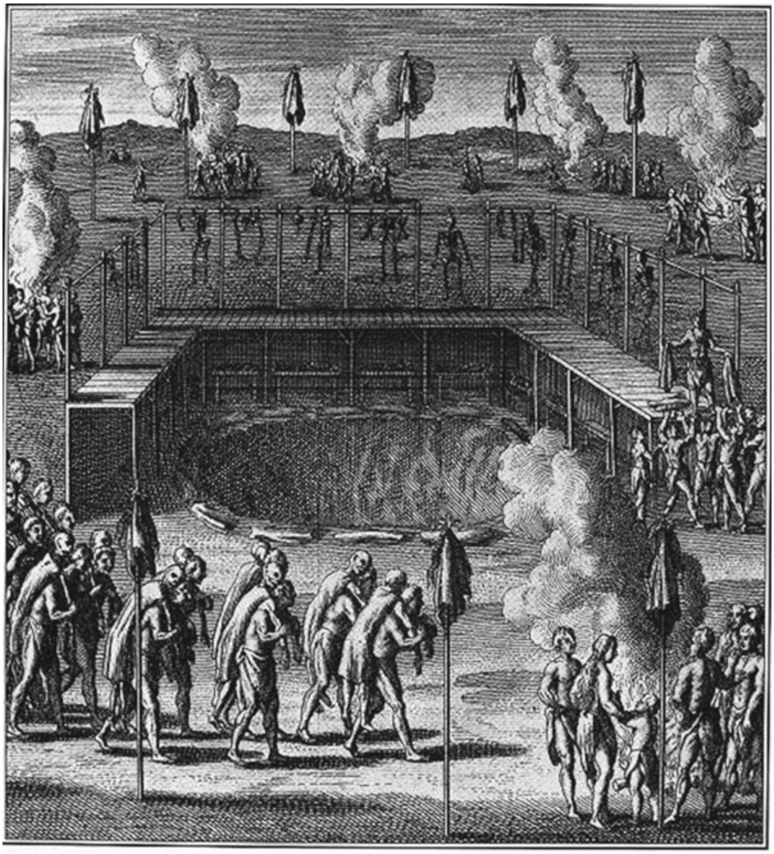

Fig. 3 The Huron, Feast of the Dead in which remains are reburied in a large communal pit (ossuary). From Lafitau, J.F. (1724), Moeurs des sauvages amériquains, comparées aux moeurs des premiers temps, vol. II

that certain persons were excluded from the ossuary. As a result, some attention has been given to the extra-ossuary burial of Wendat infants and war captives (Kapches, 1976; Knight & Melbye, 1983; Sutton, 1988).

Yandasqua: Prisoner

Wars within and between Iroquoian groups and with some of their neighbors were rarely fought for territories, scarce resources, commercial gain, or religious differences (Knowles, 1940; Trigger, 2000, p. 68). The major reason was to avenge the injury and deaths of warriors caused by other tribes (Knowles, 1940, p. 68; Trigger, 2000) while also providing the principal means for warriors to gain prestige and respect (Trigger, 2000, p. 68). The consequence was a perpetual cycle of capturing or killing members from the "other" group. Captives or "Yandasqua" were adopted by families from the captor's village. The adoptive family was responsible for determining the captive's fate. Yandasqua could be spared and integrated into their new family as a replacement for the dead family member. Alternatively, Yandasqua could be tortured and sacrificed to the sun to avenge the loss of a family member. Bones of sacrificed captives were eventually "scattered" (e.g., discarded in village middens and in-house refuse pits or left on the ground) creating an additional context in which commingled human remains are encountered in southern Ontario.

Vivid accounts of the rituals accompanying Yandasqua sacrifice are provided by the Jesuit fathers who lived among the Wendat. Sacrifices were made to sun or war gods and often involved public display on a platform. Rituals emphasized death by knife and removal and consumption of vital organs and/or body parts (Thwaites, 1896–1901). In March of 1649, one thousand Iroquois warriors from New York converged on Wendake. Villages were burned and their inhabitants killed or captured including the two Jesuit priests Jean de Brébeuf and Gabriel Lallemant (Thwaites, 1896–1901).

Archaeological evidence demonstrating torture, killing, and discard of captives' remains is far less substantial than that for ossuary burials. Only nine archaeological sites exist from which scattered human remains have been collected and examined (Williamson, 2007). Ethnographic accounts explain that peri-mortem rituals involved defleshing and the removal of body parts particularly the head and limbs. These remains were then scattered. Based on this evidence, Cooper (1984) suggests the following characteristics should be present to identify sacrificed captives: human skeletal remains in disproportionate numbers (e.g., high frequencies of cranial and long bone material), fragmented bones, bones that are modified with cut marks and/or burning, and human bone artifacts. However, the preparation of primary burials for secondary ossuary burial can also produce similar patterns in skeletal assemblages. Context is an important differentiating factor. Scattered human remains recovered from in-house refuse pits, village middens, or on the ground are considered the best candidates for representing captive's remains.

Both unmarked aboriginal ossuaries and scattered human bones have contributed to the tradition of commingled human remains in southern Ontario. However, the excavation of Iroquoian ossuaries has furnished large skeletal samples that have become the primary focus for bioarchaeological investigations.

The Bioarchaeology of Commingled Human Remains in Southern Ontario

The beginnings of a formal biological anthropology and eventually bioarchaeology in Canada emerged in the late nineteenth century. Trained anatomists interested in morphological variation as an indicator of race sought answers from archaeological skeletal collections. Craniometry was used as a descriptive tool to define and make distinctions between culture groups (see, e.g., Knowles, 1940; Wilson, 1872). The usefulness of craniometric studies was limited since skulls from ossuaries were often damaged from the intentional mixing of remains.

The study of ossuary materials took on new dimensions and importance in Ontario in the middle of the twentieth century. An increased number of archaeological excavations drove biological anthropologists to reconsider ossuary materials. James Anderson, anatomist and biological anthropologist, led the movement with his study of the Fairty Ossuary collection (Jerkic, 2001). Anderson (1964, p. 29) makes the following observations about the people of Fairty:

> The physical anthropologist who deals with Huron-Iroquois material feels cheated when he surveys the burial practices of other areas where large numbers of individual burials are available, where well preserved crania may be associated with their infracranial skeleton, and where the bones, if not intact, are readily reconstructible because of their proximity to each other. Not so in ossuary burials, where large pits yield…hundreds of individuals whose parts are incomplete and are totally dissociated…

Anderson (1964, p. 29) concluded that the nature of ossuary samples precludes the analysis of individuals because, "one deals not with populations of people, but with populations of humeri, femora, temporal bones, and so on." Anderson (1964) also felt that studies of ossuary material were limited by not knowing the extent to which sample composition was influenced by selective burial practices or the regularity of ossuary burial.

Despite the challenges, Anderson's (1964) analysis of the Fairty Ossuary collection was extremely innovative. He made observations on which bones were most susceptible to selective and diagenetic influences based on discrepancies in the numbers of major bones recovered during excavation. He recorded pathological changes on segregated elements including those of the infracranial skeleton. Additionally, he recorded both metric and nonmetric traits and noted that discrete traits could be used to determine the affinity of different groups and that morphological variation gave insights on successive stages of development when considered in a population of elements.

James Anderson's (1964) approach to studying commingled remains quickly became the modus operandi setting the tone for research over the next 20–30 years. During this period, substantial contributions were made to our understanding of the demography, health, diet, and diseases of the prehistoric and historic Iroquoian peoples of southern Ontario (see, e.g., Churcher & Kenyon, 1960; Clabeaux, 1977; Glencross & Stuart-Macadam, 1999; Harri, 1949; Hartney, 1978; Jackes, 1986, 1988; Katzenberg & White, 1979; Kidd, 1954; Molto, 1983; Patterson, 1984; Pfeiffer, 1980, 1983, 1984, 1985, 1986; Pfeiffer & Fairgrieve, 1994; Pfeiffer, Katzenberg, & Kelley, 1985; Pfeiffer & King, 1983; Pfeiffer, Stewart, & Alex, 1986; Saunders & Melbye, 1990; Saunders & Spence, 1986; Schwarcz, Melbye, Katzenberg, & Knyf, 1985; Sutton, 1988).

Concerns over the use of ossuary collections voiced earlier by Anderson (1964) were soon echoed by those conducting demographic research. Ossuary materials first seemed ideal in that the minimum number of individuals was usually quite high, numbering in the hundreds. Yet, the mixed and fragmentary nature of ossuary remains forced biological anthropologists to use different ageing techniques depending on which elements were best preserved. Ageing from a variety of elements had the potential to increase the sources and types of error associated with age-at-death estimates for a collection (Katzenberg & White, 1979; Pfeiffer, 1984). Representativeness of ossuary samples, who were included or excluded from the ossuary, and the unknown length of time over which a sample had accumulated were reevaluated. Ethnographic data suggested that Huron infants, the elderly, warriors, and those experiencing unusual deaths (e.g., violent) were often excluded from the ossuary (Tooker, 1991). Also, it had been assumed that ossuary samples were ideal for affinity studies. Ossuaries were considered homogenous local breeding populations despite ethnographic evidence for the inclusion of "foreigners" (Katzenberg & White, 1979; Molto, 1983). Sutton (1988) cautioned that practices were likely quite variable given the influence of wider social and political relations and change through time. As a result, any perceived biological homogeneity in the composition of a sample remained unsubstantiated. With a renewed outlook towards critical reconstruction and interpretation, Katzenberg and White (1979, p. 26) state:

> …in comparison to other skeletal samples, ossuaries are probably the single best source of demographic information … the major problem is not whether the sample represents the population, but how to reconstruct a population of individuals from a mass of (dis)articulated bones.

Ossuary samples of commingled skeletal remains also provided a strong foundation for epidemiological-based investigations of health and disease. For example, the state of Iroquoian health pre- and post-contact has been investigated extensively (Glencross & Stuart-Macadam, 1999; Pfeiffer & Fairgrieve, 1994; Saunders, Ramsden, & Herring, 1992; Warrick, 1992). Aboriginal groups of southern Ontario prior to contact became increasingly dependent on maize as reflected in stable isotopes (Katzenberg, Schwarcz, Knyf, & Melbye, 1992). Periodic episodes of epidemic disease are likely based on evidence for increased population size, numbers of individuals residing in villages and houses, as well as increased interpersonal contacts and interactions with animals. Dental disease (Patterson, 1984), poor bone quality (Pfeiffer, 1983), and the presence of tuberculosis and treponemal infections (Glencross & Stuart-Macadam, 1999; Hartney, 1978; Pfeiffer, 1984) are cited as clear indicators of compromised health prior to contact.

However, indicators from skeletal material recovered from the contact period are much more elusive in demonstrating the effects of contact. The archaeological and historical evidence suggests social disruption, heightened conflict amongst aboriginal groups, and regular bouts of acute epidemic disease (Trigger, 2000). Comparisons of pre- and post-contact health are difficult to interpret since results based on lesion frequencies often conflicted (Pfeiffer & Fairgrieve, 1994). This uncertainty highlights the interpretative dilemma of the "osteological paradox" first addressed in 1992 by Wood, Milner, Harpending, and Weiss. The crux of the problem is whether aggregate evidence for morbidity or lack thereof indicates a healthy population or a population experiencing disease. Wood, Milner, Harpending, and Weiss (1992,

p. 344) suggest that "hidden heterogeneity, selective mortality, and demographic non-stationarity" confound aggregate-level data and highlight the false dichotomy between individual and population characteristic of epidemiological analyses. Wood et al. (1992, p. 345) state:

> Just as it is a truism in epidemiology that the single case study is of limited value, it is widely recognized in paleopathology that reports on single specimens tells us little about the disease experience of ancient populations. However, when the population of interest is heterogeneous for factors that affect health, the relationship between aggregate measures and the experience of individuals making up the aggregate can be remarkably tenuous.

Consequently, the osteological paradox and its implications for the interpretation of prehistoric health have been fervently debated. Researchers (see, e.g., Armelagos, Goodman, & Jacobs, 1991; Cohen, 1997; Goodman, 1993) using the Biocultural Model have argued that the morbidity status of their study samples do in fact reflect the health status of the living population that they represent. Advocates of the model emphasize the importance of cultural context and suggest the use of multiple lines of evidence to evaluate the extent to which the osteological paradox operates on any given study sample.

Particularly important to this discussion of commingled remains is that Wood et al. (1992) call to reevaluate population-level studies can also be viewed as an appeal for the avoidance of simplistic binary conceptions of the individual and population in skeletal research. Analyses focusing on either individual or population at the expense of the other cannot fully reflect the complexities of prehistoric health. Here the two levels of analyses are viewed as inextricably linked and essential to comprehensive investigations. Historically the commingled nature of skeletal assemblages from southern Ontario was seen as the major force driving the dichotomization of individual and population. But recent contributions, framed within a strong cultural context and using multiple lines of evidence, have actively transitioned between individual and population. Two examples from Ontario that are drawn from different archaeological contexts (ossuary and scattered remains) exemplify this concern. Further, both examples explore current directions in bioarchaeology that emphasize the study of human social identities that relate to age, life course, and community.

Research on the Concept of Identity: Age, Life Course, and Community Identity

Recent archaeological and bioarchaeological investigations have begun to employ social theory in the investigation of identity (Knudson & Stojanowski, 2008). Central to identity is the age of the individual. Bioarchaeologists working with osseous materials have traditionally relied on methods that measure biological age. Commingling compounds these analytical problems. Bioarchaeologist Joanna Sofaer (2011) advocates a change in the notion of age. She suggests a developmental-behavioral conceptualization that takes into account both biological growth and the acquisition of culture. Sofaer (2011) argues that changes to teeth and bones that are related to human experiences highlight aspects of human development while lending to a phenomenological approach to behavioral age. She also notes methodological difficulties in knowing which behaviors or activities are specific to certain skeletal modifications.

Skeletal trauma is a common event with overwhelming antiquity. Fractures and dislocations produce recognizable skeletal modifications that are related to both development and behavior. Skeletal fractures and dislocations also remain an important focus for investigations based on commingled remains from Ontario. Current work has incorporated individual- and aggregate-level data in a developmental-behavioral approach that provides insights on not only age-at-injury and individual heterogeneity in risk but also community identity.

In the course of their investigations, bioarchaeologists have often hesitated to consider the age at which observed skeletal injuries were likely experienced by an individual (exception Lovejoy & Heiple, 1981). Reluctance to consider age is largely due to perceived methodological shortcomings. Indeed, most archaeological skeletal remains exhibit well-healed fractures. Healed fractures are considered void of clues to when or at what age an injury was sustained. Further, the dynamic nature of bone and its ability to grow and remodel was also assumed to eliminate any evidence of fractures acquired at a young age (Ortner & Putschar, 1985). Only perimortem fractures revealed the biological age at which they were experienced because of their association with age at death.

In working towards a developmental-behavioral approach to age, data from clinical epidemiology, skeletal biology, and radiography provide necessary corroborative evidence. Modern clinical data show that the frequency, location, and nature of lesions are influenced by age and that every age group is characterized by a unique pattern of fracture (Burh & Cooke, 1959; Jones, 1994). Types and sites of fracture correspond with structural features and material properties that change with the developing skeleton. Modern clinical data also show that the risk of specific mechanisms of injury change with age-appropriate behavior (Johansen et al., 1997; Peclet et al., 1990; Tibbs, Haines, & Parent, 1998). The paleopathologist's interpretation of gross skeletal evidence is strengthened with the clinical data and any supporting ethnographic and archaeological findings. This knowledge forms the basis for identifying developmental-behavioral age-related skeletal injuries in archaeological samples. Further, the loss of fracture evidence to growth and remodeling has also been reconsidered. Long-term follow-up studies show that the extent of remodeling is quite variable and age dependent (Gasco & de Pablos, 1997; Jones, 1994; Ogden, 1982). Fractures sustained at a young age can and will leave residual deformities.

Healed fractures witnessed in commingled skeletal remains from southern Ontario have been investigated via a developmental approach to age. Stuart-Macadam, Glencross, and Kricum (1998) identified two probable cases of traumatic bowing deformities in adult ulnae from the fifteenth-century Milton Ossuary and the seventeenth-century Glen Williams Ossuary (Fig. 4). Known as acute plastic bowing deformation (APBD), this type of defect is largely limited to developing tubular bones and is the result of compression usually from a fall onto outstretched hands

Fig. 4 Acute plastic bowing deformation (APBD) of the distal third in a Glen Williams ulna (*left*) compared to a second Glen Williams ulna (*right*) showing normal curvature

(Borden, 1974). Differences in bone porosity and surface anatomy of growing bones underlie the permanent bone deformation (Jones, 1994). Despite the mature status of the ulnae, the injuries could only have occurred while the individuals were still growing providing a developmental age.

In a second study, injury about the elbow was quantitatively assessed on X-rays in the Milton and Glen Williams commingled collections (Glencross & Stuart-Macadam, 2001). Supracondylar fractures at distal humerus often result in subtle non-displaced or mildly displaced fractures from a simple fall onto extended arms or less often flexed elbows. This anatomical location is highly susceptible to injury in the young due to structural changes during growth (Jones, 1994). Again, while the healed supracondylar fractures were observed in adult remains, the fractures would have been the result of childhood experiences. Both studies demonstrate that careful noting of the bones involved, intra-skeletal locations of fractures, and type of fracture allows the identification and interpretation of developmental age-related fractures in archaeological remains (Glencross, 2003; Glencross & Stuart-Macadam, 2000, 2001; Stuart-Macadam et al., 1998). The observation that skeletal fractures have the ability to *accumulate* (evidence of fractures sustained during early stages of the life course is not necessarily lost to modeling and remodeling) is important for understanding skeletal injury in the context of lifelong processes. This contrasts with our current static cross-sectional view of skeletal injury in the past. While not yet demonstrated in commingled materials, the fact that skeletal factures accumulate over a lifetime can be used to evaluate variable risk across the life course of an individual (Glencross, 2003; Lovejoy & Heiple, 1981), as well as address heterogeneity in risk among individuals of a group (see, e.g., Glencross, 2003; Judd, 2002).

Developmental age-related fractures should be considered in a broader social context. When combined with ethnographic and archaeological data on age-appropriate social roles, skeletal injury data have the ability to make significant contributions to the exploration of social identity, cultural age, and social agency in the individual (Glencross, 2011). A strong relationship between growth, development, chronological age, fracture patterns, and associated behaviors forms the basis for identifying developmental age-related patterns of skeletal injury. The added dimension of skeletal fractures as visible *accumulated* pathology also underlies our ability to understand skeletal injury in the context of lifelong processes. The combined evidence from age-centered patterns of skeletal injury, when considered in the context of traditional value systems, highlights how communities shape and guide individual behavior in social relations and responsibilities across the life course.

Finally, one example explores community identity as expressed in isolated bony elements recovered from a midden context in Ontario. Cultural groups are identified based on variations in metric and nonmetric morphology. This approach has successfully identified the movements and migration of past peoples when applied at the population level. Molto (1983), using discrete traits, demonstrated biological continuity between people of the Middle and Late Woodland periods of southern Ontario. However, social identity is multifaceted and includes ethnic and community identities. Methods used to identify broad populations are unable to distinguish group micro-differentiation of this type, which often depends on lived experience or behavior.

The bioarchaeological study of ethnic and/or community identity can be investigated through nonmetric skeletal traits and other sources of evidence consistent with competition, conflict, and deliberate exclusion. Social theorists suggest that competition lies at the root of who is and who is not perceived as belonging to a group. With competition comes conflict and actions that have the potential to leave indelible markers in the human skeleton. Identification of Yandasqua (the prisoners and enemies of prehistoric Iroquoian peoples) is sought amongst scattered commingled remains recovered from archaeological sites in southern Ontario. Exclusion from the community is evident in deliberate non-burial and is also signaled in the disproportionate numbers of skeletal elements recovered.

Only recently have investigations trained their focus on isolated or scattered human skeletal remains from Iroquoian sites in Ontario (Cooper, 1984; Dupras & Pratte, 1998; Fontaine, 2004; Gruspier, 1991; Jamieson, 1983; Rainey, 2002). Dupras and Pratte (1998) use both individual- and population-level analyses in a comprehensive study of isolated crania recovered from a midden at the Parsons site. Evidence for exclusion or nonmembership is suggested by the isolation of cranial elements in a midden. Discrete trait analyses were also used to determine biological distance to other neighboring communities. Based on multiple lines of evidence, Dupras and Pratte (1998) suggest the two individuals represented by isolated crania at the Parsons site demonstrate biological affinity with neighboring peoples found in the Uxbridge ossuary. Further, this may indicate transgressions between the people of the Parson's site and the Uxbridge population.

Conclusion

Early work with samples of commingled human remains from southern Ontario assumed that only population-level studies could be conducted because individuals were no longer identifiable. This historical approach was responsible for the dichotomization of approaches to studying commingled human remains. It is argued here that the two levels of analysis—population and individual—are inextricably linked. Commingled human remains (particularly those with strong context) are invaluable resources suitable for studies that transition between individuals and populations allowing the teasing out of aspects of individual experience in the context of larger social issues.

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Part II
Episodic Assemblages

Crow Creek Bone Bed Commingling: Relationship Between Bone Mineral Density and Minimum Number of Individuals and Its Effect on Paleodemographic Analyses

Ashley Kendell and P. Willey

Introduction

Commingled human skeletons result from combining parts of different individuals in a common, mixed assemblage. Commingled human remains occur in mass graves, ossuaries, mass disasters, and sometimes as scatters on ground surfaces or within poorly curated skeletal collections. Dividing commingled human remains into separate individuals is an important step for interpreting skeletons, in both forensic anthropological and archaeological settings. Accurate separation of elements into individuals is of the utmost importance for anthropological analyses because it prevents erroneous conclusions being drawn from the skeletal series. Without a reliable method to associate skeletal elements with individuals, errors follow in paleodemographic interpretations.

The process of segregating commingled elements into individuals has been considered recently (e.g., Scientific Working Group for Forensic, Adams & Byrd, 2008; Anthropology, 2012). Sorting begins with archaeological site or crime scene contextual information, including provenience, map documentation, photographs, and notes. The laboratory process continues sorting elements into individuals using pair matching of antimere elements, often involving element type, size, sex, age, and taphonomic pattern. Reassembling individuals may involve comparison of adjacent elements' articular surfaces, DNA sequences, and osteometric dimensions (Byrd, 2008; Byrd & Adams, 2003).

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_6,

Segregating commingled individuals has its challenges. All things being equal, the greater the number of commingled individuals, the more complex the sorting process. The more similar the individuals' ages, sizes, sexes, healths, taphonomic histories, and morphologies, the more vexing the task of segregating the individuals mixed together in a commingled lot. As a fundamental step in sorting commingled skeletons, establishing MNI has proven to be one of the most important and debated calculations. Both medicolegal and archaeological contexts require establishing MNI, usually defined as the least number of individuals required to account for the skeletal elements present in an assemblage (Shotwell, 1955, 1958). Although "critiquing MNI might be considered a growth industry among zooarchaeologists" (Reitz & Wing, 2008, p. 206), osteological studies that fail to determine MNI falter. In forensic anthropology, MNI is employed as the initial step toward sorting skeletons into meaningful units and establishing individuals' identifications. In archaeological human osteological assemblages, MNI serves as a foundation for many paleodemographic assessments but becomes increasingly difficult as the size of the skeletal assemblage increases or when commingling is extensive. An important prehistoric skeletal series exhibiting extreme complexities caused by commingling hails from the Crow Creek Site in central South Dakota (Fig. 1).

Comprised of hundreds of commingled individuals and incomplete elements, the Crow Creek bone bed resulted from a variety of cultural and taphonomic processes. Because elements and element segment representation form the basis of MNI calculations, the Crow Creek bone bed is a superb example of the difficulties associated with MNI calculations. Many intrinsic factors contribute to the survivability of a skeletal element, including, but not limited to, density, shape, size, sex, age, and health (Willey, Galloway, & Snyder, 1997, p. 527). Bone mineral density (BMD) is also among the more important intrinsic variables affecting element representation. Unfortunately, BMD is poorly documented for bioarchaeology and forensic anthropology series. There are few applicable studies of adult BMD and even fewer dealing with subadult BMD. The present work provides a modest attempt to address this deficit. We examine subadult BMD values, comparing them with adult BMD values and then relating these values to preservation of limb elements from the Crow Creek Site. Developing a greater understanding of the relationship between BMD, age at death, and element preservation will have a significant impact on the reconstruction of paleodemography and the estimation of MNI within any archaeological context.

Previous research utilizing the Crow Creek materials assessed the relationship between BMD and element survival. However, prior research employed only adult skeletal material (Galloway, Willey, & Snyder, 1997; Willey et al., 1997). Galloway et al. (1997) discussed the role of BMD and survival of bone elements in both forensic and archaeological contexts. The study reported BMD of long bones measured in a contemporary sample using single-photon absorptiometer bone scans at locations based on percentages of the maximum length of the bone (Galloway et al., 1997). Research conducted by Willey et al. (1997) also suggested that denser elements and element portions had greater survivability, suggesting that denser elements and element portions provided a better estimation of the MNI than less dense, more porous bones or bone portions. BMD differences by side, sex, and age may also

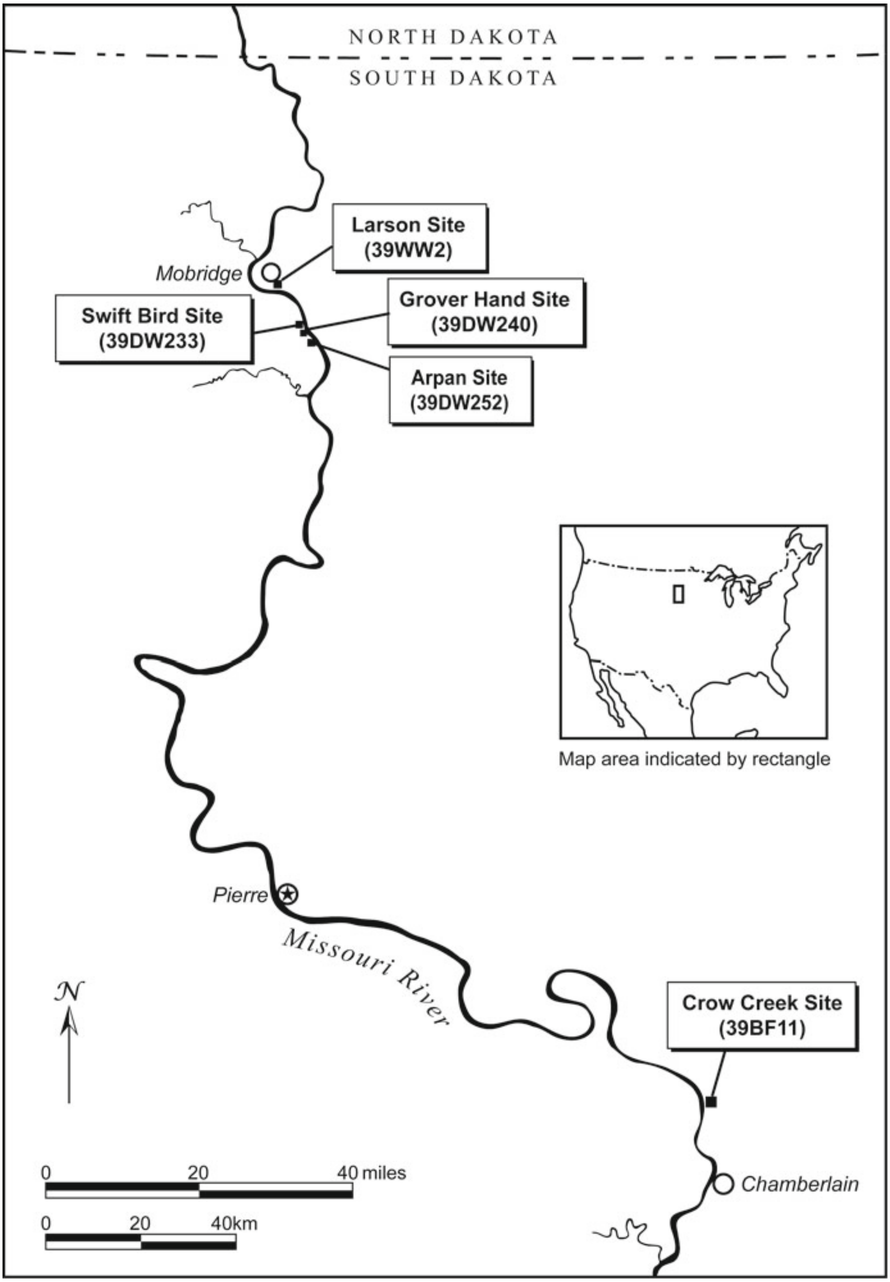

Fig. 1 Locations of Crow Creek and other important Middle Missouri River Subregion sites

alter survival of skeletal remains. In the present study, we expand the previous research in a continued effort to explore the role of BMD and element survivability at the Crow Creek Site. In this research, we include subadult skeletal remains to demonstrate that age at death is correlated with BMD and element survival at the Crow Creek Site and that age at death has an impact on the estimation of MNI.

History of Commingled Remains in the Middle Missouri River Subregion

The Crow Creek Site is located in the Middle Missouri River subregion of the Great Plains and belongs to the Initial Coalescent Variant dating to the fourteenth century AD (Fig. 1; Kivett & Jensen, 1976, pp. 77–78). Native American osteology in the subregion is relatively well known, thanks to an active excavation program by the River Basin Surveys in the 1950s and 1960s and William M. Bass in the late 1950–1970. In that area, as elsewhere, zooarchaeology influenced understanding of human osteology.

The concept of MNI, in fact, developed in Middle Missouri zooarchaeological studies.

In a seminal paper in Plains archaeology and zooarchaeology, White (1953, p. 397) identifies one procedure for establishing MNI. The process is "to separate the most abundant element of the species found (usually the distal end of the tibia) into right and left components and use the greater number as the unit of calculation…. This [procedure] may introduce a slight error on the conservative side because, without the expenditure of a great deal of time with small return, we cannot be sure all of the lefts match all of the rights" (White, 1953, p. 397). Although a major contribution to osteological concepts and theory, White failed to embrace segregating individuals of a single species by age, sex, size, or other parameters.

Moving from zooarchaeology to human bioarchaeology, late prehistoric, protohistoric, and historic Arikara cemeteries have been a major research focus in the Middle Missouri subregion. Burials excavated there were characterized as single, primary inhumations. But researchers also noted that "other variations…involved the burial of two to five or more individuals in a single large pit" (Wedel, 1961, p. 200). A maximum of ten individuals were observed in one well-studied Arikara cemetery (Bass & Rucker, 1976, p. 37). In addition, occasionally disarticulated secondary burials were placed in graves. Reuse of some graves resulted in commingling of skeletons and their elements (Ubelaker & Willey, 1978, p. 72, Table 3). For example, in the protohistoric Larson Cemetery (Fig. 1), 29.0 % of the skeletons had been disturbed by Native Americans contemporary with the site. Other taphonomic processes in that cemetery resulted in bones being moved by burrowing animals (7.0 %) and jumbled by recent looters (0.5 %; Ubelaker & Willey, 1978, Table 3). Such disturbances in a grave pit containing more than one individual often resulted in commingled skeletons. In most instances, the relatively few individuals and differing ages, sexes, and sizes of those commingled individuals simplified the segregation process and the estimation of MNI.

Greater commingling complexity occurred in earlier Plains Woodland burial mounds. Similar to the later prehistoric, protohistoric, and historic Arikara cemeteries, these mounds included primary and secondary burials. As an additional complicating factor, the Woodland skeletons were concentrated and mixed in subterranean, log-covered pits [see Lehmer (1971, p. 62, Fig. 37) for an illustration of commingled individuals]. Commingling of these assemblages has occurred through intentional contemporary reuse of tombs, disturbances by roots or burrowing animals, or by modern looters (Ubelaker & Willey, 1978, Table 3). Again, the relatively few individuals and differing ages, sexes, and sizes of those commingled individuals simplified the segregation process and the estimation of MNI during previous analyses (such as Bass & Rucker, 1976; Lehmer, 1971; Ubelaker & Willey, 1978; Wedel, 1961).

Attempting to overcome these commingling challenges, Bass and Phenice (1975) analyzed skeletal series from three Woodland burial mound complexes (Grover Hand, Swift Bird Mounds, and Arpan Mound sites; Fig. 1). As a fundamental methodological step, they acknowledged that the "intermixed nature of the remains presented a problem in determining how many individuals were represented" (Bass & Phenice, 1975, p. 106). To approximate the number of individuals, assess sexes, and estimate ages at death, they considered each mound separately and employed archaeologically identified burials within each mound as their analytical units. In addition to the archaeological context, "Duplicated bones and bones of differing age and sex were used as the basis for determining the minimum number of individuals present…" (Bass & Phenice, 1975, p. 106). They did not note any major challenges involved in the separation of individuals within burial units, likely due to the relative paucity of commingling within each burial.

Commingling also occurred in the protohistoric Larson Village lodges, the habitation area associated with the Larson Cemetery (Fig. 1). Human remains were strewn on floors of several houses, many of those skeletons demonstrating disarticulation and commingling (Bass & Rucker, 1976). The deposit resulted from raiders overwhelming the village, slaughtering its occupants, mutilating their bodies, and leaving their corpses unburied on the house floors (Owsley, Berryman, & Bass, 1977). The Larson Village materials proved to be a vexing commingling challenge because many of the remains were dismembered. Subsequently, scavenging produced extensive commingling of many of the body parts and bones (Owsley et al., 1977, p. 126).

Adams and Konigsberg (2008) pioneered a new approach to the Larson Village skeletal series. Although the approach had not been used previously in human osteological studies, it had been employed in zooarchaeology and studies of living animals. This approach used a modification of Lincoln Index (LI), a quantitative method applied to zooarchaeological samples to estimate the original population size (Adams & Konigsberg, 2008). This modification of the LI, known as the Most Likely Number of Individuals (MLNI), required matching pairs of left and right elements from the same person—a process that may be compromised with poorly preserved skeletal series. Adams and Konigsberg (2008) applied this approach to the Larson Village house with the greatest number of skeletons (Lodge 21) and employed four elements (humerus, innominate, femur, and tibia). Their modified MNI

(Max [L,R]) identified 43 individuals, while their MLNI found 49–51 individuals, depending on the element used. Although they concluded that MNI underestimated the MLNI present, a previously published MNI for Lodge 21 exceeded even their greatest MLNI estimation (≥54 individuals; Bass & Rucker, 1976, p. 36). It is important to note here that Adams and Konigsberg (2008, p. 150) suggest that "if fragmentation is extensive or preservation is extremely poor, so that accurate pair-matches are impossible to determine, the LI and MLNI are prone to gross miscalculations."

While the concept of MNI has endured increasing levels of criticism, initially in zooarchaeological studies and more recently in bioarchaeological studies, a handful of improvements have been suggested to supplant the concept. The most readily accepted methods, however, merely provide tangential insights. MLNI is chief among those suggested improvements—and even it depends on the MNI concept as a basis for its calculation.

As this brief historical sketch demonstrates, osteological studies of commingled Middle Missouri archaeological skeletal series have progressed during the past 50 years. Researchers employing these series have contributed much to understanding skeletal biology there and by extension beyond the region. The largest commingling challenge in the area—perhaps in all of prehistoric North America—emerged at the Crow Creek Site in 1978.

Crow Creek Archaeological and Bioarchaeological Background

The Crow Creek Site is one of the largest archaeological sites on the Northern Plains (Kivett & Jensen, 1976, p. 1) and has played a major role in the reconstruction of Native American history, particularly violence on the Plains (Willey, 1990). Approximately 10 miles north of Chamberlain, South Dakota, the Crow Creek Site rests on the east bank of the Francis Case Reservoir (Fig. 1; Willey & Emerson, 1993, p. 228). The archaeological site consists of a large, well-fortified village resting above the confluence of Crow and Wolf creeks and is best known for the human bone beds discovered there in May 1978 (Fig. 2; Kivett & Jensen, 1976; Willey & Emerson, 1993, p. 227).

Human remains at the Crow Creek Site were uncovered in two bone beds—upper bone bed A and lower bone bed B—both located in a fortification ditch (Willey & Emerson, 1993, p. 7). A hard-packed layer of clay, approximately 30 cm thick, lies between the two bone beds. Lower bone bed B contained the majority of the human remains, while the upper bone bed A consisted of a scattering of disarticulated human remains (Fig. 3; Willey & Emerson, 1993, p. 239). It is possible that bone bed A represented a second recovery of skeletal elements after the bones from the primary recovery had been interred in the lower of the two bone beds (Willey, 1990, p. 181).

Following excavation, the human skeletons from the Crow Creek Site were prepared and analyzed at the University of South Dakota's Archaeology Laboratory

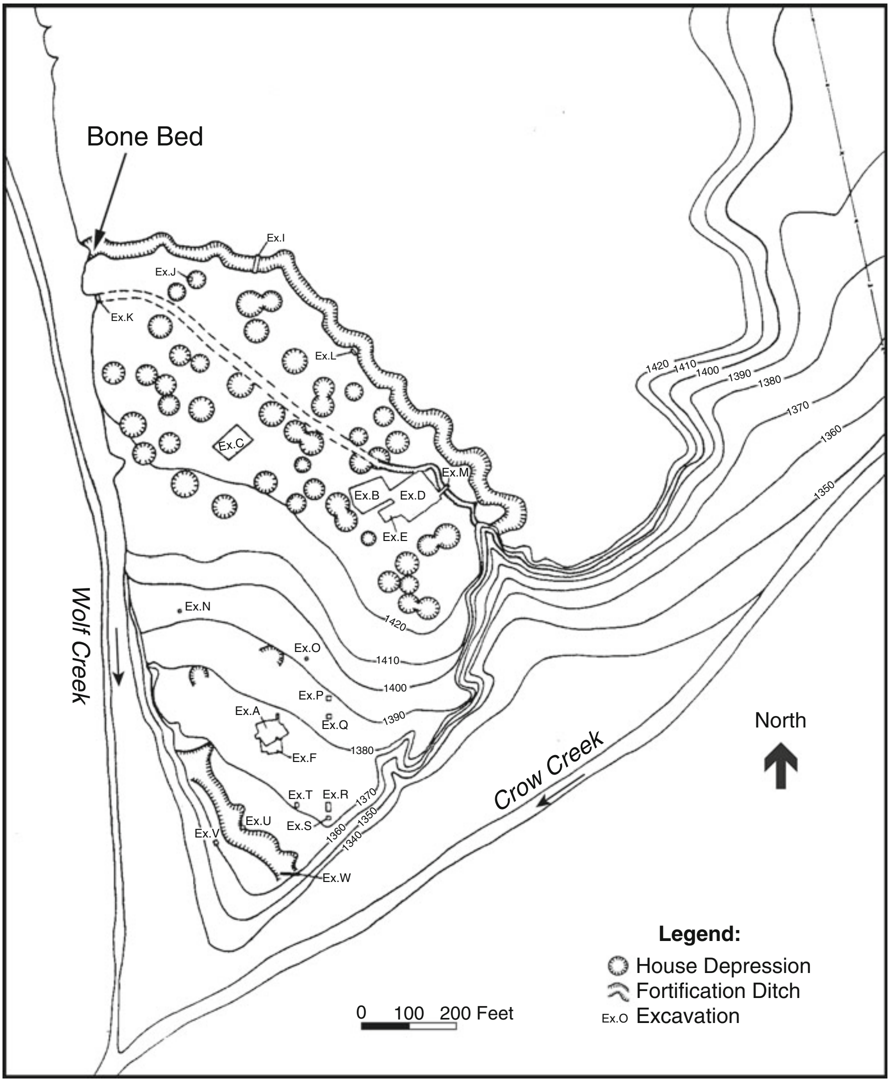

Fig. 2 Crow Creek Site, showing house depressions, fortification ditch and the Bone Bed with commingled skeletons. Modified from Kivett and Jensen (1976, p. 2), Fig. 1. Courtesy of the Nebraska State Historical Society

(Willey, 1990, p. xviii). Among the many other osteological assessments, elements were inventoried by minimum counts. The greatest minimum count ($n=486$) was from the right temporal (Willey, 1990, p. 14). The least minimum count ($n=91$) was from the left radius. The difference between the greatest and least minimum counts was attributed to variation in the size, density, and proximity to the torso of each skeletal element (Willey, 1990, p. 14). In general, larger, denser bones closer to the

Fig. 3 View of the Crow Creek Bone Bed (looking north) showing hundreds of commingled skeletons. Courtesy of the University of South Dakota's Department of Anthropology and Sociology

torso were better represented. The proximal limb elements were represented at a greater rate than distal limb elements. For example, the humerus was more common ($n \geq 213$) than the ulna ($n \geq 131$) or the radius ($n \geq 115$), and the femur ($n \geq 367$) was more common than the tibia ($n \geq 269$) or the fibula ($n \geq 156$; Willey, 1990, p. 14). The greater prevalence of larger, denser elements indicated they were more likely to survive and be recovered than the smaller, lighter elements (Willey, 1990, p. 17).

There was also a discrepancy in the minimum element count when assessing the remains according to age (Willey, 1990, p. 17). The greatest discrepancy between the counts of the temporals and the long bones was found in the proportion of subadult elements recovered. Adult elements were represented more completely than the elements from other age groups. Several explanations have been posited for this discrepancy. The greater proportion of adult elements may have resulted from destruction and scavenging of younger, smaller bodies (Willey, 1990, p. 17). After burial, smaller remains also may have been more highly fragmented through normal taphonomic processes. Finally, it was possible that element representation was correlated with BMD of the Crow Creek skeletal elements. Based on previous research (Galloway et al., 1997; Willey et al., 1997), this chapter examines the roles of BMD and element representation in the Crow Creek bone bed with respect to age of the individuals interred. Specifically, this research explores MNI disparity between adults and subadults in terms of differences in BMD between the two age groups rather than age-group differences in the original Crow Creek village population.

We hypothesize that adult–subadult differences are greatest in the more distal and more porous portions of bones.

Both Galloway et al. (1997, p. 527) and Willey et al. (1997) suggested that BMD constituted an important variable in survival of bone in archaeological and forensic contexts. In the previous study by Willey et al. (1997), density values from a contemporary sample (Galloway et al., 1997) were compared with rates of survival for adult skeletal elements of Crow Creek massacre victims. The results of this study indicated a correlation between BMD and element survival at the Crow Creek Site. The present study also explores the relationship between BMD and element preservation, and in addition to the skeletal material analyzed by Willey et al. (1997), it examines Crow Creek subadult skeletal materials. In addition to the contemporary adult BMD readings (Galloway et al., 1997), the present research utilizes late childhood BMD values drawn from the Larson skeletal series as a BMD proxy measure for Crow Creek subadults. The Larson skeletal series was comprised of 18 individuals, both adults and subadults, recovered from the Larson Village and Larson Cemetery. This sample was selected because, like the Crow Creek village, the Larson Village population was inhabited by Arikara Indians. Proxy measurements were necessary because the initial skeletal material from the Crow Creek Site was repatriated in 1979.

Materials and Methods

The Crow Creek data used in this study came from elements documented in 1979 and employed in a previous study (Willey et al., 1997). Because Crow Creek skeletal materials have been repatriated, previous researchers employed a contemporary adult skeletal sample's BMD readings as a proxy measure of BMD for adults at the Crow Creek Site. The present study utilizes subadult BMD values drawn from the Larson skeletal series as a proxy measure of BMD for Crow Creek subadults. To estimate ages in the Larson skeletal series, we utilized the work of Merchant and Ubelaker (1977). Merchant and Ubelaker correlated skeletal measurements of protohistoric subadult Arikara Indians with their age at death estimated from dental eruption. Age at death of each individual was then plotted against the maximum length of the major long bones (humerus, radius, ulna, femur, tibia, and fibula). Age categories were divided into 1-year intervals beginning with newborn to 0.5 year and ending at 18.5 years (Merchant & Ubelaker, 1977, p. 63). Maximum length measurements of diaphyses, however, were not available for every age category examined in the study. Therefore, for subadult values, the current study utilized the 11.5–12.5-year-olds as a proxy for the entire subadult category. While it was possible that proportional BMD values differed by subadult age (an assertion that requires testing), the 12-year-olds sample was the most complete BMD measure available. And the 12-year-olds sample occurred about midway in the subadult age group, thus most likely best representing subadult BMDs as a whole. In addition, Merchant and Ubelaker (1977, p. 71) suggested that Arikara limb bone lengths may be unreliable for older adolescents due to small sample sizes. From the Larson skeletal series, we identified long bones in the 11.5–12.5-year age interval based on a maximum length measurement. We employed the BMD values at the 20 % and 80 % location (Fig. 4). However, long bones of this age were not present for all elements. Ulna BMD used an individual between 9.5 and 10.5 years of age. For the tibia, BMD was available from an individual between 12.5 and 15.5 years of age. Because BMD values came from the 11.5- to 12.5-year age category for most elements, adolescents (12–18 years) were usually omitted from the subadult category in the Larson skeletal series, and the BMD dataset was drawn primarily from a late childhood age group. However, BMD values of the Larson skeletal series were used as an approximation of BMD for all Crow Creek subadults because exact ages could not be estimated for the Crow Creek limb bone segments. This limitation is discussed further in the study limitations section of the chapter.

In the original study (Willey et al., 1997), element counts were based on segments. An element segment represented a portion of an element (e.g., humerus, radius, femur) classified according to side, age, and portion of bone. Limb bones were sided and portions present were identified in 1979 at the University of South Dakota (Willey et al., 1997, p. 517). The elements considered in this study consisted of long bones making up the upper and lower limbs (humerus, radius, ulna, femur, tibia, fibula). Element segments were recorded in fractions for each bone [eights, sixths, fourths, thirds, and halves; see Willey et al. (1997, p. 518; Fig. 4)]. The segment of the element present was estimated and was not based on measurement or direct comparison to complete elements. Each long bone element was recorded by portion (proximal, distal, shaft). The proximal end of an element consisted of the proximal sixth of the long bone. The distal end included the distal sixth of the bone (Fig. 4). Elements were also recorded by side (right and left). Finally, a survival percentage was calculated for each element segment based on the maximum segment count for that element (Willey et al., 1997, p. 517).

Altogether, this study consisted of 25,963 element segments. The 25,963 segments represented a total of 2,286 elements. This total element count was based on the sum of the highest segment count per element used in the study. The 2,286 elements included both the adult and subadult age groups. Sex and exact age were not determined for each element, so for this analysis, elements were divided into adult and subadult categories based on epiphyseal fusion and/or size of the element being considered (Willey et al., 1997, p. 517). Age estimation from limb bones is difficult—especially for adults. Therefore, age of adult limb bones was rarely more precisely aged than simply “adult” (>18 years). The original element inventory (which is the source of our limb proportion data) also employed broad age categories for subadults. The broad subadult age categories consisted of infant (B-2 years), child (2–12 years), and adolescent (12–18 years). Age of subadult (B-18 years) limb bones was estimated from size and, in the rare instance of complete elements, diaphyseal length. Sometimes these subadult limb bones were difficult to identify precisely, especially in the cases of fragmentary limb bones and individuals straddling two subadult age categories. So as part of the Crow Creek analysis, those less

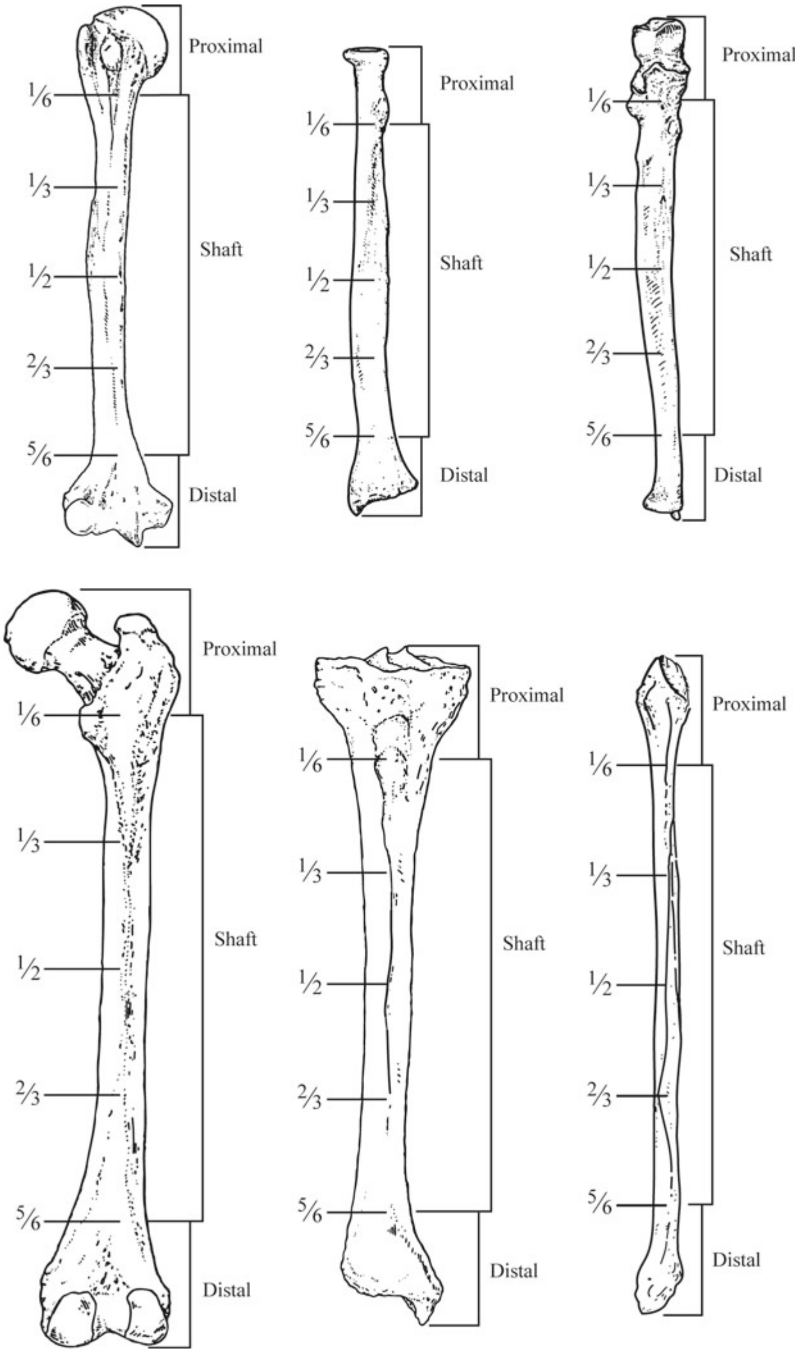

Fig. 4 Bone segments applied to limb bones from the Crow Creek Site

precisely aged individuals of less than 18 years were merely identified as “subadult.” For our purposes here, we attempted to include all possible Crow Creek limb bones, combining all four juvenile age categories (infant, child, adolescent, and subadult) into a single subadult category. This general grouping of juvenile skeletal material, while not perfect, was necessary because of the initial data collection methods. Ideally, each limb bone and each limb bone fragment would have been aged precisely, but such an effort was impossible due to time constraints, the size of the Crow Creek Site skeletal assemblage, and fragmentary limb bones. So, for the present work, rather than attempt to superimpose more refined age estimations for adult and subadult limb bones, we settled on those two broad age categories as analytical units. This point is further elaborated in the next section.

Analysis of the Crow Creek data employs three statistical tests. A binomial distribution test is applied to see if there is a difference in the representation of right and left elements. Binomial tests are calculated separately for the adult and subadult age categories and tested against a 50:50 proportion. Fisher’s exact tests are also applied to examine if proximal and distal ends of elements are equally represented in both the adult and subadult age categories. Finally, a Spearman’s rank order correlation test is applied to all late childhood skeletal materials to incorporate subadult BMD measures.

Results

Of the 22,256 adult segments in this collection, 10,961 (49.2 %) are from the left side and 11,295 (50.8 %) are from the right (Table 1). A statistically significant difference occurs between adult right and left elements ($p<0.02$; Willey et al., 1997, p. 522). A systematic difference exists in the sample, with adult right element segments outnumbering adult left element segments. In the previous study (Willey et al., 1997, p. 522), difference in adult sides was noted. It was attributed to the side differences in two upper limb elements, namely, the radius ($p<0.01$) and the ulna ($p<0.02$). Neither the humerus nor the three lower limb long bones displayed side differences.

Of the 3,707 subadult element segments, 1,904 (51.4 %) are from the left and 1,803 (48.6 %) are from the right. A statistically significant difference is observed

Table 1 Number of adult Crow Creek segments by element and binomial distribution by side

	Left	Right	Binomial distribution between right and left elements
Humerus	1,727	1,697	$p=0.298$
Radius	766	932	$p=2.498\times10^{-5}$
Ulna	899	993	$p=0.014$
Femur	3,492	3,623	$p=0.059$
Tibia	2,650	2,608	$p=0.277$
Fibula	1,427	1,442	$p=0.383$

Table 2 Number of subadult Crow Creek segments by element and binomial distribution by side

	Left	Right	Binomial distribution between right and left elements
Humerus	345	234	$p = 1.516 \times 10^{-6}$
Radius	91	67	$p = 0.023$
Ulna	35	52	$p = 0.027$
Femur	974	848	$p = 0.001$
Tibia	385	481	$p = 4.846 \times 10^{-4}$
Fibula	74	121	$p = 2.766 \times 10^{-4}$

Table 3 Number of adult and subadult Crow Creek segments by element-portion present and Fischer's exact test results

	Adults			Subadults		
	Proximal	Middle	Distal	Proximal	Middle	Distal
Humerus	624	1,918	882*	133**	312	134
Radius	469*	990	239**	30	89	39
Ulna	517	1,127	248	20	49	18*
Femur	1,556	4,419	1,140	410*	1,104	308*
Tibia	973	3,382	903*	19**	538	137
Fibula	541	1,813	515*	36	124	35

p-Values for significant differences per age divided segment are marked with an *asterisk* and are as follows: $^{*}p < 0.05$; $^{**}p < 0.01$

between right and left segments for all subadult long bones together (Table 2). For each element, there are more left segments for subadult humeri, radii, and femora. There are a statistically greater number of right segments for subadult ulnae, tibiae, and fibulae.

Fisher's exact tests are calculated to assess differences in the representation of proximal and distal ends for adults and subadults (Table 3). Adult and subadult elements show no observable pattern in the presence of proximal and distal ends. Therefore, BMD and end representation are not related. There does, however, appear to be age-dependent overrepresentations by joint. Subadult elements are overrepresented at the shoulder, hip, and knee, and adults display an overrepresentation at the elbow (distal humerus and proximal radius) and ankle.

A Spearman's rank order correlation is calculated to determine the relationship between BMD and element representation for subadult elements using the Larson skeleton late childhood BMD measurements. A positive correlation between BMD and element representation exists ($\rho = 0.742$, $p < 0.001$). When compared to the Spearman's rank order correlation for adults ($\rho = 0.869$, $p < 0.001$), there is an underrepresentation of lower BMD elements of subadults at the Crow Creek Site. All subadults have lower BMD levels than their adult skeletal counterparts (Table 4). It also appears that there is a larger discrepancy in BMD when comparing regions of the body (i.e., upper vs. lower appendages) than when comparing portions of a bone (i.e., proximal vs. distal).

Table 4 Proxy BMD readings for Crow Creek adult and subadult long bone segments

	Adult	Subadult
Proximal humerus	0.848	0.805
Distal humerus	1.080	0.704
Proximal radius	0.778	0.480
Distal radius	0.653	0.436
Proximal ulna	0.958	0.627
Distal ulna	0.655	0.434
Proximal femur	1.563	1.194
Distal femur	1.045	0.769
Proximal tibia	1.240	1.081
Distal tibia	1.015	0.871
Proximal fibula	0.590	0.587
Distal fibula	0.600	0.591

Discussion

The present study demonstrates that a relationship exists between BMD and element representation at the Crow Creek Site. These results are supported in the clinical literature which reports that BMD increases steadily throughout childhood (Boot, Ridder, Pols, Krenning, & de Muinck Keizer-Schrama, 1997). The medical literature indicates that bone mass peaks in early adulthood and then gradually decreases at the rate of 0.3–0.5 %/year with a possible early menopausal acceleration in females (Riggs & Melton, 1986). While there is no observable pattern in the presence of proximal and distal ends between adult and subadult element segments, there does appear to be age-dependent overrepresentation by joint. This overrepresentation may be explained by epiphyses being excluded from the subadult counts, leaving only the more durable, compact bone of the diaphysis.

Corroborating Galloway et al. (1997), the greatest element segment representations occurred at midshaft for every bone (Table 3). As predicted, this observation held true because the greatest BMD occurred in this portion of a long bone. As expected, element survival was correlated with element size. For both adult and subadult diaphyseal ends, the greatest element representation was observed for the proximal femur, followed by the distal femur, and then the proximal tibia. Adult and subadult elements parallel each other in element preservation for all long bones.

The difference observed between left and right elements for adults was discussed in the previous work conducted by Willey et al. (1997). Those authors note that it would be unlikely that BMD alone produced the observed right-left distribution (Willey et al., 1997, p. 525). When looking at the modern BMD values, ulnar BMDs displayed significant differences in sides, but the radial BMD levels did not show side differences (Galloway et al., 1997). It was, therefore, suggested that BMD may have only a general effect on element survival. Another possibility presented was that left forearms may have been removed as a form of mutilation more often than right forearms. Because sex was not recorded during the initial data collection, we were unable to assess the possibility of male warrior's forearms being taken as trophies. The results of the present work also supported the assertion that side discrepancies observed among adults may have resulted from human modification instead of other taphonomic processes.

When subadult materials are incorporated into the study, we note the apparent randomness of element distribution by side. There is no pattern in the distribution of elements by side for either the upper or lower limb of subadults. This distribution may lend credence to the assertion that adult element side differences resulted from mutilation, such as removal of forearms as trophies. If adult side differences resulted from trophy taking practices, the random representation of subadult elements may be attributed to the effects of a number of natural taphonomic processes, including exposure (burial location within the grave), decomposition, scavenging, burial looting, excavation, transportation, cleaning, and analysis. In addition to these extrinsic factors, survivability has also been associated with bone's intrinsic properties, including density, shape, size, sex, age, and health (Willey et al., 1997, p. 527). Any combination of the extrinsic and intrinsic factors listed above could have contributed to the random representation of subadult elements according to side.

It is important to consider the potential effect that the relationship between BMD and element representation has on MNI estimation. As previously noted, establishing MNI is a fundamental step in sorting commingled skeletons and has proven to be one of the most important and debated determinations. Adams and Konigsberg's (2008, pp. 243–244) simulation demonstrates that when the recovery rate of the bones is low, MNI grossly underestimates the actual number present. And they claim that even in nearly complete recoveries, MNI continues to underestimate the actual number of individuals, but to a lesser extent than in cases of lesser representation. The results of the present study show that BMD may be one of many intrinsic factors that contribute to the inaccurate estimation of the actual number of individuals when calculating MNI. This paper also indicates the subset of the population most likely to be underestimated in MNI calculations. Although we do not know what proportion of the Crow Creek villagers was represented in the bone bed, we do know that the Crow Creek MNI determination is biased in favor of adult skeletal elements. Therefore, it can be conjectured that commingled skeletal element series are skewed in favor of adult skeletal elements over subadults because adult elements have greater BMD values. Likewise, if a skeletal series has a particularly large number of elderly individuals, it is likely that many of the elderly individuals' skeletal elements and element portions will be absent and excluded from the MNI estimation due to their low levels of preservation and survivorship (Galloway et al., 1997). MNI determinations, therefore, may tend to overrepresent young and middle-age adults because their elements have the greatest BMD values and are the most likely to be represented in any skeletal series while simultaneously underrepresenting subadults and the elderly. When making inferences about the population that a skeletal sample represents, bioarchaeologists must consider the nature and extent of this ontogenic bias.

Adams and Konigsberg (2008, p. 241) also suggest that with the application of LI or MLNI, poor element preservation and/or large sample sizes may complicate the process. It is easier to resolve commingling in a situation "involving 5 people as opposed to a large-scale incident involving 500" (Adams & Konigsberg, 2008, p. 242). Due to the Crow Creek bone bed's large numbers, extensive fragmentation, and moderate preservation, LI and MLNI calculations may be prone to miscalculation or, worse yet, may be impossible to apply (Adams & Konigsberg, 2008, p. 150). Therefore, the authors of the present study suggest that in cases of extensive commingling and with large numbers of individuals in a single skeletal series, MNI remains the best and most accurate estimation of the number contributing to the sample. In addition, MNI estimations can provide more well-informed calculations if BMD is considered when selecting skeletal features to be used in the MNI estimation. As previously noted, this chapter supports the notion that midshafts of long bones are the best preserved skeletal segments. The use of other portions of long bones may decrease the likelihood of proportional representation between age groups, thereby increasing bias in any approximation of the original population.

Finally, this chapter refutes one assertion of LI and MLNI calculations, namely, the assumption that loss of elements is random (Adams & Konigsberg, 2008, p. 245). The results of the present research demonstrate that element representation is influenced by intrinsic factors, including, but not limited to, age, element side, element portion, and BMD. Therefore, uncritical use of LI and MLNI may distort the paleodemographic profile of a skeletal series.

Study Limitations

One limitation of the present study is that sex and its relationship to BMD were not taken into consideration. While it is well known that sex has an effect on BMD (e.g., Galloway et al., 1997), sex was not recorded for limb bones in the Crow Creek Site bone beds. For the demographic profile, adult sex assessment employed skulls and os coxae. Unfortunately, few limb bones were articulated with skulls or innominates, forcing sex assessment of limb bones to rely on metric means. That approach was applied to estimate sex of Crow Creek femora, employing measurements of a similar group using associated os coxae (Larson Site, Willey, 1990). The metric assessment, however, was only for complete femora, not other limb bones, or for femur fragments. For the present study, the limb bone proportion tally is for all six limb bones, whether complete or incomplete. Because sex assessments were impossible, long bones were inventoried by age and side only, not sex. Previous research suggests that sex has little effect on the BMD values for subadults, however. Evidence indicates that BMD of the long bones is comparable in boys and girls and that no differences are observed in total body BMD between the sexes during the prepubertal period (Boot et al., 1997). Because individuals attain peak BMD levels in early adulthood, this age is when differences in BMD between the sexes are the greatest (Galloway et al., 1997; Riggs & Melton, 1986).

Another limitation of the current study relates to the gross demographic age categories employed (adult and subadult). As mentioned previously, the original element inventory used only broad age categories (infant, child, adolescent, adult), sometimes combining the juveniles into a more general group (subadult). Because there is much BMD variation during an individual's life, dividing individuals into one of two broad categories undoubtedly masks much complexity in the relationship between age and BMD. As previously reported, age is one of several factors affecting the BMD of a skeletal element (Galloway et al., 1997). An example of BMD changes occurring with age is presented in the following quotation: "the pattern seen in clinical studies of females is one in which bone mass is accumulated during adolescence and early adulthood, peaking in the mid-thirties…. Following the menopause, there is a period of 8–10 years in which women lose an additional 2–3 %/year of their cortical bone and up to 8 %/year of their trabecular bone" (Riggs & Melton, 1986, p. 1676). Keeping this concept in mind, we must consider the effect that population demographics have on MNI.

The final complication of the present study is the use of a proxy measure of BMD drawn from the Larson skeletal series. As previously mentioned in the methods and materials section, BMD measurements were drawn primarily from individuals between the ages of 11.5 and 12.5 years based on age estimated from long bone lengths (Merchant & Ubelaker, 1977). These late childhood BMD measurements were employed to represent the entire subadult group from the Crow Creek Site, and the relationship between BMD and element survivability was tested between adult and subadult age groups. Because the proxy BMD measurements were drawn from a late childhood segment of the population, these measures may have distorted BMD for other juveniles. Therefore, statistically significant differences may have been observed when they did not exist for the entire subadult sample. To compensate for this proxy measure, we chose to employ BMD measures at the 20 % and 80 % location, locations just inside of the proximal and distal segments (closer to midshaft) to increase the BMD of subadult element segments. Both the 20 % and 80 % locations were closer to the midshaft, where Galloway et al. (1997) reported the greatest BMD values. As mentioned previously, the 11.5–12.5 age interval also has the advantage of occurring about midway in the subadult group and is the most likely age to provide an estimation of subadult BMDs as a whole.

Suggestions for Future Research

Because the present and previous research employing BMD at the Crow Creek Site assessed only limb bones, the resulting paleodemographic age profiles have the potential for distortion. Future research should ascertain what the relationship is between BMD and element survival among skeletal elements other than limb bones. It is worth noting that the highest segment count for any long bone segment (right femur 1/6–1/4 segment count equals 360) is still a gross underestimation when compared to the MNI calculation attained from the right temporal bone ($n = 486$) (Willey, 1990, p. 14).

Another shortfall of the present research is the inability to assess the relationship between BMD and element representation among many age groups. It is possible that BMD decreases representation of elderly for similar reasons as subadults (e.g., Willey & Mann, 1986). Because there are so few elderly in a typical paleodemographic profile, it is likely that the impact of elderly underrepresentation has less impact on the paleodemographic profile than underrepresentation of subadults (Walker, Johnson, & Lambert, 1988). Future research should be undertaken to evaluate the relationship between BMD and increasing age in elderly samples.

Future work should also assess the effect of sex on the relationship between BMD and MNI. If the sex effect is real and BMD averages are greater in adult males than in adult females, females should tend to be underrepresented in skeletal series, impacting reconstruction of a paleodemographic profile. Because sex was not recorded by skeletal element at the Crow Creek Site, further analysis using a different sample of human remains should clarify the relationship between sex and BMD and how this relationship impacts the construction of a paleodemographic profile.

As this study has proposed, BMD represents only one of the many intrinsic variables that likely affect survival of elements and element segments. Other intrinsic variables, including element size, shape, and proximity to torso, should be assessed.

Finally, the effect of additional extrinsic variables, not evidenced at Crow Creek, might alter element and element portion survival at other sites. Other skeletal series with differing taphonomic processes should be analyzed to determine how broadly applicable Crow Creek element preservation and survivability are to those different conditions.

Summary

During the last several decades, many strides have been taken to increase precision and reliability within archaeological and forensic osteology. Some of these strides include the separation of commingled skeletal series and providing better estimations of the number of individuals in an assemblage. The history of commingled remains in the Middle Missouri River subregion provides just one example of that process.

The goal of the present study is to demonstrate that a relationship exists between BMD and element survival. Elements and element portions with greater densities are more likely to be preserved and represented in the skeletal series. Likewise, elements with lower densities are less likely to be preserved and have a lower likelihood of being represented in a skeletal series. This relationship holds true in both bioarchaeological and forensic anthropological settings. Viewed from a bioarchaeological perspective, the relationship between BMD and element survivorship impacts the paleodemographic age profile of a skeletal sample.

As this study has demonstrated, the paleodemographic profile of any skeletal series has the potential for bias when one ignores the relationship between BMD and element survival. Because adult skeletal elements have a higher BMD than subadult elements, the denser and larger elements have a greater likelihood of being represented. Therefore, skeletal series tend to be biased in favor of adult skeletal elements. When assessing limb bones, paleodemographic age profiles may distort subadults by underrepresentation, and BMD decreases in the elderly may have a similar impact on age profiles.

While this study provides a statistical analysis of the relationship between age, BMD, and element representation, it has not tested age- or sex-related effects on element survival. Future research should explore extrinsic and other intrinsic variables that may affect the survivability of skeletal elements and element portions.

Two themes of this volume are innovation and applicability, both of which have been demonstrated in the current research. This chapter highlights that MNI is a valuable and perhaps poorly understood concept in commingling issues, emphasizing element representation and BMD. Therefore, the authors have outlined the substantial impact that BMD has on MNI estimations and paleodemographic reconstructions involving commingled series. In reassessing the Crow Creek skeletal series' commingling 30 years after its reburial, the chapter attempts to breathe hope into dealing with other commingled series that remain available for study.

Acknowledgments Frank Bayham for discussion of MNI in zooarchaeology.

Alison Galloway and Lynn Snyder for access to the BMD values and Wenner-Gren Foundation for Anthropological Research funding (Grant No. 5251) for the original BMD research.

Nebraska State Historical Society for permission to reprint Fig. 2.

Judy Stolen of Chico Map Works produced the maps and bone segments.

Larry Bradley and Adrian Holtzer of the University of South Dakota's Archaeology Laboratory for Fig. 3.

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Extreme Processing at Mancos and Sacred Ridge: The Value of Comparative Studies

Anna J. Osterholtz

Introduction

Assemblages exhibiting extreme processing (Kuckelman, Lightfoot, & Martin, 2000) have been identified in San Juan region and typically date to the PII or PIII periods (ca. AD 900–1200). The Mancos assemblage was invaluable for quantifying the kinds of extreme processing described by Kuckelman et al. (2000) and provides the first truly detailed analysis of an assemblage of this type. The degree of variability in the extent of processing and the methods by which that processing occurred are rarely the focus of study by bioarchaeologists. Some have relied on a presence/absence model for the identification of tool marks, and so the fine details of the location and muscle groups affected by the processing have been lost. The Sacred Ridge site (PI) located in Durango, Colorado, exhibits many of the bone changes associated with extreme processing; a detailed comparison of this collection with the findings from Mancos, Colorado, is presented here.

In order to illustrate the value of a comparative method for disarticulated assemblages, an element-by-element comparison of two commingled and fragmentary assemblages, Mancos and Sacred Ridge, both of which have been identified as showing extreme processing, is provided. Though both are located in the Mesa Verde region, there are significant differences between the two sites. Sacred Ridge (5LP245) is a large PI site (available radiocarbon dates pinpoint occupation between approximately AD 700 and shortly after AD 800), one of the 34 sites within the Ridges Basin area. The Sacred Ridge site is located on a natural bluff and would have allowed for unobstructed sightlines within the basin. During the latter portion of occupation, one cluster of pit structures expanded to include oversized pit

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_7,

structures. Potter and Chuipka (2010, p. 512) identify this as an area containing possible "communal ritual facilities for a population that extended beyond the immediate site occupants." Potter and Chuipka (2007, 2010) argue, in essence, that the area served as an early pilgrimage center for the surrounding area as supported by evidence of feasting activities at the site (Potter, 2000).

Mancos (5MTUMR-2346) is a late PII/early PIII site dating to the with the skeletal deposits dated using ceramic chronology to around AD 1150 (Nordby, 1974). At the time when this assemblage was uncovered (early 1970s), Turner and Morris (1970) had recently published their analysis of bones they attributed to a massacre, and so the prevailing opinion about assemblages showing processed remains leant towards cannibalistic or other violent explanations. In his analysis of the Mancos assemblage, Nickens (1974) essentially uses a checklist approach, finding that the presence of patterned fracturing (presumably for marrow extraction), dismemberment, and burning may be indicative of cannibalism; he does provide a cautionary note that these indicators provide no conclusive evidence for consumption of flesh and calls for more extensive research. White's (1992) analysis of the Mancos assemblage marks the first truly systematic element-by-element analysis of a processed assemblage in the southwest.

The skeletal assemblage from Sacred Ridge was analyzed over a 3-year period. Analysis used similar protocols to White's (1992) analysis of Mancos with an additional zonal approach adapted from faunal analysis (Knüsel & Outram, 2004; Outram, 2001). Fragments were first identified and sorted by element and demographic identifiers (e.g., age and sex where possible). An extensive refitting exercise was then performed so that the basis of the taphonomic analysis could be the refitted elements (Osterholtz & Stodder, 2010; Stodder & Osterholtz, 2010). Overall, approximately 35 % of the fragments were refitted into conjoins allowing an examination of tool marks and fracture patterns extending over multiple fragments. This proved particularly useful in the identification of foot trauma consistent with hobbling and torture (Osterholtz, 2012, 2013). Without the associated elements, these activities would have been impossible to infer.

Analysis of assemblages exhibiting extreme processing has become something of a lightning rod in Southwest bioarchaeology since it has been argued by multiple sources that these assemblages are solely the result of cannibalistic activity (e.g., Flinn, Turner, & Brew, 1976; Somers, 1920; Turner & Turner, 1999). Turner and Turner (1999), specifically, promoted a checklist approach that simplifies the identification of taphonomic indicators and may underestimate synergistic cultural effects. Essentially, they do not take into account that multiple actions can lead to similar assemblages. It is detailed analyses such as White's (1992) interpretation of Mancos and Stodder, Osterholtz, Mowrer, and Chuipka's (2010) analysis of Sacred Ridge that can help to identify specific actions that create an assemblage as viewed by the archaeologists. Where Turner and others have simply noted the presence of tool marks on bone, the location and appearance of those tool marks may help to identify whether they were more likely the result of defleshing, the removal of desiccated soft tissue as part of a secondary processing activity, or due to perimortem injury (Pérez, 2006, 2012; Raemsch, 1993).

What these assemblages *mean* (i.e., cannibalism vs. witchcraft vs. political massacre) is open to debate, but it is only through detailed analyses that we can begin to unravel how they were created. Understanding how an assemblage is formed is the first step towards revealing the cultural construct in which it is created (Stodder et al., 2010). In many ways, assemblages such as Mancos and Sacred Ridge need to be examined synergistically. The checklist approach where an assemblage is interpreted as cannibalistic or not based on traits present (e.g., Flinn et al., 1976; Melbye & Fairgrieve, 1994; Turner & Turner, 1992, 1999) does not capture the totality of the picture. This approach does not take into account environmental change (Billman, Lambert, & Leonard, 2000), cultural change and social stresses (e.g., Friesen, 1999), or other factors. Analyzing this debate from a technical writing perspective, Youngblood (2012) notes that those who interpret extreme processing as cannibalism are dependent upon explanations drawn from physical examination of the remains, while those who interpret it as something other than cannibalism are more dependent on ethnographic analogy. She cautions, however, that both arguments have "…an element of circularity, using interpretations of data (archaeologically or ethnographically based) to define cannibalism, and then applying the defining characteristics of cannibalism or other explanations—punishment of witches, massacres, etc.—to sets of data, thereby 'confirming' the interpretation of these data" (p. 119). Essentially, according to Youngblood, both sides are creating circular arguments that have no chance of failure in their minds and no chance of success in the minds of their ideological opponents. In actuality, Youngblood's critique may also be too harsh. Ethnographic accounts and oral traditions (including traditions involving cannibalism) can provide alternative hypotheses that data can either support or help to reject. Hers is one criticism of the argument as a whole and should be viewed as a cautionary tale for us in the formulation of models within archaeology.

Cranial Modification

Comparisons of modification are presented by region. Galloway (1999) notes that fracturing of the cranium is very complex and dependent upon the location of blows, the distribution of force within and between cranial buttresses, and other factors (such as age and bony morphology).

White interpreted the fracturing of the face as secondary to the goal of separating the face from the rest of the cranium in the Mancos assemblage. While this appears to have occurred at Sacred Ridge as well, the Sacred Ridge assemblage appears to be more complex and be the result of perimortem processing (as at Mancos) and the result of interpersonal violence (based on the presence of numerous tripod, zygomatic, and Le Fort fractures). While these fractures may occur as part of the processing, they are typically associated with interpersonal violence (Galloway, 1999) and may reflect different aims of the massacre at Sacred Ridge. A detailed element-by-element comparison is given in Tables 1, 2, 3, and 4.

Table 1 Comparison of Frontal Bones

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	17 (5 <12 years)	32 (4 <12 years; 24 >12 years; 4 of undetermined age)
Survival	3 Left and 6 Right zygomatic processes	9 Left and 17 Right zygomatic processes (ratio similar to Mancos)
Fracturing	Lateral blows to the zygomatic led to fractures of that area (most likely part of the removal of the face)	Some of the same fracture patterning as Mancos, but the Sacred Ridge frontals were more processed. Supraorbital fractures were common (at least unilaterally)
	Percussion at bregma evidenced by conchoidal scars, adhering flakes, or vault release. No percussion on endocranial surface	Percussive marks to the forehead (vertical portion) on either the right or left side also present. In general, the Sacred Ridge frontals were less complete than the Mancos frontals
Tool marks	Parasagittal cut marks [skinning marks, according to Villa et al. (1986)], circumferential cut marks (scalping). Also, "Many frontal pieces show abrasion on the ectocranial surface related to the movement of a hammerstone or anvil across the bone during percussion" (172)	Parasagittal cut marks, circumferential cut marks and scrape marks on forehead, and scrape marks on zygomatic processes
Burning	Burning was focused on the zygomatic process and frontal bosses (most projecting areas of the bone)	Burning present on both zygomatic processes and bosses, with more occurring on the right side (in general)

Table 2 Comparison of Zygomatics

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	12 (5 <12 years)	MNI not calculated based on this element
Fracturing	Fractures visible produce by a lateral blow at the maximum projection of the zygomatic arch, resulting in a hairline fracture near jugale. Temporal process of zygomatic was usually missing	Extensive fracturing. Most temporal processes were missing. Both tripod and zygomatic fractures present, indicating blows originating both anteriorly and laterally. Peeling and crushing visible
Tool marks	Most had no evidence of tool marks. One had abrasion inferolateral to orbital rim, one had slicing cut marks	Scrape marks and cut marks were common frontal processes and inferolateral to orbit
Burning	There was ample evidence of burning. Generally, burning consistent with attached element (e.g., heavily burned maxillae will have heavily burned zygomatics)	Ample evidence of burning, pattern consistent with Mancos

Table 3 Comparison of Maxillae

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	21 (9 < 12 years)	MNI not calculated based on this element
Survival	Full range of preservation, from intact element to very small, eroded alveolar sections. No consistent patterns	Usually attached to a zygomatic, but this element was generally not present
Fracturing	Loss of zygomatic process was common. Frontal process was usually broken. There was no obvious pattern of percussion. "Most of the fractures seem incidental to the removal of the face from the cranial vault." Possible "forced dislocation" of teeth	Fractures to the zygomatic process (Le Fort fractures), frontal process, and ablation fractures of the dentition were very common
Tool marks	Cut marks were rare on maxillae; one showed cut marks on the anteroinferior root of the zygomatic process. A single hack mark was visible on the canine jugum near the base of the nasal aperture	Cut marks also rarely visible. Cut marks present near zygomaticomaxillary suture and on inferior surface of the zygomatic process. A single group of cut marks present on the side of the nasal aperture of one fragment consistent with nose removal
Burning	Full range of expression. Burning was most intense on the frontal and zygomatic processes and on the alveolar bone over the incisors and canines	Highly variable. Where both right and left sides were present, there was usually more severe burning on the right side

Table 4 Comparison of Mandibles

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	23	31
Survival	Mandible and mandibular dentition represented the most complete element in the assemblage, including five relatively complete mandibles	There was no significant difference in survival between the mandible and other cranial elements
Fracturing	Crushing from anterior applied compression of the alveolar edges by a hammer or anvil. Some peeling of adjacent alveolar bone was present. Neck of condyle presented significant peeling	Arcing fractures extending from the sides of the mental eminence, avulsion fractures of the coronoid, some condylar fractures, ablation fractures of the dentition
Tool marks	Few tool marks present. Slight abrasion on the corpus at the root of the ramus on three fragments. Another had short slicing marks in that area as well	Cut marks consistent removal of buccinators, masseter, platysma, and lip musculature. Tool marks present on inferior surface of the body (both cut and scrape marks)
Burning	The thinnest and most projecting portion of the mandible lacked significant burning damage. Burning was common on the gonial angle, base, or base and lateral corpus. Heavily exfoliated in many areas. Pattern suggests the molar and coronoid regions were protected from burning by overlying musculature	Roughly matched the pattern described by White, but patterning was difficult to determine. Burning seemed to be concentrated on the gonial angle and body

Table 5 Comparison of Parietals

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	11 (4 < 12 years)	MNI not calculated based on this element due to the degree of fragmentation
Survival	The more intact pieces were invariably attached to the portions of other parietals, temporals, and/or frontal bones	Extensive fragmentation; there were no completely elements
Fracturing	Percussion damage characterized by conchoidal impact fractures, endocranial vault release and peeling, adhering flakes, percussion striae, and hammerstone pits in outer table	Consistent with forensic accounts of blunt force trauma. Where conjoined, fragmentation tended to be more severe on one side (as compared to the other side) with more adhering flakes, vault release, and conchoidal scarring on the fragment edges
Tool marks	Immature fragments had no identified cut marks. Paracoronal cut marks near bregma occurred in more than half of the individuals. There was a parasagittal cut marks on one. Posterior portion had cut marks parallel to the lambdoidal suture. Some striae were consistent with the removal of the temporalis muscle	There were paracoronal cut marks and scrape marks, parasagittal scrape marks near sagittal suture, anterior-posterior oriented cut and scrape marks elsewhere (possible removal of the aponeuroses and temporalis muscle). Medioalterally oriented cut and scrape marks were present on the squama, some parallel to the lambdoidal suture
Burning	Exfoliation of the outer table is common, as was browning. A clear pattern of burning relative to the temporalis muscle cover on the parietal is seen in the assemblage… the burning extends to the temporal line where it ceases… This is strong evidence that the adhering temporalis muscle protected the underlying vault during burning of the head (p. 177). Only one fragment indicated burning after fracture (endocranial burning). Majority of isolated parietal pieces with evidence of burning showed only ectocranial involvement	Exfoliation of the outer table is common. Pattern on temporalis muscle was seen in many cases, but not all, and not as commonly as in the Mancos remains. There was burning down to the squamosal suture. Burning tended to be more extensive on one side or the other (mostly on the right side, but some had left-side concentrations). Differential (refitting of fragments with different degrees of burning) and uniform burning in Sacred Ridge remains indicates burning both before and after fracturing

The vault and basicranium were considered together (Tables 5, 6, and 7). Blunt force trauma is the primary mechanism resulting in fragmentation of the vault and basicranium. The Sacred Ridge assemblage tended to be more fragmented than Mancos and showed significant differential burning, a pattern not described in the Mancos assemblage. Differential burning is the pattern in which fragments showing vastly different degrees of burning refitted together in a conjoin (a unit consisting of two or more fragments found to refit). One example would be a parietal with fragments showing no burning, complete calcination, and charring refitting into a single

Table 6 Comparison of Occipitals

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	16 (4 < 12 years)	27
Fracturing	Five of seven condyles displayed crushing fractures. There was peeling on both tables adjacent to the transverse breakage at the posterior border of the foramen magnum. Based on photographic comparisons, matches pattern visible at Sacred Ridge	Fractures to the base of the skull (including peeling and vault release) is consistent with a mode of execution consisting of a sharp blow by a blunt object (e.g. a bat, branch, etc.) to the base of the skull with the victim kneeling, head down on the chest (Kimmerle & Baraybar, 2008)
Tool marks	Transverse cut marks were present on the squama, both superior and inferior to the superior nuchal line. There were no endocranial cut marks	Pattern consistent with Mancos
Burning	No burning on the basilar portions that were present, but most of the occipitals with a portion of the squama exhibited some form of burning. There is a clear demarcation on the superior nuchal line between burned and unburned bone (soft tissue protection during burning)	Pattern generally consistent with Mancos, except for the lack of burning on the superior nuchal line. Burning patterns (on cranium in general) indicated that although some burning occurred while some soft tissue was present, this was not always the case. Some burning occurred after the removal of at least some soft tissue

Table 7 Comparison of Temporals

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	17	12
Survival	Mostly petrous portions, usually with some attached squama. All zygomatic processes were broken, most with abrasions at the base. Only two intact mastoid processes showed some trauma	Mostly petrous portions, very few with squamae. All zygomatic processes broken. Most mastoid processes exhibit crushing
Fracturing	Evidence of crushing in six of 27 mastoid processes, and some evidence of percussion to the present squamae. Sutural release inferred for the squamosal suture	Evidence of crushing on squamosal edges, and evidence of conchoidal scarring. Sutural release inferred for the squamosal suture
Tool marks	"Nicks" in the root of the zygomatic processes. "These marks may indicate ear removal because cutting strokes associated with such a practice would have been parallel to the side of the head, and the most laterally projecting bone surface likely to have contacted the blade in this region would have been the zygomatic process." (pp. 185–186). No cut marks on mastoid processes of subadults	Similar cut marks to those described by White in association with ear removal. Transverse cut marks visible on one mastoid process consistent with severing the sternocleidomastoid muscle
Burning	Burning on mastoid processes was almost ubiquitous (16 of 18 adults)	Some burning was present, but not on all or even most. The squamae show some burning at fracture edges, occasional in association with crushing and adhering flakes

Fig. 1 Sacred Ridge conjoin exhibiting differential burning

conjoin (Fig. 1). This pattern is used to reconstruct events involving burning. As seen in Fig. 1, such a pattern of differential burning indicates that the burning occurred after fragmentation. Differential burning with significant variation may also indicate site clearing activities, with cleaning of hearths adding more burned fragments to the less burned assemblage.

Table 8 Comparison of Clavicles

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	18 (8 >12 years)	11 (1 b-2y, 8 >12 years, 2 <18 years)
Fracturing	Crushing visible on the superior aspect of acromial end. Spiral fracture at midshaft. "The single fully conjoined piece shows a breakage pattern that suggests fracture by a simple forceful, 2-handed bending of the bone (p. 230)"	Similar fracture patterning to Mancos. Transverse fracturing at midshaft and spiral fractures present on many elements
Tool marks	Most had cut marks in one (or more) of three patterns: 1. Superior surface, marks with posterolateral to anteromedial orientation ("a sawing motion of the tool across the bone", p. 230) 2. Superior surface, hacking marks set off approximately 2 cm from the sternal end 3. Vertical slices on the anterior surface of the bone	Most common were anteriorly placed cut and scrape marks, possibly related to removal of the clavicular and pectoralis major muscle
Burning	Only two pieces were definitely burned, on the dorsal and lateral shaft regions	No distinct pattern, though burning is present

Table 9 Comparison of Scapulae

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	12	11
Survival	Some bodies were relatively complete, damage to acromion was common (based on photographs)	Not a single body was complete. Fracturing of the spinous base of the acromion was more common in the Sacred Ridge remains. More glenoid fossae fragments present than at Mancos
Fracturing	"One adult piece shows that the spinous base of the acromion was broken away, crushed inferiorly, and peeled off anterosuperiorly." (p. 233)	Fracturing at the base of acromion (with peeling in the supraspinous fossa) indicates fracturing via pulling down (inferiorly) on the acromion, causing buckling and peeling in the supraspinous fossa
Burning	No consistent patterning	No consistent patterning

The Shoulder

The shoulder was examined as a functional anatomical unit. Fractures of this joint tend to occur in constellations as the elements are tightly bounded by soft tissue. Trauma to the shoulder is also often linked to injuries of the spine and arm. Given the high degree of fragmentation at Sacred Ridge, it was not possible to conjoin a partial or complete shoulder joint, so fracture constellations cannot be described holistically. Possible causal actions and interactions between elements are presented in Tables 8 and 9, however.

The different MNIs for the clavicles and scapulae are of interest in comparing the two assemblages. The Mancos remains had an MNI of 18 for the clavicles and 12 for the scapulae. Sacred Ridge had an MNI of 11 for either element, suggesting the shoulder may have been processed as a unit at Sacred Ridge but treated differently at Mancos. The MNI of the proximal humerus is only 6, suggesting this element was removed from the body prior to the processing. Differences in processing between the two assemblages are also observed among the scapulae. Fracture patterns are different at the two sites, with Mancos remains retaining more of the scapular body.

The Upper Limb

The upper limb consists of the humerus, the radius, and the ulna. At Sacred Ridge, processing appears to have occurred as a unit, with consistent MNIs between the elements. The elbow region is better represented than either the proximal humerus or distal radius or ulna.

The method of processing the upper limb at Mancos appears to be qualitatively different from that observed at Sacred Ridge. This inference is based on the different MNIs of elements and their proportions when compared to the cranial MNI. The MNIs reflect differences in element survival, and, given the overall excellent preservation of bone at both sites, survival must have been influenced by processing and/or discard behaviors. Essentially this assumes that more processing will lead to a lower survival rate of the elements and therefore a lower MNI derived from that element. To examine the relative representation of the upper limb in comparison to the cranium for both sites, ratios were computed for the MNI derived from the cranium and the MNI of the element in question (e.g., the radius) (Table 10). A ratio of less than 1 indicates the MNI of the upper limb element is greater than the cranium; a ratio greater than 1 indicates better preservation of the cranium relative to the upper limb. The cranial MNI for the Mancos assemblage is 23 (based on the mandible); the cranial MNI for Sacred Ridge is 33 (based on glabella). Ratios are used to remove the overall size effect and show more qualitative effects of the survival of these elements. Overall, ratios show an underrepresentation of the arm when compared to the cranium. The ratios of the cranium to humerus are very different with relatively fewer humeri recovered at Sacred Ridge (note that this MNI is based on the distal humerus, however, so the proximal humerus is significantly underrepresented). The representation of the forearm (compared to the cranium) at Sacred Ridge is even more disproportionate.

Two differences are apparent in the preservation of humeri at Mancos and Sacred Ridge (Table 11). In the Mancos assemblage, humeral shafts from individuals less

Table 10 Ratios of MNI between Mancos and Sacred Ridge for the Upper Limb

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
Cranium: Humerus	1.35	3.00
Cranium: Radius	1.76	4.71
Cranium: Ulna	1.64	4.12
Humerus: Radius	1.31	1.57
Humerus: Ulna	1.21	1.38

Table 11 Comparison of Humerii

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	17	11
Juvenile Representation	9 subadults, 4 with intact shafts. Essentially individuals older than 6 years of age were processed similarly to adults	No apparent difference in the treatment of adult and subadult remains, but the subadult MNI is only 1
Shaft fracture	Shaft fractures via: 1. Hammerstone percussion (evidenced by conchoidal scars and adhering flakes) 2. "over-anvil" breakage (p. 238) involving bending the bone on top or on the side of an anvil until it broke in a transverse, perpendicular, snap-break fracture	Consistent with Mancos, including both types of fracture (recorded as transverse fractures)
Distal shaft/ Distal end fracture	Crushing on anterior or posterior surfaces of distal shafts; interpreted as caused by the same percussive blows that produced the shaft fractures	Pattern consistent with Mancos
Shaft tool marks	Abrasion and transverse striae on shaft fragments	Tightly clustered groups of transversely oriented cut and/or scrape marks on all aspects near midshaft, usually in association with a fracture
Distal tool marks	Transverse tool marks always on anterior surface of distal shaft. "They are related to tool edge contact with the high points of the distal shaft that lie below flexor tendons crossing the elbow joint they are obviously disarticulation marks" (p. 241). Ten of the 15 moderately intact pieces exhibited these marks. One fragment also had similar marks on the posterior surface	Longitudinal marks on the posterior surface extended from distal shaft to the olecranon fossa. Transverse cut marks were not ubiquitous and appeared on both posterior and anterior surfaces
Polish	One showed polish on the broken distal end	At least two fragments with possible polish at midshaft breaks
Burning	All burned fragments were either shaft or shaft/distal end fragments. Burning occurred prior to b one breakage. "Differential burning along the shaft is probably related to the degree of soft tissue cover at the time of heating." (p. 242)	Little burning was present, usually at fracture edges or light browning at the distal end. No conjoins were made with differential burning, suggesting burning prior to breakage for this region

than 5 years of age were typically complete, suggesting that breaking these bones was not part of the patterned processing of the assemblage. There were no complete humerus shafts from individuals of any age or sex in the Sacred Ridge assemblage. Differences clearly exist between the two assemblages, but these may be the result of differential discard practices and/or preservation. The second difference is in the

Table 12 Comparison of Radii

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	13	7
Survival	Three adolescents and four juveniles fairly intact. "The correlation of shaft destruction with individual age operates as for the humerus, but radius pieces of individuals younger than 12 mostly intact; pieces of older individuals broken in midshaft region"	Only one individual with an unfused radial head was complete enough to have been identified. This radius (a right) had one percussion pit in association with a simple transverse fracture
Distal ends	Four adult distal ends retained articular surface, and seven showed only a ragged broken edge at the distal end	Only five fragments had partial distal epiphyses. Most had sawtooth- or V-shaped fracture edges at the proximal portion of the metaphysis. Of the fragments with a portion of the distal articular surface, none had a complete styloid process
Tool marks	Two pieces showed abrasion associated with hammerstone pits at midshaft. Only three showed obvious slicing cut marks. Cut marks occurred on the distal dorsal radius (presumably associated with severing extensor tendons), the anterior surface of the shaft, and the posteromedial corner of the radial tuberosity	In general, there were few tool marks. Percussion marks were present. All cut marks were transverse or obliquely oriented (consistent with Mancos). RAD-009 had cut marks at roughly midshaft on lateral, posterior, and anterior surfaces, whereas 2343.2097.1 (a loose fragment) had a set of obliquely-oriented cut marks on the anterior distal shaft, and 2362.155.1 (another loose fragment) had transverse cut marks and one oblique chop mark on the posterior and lateral surfaces at the distal shaft
Burning	Approximately half of the maximally conjoined pieces showed evidence of burning focused on the distal end	Burning was rare, centered on the proximal and distal edges of the fragments/conjoins

patterning of tool marks. The humeri from Mancos exhibited transverse tool marks on the anterior aspect of the distal shaft, consistent in location with the flexor tendon insertions. This pattern was not present on the Sacred Ridge humeri, which exhibited tool marks consistent with severing attachments for the triceps or possibly the extensors.

The forearm bones show different patterns in tool mark location as well (Tables 12 and 13). Despite the lower MNI at Sacred Ridge, the radii exhibit more tool marks than those at Mancos. The focus of burning is also different for this element, with more burning evident at Mancos, suggesting different processing methods—and possibly different motivations for the processing in general. White only describes "slicing marks" on three ulnae, while the Sacred Ridge assemblage exhibits both longitudinal and transverse cut marks on the bony shafts.

Table 13 Comparison of Ulnae

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	14	8
Juvenile fracture pattern	In younger individuals, articular surfaces and epiphyseal surfaces were usually lot but the crushing of the ends results in a set of longitudinal splinters atop an intact shaft (evidence of crushing or "mashing" p. 243)	Two individuals younger than 16 years had coronoid fractures but no crushing. No ulnar fragments from younger individuals were identified
Adult fracture pattern	Broken shafts, heads either intact or entirely missing	Shaft fractures, mostly intact heads, one missing entirely. Consistent with Mancos patterning
Distal Survival	Eight adult distal ends	Two with partial distal epiphyses (none complete)
Juvenile tool marks	Nearly complete lack of cut marks on immature pieces	Of the two subadult/older child ulnae, one had evidence of percussive damage to the dorsal surface on the distal 1/3 of the shaft and an incomplete bending fracture
Adult tool marks	Of the 11 conjoins with tool marks, five were associated with shaft breakage (percussion striae) and three had slicing marks. One hack mark was present on the distal interosseous crest	Transvers and longitudinal cut marks were present on anterior and posterior surface, percussive pitting on anterior. Longitudinal cut marks extended along the middle shaft, transverse were clustered at the proximal end of the shaft or the distal end of the fragment conjoin (distal 1/3 of shaft)
Burning	Of 37 conjoins, 15 were unburned, 8 showed certain burning, others were uncertain. In 4 of the 8 definitely burned pieces, burning was most intense along the posterior surface of the shaft or the posterior surface of the olecranon	Light areas of browning were present on many fragments, and dark browning occurred on a few. One coronoid process was completely charred, with areas of calcined bone

Vertebrae

The vertebrae serve as an anchor point for musculature for the shoulder, thorax, and hip. As part of processing at both sites, vertebrae were essentially destroyed, leaving little to observe for perimortem trauma or processing. Differences do exist between the two assemblages, however (Table 14). Although the prevalence of tool marks in the lower cervical, thoracic, and lumbar vertebrae was lower than other components of the Sacred Ridge assemblage, fewer occurrences were noted in the Mancos assemblage. Sacred Ridge also has higher rates of tool marks than other processed assemblages as well. Processing of the vertebrae has been noted for other assemblages in the southwest exhibiting processing. Cut marks were recorded on the two thoracic vertebrae from Cowboy Wash (Lambert, 1999, p. 150). Burning and

Table 14 Comparison of Vertebral Elements

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
C1		
MNI	10 (2 < 12 years, 10 adults)	10 (1 infant, 9 > 12 years)
Fracturing	All superior articular facets of adults exhibit damage to edges of the articular surface. All transverse processes show some damage	Fracturing variable. One was complete, but several had fractures on both anterior and posterior arches. Consistent with Mancos, many (not all) superior articular facets had crushing to the edges of the articular surfaces
Tool marks	No cut marks, but abrasion present in association with percussion fracturing	Four with chop marks visible on the margins of the articular surfaces
Burning	No unequivocal burning	One fragment completely charred, with small areas of calcined bone
C2		
MNI	6 (1 < 12 years, 5 > 12 years)	14 (4 subadults, 10 > 12 years)
Fracturing	Posterior arch fractures	Lateral mass fractures, posterior arch fractures, spinous process fractures
Tool marks	No visible tool marks	Cut marks present on the inferior surface of transverse processes and body (both near articular surfaces)
Cervical 3-7		
MNI	5 (2 < 12 years, 3 > 12 years)	14 (6 < 12 years, 7 > 12 years, 1 undetermined)
Survival	One subadult and one adult had complete bodies; even these had peripheral damage	The only complete bodies were subadult
Fracturing	Vertebral foramina usually incomplete. Fracturing to the anterior body, though some bodies were complete. Based on photos, spinous processes had some fracturing, but some were complete	Fracturing of bodies. There were only two vertebrae with intact spinous processes (both subadult)
Burning	Browning, discoloration, and erosion in some pieces is suggestive of burning	Burning light and uniform, clustered on posterior and lateral aspects
Thoracic vertebrae		
Survival	Very fragmentary. The general pattern was the loss of the transverse processes and destruction of the body	Pattern consistent with Mancos
Fracturing	Some crushing to superior articular facets, and spinous process fractures. Transverse processes probably broken as part of rib slab removal (p. 214)	Pattern consistent with Mancos
Tool marks	One fragment had percussion-related abrasion. No transverse processes or bodies to examine for tool marks	One fragment had a single cut mark on the stub of the transverse process. Same fragment showed two chop marks. One other fragment had a single set of scrape marks
Burning	No discernible pattern	No discernible pattern
Lumbar vertebrae		
Survival	Very fragmentary. The general pattern was the loss of the transverse processes and destruction of the body	Pattern consistent with Mancos
Tool marks	Unilateral cut marks present on the posterior surface between superior and articular facets on one fragment. Two transverse chop marks present on one fragment	One group of transverse cut marks present on one fragment, another fragment had two chop marks; another had a transverse set of scrape marks.

gnawing were present on vertebral fragments from the kiva assemblage at Towaoc Canal Reach III5MT10207, but there were no tool marks (Dice, 1993, p. 27). The presence of more tool marks at Sacred Ridge could be a function of a higher fragment count or larger MNI, but this could also indicate different methods of processing at the site.

Pelvis

The pelvis appears to have been processed differently at the two sites (Table 15). First, the MNI at Sacred Ridge is higher than that at Mancos. While both assemblages exhibit pitting and tool marks on the arcuate line of the ilium, the Sacred Ridge assemblage has substantially more tool marks on the internal surface of the ilium (a pattern postulated to be indicative of disembowelment). The lack of tool marks on the internal surface of the ilium at Mancos suggests that disembowelment

Table 15 Comparison of the Pelvic Girdle

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	11 (5 <18 years)	15 (4 <12 years, 10 >12 years, 1 undetermined)
Fracturing/ Fragmentation	1 adult has percussive pitting on the arcuate line anterior to the apex of the auricular surface. Another adult has adhering flakes. Peeling on the lateral surface opposite the auricular surface. "…the general impression is one of percussion-induced fracture focused on the trabecular bone tissues of the os coxae" p. 219	All acetabula (where fused) were fractured (all but 2 are complete fractures). All pubic rami are fractured. Most have fracture through ischial tuberosity. Ilia alar fractures are also ubiquitous. Some avulsion fractures of the inferior anterior iliac spine. Percussive pitting visible on multiple surfaces, crushing also common on alar surfaces (internal and external). Fracture patterning seems qualitatively different, especially fractures to the pubic rami (both superior and inferior)
Tool marks	One vertical cut mark on the internal surface of the iliac fossa. Four fragments have cut marks around the acetabulum. One fragment has several cut marks in groove between the acetabulum and ischium. Circumacetabular cut marks present	Lots of cut marks on arcuate line near GSN and auricular surface. Horizontal and vertical cut- and scrape-marks in iliac fossa (both internal and external surfaces). No identified circumacetabular cut marks
Burning	Exfoliation of internal and external surfaces. "…the pattern… is one where the projecting parts (crest, spines, pubes) are lost from crushing and or burning" p. 221	No definite patterning to the burning, though burning is definitely present. Projecting parts don't seem any more likely to be burned than non-projecting parts

was not part of that mortuary program. Processing differences extend to dismemberment strategy, with the hip capsule severed on the os coxa (as evidenced by circumacetabular tool marks) at Mancos and at the femur at Sacred Ridge (as evidenced by circumferential cut marks on the femoral necks). Essentially the same goal was present during both episodes of processing (i.e., the removal of the femur from the pelvis), but the methods implemented to accomplish it were different. Another difference is that there is a distinct burning pattern visible on the Mancos remains, with more projecting parts tending to be more burned than those that don't. At Sacred Ridge, no such pattern exists.

The Lower Limb

For all the lower limb bones (excluding the foot bones, which are discussed in the Extremities section), the main differences between the Mancos and Sacred Ridge assemblages involve the survival of the proximal and distal ends and the burning and tool mark distribution of the patella (Tables 16, 17, 18, and 19). For the long bones, the assemblage at Sacred Ridge has a higher survival rate for the proximal and distal ends of the elements. Fracture patterns are also different, with White describing few shaft fractures but more fragmentation of the ends; Sacred Ridge exhibits more shaft fractures with V-shaped edges, indicating perimortem fracturing. White (1992) also found a greater number of subadult remains.

As noted for the pelvis, dismemberment of the hip appears to have occurred differently at both sites, with the severing of the synovial capsule occurring on the femur at Sacred Ridge and around the acetabulum of the os coxae at Mancos. Therefore, cut mark distribution varies for the two assemblages. The Mancos femur assemblage also had more percussion pitting: in general it appears that there was a substantial use of blunt force used in creating the Mancos assemblage. This is contrasted with more precise disarticulation and removal of flesh preparatory to intentional fragmentation and burning visible in the Sacred Ridge assemblage.

Tibia midshafts were the most commonly burned part of the tibiae at Mancos (White, 1992, p. 261). In the Sacred Ridge assemblage, this area of the tibia was not burned more than any other part of the bone or the other long bones. Browning was observed on the anterior crest in numerous fragments, but there is no consistent pattern. Overall, the condition of the tibiae from the two assemblages was similar. Less intense thermal alteration indicates that this took place while some of the muscle tissue was intact. Chop marks to the anterior crests were present in both assemblages; this location is inconsistent with the removal of connective or muscle tissue, suggesting they were inflicted during violent assault or as part of intentional bone fragmentation (Table 18).

Although tibia processing is consistent for the two assemblages, the fibulae exhibited marked differences (Table 19). The largest difference was the presence and location of tool marks: the Sacred Ridge assemblage had tight clusters of tool marks located at soft tissue insertion sites. These were lacking in the Mancos assemblage.

Table 16 Comparison of Femora

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	20	14
Juvenile Fragmentation	Intact femur shafts for immature individuals. Survival of immature specimens is greater than adult specimens	Very few subadult remains identified, none were whole. Survival of subadult remains is far less than adult remains. Reconstructed femoral shafts outnumbered identified fragments
Survival	"Overall survival of the femur is poor. The femoral shaft is over-represented relative to the ends, but the shaft is universally fragmented." p. 250	Pattern consistent with Mancos
Adult Fragmentation	Complete shaft tubes rare, almost all are splinters	Pattern consistent with Mancos
General processing	"It is clear that the proximal and distal femoral ends from individuals older than 6 years were crushed and the shafts broken open by percussion. This resulted in a collection of fragments that is heavily conjoined, but poorly identifiable in the loose state." p. 253	More heads and necks, with four left heads and seven fragments containing at least a portion of the neck (left side), and seven partial right heads and necks. More complete distal articular surfaces. At least three left and two right have partial articular surfaces; fragment 2343.17.1 is the most complete with damage to the epicondyles but a mostly intact articular surface
Tool marks	Few slicing marks on anterior and posterior shaft (potential dismemberment marks would be in areas not well preserved, i.e. proximal and distal ends). Lots of percussion marks "several pieces show intense, heavy battering and hacking perpendicular to the linea aspera." p. 254	Lots of circumferential cut marks around necks (classic dismemberment marks). Also common are transverse cut marks in the subtrochanteric region, probably also due to cutting muscle attachment sites. Not nearly as many percussion marks as illustrated in White (1992)
Burning	Burning after shaft fragmentation. No clear pattern of burning on femur	Differential burning is visible. Burning while soft tissue still attached as visible edge where muscle tissue retracted during burning

White argues that the fibulae were removed through a wrenching action, pulling the bone away from the rest of the leg. The tool marks on the Sacred Ridge fibulae indicate the bone was cut free of soft tissue before removal. Fracturing was different as well, with more midshaft fractures in the Sacred Ridge assemblage. White reported few shaft fractures of this bone, but they were common at Sacred Ridge, usually with V-shaped edges. This type of fracture can be an outcome of a direct blow where no weight is being placed on the bone (Galloway, 1999). In other words, the bones were intentionally broken either before removing it from the rest of the leg or afterward.

Table 17 Comparison of Patellae

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	7	6
Fracture	One transverse fracture. The youngest individual has a puncture on the articular surface. Some crushing on articular surface	Transverse fractures are present in a few individuals. Some crushing on both anterior and posterior surfaces
Tool marks	No tool marks except percussion striae	Tool marks present on both anterior and posterior surfaces in the form of cut marks. All are transverse in orientation
Burning	One possible burned element	One has charring along the inter-articular ridge on articular surface. Little other thermal alteration except for light browning

Table 18 Comparison of Tibiae

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	18	11
Ends	"…overall pattern of nonsurvival of proximal and distal ends and splintering of the shaft is similar to that characterizing the femur." p. 259. Only one distal articular surface	In general follows the same pattern as Mancos. At least five elements have the tibial tuberosity, though
Tool marks	"…the paucity of proximal and distal tibial ends coupled with extreme shaft fragmentation makes interpretive, quantitative, and functional work on tool marks very difficult… These marks, particularly in the adults, are 'hacking' marks…, a few slicing marks, and an abundance of anvil-hammer-related abrasion patches" p. 261	Chop marks on the anterior crest, slicing at muscle attachment sites, etc. The lack of concentrations of tool marks on the lateral surface suggests processing of the lower leg occurred as a unit (with the fibula in articulation)
Burning	Burning most common at midshaft, "the subcutaneous medial tibial surface and anterior tibial crest were burned when the muscle-bound tibia was heated, followed by the removal of the tissue and percussion into the midshaft and crushing of the proximal and distal ends" p. 262	Burning common and mostly light along the anterior crest, suggesting the rest of the bone more protected by soft tissue

Table 19 Comparison of Fibulae

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
MNI	18	11
Fracture	Fibula shafts tend to be intact, missing only the ends	Fracturing common on midshafts
Tool marks	Few tool marks, most abrasion patches associated with fracture points. "If disarticulation of the bone from the tibia was accomplished by cutting, it should have shown up proximally and distally, but it did not, presumably because the disarticulation was done without cutting, perhaps by breaking the midshaft away from the fibular ends that remained articulated with the tibia" p. 267	Tight clusters of cut marks at muscle insertions/attachments, scrape marks, chop marks, etc. lots of tool marks, including several at midshaft. Different pattern than seen at Mancos

Extremities

In general, elements from the hands and feet were underrepresented in both assemblages. For the few hand elements identified, both assemblages show intentional fractures and cut marks on the palmar surface of the hand bones (Table 20). This is consistent with trauma and may be indicative of defensive wounds (Galloway, 1999).

Table 20 Comparison of Hand Elements

	Mancos (5MTUMR-2346)	Sacred Ridge (5LP245)
Carpals		
MNI/ Survival	2 (all >12 years)	1 (adult)
Fracture	No intentional fractures	No intentional fractures
Tool marks	No Tool marks	No Tool marks
Burning	No burning	Burning present, concentrated on the palmar surface
Metacarpals		
MNI	10 (one <6 years old, four 7–12 year olds, five adults)	2 (ages undetermined)
MNE	43 (based on a count made of those presented in Figure 1 of Chapter 11)	22
Fracture	Proximal and distal ends are crushed, with relatively intact shafts. Crushing blows were dorsoventrally oriented. Mediolateral crushing is not present. "…the irregularity of damage (some pieces exhibit slight crushing, others lack the entire end) suggests a method using a hammer and anvil for crushing rather than intraoral processing…" p. 269	Consistent with the patterning at Mancos
Tool marks	Two metacarpals have perpendicular cut marks on palmar surface	Cut marks on medial and lateral aspects, one MC5 has transversely AP oriented cut marks on latero-palmar surface. all are clusters of 2–5 cut marks
Burning	All adult metacarpals that have burning have dorsal burning and retain at least part of the base	Variable, occurs on both dorsal and palmar surfaces, ranges from light browning to complete charring
Hand phalanges		
Survival	32 proximal phalanges, 13 middle phalanges, 1 distal phalange	13 phalanges (either Proximal or Intermediate), 5 proximal phalanges, 6 middle phalanges, 6 distal phalanges
Fracture	Two shafts without bases have depressed fractures on dorsal surface	Crushing on dorsal surface of 4 phalanges and the palmar surface of 1 phalange
Tool marks	No tool marks	One phalange has a group of 5–10 obliquely oriented cut marks on palmar surface
Burning	At least 19 phalanges burned, where unilateral, always on dorsal surface	Five have burning, all on dorsal surface

Table 21 Comparison of Foot Elements

	Mancos (5MTUMR-2346)	Sacred Ridge (SR) (5LP245)
Tarsals		
Calcaneus MNI	6 (all adult)	5 (all >12 years). At least 1 male present
Calcaneus Processing	Six of the 10 pieces show crushing at broken edges. Fracture on plantar surface on the edge of the anterior articular facet. No tool marks	Crushing fractures to the lateral aspect of most calcanii (corresponds to crushing on conjoined cuboid in one conjoin). Transverse cut marks on medial aspect of one calcaneus
Talus MNI	4 (3 adult, 1 nonadult)	6 (all subadult or older). At least 2 females and 1 male present
Talus Processing	Medial side of the talar head is missing in all pieces	Lateral articular facets are missing from all tali
Other Tarsals Processing	Three cuneiforms and 2 naviculars "show obvious evidence of compression. The presence of this crushing on the articular surfaces indicates that the bones were smashed individually after disarticulation." (p. 273)	No evidence of crushing on the articular surfaces, but crushing present on other surfaces. One conjoin consisting of most of the foot bones has a long linear area of crushing crossing at least three bones indicating a blow while the foot was articulated
Other Tarsals tool marks	No tool marks	Evidence of punctures to one cuboid
Metatarsals		
MNI	8 (2 less than 6 years, 3 between 7 and 12 years, and 3 older than 12 years)	6 (all subadult or older). At least one Male present
MNE	54	19
Fracturing	Mediolaterally oriented crushing on 15 immature fragments and 11 adult fragments. Crushing of bases and heads	Crushing on bases and heads
Burning	"This burning is much more poorly patterned than on the hand, and the overall impression is one of much less burning on the metatarsals than on the metacarpals." (p. 275)	No visible patterning: some occurred while articulated, some after disarticulation
Foot Phalanges		
MNE	44: 42 Proximal, 0 intermediate, 2 distal phalanges	19: 11 proximal, 4 intermediate, 4 distal phalanges
Fracturing	Crushing of heads and bases common	Mostly whole, some crushing around bases. Numbers are so small as to make pattern recognition difficult

Damage to the foot bones is also present, though the patterns differ significantly (Table 21). Trauma to the foot bones at Sacred Ridge is consistent with hobbling and torture has been thoroughly analyzed by Osterholtz (2010, 2012, 2013).

Conclusion

In general, the Mancos assemblage has less processing of juveniles than that at Sacred Ridge. Also, the joints appear to have been treated differently at the two sites, with Sacred Ridge having a better representation of bone ends than Mancos. Sacred Ridge also has more tool marks at muscle insertion points on the long bones, suggesting that while the muscle and tendon attachments at the joints were destroyed via crushing at Mancos, the soft tissue in these areas was cut away at Sacred Ridge in conjunction with crushing. Alternatively, tool marks at Mancos may have been obscured by the crushing. Vertebrae also show increased tool marks at Sacred Ridge. The overall impression given by the Mancos assemblage is one of dismemberment through crushing, while Sacred Ridge exhibits a more surgical approach with cutting and dismemberment in addition to crushing. This pattern is consistent with a combination of approaches to disassembling the body. Essentially, different choices were made during processing that created different archaeological assemblages, an excellent example being the differences in hip disarticulation. While both methods (cutting the joint capsule at the os coxa at Mancos and on the femur at Sacred Ridge) would ultimately lead to the disarticulation of the joint (Fig. 2a from the Sacred Ridge assemblage and Fig. 2b from the Mancos assemblage), different techniques were used that may be culturally significant.

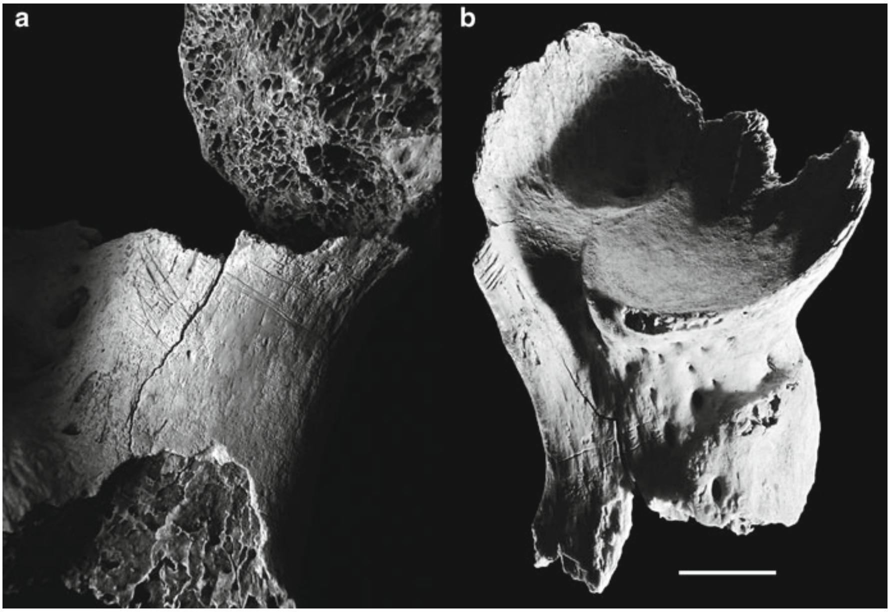

Fig. 2 Different methods for dismemberment of the hip: (**a**) Sacred Ridge, with circumferential cutmarks on the femoral neck (photo by Anna Osterholtz) and (**b**) circum-acetabuluar cutmarks on the os coxa (photo courtesy of Tim White)

This chapter compares the processing of individual elements from the Mancos (5MTUMR-2346) and Sacred Ridge (5LP245) assemblages. White (1992) described processing in an element-by-element fashion, which allowed for a detailed comparison of processing methods. By an examination of the distribution of burning, tool marks, the survival of various elements, and the fracture patterning, it is possible to reconstruct the behaviors leading to the creation of an assemblage. In effect, it is possible to make a well-founded explanation of how the human body was disassembled at each site. The patterns for these two sites show that while some elements are similar in their appearance, the location of tool marks indicates that different methods were used to achieve disarticulation. A detailed analysis of fragments is the only way that such a comparison could have occurred. While on first glance, the two assemblages seem to be similar, different patterns of processing can be identified through careful analysis and comparison.

White (1992) provided innovation by publishing the analysis of the assemblage in an element-by-element manner and allowing for future scholars to perform direct comparisons. Stodder and Osterholtz (2010) applied White's original methodology while adapting some aspects (such as the recordation of taphonomic change to conjoined units as the primary analytical unit) to better fit the research questions at hand. The comparison of Sacred Ridge and Mancos presented here will hopefully foster future comparisons on an element-by-element basis.

Acknowledgements This research was conducted while the author was employed by SWCA Environmental Consultants. Thanks are owed to everyone who supported that analysis. Additional thanks go to the Ute Mountain Ute Tribe and the Bureau of Reclamation and Dr. Tim White for his careful review of the manuscript, photo, and helpful comments.

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Disarticulated and Disturbed, Processed and Eaten? Cautionary Notes from the La Plata Assemblage (AD 1000–1150)

Debra L. Martin, Nancy J. Akins, and H. Wolcott Toll

Introduction

The La Plata River Valley in northern New Mexico has a long history of precontact occupation with the population peaking in the Middle to Late Pueblo II period (AD 1025–1125). In connection with road improvements in the region, archaeologists from the Office of Archaeological Studies out of the Museum of New Mexico conducted testing, survey, and excavation. A report was published that details the analysis and interpretation of 67 burials and 3,542 disarticulated elements retrieved from 17 sites (Martin, Akins, Goodman, & Swedlund, 2001). In addition to this analysis, three disarticulated assemblages from sites LA 37592, LA 37593, and LA 65030 were analyzed by Turner and Turner (1999). The interpretations differ widely regarding these three assemblages, and these differences have been briefly addressed in two publications (Martin, 2000; Toll & Akins, 2012) and one dissertation (Pérez, 2006). In this chapter, a more complete accounting of the taphonomy and context of the three disarticulated assemblages is provided to highlight the complexities involved in the analysis and interpretation of fragmentary, disarticulated, commingled, and poorly preserved bone assemblages.

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_8,

Turner and Turner (1999, p. 24) have suggested that six taphonomic changes need to be present on disarticulated remains to be able to conclude that the deposit was created by the act of cannibalism. They state that the “taphonomic signature” of cannibalism includes breakage, cut marks, anvil abrasions, burning, missing vertebrae, and pot polish (although pot polish may be absent in some cases and is not always required). They state that “Although it is theoretically possible that some unknown form of natural, nonhuman taphonomic agency could produce an assemblage of human skeletal remains with these six features, it is unreasonable to believe that such a thing ever happened” (1999, p. 24). For each of the La Plata bone assemblages, Turner and Turner report breakage, cut marks, anvil abrasions (impact scars), and a lower frequency of vertebrae than would be expected for the MNI represented by each assemblage. Burning and pot polish were not found in all three deposits. Regardless, the short report on each of these sites concludes that the bone deposits were the result of cannibalism (1999, pp. 311–318).

A summary of the original analysis by Martin and colleagues (2001) is provided here to show how these two very different interpretations were formed. The LA 37592 assemblage has breakage and other characteristics considered by Turner and Turner (1999) to result from intentional dismemberment and cooking, but the cut marks are only on a few of the bones and some are questionable as to if they were made by natural or human forces. The bones also had less reduction and breakage than reported by other sites with cannibalism (e.g., White, 1992). Some of the disarticulated bones showed intentionality in their placement within the deposit, and this also does not fit the pattern noted by Turner and Turner (1999) for cannibalism. For LA 37593, the breakage is more likely due to the movement of burials in varying states of decomposition and dumping or tossing cobbles into the assemblage causing further breakage. The relocation of burials and bone elements could have occurred during both ancient times and more recent times with construction activities. Attributes of the disarticulated assemblage at LA 65030 are intermediate in frequency compared to the other two sites. Carnivores contributed to the breakage and disarray at that site, and redeposition damage, as at LA 37593, is also likely. Thus, cannibalism is not the most parsimonious explanation for any of these deposits.

Methodological Considerations

Faced with infinite causes of modification, a great deal of caution is necessary when evaluating breakage in a bone assemblage. Even seasoned analysts find it challenging to distinguish perimortem from post- or antemortem breakage. The assumption made by many is that if the fracture is smooth, the bone was fresh and damage occurred around the time of death. This section provides a brief summary of the methods used as taken from Martin and colleagues (2001, pp. 121–123).

Cut marks were examined under a binocular microscope (stereo zoom .7–4.5X) that provided information for distinguishing among marks produced by dental picks and other excavation tools, natural features of the bone such as blood vessel impressions or indentations, and other marks from deliberate cuts. The following attributes were required before marks were recorded as cuts: (a) a V or V-like cross section and (b) at least two persons agreed they could be cuts. Other marks that resemble cuts but do not meet all these criteria were generally considered abrasions.

Butchering marks generally result from skinning, disarticulation, or filleting (Binford, 1981, p. 47). Cuts made with stone tools tend to be short, occur in groups of parallel marks (Binford, 1981, p. 105; Marshall, 1989, p. 17), and occur in low frequencies on bones of animals processed in replicative experiments (Marshall, 1989, p. 17). Marks closely resembling stone tool cuts can be produced by hoofed animals trampling a sandy substrate (Gifford-Gonzalez, 1989, pp. 192–193). Other agents reported to cause groove-like cut marks or slice-like scratches include excavators or preparators, carnivore gnawing, rodent gnawing, rockfall, water transport, and movement (Marshall, 1989, p. 12). The problematical cuts in the La Plata assemblage were flagged by adding a code to the modification variable indicating difficulty in interpretation of the exact nature of the morphological feature.

Fracture morphology and timing of breaks were also a challenging problem. Distinguishing perimortem from postmortem breakage is difficult, and there are different methods that can be used to aid in distinguishing these (Bonnichsen, 1983; Morlan, 1983). A great deal of consideration was given to whether certain fracture types are strictly human in origin and classified as forms of breakage (Marshall, 1989). Gifford-Gonzalez (1989, p. 188) favors a strictly descriptive typology rather than one imputing cause. She records three major break shapes for compact bone (transverse, longitudinal, and spiral) and notes the texture of the break surface as smooth or stepped. Her data (1989, p. 235) show that impact fractures (indicated by internal and external flaking) can result in almost any combination of shapes and textures.

Spiral fractures often can be found in ancient and fossil human remains (Myers, Voorhies, & Corner, 1980, p. 486). Human percussion, marrow processing, trampling, rockfall, carnivores, water transport, cryoturbation (freezing and thawing), and traumatic accidents have all been reported to cause spiral fractures. Similarly, spalling or bone flake removal has been attributed to human percussion and marrow processing, tool manufacture, trampling, carnivore gnawing, rockfall, water transport, and cryoturbation (Marshall, 1989, pp. 12, 20).

Experimental studies have demonstrated that bones exposed for about a year can have spiral fractures, longitudinal cracks, concentric flakes, and spalling from the outer surfaces after being stepped on by the experimenters (Myers et al., 1980, p. 488). Another analyst, amazed at finding recent, green-appearing and older dry spiral fractures on the same bone, proposed that the bone had absorbed enough moisture to fracture in a fresh manner and that bone deposited in cold and damp contexts could remain mechanically fresh for some time (Oliver, 1989, pp. 84–85).

In the La Plata analysis, alterations in each bone element were coded as cuts, splits, chops, percussion pits, grooves, impact fractures, spiral fractures, abrasions, snap breaks, scrape marks, peeling, crushing, or drilling (see White, 1992, pp. 119–162 for descriptions and photos of these kinds of alterations). These aspects of possible human processing were used to describe morphology rather than to attribute causation. Longitudinal fractures were coded as longitudinal splits and transverse fractures as transverse splits based on morphology. To be an impact fracture, external flakes, notches, concentric cracks, or some definite indication was required. Postmortem breakage was noted as such and was not coded as a type of alteration.

Patterns of Breakage and Disarticulation at La Plata

Documenting the full range of taphonomic forces (both natural and cultural) that may have been at work to create disarticulated assemblages is critically important in order to avoid faulty conclusions. Without detailed taphonomic and contextual analyses, it is very possible to misinterpret the nature of the assemblage. Detailed taphonomic analyses of the fragmentary assemblages from the three sites (LA 37592, LA 37593 and LA 65030) demonstrate the complexity and difficulty in establishing and differentiating natural from cultural forces. It also shows the importance of reconstructing the full context of the disarticulated assemblages. The analysis of taphonomic changes in the articulated and mostly undisturbed burials from these sites revealed that it is possible to have some of the kinds of breakage that have typically been associated with perimortem cultural processing (e.g., spiral fractures, spalling, and cracked, broken, and missing bones). Because these taphonomic signatures are found on bones from largely intact burials, no one would suggest that it represents possible cannibalism. Yet, when these same features are found in disarticulated assemblages, they are more quickly assumed to represent perimortem cultural processing. The pattern of missing elements from "normal" burials is also crucial to document for sites where there are both burials and disarticulated remains because it is highly probable that some of these elements ultimately came from the intentional burials.

LA 37593: Ancient Excavations and Modern Construction

As detailed in the site report by Martin and colleagues (2001), the excavation of this site (within the confines of a highway construction project) revealed two room blocks, several large storage cysts, and a pit structure from the Pueblo II/III period (AD 1000–1150). The upper fill of the pit structure had a large disarticulated assemblage of human remains (2,049 fragmentary elements of the 2,204 from the site) (Fig. 1). A waterline passing through the fill of this structure scattered human remains across the site surface. Based on element side and type, the disarticulated human bones represent at least 17 individuals. These range in age from infants to older adults. Adults who could be aged and sexed (aged by maxillary and mandibular dental attrition relative to the burial population and sexed by size and morphology) include a female and a male between 15 and 20 years, a male between 25 and 29 years, a male between 35 and 40 years, and two females over 40 years of age. Other than the adults, elements from children between six and ten years of age are the most numerous (29 %). Elements highly susceptible to loss and movement

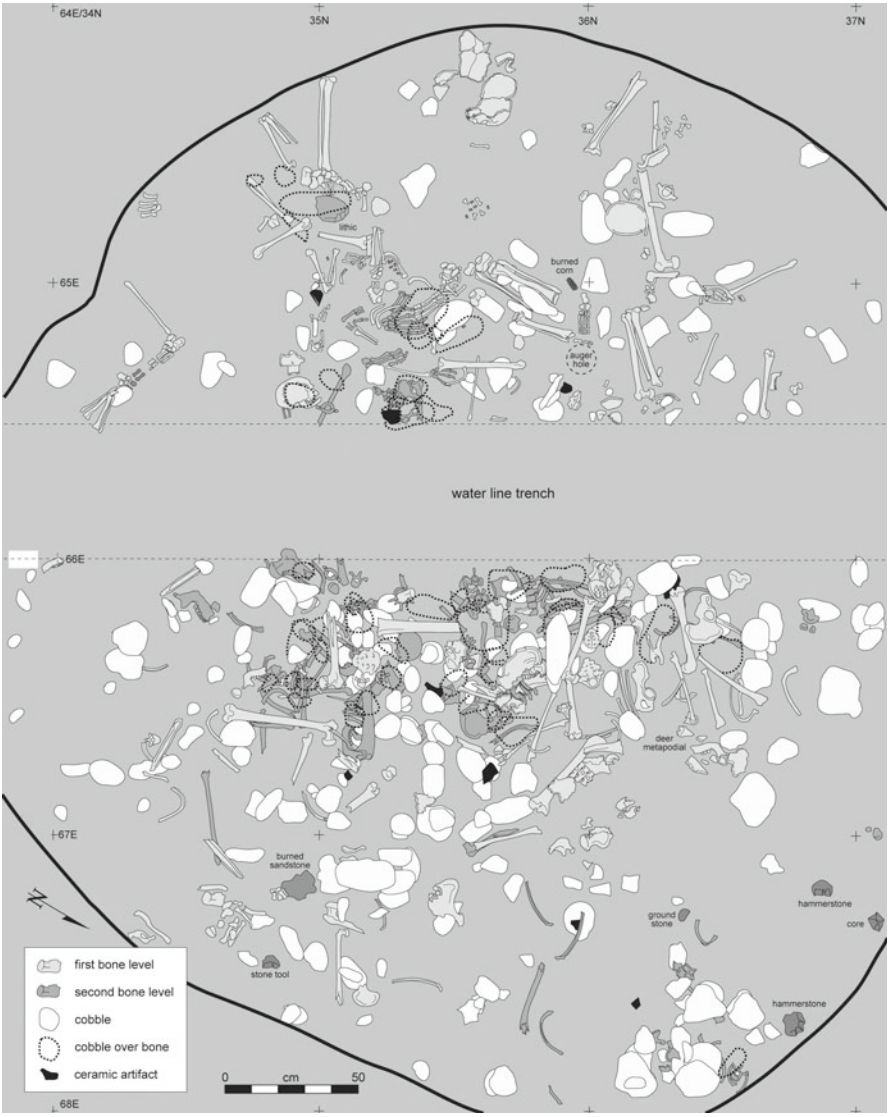

Fig. 1 Drawing of the disarticulated bone deposit located in the fill of a pit structure from site LA 37593. Courtesy Robert Turner, Office of Archaeological Studies, Department of Cultural Affairs, Santa Fe, NM

within a site due to normal taphonomic processes are relatively common in this assemblage. For example, 12 individuals are represented by metacarpals and ten by metatarsals (234 phalanges were recovered).

For the disarticulated assemblage as a whole, a small amount of carnivore damage was noted (2.6 %) indicating an additional source of disturbance at the site.

Complete postcranial elements are relatively common (32.8 %) with a slight majority representing less than half of the element (54.3 %). Unidentified elements account for only 16 % of the assemblage. Partial burning was recorded for three small pieces of bone that may or may not be human. Much of the alteration observed is ambiguous.

Subadults

Alterations on bones of children (individuals less than 15 years of age) are all spiral breaks ($n=5$ incidences). These occur on long bones (humerus $n=1$, femur $n=2$, tibia $n=2$) that tend to normally break in this manner. Alterations of elements from two 16- to 20-year-old females ($n=6$ incidences) are impact breaks of the parietal ($n=3$) and orbit area ($n=2$) for one individual and an impact break in the orbital region and a transverse break of a mandibular body for at least one other individual. For the first female, two adjoining pieces of the left parietal have a circular hole with a concentric crack along one edge. The bevel expands from the endo- to the ectocranial surface, and there is a radiating crack on the interior. The two orbital pieces articulate, with an irregular piece missing. Field photos of the grid demonstrate that this element is face down on a cobble in situ. The right parietal is essentially complete except for a half circle of bone missing from along the suture line. The adjoining piece of the left parietal has a small spall missing along the suture. Other pieces of this same cranium are unaltered. Except for breaks of the left parietal and frontal, it is disarticulated along suture lines (frontal and parietals, parietals, parietals and temporals), suggesting a postmortem natural process. Because the bevels are the opposite of what Milner, Anderson, and Smith (1991, p. 583) consider the result of lethal perimortem blows, the cranial bones quite likely were disarticulated or separated by natural processes. The adjoining levels of the grid from which these were recovered are full of cobbles. Thus, these fractures probably occurred when the bones and cobbles were tossed into the pit structure. The remaining bone elements from older teenagers (16–20 years old) include a mandible with a transverse break and peeling on the interior body just below the teeth and a parietal bone with a transverse break.

Adults

The majority of the alterations were on the adult bone elements. A mandible from an older female has a diagonal break, and an older individual has a transverse break of the mandibular body. The adult male element is a femur with a spiral fracture. Other adult cranial elements have numerous impact fractures. Of the 31 recorded cranial elements, 28 are small fragments (mostly parietal and occipital) often with bevels that expand from the endo- to the ectocranial surface. Two zygomatic arches have diagonal breaks where the posterior portion joins the temporal. Three cranial elements have marks best described as abrasions. A left parietal has a 6-mm-long mark with a U-shaped profile and step on one edge and a fine parallel line perpendicular to the sagittal suture. Two impact breaks are within a few centimeters. A second abrasion is on a right parietal fragment. Four scratches, the longest 14 mm, again are perpendicular to the sagittal suture. An adjoining piece of the left parietal from the same cranium has fine random striae, concentric and pressure cracks, and at least one impact spall. The third has four small scratches on a frontal just above the orbit. Cracks radiate from a break just above the orbit and almost reach the striae.

Postcranial alteration of adult elements is mainly on long bones. These include impact breaks of the humerus ($n=2$), femur ($n=1$), and tibia ($n=1$); spiral breaks of the humerus ($n=2$), radius ($n=1$), femur ($n=7$), tibia ($n=2$), and fibula ($n=1$); and horizontal breaks of the radius ($n=1$), tibia ($n=2$), and fibula ($n=2$). One humerus with an impact break also has a number of small abrasions on the posterior and medial edge of the shaft above and perpendicular to the distal end. Four ribs have smooth diagonal breaks, a metacarpal has a gash near the distal end, and a calcaneus is missing much of the inferior surface from some sort of impact, possibly mechanical equipment.

The relatively low frequencies and types of alteration are consistent with the excavator's interpretation of the deposit as resulting from precontact human disturbance. The burials may have been encountered by ancient inhabitants while cleaning out an abandoned pit structure for reuse. It is plausible that rather than excavating for a new structure, the fill and contents of an existing structure were removed and redeposited in the upper fill of another abandoned pit structure (Fig. 1). This explanation suggests that the creation of the disarticulated and broken remains was largely unintentional or secondary to human activity involved in construction of a dwelling place.

Additional evidence for this can be found in the excavators' photos and notes that indicated that some of the bodies were still partially intact when moved, while others were not. Intentional removal of individual elements and dumping of these along with cobbles and other debris could account for the breakage and abrasions. Bone would have been relatively fresh so that digging implements and cobbles could have caused the impact breaks and abrasions. Transverse and spiral breaks could have also occurred at that time. Fill in this layer consisted of thin alluvial deposits. The abrasions could result from movement of the bones or cobbles within this layer.

Taken as a whole, the assemblage from LA 37593 appears to be the result of a set of circumstances involving the relocation of human remains across the site. There is little evidence to support a hypothesis of intentional perimortem human processing of individuals represented by fragments and disturbed skeletal elements. Data on site formation processes affecting LA 37593 instead strongly suggest that movement of a number of burials from one place to another during precontact construction activities, low-level carnivore activity, rodents, and modern construction activities can account for the patterning evident in the collection from this site. That at least 17 individuals are represented by bones of the hands and feet suggests that the re-interment process of many of these individuals occurred while limbs were still somewhat articulated. The lack of cut marks or longitudinally split bones rules out intentional dismemberment of the individuals. Because of proximity to cobbles, the skeletal elements were most likely removed in concert with other debris in the excavation of a formerly abandoned pit structure.

LA 37592: Ritual Processing, Burning, Cannibalism, and Intentional Interment

The description and analysis of this site can be found in Martin and colleague's (2001) site report, but a brief synopsis is provided here. Site LA 37592 was occupied in several phases from the mid-1000s to almost AD 1200. A large deposition of disarticulated bone was placed in the uppermost fill of the only pit structure (or, also referred sometimes as a kiva) during the final phase of habitation (Fig. 2). This disarticulated assemblage (395 bone elements out of the 437 from this site) is very complex. Most of the bones are broken into small pieces, and many of the breaks are typical spiral or impact breaks suggesting that the bones were green when broken (White, 1992, p. 135). Also, many of the elements display a range of surface changes related to burning, and there are indications that flesh was present at the time the bones were burned. The fragments show a broad range of processing and alteration that includes longitudinal breaks, impact breaks, spiral fractures, peeling, cut marks, chop marks, abrasion, and hollowing of the long bones (White, 1992, pp. 146–150). In addition to this, the in situ arrangement of the bones appeared to be intentional and not random.

Excavation of the site revealed three small rooms and an underlying activity surface, a pit structure or kiva, several extramural features, and seven articulated human burials (dated to after AD 1050). The bulk of the bone assemblage (90.4 %) is from deposits dating to the early AD 1200s within the Pueblo III period (AD 1125 to 1300) with a few from Pueblo II (AD 1000–1125) deposits (4.6 %), and the rest undated (5.0 %). Between 7 and 10 individuals ranging in age from infants to adults are represented by the disarticulated remains.

Adult elements represent over half of the sample (58.6 %). Adults (using maxillary and mandibular dentition) include a male between 30 and 35 years of age, a male between 40 and 45 years, and a female over 40 years of age. Unidentified fragments make up a considerable portion of the assemblage (32.3 %). Few postcranial elements are complete (6.3 %) with most (80.0 %) represented by less than half of the bone.

Eighty-three elements show signs of perimortem alterations suggestive of human processing. Collapsed structural remains overlain by a layer of cobbles and dense trash characterize the fill below where the elements were found. While most of the bones were randomly scattered throughout, nestled among these was a carefully arranged broken skull cap with long bones resting or bundled within the skull cap. One other subset of fragmentary bones within this assemblage also seemed to be intentionally arranged (Fig. 2).

Some of the alterations on the LA 37592 bones are those that *can* occur through nonhuman forces (such as longitudinal and spiral breaks), but it is the patterned

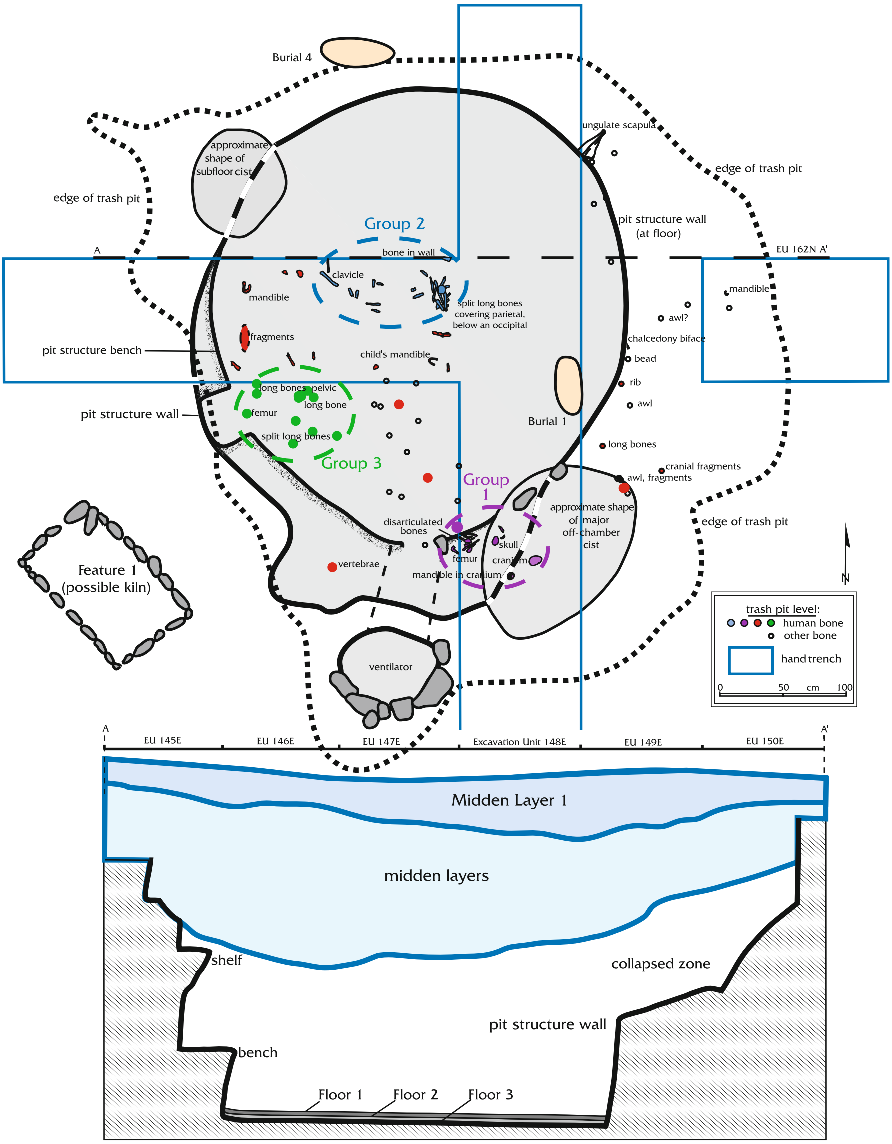

Fig. 2 Drawing of the disarticulated bone deposit located in the fill of a pit structure from site LA 37592. Group 2 shows evidence of intentional arrangement and placement of bones. Courtesy Robert Turner, Office of Archaeological Studies, Department of Cultural Affairs, Santa Fe, NM

location of these on long bones that suggest perimortem human processing. Cut marks, peeling, and abrasion are found on different bone elements, but the cranium and long bones have the most. Many of these bones have more than one kind of processing.

Subadults

Processing on the infant crania involves a series of four parallel cuts on an occipital fragment. The right lateral edge is broken, and the cuts extend from the break to about the center of the piece (5.6 mm). A small corner along the old break is burned. The burning occurred after the piece was broken and possibly after the bone had dried. The cuts are almost diagonal below the nuchal crest. White (1992, Figs. 19, 20 of Chapter 7) found similar cuts on adults from the Mancos assemblage. A partial mandible from a five-year-old child has an impact spall on the right side and a small peel on the inferior margin of the left side. The inferior and posterior edge is missing from the left side. In addition, the right side is lightly scorched, and a tooth (also scorched) from this mandible was recovered in an adjacent area.

A frontal fragment from a slightly older child (6–7 years of age) has small spalls indicating at least one impact break, striations suggestive of an impact in the area of the sagittal suture, and bite marks on the superior edge. The bites are small dents in both the endo- and ectocranial surfaces and could represent human or animal activity. Two halves of a mandible from a nine-year-old child were also recovered from two separate layers in different quadrants of the kiva. An irregular break separates the two pieces, and both have peels on the interior. A frontal fragment from above the orbits to the coronal suture, consistent in size and thickness with an eight- to ten-year-old child, has one long (29 mm) and series of shorter cuts (8 mm) in the location of the sagittal suture. White (1992, Fig. 6 of Chapter 7) shows nearly identical cut marks on an adult in the Mancos disarticulated assemblage.

A tibia shaft fragment from a child about the size of a 9-year-old has a longitudinal break. Elements from children in the 5–15-year age group, judged by size, surface texture, or unfused epiphyseal surfaces, are mostly small pieces of long bones (3 humerus, 3 ulna, 1 tibia, 1 unidentified long bone) but also include an orbit and a rib. The long bones have a spiral break, longitudinal breaks ($n=3$), impact breaks ($n=3$), and peels ($n=2$ rib and ulna). The orbit fragment has at least one impact break on the medial edge, and the lateral edge is crushed. Elements from the 15–20-year-old group include a femur and at least two tibiae. All have spiral breaks.

Adults

Two bone elements that could be assigned adult female are a fragmentary facial bone (part of the right orbit and the maxillary portion) and an innominate. Based on maxillary dental wear, the age appears to be over 40 years. At the margin of the orbit are a number of shallow rounded abrasions. Some of the marks resemble shallow cuts; others occur in clusters suggestive of an impact abrasion. The innominate has a small peel along a break and a crenulated edge. Other adult elements include small cranial fragments with impact fractures ($n=6$). One, a probable parietal fragment, also has two small cuts. Another is also burned. A parietal fragment has an impact, and a parietal and occipital fragment has two impact notches and an abrasion, probably resulting from an impact. An orbit has an impact break.

Altered adult male elements include long bone fragments (humerus $n=3$, radius $n=1$, ulna $n=1$, femur $n=11$) (unconjoined) and a calcaneus. A distal humerus has three elongated cuts (7.2 mm, 18.9 mm, and 21.2 mm) just above the distal end and a cluster of diagonal cuts (7.5 mm) below the elongated cuts. The lateral condyle is damaged and mostly missing. The anterior portion has five small transverse cuts (1.4 mm to 4.1 mm) just above the condyle. White (1992, p. 241, Fig. 5 of Chapter 9) found cuts similar to those on the anterior aspect of humeri in the Mancos collection, and he interprets them as disarticulation marks. An adult clavicle has a cluster of small cuts (2.1 mm) on the superior aspect.

A proximal humerus fragment has a spiral break and crenulated edge. Another humerus has a spiral break. Also represented is an ulna with a more ambiguous break. Both the radius and ulna have surface damage on their proximal anterior surfaces and are broken at different locations along the shaft. Two humeri have single instances of impact and spiral breaks. A third has an irregular break at one end and is battered or chewed at the distal end. This configuration could have been caused by a carnivore or could result from human actions. One radius has two impacts and a peel; a second has a longitudinal break. Two metacarpals have a peel and an impact break, and both are burned. One right femur fragment from near the proximal end has three small cuts on the posterior neck, a spiral break, and an impact notch. Three other femur fragments have spiral breaks. A patella has a crenulated edge and is burned. Five unsided and one right tibia shaft fragments have spiral breaks. Two are also burned. One right tibia fragment has a small diagonal mark, possibly a cut, on the posterior shaft, an impact fracture, and a crenulated proximal end. Furthermore, a cylinder of cancellous bone is missing from the proximal end of the shaft. Another right tibia shaft fragment has spiral and impact breaks. Three pieces of a burned left tibia all have spiral breaks, and one has a possible chop transverse to the shaft just above the distal end. Two other left tibia fragments have longitudinal and impact breaks. Finally, a fibula and talus both have impact breaks.

Burning, with and without other alteration, occurs on 40 (9.7 %) elements, largely cranial parts (40.0 %) and legs (37.5 %). All but two of the burned bones are from the deposit containing the altered bone. Seven of the eleven femur fragments are burned (mostly lightly) or scorched, but one has a graded light-to-medium intensity burn. In conjoining, six of these are from the same right femur and two others are from the same left femur. Alteration on a single piece of a right femur includes a spiral break, a longitudinal break, an impact fracture, and crushing. The six pieces from another right femur have spiral breaks and impacts. The left femur has several impacts and a crenulated proximal edge, and the cancellous bone is missing from the central portion of the shaft. The calcaneus has an impact fracture and a crenulated edge.

In summary, using a conservative estimate of the minimum number of individuals represented in the disarticulated remains from LA 37592, there were between seven and ten individuals (2 infants, 2–3 juveniles, 1 teenager, 1–2 adult females, 2 adult males, and up to 2 other adults). Both burning and human alteration occur on elements from all age and sex categories, suggesting that all of the individuals had bone elements that were culturally modified at the time of death or sometime afterward.

LA 65030: Carnivore Activity and Other Nonhuman Alterations

The description that follows is summarized from the site report (Martin et al., 2001). LA 65030 has the smallest disarticulated remains sample (400 elements) of the three sites discussed here. Most of the commingled and disarticulated fragments are from the fill of one of the eight pit structures at the site. The site was occupied from mid-Pueblo II through early Pueblo III (AD 1000–1150). This assemblage comes from the fill of one of the earliest, mid-Pueblo II structures. Five burials were recorded from Pit Structure 8, three of which were intact. The burned roofing layer contained a large quantity of human bone in varying states of disarticulation. Carnivore damage is extensive, and disarticulation was exacerbated by mechanical trenching but was clearly present before. Some of the burning is heavy, indicating the absence of flesh when burned. Other bone is remarkably sound, indicating minimal exposure to weathering. This bone assemblage shows impacts from being moved during site occupation, supplemented by carnivore activity.

Most of the approximately 300 elements were located in the roof fall layer of Pit Structure 8 (75.0 % of the site total). Carnivore bite marks and gnawing are relatively common (12.6 %). Burned bone is present (4.3 %) which is lower than that found at LA 37592 (9.7 %). The same is true for altered bone (9.7 %) in this structure compared with 22.4 % at LA 37592. Breakage is fairly high; most of the postcranial elements are represented by less than half of the element (79.3 %), and only 6.6 % are complete.

The disarticulated assemblage from Pit Structure 8 represents at least 11 individuals (6 subadults and 5 adults consisting of 3 females and 1–2 males). Most burned elements were adult bones. Burning was light-to-heavy ($n=1$) or heavy/sooted ($n=12$). Burned fragmentary elements include indeterminate fragments ($n=2$), mandible fragments ($n=2$), ilium fragments ($n=3$), humerus fragments ($n=4$), and femur fragments ($n=2$).

Impact breaks and abrasions are primarily located on three of the crania found in Pit Structure 8. Of the 25 elements with alterations, at least 14 (60.9 %) are from a child around 10 years of age, a female 25–30 years of age ($n=7$), and a female 35–40 years of age ($n=2$).

Subadult

Alterations in the youngest group are peels on a rib shaft and a humerus and the impact and abrasions on the cranium from Pit Structure 8. Parts of this cranium were collected as disarticulated elements and parts as a burial that was treated as disarticulated since more than one individual is represented. Unaltered pieces of the cranium include the frontal, left maxilla, zygomatic, right temporal, a piece of the occipital, and the vomer. The right parietal has a small impact fracture along the coronal suture.

It also has three small cracks radiating from the edges and suggesting pressure exerted on the piece. A piece that includes the maxilla, frontal, temporal, and much of the left parietal has at least three pressure-like cracks, a possible impact on the posterior portion of the parietal, and an unusual scrape or abrasion on the temporal and parietal. The scrape consists of numerous very fine and shallow scratches diagonally bridging the parietal-temporal suture. Two other pieces of the left parietal have impact breaks, and one has a series of four small abrasions near the sagittal suture. Two pieces of the occipital have impact breaks. One has a concentric crack around the impact and three small abrasions just off the crack. Given the placement and lack of patterning of these alterations, they could easily have been caused by the bone moving against coarse sandstone or could be an isolated scrape mark.

Adults

Four of the 12 pieces of the cranium from a 25- to 30-year-old female show alterations. Pieces with no obvious alteration include a maxillary fragment, two sphenoid fragments, two pieces of the left parietal, the right temporal, the occipital, and the base. The parietal fragment does have pressure cracks along the broken edge. Alteration of these bones consists of two series of three small abrasions and a single abrasion. These cluster in the same area, but one set is perpendicular to the sagittal suture, and the others are more or less parallel to this suture. The anterior right parietal fragment has an impact break along the coronal suture. It is roughly half circular in shape with the bevel expanding from the endo- to the ectocranial surface. There is no corresponding mark on the frontal. This and the direction of the bevel suggest the impact is postmortem, well after the parietal separated from the frontal. The posterior portion of the right parietal has two small spalls along the break and abrasions. The spalls are probably edge damage but have been considered as resulting from an impact in the tables. A series of four short scratches just off and diagonal to the occipital suture comprise the abrasions. The left parietal has a percussion pit or, in this case, a line or light chop, an impact fracture, and a series of three small scratches that are probably abrasions. Many of the cranial fragments from Pit Structure 8 have both recent abrasions caused by cleaning and movement in the soil matrix. These, and very similar but not obviously fresh scratches, are very difficult to assign a cause. Again, much of the disarticulation is along sutures.

The cranium of an older female (35–40 years old) had two pieces that were altered; 15 have no obvious alteration. Unaltered pieces include two upper molars and a central incisor, the right temporal, three maxilla fragments, the vomer, zygoma, two pieces of the right parietal, two pieces of the occipital, a malar, and sphenoid fragment. The left parietal is missing the portion along the temporal and part of the occipital suture and has two pressure cracks radiating out from this edge. The temporal has numerous recent scratches and abrasions and one that could possibly be old. Breaks on both temporal and zygomatics are well rounded, probably from soil movement as the fill in much of layer 10 is alluvial wash. The frontal has a small impact depression and crack radiating out to the suture line. The bone still adheres to the interior with an acute bevel from the ecto- to the endocranial surface. An unusual sharp break occurs across the bridge of the nose. The right parietal has a crack along a broken edge that may result from an impact and vessel depressions that could be mistaken for cuts. Disarticulation is mainly along the sutures. Some breakage occurs in the orbital area, at bregma, the left parietal-temporal area, and the base of the occipital.

Two other elements from this site deserve mention. One is an almost complete right ulna with red pigment stains found in Pit Structure 6. Patches of pigment occur on the anterior surface just below the articular processes and scattered around the bottom third to half of the shaft. A black dot is on the anterior about a quarter of the way from the distal end. The pigment coverage is patchy and therefore may not represent a deliberate attempt to coat the element. The other is much of a left temporal from a large child or adult from Pit Structure 8. Small step fractures and polish along the temporal suture edge are suggestive of wear.

The disarticulated assemblage from this site differs from that at LA 37592 and LA 37593. Burning occurs but is largely complete burning or sooting, a pattern typical of discard and one rare in the LA 37592 assemblage. For the most part, the breakage is more like that from LA 37593 with less long bone damage. The break on the older female could be perimortem, but the impact breaks and the abrasions are reminiscent of those caused by rocks from site LA 37593.

Assemblage Comparisons

Burials disturbed by carnivores or heavy equipment in modern times show the full range of breaks (smooth, transverse, spiral, green), spalling and flaking, cuts, splits, abrasions, scrape marks, and peeling. For example, at La Plata, a backhoe produced not only a green fracture but peeling as well on cranial and postcranial fragments (normally considered breaks indicative of fresh bone). Midshaft erosion in several of the burials due to natural causes closely resembled a condition attributed to "roasting" (White, 1992, pp. 162–163). The pattern of rib breakage in intact burials from La Plata was identical to breakage patterns attributed by White (1992, p. 224) to the human activity of removing ribs in slabs, presumably for roasting and consumption.

At LA 37592, the human bone is high in the pit structure fill above a dense trash deposit. Located in three clusters (see dashed-lined circles in Fig. 2), Cluster Two had a series of split long bones covering a parietal bone and an occipital bone. The patterned nature of this deposit suggests deliberate and intentional placement of the long bones and cranial vault pieces. The LA 37593 deposit is also high in the fill of a pit structure, but there is virtually no trash in that structure with the bones. Fill is a combination of windblown and ponded sediments and an abundance of large river cobbles. This deposit is likely the result of ancient activities involving the redeposition of human burials, probably as a result of clearing out a previously abandoned structure which had been used for burials (Charles Hannaford, Personal

Communication, 1993). At LA 65030, the human remains were just above the floor in the roof fall layer. Again, trash was sparse, and fill was windblown and ponded sediments. Both the LA 37593 and LA 65030 assemblages are incomplete. It is important to keep in mind that a waterline trench bisected the LA 37593 deposits. Likewise, an exploratory backhoe trench made by archaeologists in the course of excavation at LA 65030 removed an undetermined amount of skeletal material from that sample as well (Stephen Lent, Personal Communication, 1994).

The LA 37592 assemblage has many characteristics considered by White (1992) and others (Turner II, 1993) as attributed to intentional dismemberment and cooking. Assemblages from the other two sites have some of these same patterns but can be better explained by other kinds of ancient human behavior, taphonomic processes, site formation processes, and modern activities (Table 1). Comparing the amount of postcranial breakage (crania are not included because cranial bones were coded to reflect completion), LA 37592 has the most breakage and LA 37593 the least.

LA 65030 falls in between in the degree of human modification but has by far the most carnivore damage. Considering that much carnivore damage goes undetected because it lacks actual punctures or furrows, carnivores probably contributed substantially more to the breakage. In the LA 37592 assemblage, the parts that have the most breakage are long bones. All of the femur fragments and most of the tibia (96.3 %), humerus (84.6 %), radius (62.5 %), and rib (85.2 %) fragments represent less than half of the bone. In the LA 37593 and LA 65030 assemblages, the elements with the most breakage are ribs (88.7 and 94.1 %) and vertebrae (52.0 and 38.9 %).

Burning, like breakage, is more common in the LA 37592 assemblage (Table 1). Burn intensity also differs in LA 37592 and LA 65030. Burning in the LA 37592 assemblage tends toward light-brown patchy and incomplete burns while that at LA 65030 is heavily and completely burned (sooted or smoked). Heavy burning occurs when flesh has been removed (Gifford-Gonzalez, 1989, p. 193). Buikstra and Swegle (1989, p. 252) found it was impossible to incinerate a fleshed bone until it was deeply and uniformly smoked. Burning of flesh produced calcination of some areas before all parts were smoked. This suggests that most of the burned bone from LA 65030 lacked flesh when it was burned, while that from LA 37592 may have had flesh still present.

Altered bone was relatively common at LA 37592 and less so at the other two sites. It also has the greatest variety of alteration. Cuts, crenulated edges, and hollowing (for marrow extraction) occur only in this assemblage, and elements were more likely to have more than one type of alteration on a single piece.

Comparison of element representation for the three sites shows important differences for bones such as the ribs, hands, and leg bones (Fig. 3). LA 37592 (solid black line) is somewhat similar to the Mancos assemblage (see White, 1992, p. 307), but not for all elements. The Mancos assemblage represents a relatively uncontested interpretation of cannibalism in the ancient Southwest (see Osterholtz, 2013). For Mancos, crania, ribs, and large leg bones are the most represented parts. LA 37593 differs, in that except for ribs, there is a more even representation of all bone

Table 1 A comparison of dates, location, MNI, element frequency and alteration types for the sites LA 37592, LA 37593 and LA 65030

Sites	LA 37592	LA 37593	LA 65030
Dates	Puedblo III 1125–1300	Late Pueblo II 1075–1125	Middle Pueblo II 1000–1075
Location	Kiva upper fill	Pit structure upper fill	Pit structure just above floor
Deposit	Above Midden	Cobbles in clean sandy fill	Alluvium, cobbles and burned roof material
Individuals	7–10	17	11–12
Males	2	3	1–2
Female	1–2	3	3
Children	4–6	10	7
All elements	395	2,049	300
Post cranial bones	304	1,559	227
% Complete	2	32.8	6.6
% >50 %	18.1	12.9	14.1
% <50 %	79.9	54.3	79.3
% Carnivore damaged	1	2.6	12.6
% Light burn	5.8		
% Light to medium burn	2.3	0.1 (Human?)	0.3
% Heavy burn	1.3		4
% Calcine	0.3		
Total burned	9.7	0.1	4.3
% Longitudinal breaks	4	0.3	
% With transverse breaks		0.2	
% With diagonal breaks		0.4	
% With spiral breaks	9.6	0.2	
% With impact breaks	8.9	0.8	5.7
% With peels	2	0.1	1.3
% With chops	0.3		0.3
% With cuts	1.7		
% With scrapes or abrasions	1.0	0.3	2
% With crenulated edges	1.5		
% Hollowed	0.5		
Total altered bone	22	3.8	9.7

elements. LA 65030 has many ribs and cranial parts but a fairly low representation of other bones.

Although LA 37592 resembles Mancos, the La Plata assemblage has far less evidence of violent perimortem battering and mutilation than Mancos. The percentage of elements with cuts (1.7 %) is at the low end of that reported by White (1992, p. 327) which ranges from 1.0 % at Grinnell (another disarticulated site from the Southwest thought to demonstrate cannibalism) to 11.7 % at Mancos.

Breakage patterns at LA 37593 are best attributed to ancient movement of burials from one place to another. In addition to this movement, there were cobbles mixed

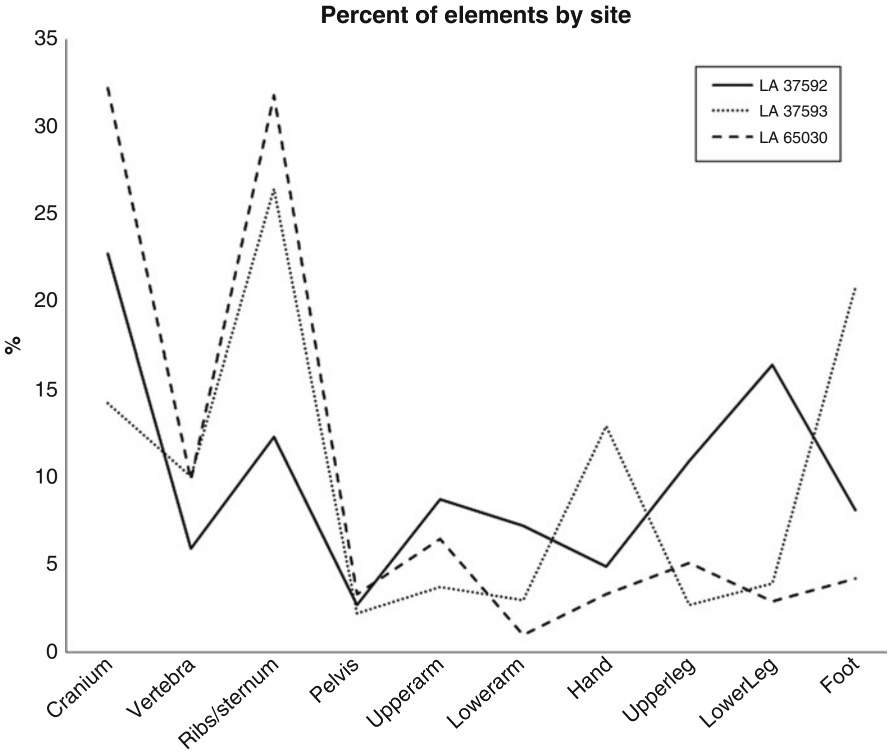

Fig. 3 Graph showing the percent of bone elements by site for LA 37592, LA 37593 and LA 65030

in when the burials were relocated, and these likely contributed to some of the impact fractures and other kinds of alterations of the bones. Modern construction activities and the waterline trench (see Fig. 1) also likely contributed to bone movement and breakage.

The explanation for the disarticulated assemblage at LA 65030 is less straightforward, but that is because there may be multiple causations. Carnivores certainly contributed to the breakage and disarray in the assemblage (Table 1). The burned elements and broken crania may be the result of secondary disposal unrelated to the filling of Pit Structure 8.

There is little question that assemblages containing altered, modified, burned, and broken human bone exist throughout the Southwest during the Pueblo II–III period as White (1992) and Turner and Turner (1999) have demonstrated. However, as the La Plata Valley sites illustrate, while there may be superficial resemblances across all disarticulated and commingled assemblages, not all are the result of similar activities. Overzealous inclusion of deposits like that from LA 37593 and LA 65030 can obscure any real patterning and hamper attempts to understand the conditions that produced the disarticulation and breakage.

The La Plata Valley study presented here demonstrates that three seemingly similar bone assemblages (LA 37592, LA 37593, and LA 65030) were the likely products of several very different processes. Without contextual information on taphonomic and site formation processes and curation and laboratory handling of the material, the case for cannibalism cannot be made. One of the innovations suggested in this study is to also include an analysis of the burials from the same site. Missing elements from burials can be sometimes found in the disarticulated deposit as was seen in the analysis of LA 65030.

That the remains from LA 37592 were modified and altered around the time of death is clear; the behaviors that produced the remains are not so clear. Cannibalism is only one of several possible competing hypotheses for modified and altered remains. Witchcraft and an associated ritual is a conceivable alternative working hypothesis. Likewise, warfare, conflict, "headhunting," and ritualized dismemberment are others.

The methodology used here is applicable to all disarticulated human remains that are suspected of showing human processing. Turner and Turner (1999) attributed cannibalism to the interpretation of the bone alterations from all three sites. Yet, for two of the sites (LA 37593 and LA 65030), the taphonomic forces were shown to not be that of humans culturally modifying the bones with dismembering, fracturing, and cutting. Rather, the data strongly suggest movement of burials in ancient times, damage from modern construction activities, and carnivore and other natural agents. For example, peeling, smooth spiral, and longitudinal breaks were produced by a backhoe; spiral breaks were produced by a utility line; and crushing and warping of human bone were caused by mechanical equipment. Finally, carnivore damage is only sometimes distinguishable from other kinds of damage; at other times, it produces patterns of dispersal, breakage, and changes in appearance that could be mistaken for other causes.

In summary, documentation of the full range of variability demonstrates that any number of agents can produce alteration in human remains that resemble changes attributable to perimortem modification by humans. This study highlights the need for such baseline data, particularly for project areas that contain both articulated burials and disarticulated assemblages. The contrasting of bone elements and alterations across the three sites (Table 1) and the comparison of bone element frequencies with others such as Mancos (Fig. 3) revealed subtle but crucial variation in patterning. This provided a more parsimonious interpretation for each of the assemblages.

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Partible, Permeable, and Relational Bodies in a Maya Mass Grave

William N. Duncan and Kevin R. Schwarz

Introduction

Over the past 30 years, research on the anthropology of the body has demonstrated that some basic western perceptions about bodies, such as the concept of the individual, are far from universal [see DeMello (2011), Haraway (1991), Sharp (2011), Shilling (2008), Strathern (1998), Turner (2011) for recent discussions of various aspects of the boundedness of bodies]. In most Western societies, individuals' bodies have clear boundaries between the inside and outside and are self-contained units. However, ethnographers have demonstrated that many cultures view bodies not as individualized, but as permeable, partible, and highly relational entities (Strathern, 1998). Permeable bodies have porous boundaries with the outside world and may gain or lose animating essences or aspects of personhood throughout life. Partible bodies are internally divided, which is to say they have animating essences found in specific locations throughout the body. Relational bodies are defined in terms of their relationships with other people and objects and, as such, may well be quite fluid in definition and composition. There are many other potential aspects of non-individual bodies, but these characteristics are among the most common in non-individualized corporeal perspectives. In the past 15 years, bioarchaeologists have begun to engage such social constructionist perspectives (Sofaer, 2006). Archaeologists, notably John Chapman (Chapman, 2000; Chapman & Gaydarska, 2007), have explored the notion that a variety of media in the material record,

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_9,

including ceramics, lithics, figurines, and human bodies, were broken intentionally. Considering the intentional fragmentation of human bodies can shed light on aspects of individuality of bodies, particularly aspects of partibility, permeability, and relationality. One challenge for using fragmentation as a window into such aspects of embodiment is identifying intent. This is particularly challenging when considering bodies in disarticulated, commingled, and secondary contexts.

Here, we employ Ripley's *K* function to explore the spatial distribution of remains in a Postclassic (AD 950–1524) Maya mass grave. The statistic permits us to show empirically that bodies in the grave were fragmented and manipulated intentionally on the basis of side and element. We argue that this is a function of the fact that Maya bodies were non-individualized and reflected a host of processes in life and death. Considering the spatial distribution of the remains in light of the grave's historical and political context suggests that the grave was created as an attempt to fragment, appropriate, and agglomerate enemies' bodies into a collective but highly public monument to their defeat. This case study highlights the fact that understanding the manipulation of remains in some contexts is contingent on engaging non-individualized views of bodies and that spatial analyses, especially when considered in light of contextual data, can permit researchers to engage such perspectives in an empirically rigorous fashion.

Relational, Partible, and Permeable Bodies

Individuals, as considered in Western society, are circumscribed from nature and exist in a closed or bounded state. Norbert Elias (1991, p. 91) described this closed individual as kind of a "thinking statue" in which the mind largely defines personhood and is separated from the outside world (Shilling, 2008). Personhood is typically not embodied except in the mind in such a view. Losing a finger, from this viewpoint, has no inherent impact on your personhood any more than cutting your hair might. These bodies may be contrasted with a collective or corporate group, by virtue of their self-containment, but are otherwise not defined in terms of their relationship to other bodies or objects. Anthony Giddens (1991) argued that the individual body seemed to emerge with modernity in the West, though it is an oversimplification to suggest that the individual/non-individual distinction reflects solely a Western/non-Western dichotomy.

This notion of the individual has been challenged recently from a clinical standpoint. As Chris Fowler (2008) and Lambros Malafouris (2008) note, topics such as ghost pain in amputees, and the prospect of muscle memory among patients with memory problems, have highlighted the fact that aspects of personhood may be embodied to a greater degree than previously imagined in Western medicine (see also Csordas, 2011). At the same time, ethnographic research has contributed the idea of relational bodies. The two best known ethnographic concepts in this discussion are dividual and fractal bodies. The notion of the dividual is most frequently associated with Marilyn Strathern's (1998) work, though she credits the term to McKim Marriott (1976, p. 111). Marriott notes that

> Persons—single actors—are not thought in South Asia to be "individual", that is, indivisible, bounded units, as they are in much of Western social and psychological theory as well as in common sense. Instead, it appears that persons are generally thought by South Asians to be "dividual" or divisible. To exist, dividual persons absorb heterogeneous material influences. They must also give out from themselves particles of their own coded substances—essences, residues, or other active influences—that may then reproduce in others something of the nature of the persons in whom they have originated.

The Hagen people in New Guinea are dividual; people are connected by gifts (Strathern, 1998). Gifts are not simply discrete possessions exchanged between separate individuals. Dividual people are never alienated from the gifts that they produce because "the labor is never extracted: it remains embedded" within the objects being exchanged (Strathern, 1998, p. 155). Thus, people give and take part of each other through their gifts, and accordingly, their bodies are the emerging outcome of such ongoing relations. Among the Mt. Hagen people, such gifts and exchanges are highly gendered and thus can influence and even change people's genders through the performance of exchanging objects (Strathern, 1998).

Roy Wagner (1991) originally proposed the concept of fractal bodies as a way to account for persons whose bodies are actually integral, being neither separate individuals nor truly corporate groups. Fractals are shapes in which the subsidiary parts have the same form as the larger whole, so zooming in or out results in seeing the same shape just on a different scale. Fowler (2008, pp. 48–49) succinctly illustrated the point by describing a person's fractal body as a potentially nested culmination of ancestors. In a single body, substances are passed on from our parents, grandparents, and great grandparents. Similar cumulative blending of genders, moieties, or entire communities within a particular person could result in other manifestations of fractal bodies. These relational bodies are defined, and in fact inextricably chained to one another, by virtue of their relationships to other people and objects.

Embodiment may be considered to be the corporeal manifestation of these and other (continuously unfolding) processes. The discussion of relational bodies opens up a host of other potential characteristics and processes of embodiment for consideration. Fowler (2008) describes a number of these aspects, but we would like to focus on two in particular: partibility and permeability. Partible bodies are internally divided and thus have mosaic corporeality, which is to say body parts have particular characteristics in and of themselves that may not be shared with other parts in the same body (Busby, 1997, p. 274). By virtue of this mosaic corporeality, partible bodies permit detachment and attachment of parts that contain their particular characteristics. Strathern (1998, p. 185) and Cecelia Busby (1997, p. 274) note that Melanesian bodies are partible and that this has implications for their relational nature. Since objects produced by labor are not alienated from the person who produced them, "transactions appear as the extraction, and absorption, of parts of the person" by others (Busby, 1997, p. 274). Permeable bodies, on the other hand, may also be dividual but are not necessarily internally divided. They are blended rather than mosaic. Busby (1997) notes that in South Asia, maternal and paternal substances are recognized in such bodies, but they are not identified as separate entities or specifically embodied in anatomy. Substances can thus flow from individuals to others and can be relationally defined, but are not inherently partible.

Maya Bodies

Maya bodies illustrate how partibility, permeability, and relationality can co-occur, but before describing them, a caveat is in order. As the above (abbreviated) comparison of Melanesian and Southern Indian bodies demonstrated, non-individualized bodies are not all the same, and the presence or absence of specific characteristics of such bodies in the past needs to be evaluated on a case-by-case basis. In other words, hopefully, efforts to draw ecumenically from the ethnographic record will identify new concepts that may shed light on past cultures, but should not lead one to find Melanesian bodies in Mexico (see Jones, 2005). Even within a particular culture, such as the Maya, there is no inherent reason to think that bodies were uniform or even stable through time. Bodies are almost inherently political (Scheper-Hughes & Lock, 1987) and thus may have differed in important nuanced aspects of composition and construction between kingdoms in the Classic period (AD 300–950; Scherer & Golden, in press; Scherer, pers. comm.). To this end, future studies will no doubt refine our understanding of Maya bodies through space in time, but currently, we can demonstrate that ancient Maya bodies were not individualized (Geller, 2012; Gillespie, 2001, 2008; Houston, Stuart, & Taube, 2006; Meskell & Joyce, 2003).

The easiest way to characterize Maya bodies is to describe four concepts, the first of which is *baah*. *Baah* is not so much a soul or animating essence as it is a conflated manifestation of personhood, the self, and the head (Houston & Stuart, 1998; Houston et al., 2006). *Baah* could be taken and manipulated by others (Houston & Stuart, 1998; Houston et al., 2006). Research has shown that animating essences could be lost through the head (Duncan, Elson, Spencer, & Redmond, 2009; Duncan & Hofling, 2011; Tiesler, 2012), though it is unclear if this characterized *baah*. By virtue of its properties, heads were frequently targeted for violence. The vitality associated with skulls in Mesoamerica is well documented (Houston et al., 2006; Moser, 1973), but one example is the fact that maize seeds are called little skulls by Tzutujil Maya speakers even today (Carlsen & Prechtel, 1991). As a result, *baah* could be absorbed by captors after decapitation (Houston et al., 2006) or appropriated for other purposes such as to animate buildings (Duncan, 2011).

Although *baah* was associated with the biological head, the concept could be extended to metaphoric references, such as the head of a corporate group (Houston & Stuart, 1998; Houston et al., 2006). Also, images of the head in some cases likely reflected *baah*, indicating that its presence extended beyond the physical body (Houston & Stuart, 1998; Houston et al., 2006; Stuart, 1996). Thus, stelae depicting rulers' heads permitted them to be spiritually present and potent long after their biological death. Similarly, iconography showing captives' heads not only commemorated their humiliation but perpetuated their shame and suffering across generations (Houston & Stuart, 1998; Houston et al., 2006).

Ik' was breath soul and was associated with wind (Taube, 2004). Breath and wind were both food for, as well as manifestations of, the gods' and ancestors' spiritual essences (Taube, 2004). Public speaking and singing were important methods for communicating with gods and ancestors (Taube, 2004), and thus, the word *ajaw* meant either "lord" or "he who shouts or proclaims" (Rice, 2004; Stuart, 1995, pp. 190–191). Rulership was not, of course, open to everyone in society, and *ik'* may not have been equivalent among all members of society. Words from rulers were likely regarded as particularly "precious" (Houston et al., 2006, p. 79). *Ik'* was explicitly embodied and was associated with the mouth, nose, and other orifices (see below). Researchers (e.g., Meskell & Joyce, 2003) have long noted that one style of dental modification looked like the *ik'* glyph. As a result of this emphasis on the mouth, caches of teeth have been reported at multiple sites in the Maya area (Duncan & Schwarz, in review), and maxillae were used as trophies in multiple areas in Mesoamerica (Duncan et al., 2009; Spence, White, Longstaffe, & Law, 2004).

Ik' is particularly interesting by virtue of its explicit relationship with other media, specifically jade, as well as a flowery afterlife. Iconographically and epigraphically, *ik'* is frequently associated with the *ochb'ih*, a death verb that means "enters the road" (Taube, 2004). This probably refers to *ik's* association with passage to a flowery paradise after death, though in the same way that not everyone had equal amounts of *ik'*, not everyone would have had access to this afterlife (Taube, 2004). This paradise was likely reserved for nobility or brave warriors who had died in battle (Taube, 2004). Placing a jade bead in the deceased's mouth after death reflects the explicit association between *ik'* and jade. Additionally, *ik'* was associated with jade earspools. Taube (2004) has argued that the opening of the ears for the spools constituted a gateway through which *ik'* could pass. This is interesting because it suggests that orifices could be created within the body to reflect its permeability. This may have implied a need to guard against loss of *ik'* (cf. Duncan and Hofling, 2011).

Finally, *ik'* is notable because it has been associated with evil airs in contemporary times (Helmke and Nielsen, 2009). The fact that *ik'* was associated with sweet wind and air and a flowery paradise in Classic period contexts strongly suggests that the meaning associated with *ik'* changed through contact and conquest to reflect medieval European humoral notions about health (Helmke and Nielsen, 2009).

The *wahy* were animal companion spirits that were active during sleep and could move independently of the body (Helmke & Nielsen, 2009). The *wahy* seem to have been "strangely impersonal" (Houston et al., 2006, p. 35), and thus, their manner and location in the body are not entirely clear. However, *wahy* beings seem to have had masculine characteristics (Houston et al., 2006), may have contributed to personhood, and may even been hereditary (Helmke & Nielsen, 2009). The *wahy* were unruly, wild, and associated with the forest (Taube, 2004). *Wahy* beings were also associated with the underworld, and it was precisely during sleep that sorcerers could attack people's *wahy* in dreams. Diseases were the manifestations of such attacks and were thus embodied. As such, diseases were in fact viewed as beings that people could engage in their dreams (Helmke & Nielsen, 2009).

Ethnographic descriptions of the *wayhel* from Tzotzil Maya speakers indicate that the *wayhel* die upon death (Guiteras-Holmes, 1961), unlike some aspects of personhood.

Finally, *ch'ulel* is an "eternal and indestructible" soul among the Tzotzil Maya (Gillespie, 2002; Houston et al., 2006; Meskell & Joyce, 2003, p. 24; Vogt, 1969, p. 370). Ethnographic descriptions of the *ch'ulel* indicated that it is associated with the essence of the individual, and with the heart and blood (Taube, 2004). Houston et al. (2006, p. 79) and Stuart (1996) have argued that *k'uh* or *ch'uh* was a cognate of *ch'ulel* that likely referred to holy things or essences and may have come "from royal hands, perhaps within blood." The association with royalty may imply that *k'uh* (like *ik'*) was not equally present in all members of society.

Given these aspects of Maya bodies and personhood, it is clear that they were thoroughly partible and permeable, and relational. This is an important point because it highlights the fact that Maya bodies are (and were) neither just like the internally divided Melanesian bodies nor like the permeable South Asian bodies described above. Additionally, we should note that many aspects of Maya bodies and personhood have yet to be tied to emic concepts. For example, long bones were important symbols for either establishing or undermining claims to legitimate political authority throughout Mesoamerica. Tombs in Oaxaca with missing femora have been interpreted as attempts by rulers to demonstrate a legitimate claim to power from deceased relatives (Feinman, Nicholas, & Baker, 2010). In the Maya area, though, similar examples of missing long bones have been interpreted as attempts to desecrate the deceased (Beck & Sievert, 2005; Hurtado Cen, Tiesler, & Folan, 2007; Miller, 2007). We still are not sure exactly of which soul or aspect of personhood was manifest in these long bones.

The relational aspect of Maya bodies stemmed in part from the intimate and dynamic connections between the living, the dead, and territory in Maya society as well as the role of cyclical time in the Mesoamerican religious worldview. Everything, including people, was caught up in cycles of birth and death and rebirth in Mesoamerica (Gossen, 1986; Mock, 1998). Parents passed on the connections of ancestors to their children, of course, but children were actually manifestations of ancestors (Meskell & Joyce, 2003). This is reflected today in Tzutujil speakers' description of the *jaloj k'exoj* cycles (Carlsen & Prechtel, 1991). *Jal* is associated with the changes that occur between birth and death—normal processes of aging. *K'ex* is the process (or processes) of essential change or transformation from one substance to another (Stuart, 1996). In this context, it is the change that occurs after death and before rebirth, a change that linked individuals over generations. Children were named for ancestors, and this link reflected and thus helped create "a form of consubstantiality with deceased predecessors" (see Geller, 2012 for discussion aspects of relational bodies in other contemporary Maya communities; Gillespie, 2002, pp. 68, 71). This was one reason the living, the ancestors, and the land were so closely tied. If the living were manifestations of the ancestors, and the ancestors were buried in the communities' land and houses, then there was an inescapable connection between the three. Legitimate claims to corporate territory were contingent on demonstrating and renewing that relationship (Houston & McAnany, 2003; McAnany, 1995; Stanton & Magnoni, 2008).

Considering Past Bodies

Researchers have used two principal approaches to engage notions of unbound and relational bodies in the material record: considering the relationship between human bodies and other media, such as animal bones or figurines, and the study of fragmentation. These approaches are not exclusive, but we focus on fragmentation here (Brittain & Harris, 2010; Chapman, 2000; Chapman & Gaydarska, 2007). Fragmentation theory considers whether and when the presence of broken objects in the material record is the result of a purposeful act rather than the product of accidental breakage, being thrown away, and/or decomposition. In the broadest sense, body fragmentation occurs in myriad circumstances including losing teeth; cutting fingernails or hair; circumcision; amputation via trauma, medical procedure, or punishment; organ donation or transplantation; trophy taking; some forms of ancestor veneration; the use of religious relics; dissection or autopsy; archaeological excavation and subsequent curation; or display of parts of human remains in museums. For Chapman, though, there are several key ways that fragmentation may occur (Chapman, 2000, p. 23; Chapman & Gaydarska, 2007, pp. 6–8): accidental breakage, intentional burial because objects have been broken, ritual killing, dispersal of objects to aid in fertility, and deliberate breakage to facilitate the distribution of an object's parts among individuals. A host of processes that follow intentional fragmentation, such as addition, removal, recombination, substitution, and reintegration, can happen in varying degrees to ceramics, figurines, houses, lithics, or human remains (Chapman, 2010; Garber, Driver, Sullivan, & Glassman, 1998; Joyce, 2008). Thus, for bioarchaeologists, a principal utility of fragmentation theory is that it provides a theoretical tool designed for the material record that can shed light on aspects of non-individualized bodies.

Two specific concepts that Chapman uses, enchainment and accumulation, are particularly relevant to this discussion. Enchainment is "the linking of person to person through object (fragment) exchange" (Chapman, 2010, p. 31). The idea is that by exchanging goods between individuals, cumulative social bonds are created between individuals and groups. As Chapman (2000, p. 31) notes, "each exchange act is pregnant with the whole history of these persons and their relationship." In societies with individuals, this may be imbued with varying degrees of importance or meaning, but in societies with relational bodies as described above, this may be a primary mechanism of embodiment. Accumulation occurs when complete objects (whether vessels or human bodies) are collected and interred together. In the case of many media, the value of a particular set of accumulated objects is defined not in terms of the relationships framed through enchainment, but rather in the value of the objects themselves. As such, accumulation is a complementary concept to enchainment (Chapman, 2010). The tension between fragmentation and accumulation is one that defines societies' relationship to a particular object or body and, as such, highlights the potential for investigating concepts such as dividual or fractal bodies in the past.

Researchers who have begun studying fragmentation among human remains in archaeological contexts typically focused on aspects of the relationship of parts to the whole (Chapman & Gaydarska, 2007; Lorentz, 2010; Rebay-Salisbury, 2010), social enchainment (Chapman & Gaydarska, 2007; Feinman et al., 2010), the boundaries of bodies and other media (Hedager, 2010; Sørensen, 2010), body commodification (Cherryson, 2010), and the historical change in meaning associated with fragmented bodies over time (Tarlow, 2008; Weiss-Krejci, 2010). The degree to which people are able to engage concepts of non-individualized bodies and their fragmentation may reflect a host of factors that limit our knowledge about cultural context or our ability to historicize bodies precisely or thoroughly. These include sample size, preservation, written records or iconography, or even the number of bioarchaeologists working in a particular region to generate comparative data. However, one important challenge for engaging fragmentation theory is the degree to which intent may be assessed in an empirically rigorous fashion. This is particularly true for secondary, commingled contexts. Thus, here, we would like to build on this work and present a case study for how aspects of fragmentation may be considered in a contextual but statistically rigorous fashion to identify aspects and processes of non-individualized embodiment.

A Maya Mass Grave

Ethnohistoric sources have shown that two politically dominant social groups lived around the Petén lakes in northern Guatemala prior to contact with Europeans (Fig. 1; Jones, 1998, 2009). The Kowoj controlled the north and the Itzá controlled the south. These distinctions were probably based on ethnic, political, and linguistic differences (Jones, 2009). Research at the site of Zacpetén demonstrated that the

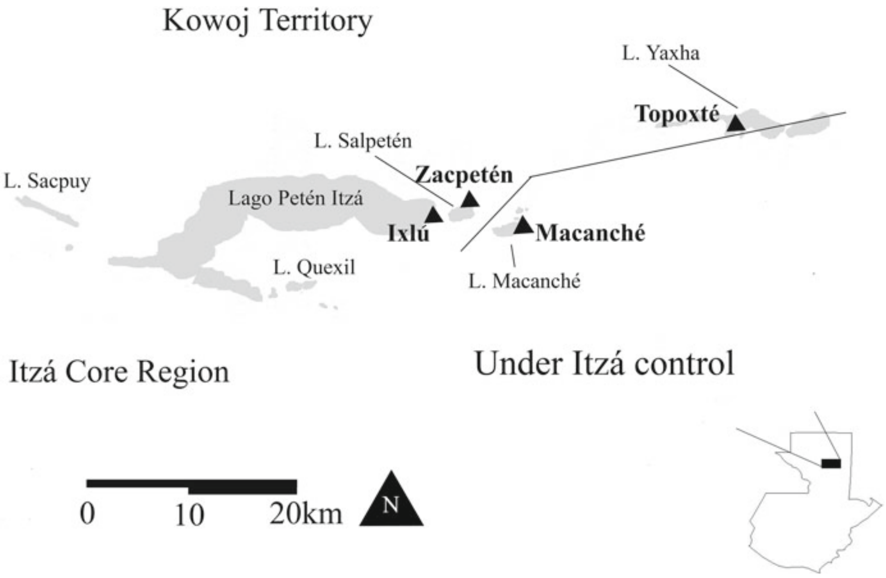

Fig. 1 Map of Petén lakes region with sites mentioned in text

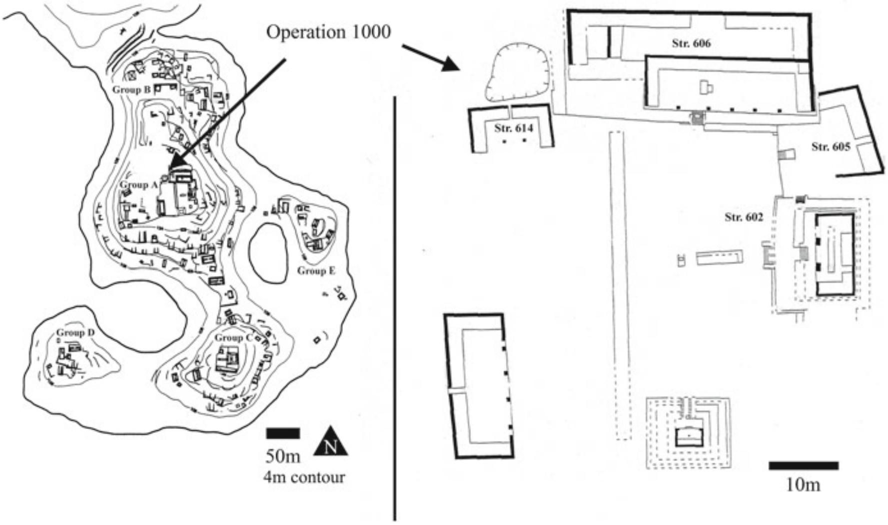

Fig. 2 Map of Zacpetén and Group A, the principal civic-ceremonial architectural group at the site

Kowoj controlled the site in the Late Postclassic (ca. AD 1200–1524), by virtue of the presence of Mayapán-style temple assemblages at the site (in Groups A and C; Fig. 2). The presence of these temple assemblages has been documented at other sites in the Petén lake region (at Topoxté) and at the site of Mayapán in the Yucatan peninsula. Mayapán-style temple assemblages constitute material evidence of Kowoj occupation (Pugh, 2001). Operation 1000 is a large depression on the northwest corner of the Mayapán-style temple assemblage in Group A at the site of Zacpetén. In Mesoamerican archaeology, major excavations are sometimes called operations, and hereafter, we refer to the excavation of the mass grave as Op. 1000. Excavations of Op. 1000 in 1997 identified a mass grave in the depression (Pugh, 2001). This was significant because other mass graves have been found on the western side of Mayapán-style temple assemblages, notably at Topoxté (Bullard, 1970), and thus, the mass graves are also thought to have been created by the Kowoj (Duncan & Schwarz, in review). Subsequent fieldwork by the senior author in 2002 excavated and analyzed the remainder of the mass grave at Zacpetén.

Op. 1000 was used most intensively in the Middle Preclassic period (1000–300 BC), Terminal Classic period (ca. AD 800–900), and Late Postclassic period (ca. AD 1200–1524) (Duncan & Schwarz, in review). The evidence for use in earlier time periods (the Preclassic and Terminal Classic) included three (and possibly four) features with temporally diagnostic ceramics on the edge of the feature. In the Late Postclassic, the northern portion of Op. 1000 was excavated and filled with fist-sized chunks of white limestone (Layer 8; Fig. 3). Layer 7 lay on top of layer 8 and consisted of smaller white limestones mixed in a brownish gray matrix. Layer 7 included a considerable amount of charcoal that indicated in situ burning. Layer 6, the mass grave, was placed on top of layer 7. The remains were then covered with a layer of

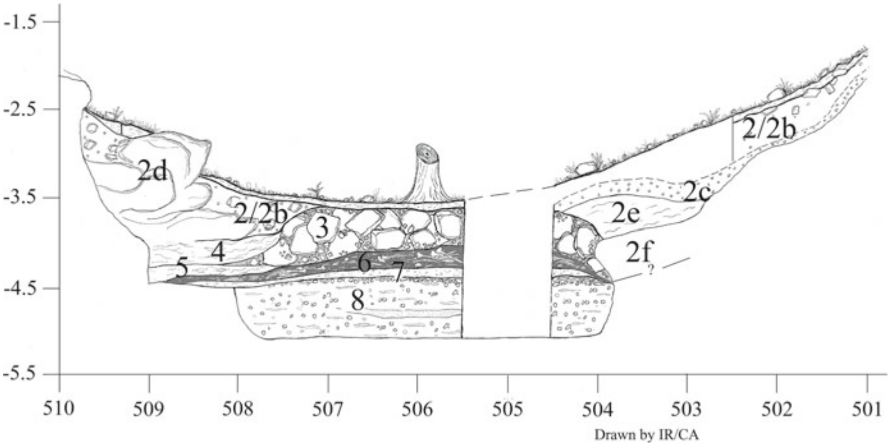

Fig. 3 Eastern facing profile of Op. 1000 on the 106 line

Table 1 Radiocarbon dates from Op. 1000, Zacpetén

Sample number	Level	Material	Measured C14 age	Conventional C14 age	2 sigma calibrated date
Beta-226378[a]	6	Bone collagen	160 ± 40 BP	410 ± 40 BP	AD 1430–1520; AD 1580–1630
Beta-226379[a]	6	Bone collagen	170 ± 40 BP	420 ± 40 BP	AD 1430–1520; AD 1590–1620
Beta-226380[a]	6	Bone collagen	190 ± 40 BP	470 ± 40 BP	AD 1410–1460
Beta 226381[b]	6	Wood charcoal	700 ± 60 BP	690 ± 60 BP	AD 1230–1400
Beta-226382[b]	6	Wood charcoal	580 ± 40 BP	580 ± 40 BP	AD 1300–1430
Beta-112318[a,c]	7	Wood charcoal	540 ± 30 BP	540 ± 30 BP	AD 1380–1440; AD 1310–1360

[a] AMS date
[b] Standard date
[c] From Pugh 2001

white limestone chunks in the center of the pit (layer 3). The periphery of the grave was covered by chipping off limestone from the sides of the feature (layer 5). All strata on top of layers 5 and 3 were produced by erosion from the surrounding plaza and structures. Radiocarbon dates from layers 6 and 7 all indicate that the grave was created around the time the Kowoj established a significant political presence in the Petén lakes region, in the 1400s (Table 1). Overall, the association with the Mayapán-style temple assemblage, the radiocarbon dates, and the stratigraphy indicate that Op. 1000 had been a focal point for ritual activity for over 1000 years, but the placement of the grave into the depression in the Late Postclassic period occurred when the Kowoj established control of the site. It was the last intentional act associated with the feature prior to its archaeological excavation.

The remains from the mass grave were inventoried and analyzed as outlined by Jane Buikstra and Douglas Ubelaker (1994) and by Ubelaker (1974). The MNI for Op. 1000 is 37 (left temporal and left femur) and underrepresentation of smaller

Table 2 Quantification and cutmarks of long bones in Op. 1000

Element	Side	Adult MNI	Juvenile MNI	Total MNI	PS	PSC	MS	MSC	DS	DSC
Humerus	L	15	5	20	5	0	16	0	10	1
Humerus	R	7	6	13	6	2	14	0	6	0
Radius	L	15	7	22	14	1	22	1	16	5
Radius	R	10	4	14	10	1	14	2	8	1
Ulna	L	17	11	28	19	1	24	1	17	3
Ulna	R	11	3	14	7	0	11	1	7	2
Femur	L	33	4	37	7	0	27	1	9	1
Femur	R	24	11	35	14	1	26	1	11	2
Tibia	L	28	6	34	5	1	24	3	10	1
Tibia	R	26	4	30	5	0	22	1	10	0
Fibula	L	20	2	22	13	2	22	2	16	1
Fibula	R	27	3	30	19	1	30	4	15	1

MNI minimum number of individuals, *P* proximal third of the diaphysis, *M* middle third of the diaphysis, *D* distal third of the diaphysis, *S* scorable segment, *SC* scorable segment with cutmarks

skeletal elements (e.g., MNI = 7 and 9 for distal manual and pedal phalanges, respectively) indicated that layer 6 was a secondary deposit (Table 2). Deposition occurred in a single event and articulation was rarely evident during excavation, which also suggests that the assemblage was a secondary deposit. However, spatial analysis indicated there some of the remains were paired, which could reflect intentional placement of bone pairs in the grave or postdepositional movement that masked articulation (see below). There were adult and juvenile remains in the assemblage (including an infant), and both sexes were represented, though sex was not quantified due to poor preservation. One skull, an adult male, exhibited cranial modification (contra Duncan, 2005).

Analysis of the remains indicated evidence of cutmarks, grinding, and drilling. The data on cutmarks demonstrated that the long bones were cut in the middle of the shafts as well as the ends (Table 2). This fact implied that the mortuary processing was more complex than simple dismemberment. Virtually, no cutmarks were found on flat bones, but as almost all were unscorable (75% present), this may reflect preservation. Additionally, two femoral shafts showed evidence of grinding. One had been split longitudinally and ground on the proximal end. One animal canine, one human canine, and one human molar exhibited holes drilled in their roots, out of a total of 372 permanent human teeth with scorable roots. These likely reflect desecratory acts (Duncan & Schwarz, in review).

In addition to the grinding and drilling of the femora and teeth, maxillary molars and right forearm bones were underrepresented relative to their mandibular and left counterparts, respectively. This discrepancy is significant for the comparison of left and right forearm bones even if you adjust the level of significance through a Bonferroni correction. That is to say, performing eight tests on the same sample would modify an original alpha value of 0.05 to 0.00625 (right versus left arm bones; $x^2 = 7.577$; df = 1; p-value = 0.0059). Chi-square tests comparing the MNI for the permanent and deciduous maxillary versus mandibular molars were also significant at a 0.05 level, though only the permanent chi-square was significant at the modified alpha level (permanent molar $x^2 = 13.52$; df = 1; p-value = 0.00024; deciduous molar x^2 with Yates' correction = 6.72; df = 1; p-value = 0.0095). Did the Kowoj intentionally cause the discrepancy during the creation of the grave? The Kowoj moved to the Petén lakes region from Mayapán in the Yucatan peninsula (Jones, 1998) and there are collective graves at that site that may be family shrines. If the creators of the grave took remains from such a shrine and a side-based discrepancy already existed, then such a discrepancy might not reflect any volition on the part of the Op. 1000's creators. One way to test this notion is through a spatial analysis.

Recently, archaeologists have been using geographic information systems (GIS) and specialized software to create compelling analyses of spatial point patterns (Dirkmaat, Cabo, Adovasio, & Rozas, 2007; Kvamme, 1993; Schwarz & Mount, 2005, 2006). These methods employ the spatial location data (e.g., coordinates) of the variables of interest to assess strength of association among elements. The analysis presented here assesses spatial relationships among kinds of bones and provides comparisons of two categorical variables, such as side. We use Ripley's *K* function, which offers a number of advantages over other methods (Connolly & Lake, 2006), particularly when used in combination with Monte Carlo methods (Manly, 1997).

Ripley's *K* function is a scaled-distance algorithm that compares a spatial point pattern with a homogenous Poisson distribution, thus providing a baseline expectation of complete spatial randomness (CSR). The statistic defines a point process of intensity λ, where $\lambda K(t)$ defines the expected number of neighbors within a circle of radius (t) at an arbitrary point in the spatial point pattern (Connolly & Lake, 2006, p. 166; Pélissier & Goreaud, 2001). The statistic, $K(t)$, is a cumulative frequency distribution of the average density of points at fixed distances, which is then graphed. The interpretation of the statistic utilizing appropriate confidence limits can identify aggregation, CSR, and/or regularity at different scales across a spatial point pattern. Thus, Ripley's *K* analysis provides the user with a detailed, scaled analysis of pattern(s) of spatial association that is visually intuitive.

Ripley's *K* function was first used in plant ecology and has been used in the social sciences as well (Levine, 2002; Ripley, 1977, 1981). We reference Dirkmaat et al.'s (2007) use of Ripley's *K* function to analyze commingled remains from the Orton Ossuary in Pennsylvania. It is a good example of the value of the method in archaeology. These researchers utilized the bivariate extension of Ripley's *K* function (Diggle, 2003; Lotwick & Silverman, 1982). The bivariate extension allows for an assessment of the contribution that categorical variables (i.e., right and left bones) have on the overall spatial distribution of long bones, which in the present study is important given the side discrepancy of arm bones. Monte Carlo methods (Manly, 1997) were used to generate confidence limits for the statistic. We used the software package PASSaGE 2.0 (Rosenberg & Anderson, 2011) to complete the analysis presented below.

The bivariate extension of Ripley's *K* function outputs to a graph against distance (t), as Khat(t). The expected value for Khat(t) is a parabolic curve (Ripley, 1977) though, so in practice, a related statistic, Lhat, which is visually simpler to comprehend, is often used instead. Lhat creates an expectation of CSR at values of around 0,

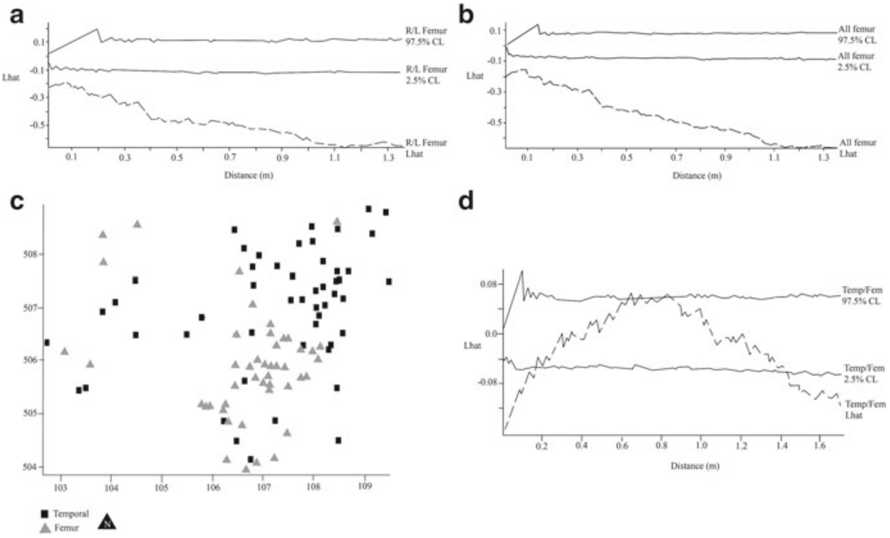

Fig. 4 (**a**) Bivariate plot of Lhat comparing left and right femora; (**b**) univariate plot of Lhat comparing all femora; (**c**) map of femora and temporals; (**d**) bivariate plot Lhat comparing femora and temporals

where the confidence envelope is centered (Rosenberg and Anderson, 2011). In PASSaGE, negative values below the lower confidence limit demonstrate a statistically significant aggregated (or clustered) pattern while positive values above the upper confidence limit (CL) demonstrate a statistically significant regular pattern. Given the exploratory nature of the statistical study of the Zacpetén mass grave, we selected an alpha level of 0.05 for the two-tailed analysis.

We employed Ripley's *K* analysis to identify evidence of intentional manipulation of the remains by side or element, or evidence of previous articulation that was disturbed by taphonomic processes. Thus, the analysis included mapping of individual elements, a univariate Ripley's *K* analysis of each element, and bivariate Ripley's *K* analyses, generally based on side. Additionally, we conducted by element comparisons that were relevant to the research problem. This focused on identifying evidence of articulation within long bones (e.g., right ulnae and right radii, left ulna and left radii, radii and humeri) and evidence of clustering of crania versus long bones.

Individual long bones showed a pattern of limited aggregation at low distance scales (e.g., below 0.4 m) with aggregation increasing with distance (Fig. 4a). This pattern of association could be termed weak-followed-by-strong aggregation. The Lhat trend line is outside of the confidence interval and is shown descending, which indicates increasing or stronger aggregation at greater distance scales. The femora exhibited the weak-followed-by-strong aggregation pattern and the bivariate comparison by side shows almost no variation from the univariate graph (Fig. 4b). The femora exhibited no differences in spatial association based on side, nor did the humeri, tibiae, and fibulae.

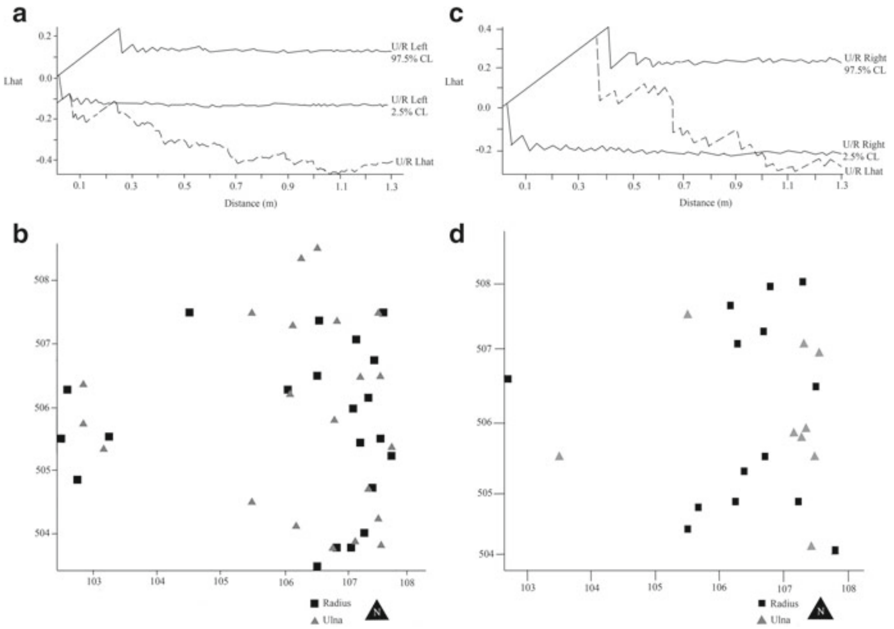

Fig. 5 (**a**) Bivariate plot of Lhat comparing left ulnae and radii; (**b**) map of left ulnae and radii; (**c**) bivariate plot of Lhat comparing right ulnae and radii; (**d**) map of right ulnae and radii

Element-by-element comparisons identified that cranial bones (as measured by the temporals) were predominantly aggregated in the northeast corner of the mass grave (Fig. 4c). Large numbers of long bones, such as femora, were just to the southwest. Although distributions of the two elements overlap and come into close contact (between N506 and N506.5; Fig. 4c), for the most part, they can be separated visually in clusters. The Ripley's *K* analysis showed this clustering at low distance scales (0–0.15 m) and then CSR at distance scales up to 1.4 m (Fig. 4d). Above 1.4 m, aggregation was present. This pattern fit the visual examination of Fig. 4c in which the visually evident clusters of femora and temporals approached 2.0 m in size.

Element-by-element comparisons also identified some evidence of paired bones in the grave, specifically the left ulnae and radii. The bivariate Ripley's *K* analysis indicated the jagged Lhat line running near and crossing the lower confidence interval just above 0.2 m (Fig. 5a), demonstrating slight aggregation and then increasing aggregation with distances up to 1.08 m. Left ulnae and left radii would be paired or near each other if the forearm was articulated during burial. In fact, a map shows a limited amount of pairings (Fig. 5b) among left forearm bones, suggesting some articulation may have been present, although none was noted during excavation. This patterning is consistent with pairing of some elements that had articulation during burial or that the bones were interred in pairs. It is likely that some bones separated slightly during the postdepositional period.

The right ulnae and right radii exhibited a differing pattern than the left. At low distance scales, the Lhat estimator ran along the confidence limit signifying CSR but trended toward a weakly regular pattern (Fig. 5c). From 0.35 m to 0.98 m, CSR was evident with weak clustering from 0.98 m to 1.28 m, at which point the statistic reached the limits of estimation. This pattern was consistent with the map, which showed few right radii in close proximity to the right ulnae (Fig. 5d). At larger distance scales, the elements clustered by side, particularly right radii ($n=6$) in the southeastern part of the mass grave (E105.5–E107.25).

In summary, the Ripley's K analysis illuminated four aspects of spatial distribution within the grave. First, most individual long bones reflect a weak-followed-by-strong aggregation as spatial intervals increased for both the univariate and bivariate analyses. This indicates that individual elements were not placed in bundles or pairs with like elements when interred (e.g., femora were not placed with other femora) and that they were not significantly regularly spaced at any interval. Second, there was a difference in large-scale clustering of cranial elements (based on the temporal) and long bones (based on the femora). The crania seem to have been placed in the northeast corner of the feature while most long bones were located farther south. This confirms the fact, suggested by quantification and excavation observations, that the remains were not completely articulated when interred. It also confirms the scenario that the spatial distribution of the remains was manipulated intentionally. However, the analysis also suggested that some of the remains, specifically the left radii and ulnae, may have been articulated when interred. This pattern may reflect skeletal articulation that was attenuated by the conditions of deposition and commingling, but nonetheless was detectable statistically. Finally, the analysis indicated the absence of right radii and ulnae aggregation at small and mid-scale distance. The large-scale clustering of the right radii and right ulnae, and difference between the right and left forearm bones, reflected intentional manipulation of these bones within the mass grave. A pattern such as this is unlikely to arise randomly and the scale of disarticulation of the right forearm elements was the result of a form of intentional fragmentation and manipulation.

The omission of right forearm bones and their spatial distribution implied cognizance and intentional action on the part of the grave's creators. We argue that this was consistent with left/right symbolism seen elsewhere in the Maya region. Joel Palka (2002) and others (Houston et al., 2006; Stuart, 2002) have demonstrated that the left side was associated with subordinate status and sacrificial victims in the Maya area, while the right was associated with superordinate status. Thus, the skeletal element representation and spatial distribution were consistent with an attempt to desecrate the individuals in the grave by associating them with the left side. On the basis of these data, the most likely scenario to account for the creation of Op. 1000 is that the Kowoj made it when they took control of the site and desecrated the remains of the previous occupants. This may have involved sacrifice, desecration of war dead, or exhumation of enemy ancestors or some combination of the three (Duncan & Schwarz, in review).

Discussion

Here, we have demonstrated statistically that bodies were intentionally fragmented and manipulated on the basis of side and element in a commingled secondary context. The remains reflected desecration and the radiocarbon dates of the grave clearly linked the grave with the emergence of the Kowoj as a political force in the Petén lakes region. The act of making the graves in part dislodged the previous occupants' ties to the respective sites. However, the Kowoj did not simply violate enemies' bodies. They presumably could have desecrated enemy bodies in a host of ways up to and including throwing them in the lake. They chose to keep them and place parts of different people in a disorganized fashion in the corner of the principal civic ceremonial center of the site to make a public symbol from enemy remains. The motivation for doing so stems in part from several specific characteristics of Maya bodies. The first such characteristic is permeability. The remains in the grave were potentially harmful by virtue of their permeability. The evidence for this is that the remains were wrapped in a white layer to seal in the potency and that a taboo was associated with the deposit. Previous research has shown that wrapping materials in layers of white (Wagner, 2006), whether it was white textiles that enveloped sacred bundles (Stenzel, 1968; Wagner, 2006) or white limestone marl for architecture and graves (see Duncan, in review for a recent discussion; Reilly 2006; Wagner, 2006), was a way to ritually seal in spiritually potent essences. Wrapping media in white marl following termination was particularly important when the Maya continued to live around the terminated media (Wagner, 2006). This seems to be particularly relevant to the case of Op. 1000. Layers 8, 5, and 3 were all white limestone and were placed under and over the grave layer in Op. 1000. Additionally, the creation and sealing of the grave were the last acts in the depression, even though Op. 1000 had been targeted for over 1,000 years for ritual use (Duncan & Schwarz, in review). The Kowoj continued to use the architectural complex surrounding Op. 1000 after the grave was created though, suggesting that there was a taboo associated with the feature. Houston et al. (2006) suggest that Colonial Tzotzil speakers referred to secrets as having been buried, and a similar sentiment may have applied to the mass grave in the context of this taboo. Thus, the remains seem to reflect a permeability that was threatening to the Kowoj after the grave was made.

Partibility is the second aspect of Maya bodies manifest in the grave. The emphasis on the left side of the body and the removal of the right forearm bones and maxillary molars reflects specific differences within the skeleton, though it is unclear what particular essences (emically speaking) were found in the right or left side. The mouth, on the other hand, was clearly associated with *ik'*, as described above, and thus targeting it for violence may have been associated with denying the deceased passage to a flowery paradise after death.

In the context of fragmentation theory, accumulation is the grouping of sets of objects or individuals into a larger set. The grave clearly is an accumulation in the strict sense but not of whole bodies, and thus does not reflect accumulation as originally described by Chapman (Chapman, 2000; Chapman & Gaydarska, 2007). Chapman (2010, p. 33) defines recombination as “the creation of a hybrid body by the placing of part of one human body in juxtaposition to that of part of the body of another human of different age/sex or another species." Op. 1000 may be consistent with this idea, but we suggest that the notion of agglomeration (a heap or cluster of disparate elements) better captures the characteristics of the grave in Op. 1000 than recombination because of the disorganized nature of the grave. Bodies are normally not shown touching one another in Maya iconography, and the placement of people's bodies in a collective grave clearly would have been an insult (Houston et al., 2006). Additionally, these researchers have argued that the lowest form of victimhood was anonymous victimhood, and thus, the agglomeration of the previously separate people into an unnamed mass grave would have been a singular degradation. This is not to say that the Kowoj did not know who were in the grave, just that victims' individual identities were not publically commemorated. It is likely that the Kowoj (and their enemies) knew exactly who were in the grave, and their specific bodies were targeted for violence and commemoration of that violence as a group. Finally, Cecelia Klein (1982) has argued that in the Maya worldview, the heavens were perceived as an orderly tapestry, while the underworld was perceived as disorderly, and thus, the disorganization of the grave may have been a form of insult in and of itself. The grave, then, reflects a process of agglomeration, which stems from permeable and relational bodies' potential be melded into one collective unit. The grave makers not only disrupted the previous occupants' claim to the site but used their bodies to create a collective, public, and enduring monument to their defeat and humiliation at the center of the civic-ceremonial core of the site.

The distinction of accumulation and agglomeration raises the question of whether or not the grave implies enchainment of the missing remains. The missing right arm bones and teeth are perfectly consistent with the scenario of trophy taking, which would have linked the deceased from whom trophies were taken and those who took and owned the trophies. Currently, there is no established method for identifying trophy taking in commingled secondary contexts on the basis of missing elements, and ultimately, we cannot know what happened to them. However, the possibility exists that the right forearm bones were exchanged and thus could have enchained the Kowoj with both the living and the dead.

To conclude, one ongoing challenge for contemporary bioarchaeologists is to engage non-individualized views of the body. In this chapter, we used a Ripley's *K* analysis of a Maya mass grave to consider, empirically, whether or not the bodies in the grave were fragmented and manipulated intentionally. Doing so permitted the identification of multiple aspects and processes associated with Maya embodiment and highlighted the fact that spatial analyses, particularly when considered in light of historical and political context, can shed light on aspects of non-individualized bodies in an empirically rigorous fashion.

Acknowledgments We would like to thank the editors for inviting our participation. All of the members of Proyecto Maya Colonial, in particular Drs. Prudence M. Rice, Don Rice, and Leslie Cecil, were particularly helpful throughout the various stages of this work. We would like to thank the faculty and students of Centro Universitario del Petén (CUDEP) in Guatemala, notably Lics. Rómulo Sánchez Polo, Rolando Torres, Ivo Romero, Mara Reyes, Edy Barrios, Aura Soto, and Tierso Morales, for their valuable contributions to this project. Timothy Pugh provided data from a test trench. This project could not have been possible without cooperation of IDAEH in Guatemala, in particular Lics. Boris Aguilar and Sheila Flores. Several conversations with Drs. Andrew Scherer, Gabriel Wrobel, Vera Tiesler, Andrea Cucina, and Rosaura Yépez about Maya bodies were particularly helpful as this manuscript was being written. Drs. Andrew Scherer and Melissa Schrift gave particularly constructive peer reviews of this manuscript. Dr. Della Cook gave similarly constructive comments and encouragement regarding an earlier version of this paper. Carmen Arendt and Felix A. Duncan provided unflagging support, for which W. N. D. is most grateful. Funding was provided in part by NSF doctoral dissertation improvement grant BCS 0125311. Any remaining errors are solely ours.

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Part III
Caveats and Contributions from Other Disciplines

Unmingling Commingled Museum Collections: A Photographic Method

Katie J. Zejdlik

Throughout curation, long-term collections are subject to multiple accessions and deaccessions, cataloguing changes, and research analyses as well as limited institutional resources and administrative agendas. Human remains from individual burials can become mixed within a single assemblage, between assemblages at the same institution, or between assemblages at different institutions. These extra dimensions of commingling are less likely to occur in a field or laboratory context where only one assemblage is analyzed at a time.

Despite the many potential issues associated with research on curated collections, these materials are exceptionally valuable resources to osteologists for a variety of reasons: (1) information provided by formal collections of human remains has set standards for much of modern forensic and bioarchaeological skeletal analyses (Lovejoy, Meindl, Pryzbeck, & Mensforth, 1985; McKern & Stewart, 1957; Meindl & Lovejoy, 1985; Phenice, 1969; Todd, 1920), (2) collections are visited and revisited many times (Buikstra & Gordon, 1981; Roberts & Mays, 2011), (3) research on curated collections is growing as laws associated with the excavation and analysis of human remains become more restrictive (Rose, Green, & Green, 1996), and (4) the pace of skeletal research is increasing as analysts worry about the possibility of repatriation, reburial, or institutional deaccession of human remains.

Increasing use of skeletal collections raises the possibility that materials may become commingled, damaged, or misplaced. Thus, inquiry into the institutional history of a collection is important for identifying completeness of the skeletal

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_10,

collection and what processes might have resulted in taphonomic modification to the remains. Use of original excavation documentation is particularly important for refining the organization of an institutionally commingled collection. The most useful of these documents are photographs. Photographs record the object of interest but also the associated background information, which can be valuable for establishing the social and physical context of an item. However, despite the wealth of information they offer, photographs are often overlooked by individuals working with collections. The photo-matching method discussed here is simple but applicable to a wide range of materials. In the case provided, knowledge of the collection's history and use of the photo-matching technique restored provenience information to previously unprovenienced remains, enhanced interpretation of multiple features, and helped to rearticulate the locally famous Aztalan Princess.

Institutional Commingling

Working with any curated anthropological collection that has been constructed and maintained over years of donation and accession requires researchers to wear the proverbial pith helmet of an archaeologist. Historically, museums were private collections of unique, exotic items such as rare biological specimens or ancient artifacts. These "cabinets of curiosity" were often purchased by public museums for display. Acquisition of World's Fairs exhibits also contributed to the early collections of many currently renowned museums in the United States such as the Field Museum in Chicago, the American Museum of Natural History in New York, and the Smithsonian National Museum of Natural History in Washington D.C. Interest in formalized research programs led many museums to sponsor expeditions and to support the research of their staff. The result was the attainment of large archaeologically derived collections (Ames, 1992; Sullivan & Childs, 2003). The enormous amount of materials entering collections facilities often overburdened the available curatorial resources of most institutions and directly affected collections management. Immediately, curators were overwhelmed with finding time to properly process the materials. Also, space to house objects was swiftly running out. Little attention had been given to issues of long-term management and curation (Childs & Sullivan, 2004; Rose et al., 1996). Unfortunately, the desire for large collections of exhibit quality also impacted the research value of many assemblages; collections which involved artifacts and human remains were sometimes separated for exhibition or research purposes (Griffin, 1981; Moore, 1908).

The discovery of institutional commingling when attempting to collect data provides a frustrating challenge to the analyst. Typically collections are not intentionally commingled; therefore, when commingling occurs, it is often unknown to curation staff and researchers alike. Further, museum mix-ups are not typically publicized when they are recognized, and the researcher is left on his/her own to determine if the collection is complete. Many large collections in old museums are still going through the process of collections digitization. As collections become digitized, problems of commingling will likely decrease. The comparison of modern inventories with original inventories may be the only way to determine if items are missing or if additional materials are present. In cases where the inventory and materials do not match, an investigation of the collection's history is requisite in order to return the collection to its original status.

Cross-Institution Commingling

James Griffin's (1981) article *The Man Who Comes After; or, Careful How You Curate* is an excellent account of how institutional processes affect collections and research. Two cases in particular offer examples of cross-institutional commingling. The first case is that of the University of Chicago's internationally recognized North American Midwestern archaeology research program organized by Fay-Cooper Cole. For many years, the University of Chicago and private donors sponsored archaeological excavations that would provide foundational knowledge of Midwestern prehistory. In the 1950s, shortly after Cole retired, the university changed its research goals to focus on more "exotic" collections. Midwestern archaeology was no longer a priority, and no funds were allocated for maintenance of the collections. Archaeological materials, including human remains, were deaccessioned to institutions that would give them better care. This was done with the best intention; however, the distribution of the collection across many institutions resulted in lost notes and damaged or misplaced materials. Griffin writes that the collection was so impacted by multiple exchanges that the use of original field notes or attempts to reconstruct the site became challenging if not impossible (Griffin, 1981).

The second example Griffin discusses is the curation of materials excavated by Clarence B. Moore. Moore, himself, presented pieces of his collection to multiple institutions including the Academy of Natural Sciences of Philadelphia, the Peabody Museum at Harvard, the Peabody Foundation of Andover, the Buffalo Museum of Science, and possibly the American Museum of Natural History and the Smithsonian (Griffin, 1981). Rose et al. (1996) add that human skeletal remains with pathological indicators were sent to the Army Medical Museum. Rose and colleagues write that the dispersal of skeletal collections in early American archaeological history is not unique and that by "changing the names and dates in this story one can describe the early history of osteology anywhere in the United States" (Rose et al., 1996, p. 82). They point out that in many cases archaeologists and osteologists would send some materials to a museum and use others for teaching collections and their personal research. The distribution of artifacts and materials across the institutional landscape requires diligence on the part of the analyst to identify which piece of the picture one is seeing.

Documentation

Original site documents and collection documentation files are necessary tools for successful museum research. Typical documentation files include information associated with a collection through time in addition to excavation notes, accession records, and catalogue cards. Not every institution maintains documentation files, but when present, they should be used to supplement and double check research materials. James Brown writes that site documents are a "veritable treasure to be found in museums and other repositories, if brought to the attention of the archaeological profession and the general public, would substantially fill many apparent gaps in the archaeological record" (Brown, 1967, p. iii). The maintenance of contextual documentation and associations between recovered materials at the time of excavation cannot be overemphasized. Without proper documentation, important information is lost and cannot be recovered. Documentation can be broken into written and photographic categories. Innovative and applicable methods gathering and maintaining documentation, such as the ones describes in this volume, are the foundation for subsequent analysis.

Importance of Using Site Documentation: The Spencer Lake Site Example

The Spencer Lake site provides an excellent example of good field notes and curatorial diligence. The site, located in northwestern Wisconsin, was excavated in the 1930s by a talented crew, most notably: William C. McKern, Ralph Linton, George Quimby, Joffre Coe, and Albert Spaulding. During excavation, a horse skull was found in a Late Woodland Native American conical mound. There was no visible modification to the stratigraphy that would indicate an intrusive burial. Word began to spread about a pre-European horse in the New World. Eventually, someone admitted to the hoax, but the archaeological evidence did not support the admission of guilt (Barker, 2004).

Over the course of the next 60 years, documentary evidence associated with the site was collected, and in the early 2000s, Alex Barker, curator at the Milwaukee Public Museum (MPM), investigated the incident. Using the site-associated documentation file that had been built over decades and the excellent field notes, Barker was able to determine that the horse skull was indeed intrusive. The looters had tunneled horizontally from a vertical looter's hole. This horizontal tunnel occurred entirely within the same stratum which, when combined with the coarse soil at the site, left the intrusion unidentifiable to the contemporary field team (Barker, 2004). Barker's reanalysis of the site demonstrates the importance of excellent site documentation, the benefit of continually adding to a site's documentation file, and the value in reexamining old collections with a new perspective.

Site Photographs to Correct Institutional Commingling: The Pueblo Bonito Example

Unrecognized cataloguing and commingling from the Pueblo Bonito site in Chaco Canyon, New Mexico, led to an erroneous observation of four individuals with unspecific lesions possibly related to treponematosis. Using high-quality excavation photos that had been taken over 70 years earlier, Marden and Ortner (2011) were able to identify specific bone specimens and reassociate skeletal elements to a single individual. Matching elements to photos, Marden and Ortner specifically identified a pathologically modified tibia in situ as well as its associated skeletal elements. This identification led to the realization that the elements associated with the tibia had received a different catalogue number after excavation. The different catalogue numbers superficially suggested that these were different individuals. This curatorial error had resulted in previous investigators identifying a higher frequency of treponematosis at the site than was actually present, thereby changing the paleopathological and thus overall health interpretations for the site. Photo-matching allowed the post-excavation commingling to be sorted out and also resulted in an important reanalysis of the materials which changed the frequency of treponematosis at Chaco Canyon from four individuals to one (Marden & Ortner, 2011).

Site Photographs and Environmental Context: The Angel Mounds Site

In conducting DNA research for her dissertation on the Angel Mounds site in southern Indiana, Marshall and others noticed the better-than-average preservation of infant and child remains (Marshall, 2011). Observation of the site photos demonstrated that after excavation, adult remains were left exposed in situ for an extended period during excavation. This was likely done in order to obtain photographs of multiple burials and their spatial relationship to each other. Child skeletons appear to have been excavated and recovered immediately. The increased exposure to the sun and environment had a significant negative effect on the overall preservation of the adult skeletons, which further impacted and informed Marshall's interpretation of DNA preservation and demographic profile at the site.

Photographs are especially useful for the background information that they provide. Many published site reports and field maps offer an "X" or a stick figure to indicate where a burial was located. These types of documentation are often readily available and usually the only documentation used by researchers. Original site notes and photos are often underutilized by osteologists despite being the best resource for understanding context when the investigator has not had the privilege of excavating the materials themselves. Photographs may show burial orientation, associated grave goods, and overall preservation. Additionally, pictures may provide valuable information about taphonomic processes that may have affected bone. Close examination of a picture's background will provide the analyst with information regarding environmental context, extent of bone preservation at excavation, excavation methods, excavation tools, and other taphonomic modifiers.

Aztalan: A Case Study

The Aztalan archaeological collection is an example of a collection that was affected by commingling at initial deposition, commingling between institutions, and commingling within the collection. Use of original site documentation and a photographic matching method helped restore the research value of the skeletal collection. It also corrected previously published misinterpretation, reestablished archaeological provenience, and helped rearticulate a locally famous set of skeletal remains.

The Aztalan archaeological site is located in southeast Wisconsin. Primarily occupied from AD 1000 to 1200 (Richards, 1992), it consisted of a palisade with square bastions that enclosed a mound-village complex. To date, all of the known curated remains from Aztalan have been analyzed, resulting in the observation of 12 burials, 11 cremated individuals recovered from a charnel structure, and approximately 3,000 pieces of isolated, processed, and commingled human bone. In the nearly 100 years of sporadic excavation, loans and accession by various institutions have further commingled the remains. Moreover, no original site notes from these excavation projects have been located.

Background

The first documented account of Aztalan appeared in the *Chicago American* on December 17, 1836. The anonymous article titled: "Ruins of the Ancient City of Aztalan" included a rough sketch and a written description of the site as well as a discussion of how Aztalan received its name as the northern homeland of the Aztecs (Birmingham & Goldstein, 2006; Richards, 2007). Later, Judge Nathanial Hyer's description and sketch of the site was printed as a "Letter to the Editor" on February 25, 1837, in the *Milwaukee Advertiser* (Hyer, 1887). Hyer's account later appeared in the *Chicago American* and several other newspapers across the country (Richards, 2007, pp. 34–35). The uniqueness of this site was immediately obvious, and it was soon lauded as "one of the wonders of the western world" (Lapham, 1855, p. 42). A journal kept by Henry Tathem in 1837 describes a trip that he took with his brothers across the country from Philadelphia to Aztalan (Richards, 2007). Aztalan had reached national recognition. The importance of the site for Wisconsin and the Milwaukee Public Museum was obvious, and like other museums of its time seeking prestigious collections, excavation of the Aztalan site was of material and cultural importance.

The first formal and largest excavation of the Aztalan site took place in 1919, 1920, and 1932 under the auspices of Samuel Barrett (1933). Barrett was a talented anthropologist who had worked with foundational anthropologists and curators such as Frederick Ward Putnam, Franz Boas, Marshall H. Saville, and Alfred L. Kroeber (Peri & Wharton, 1965). In 1919, Barrett was the Curator of Anthropology at the MPM, and in 1920 he would be appointed to its directorship. As an accomplished anthropologist and a museum curator, the cultural importance and material abundance of the Aztalan site attracted Barrett and his supporters from the museum and Wisconsin Archaeological Society (Barrett, 1933).

Documents

Barrett's 1933 publication *Ancient Aztalan* is some of the only documentary evidence available from the first years of field excavation. It is an extensive report complete with maps, photos, sketches, interpretation, and narrative that show Barrett's insightful, methodological intuition. Unfortunately, Barrett's original field notes have been lost and only a few isolated maps remain.

Items from Barrett's excavation of Aztalan are currently curated at the MPM. All of the known human skeletal material is accounted for in catalogue books mostly organized by block and feature numbers. Human remains are housed in storage drawers; however, organization of bones within the storage drawers is less clear.

The second largest excavation project of the Aztalan site was done by the Wisconsin Archaeological Survey from 1949 to 1951. Materials recovered from this project were curated primarily at the University of Wisconsin in Madison (Baerreis, 1958; Maher, 1958; Rowe, 1958). Unfortunately, field notes for this project have also been lost. The only information regarding human remains recovered from these years of excavation are photographs, a short write-up in Holcomb's (1952) Master's thesis, and an excavation map of the site created by Lynne Goldstein (1999a, 1999b).

In addition to these two large projects, Aztalan has been excavated and researched by numerous different individuals and institutions for over 100 years. As with many things that change hands over time, records have been lost, items have been loaned and forgotten, pieces have been mixed up in collections, and details have been misidentified in reports.

Investigation of the Aztalan collection's history was the first step in identifying what should be present in the collection. To do this I examined many forms of documentation including NAGPRA inventory sheets, accession cards, catalogue cards, catalogue books, artifact documentation files, published and unpublished papers, Master's theses and PhD dissertations (Anderson, 1994; Holcomb, 1952; Richards, 1992), written letters, maps, personal communication, and excavation photos. Additionally, numerous inquiries were sent to various institutions to locate missing human osteological material. The most up-to-date listing of the known Aztalan skeletal material is available in Tables 1 and 2 (Rudolph, 2009).

Locating the human skeletal remains was the next step in reorganizing the collection. Investigation of the collection history showed that the Aztalan assemblage was

Table 1 All known burials and cremations from Aztalan

Literature Reference	Excavator and year	Total Ind.	Sex est.	Age est.	Description	Burial treatment
Sterling (1920)	Dr. V. C. Porter (1838)	50+	NA	NA	Bundles of 6–12 forearm bones, wrapped around once with a three-strand cord tied in a bow knot; broken in two places and burnt black (Sterling, 1920, p. 19)	Secondary bundles
Lapham (1855)	J. C. Brayton (unknown)	1	NA	NA	An individual wrapped in a course textured cloth (Lapham, 1855, p. 47)	Unknown
Lapham (1855)	I. A. Lapham	2	NA	NA	Two highly decayed bodies, likely interred in a sitting position in the northwest mound (Lapham, 1855, p. 44)	Primary, in-flesh
Barrett (1933)	Barrett (1919, 1920, 1932)	2	I	C	Two children buried, in-flesh, beneath a cone of gravel in Section II-37 (Barrett, 1933, pp. 137-139)	Primary, in-flesh
Barrett (1933)	Barrett (1919, 1920, 1932)	1	M	A	Male, flexed in a pit along the river; Barrett's excavation Section II-41	Primary, in-flesh
Holcomb (1952)	WAS (1949–1951)	1	I	J	Burial 1: fully flexed burial of a juvenile of undetermined sex. (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952)	WAS (1949–1951)	1	M	A	Burial 2: fully flexed burial of an adult male (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952)	WAS (1949–1951)	1	M	A	Burial 3: fully flexed burial of an adult male (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952)	WAS (1949–1951)	1	I	C	Burial 4: fully flexed burial of a child (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952)	WAS (1949–1951)	1	I	C	Burial 5: fully flexed burial of a child (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952)	WAS (1949–1951)	1	M	A	Burial 6: extended burial of an adult male (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952), Maher (1958, p. 82)	WAS (1949–1951)	1	F	A	Burial 201: flexed burial of a young adult female (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952), Maher (1958, p. 99)	WAS (1949–1951)	1	F	A	Burial 202: fully extended burial of a young adult female (Holcomb, 1952, p. 4)	Primary, in-flesh
Holcomb (1952), Maher (1958)	WAS (1949–1951)	2	F & I	A & F	Burial 203: fully extended burial of adult female. A child or fetus was found interred between the legs of this female (Holcomb, 1952, p. 4); Maher, (1958, p. 99) lists these as two separate burials: 203 and 204	Primary, in-flesh
Maher (1958)	WAS (1949–1951)	1	I	I	Feature 213: partially cremated infant remains in a post mold	Cremated
Rowe (1958)	Rowe (1954)	11	M & F	A	Ten adult fleshed burials in an extended position facing southwest. One bundle burial (Rowe 1958)	Charnel structure-cremation
Wittry (1963)	Hurley and Freeman (1962)	1	NA	NA	Unknown (Wittry 1963); possibly feature 31, burial 1 indicated in Hurley (1977, p. 291)	Unknown
Goldstein and Gaff (2002)	Goldstein (1996)	1	F	A	Lower portion of articulated adult female with accessory cut femur (Goldstein, 2010)	Primary, in-flesh

WAS Wisconsin archeological survey; Sex: *M* male, *F* female; *In.* indeterminate; Age: *F* fetus, *I* infant, *C* child, *J* juvenile, *A* adult (Rudolph 2009)

Table 2 All known isolated, fragmented and commingled remains from Aztalan

Literature reference	Excavator and year	Description
Richards (2007)	Henry Tatham (1837)	Broken and fragmented bones as part of midden refuse and piled up against the stockade
Lapham (1855)	I. A. Lapham (1850)	Mass of half burned human bones
Somers (1920)	Rever and Somers (1888)	Hundreds of cut and broken bone from refuse pits
Barrett (1933)	Barrett (1919–20, 1932)	Hundreds of isolated and processed human remains found in fire and refuse pits
WHS artifact notes	Leland Cooper (1938)	Two ribs fragments and a partial left humerus were donated to the WHS
Holcomb (1952, pp. 62–64)	WAS (1949–1951)	Features 25, 34, 37, 38, 39, 49, 58, 70, 73, 76, 66, 79, 81, 82, 83
WHS artifact notes	Wittry and WHS (1953)	Excavated near Bastion B at the SE corner of the site
WHS artifact notes	Wittry and WHS (1953)	Feature 97: Near Bastion B at the SE corner of the site.
WHS artifact notes	WHS (1964)	248R82
WHS artifact notes	WHS (1967)	Feature 51: refuse pit
WHS artifact notes	Hurley (1974)	East stockade wall: donation from Hurley
Bag label	WAS (1949–1951)	222R8 contained right acetabulum; excavation photos list this as Feature 61
Bag label	Unknown	F78
Bag label	Unknown	Aztalan fill
LU bag label	Unknown	Pit 15
LU bag label	Unknown	Pit 35
LU bag label	Unknown	109-L1
LU bag label	WAS (1949–1951)	221 R105; determined to be WAS by consulting the combined excavation map
LU bag label	Unknown	F75 221 R88
LU bag label	Unknown	Wells collection
UWM	Hurley (1962)	Stockade; f31-62-B1; this may be the feature 31, burial 1 from Hurley (1977, p. 291)
UWM	Wittry (1956)	West stockade line as indicated by a note from Wittry held with the collection at UWM
Excavation photo	WAS (1949–1951)	F61 222R85
Excavation photo	WAS (1949–1951)	F77 224R81
Excavation photo	WAS (1949–1951)	F45 218R89
Excavation photo	WAS (1949–1951)	F47 212R88
Excavation photo	WAS (1949–1951)	F59 224R87
Excavation photo	WAS (1949–1951)	232R92
Excavation photo	WAS (1949–1951)	222R94
Excavation photo	WAS (1949–1951)	221R91
Goldstein and Gaff (2002)	Goldstein (1996)	Scattered, isolated and processed human remains found on the top tier of the “sculptuary”

WAS Wisconsin archaeological survey, *WHS* Wisconsin historical society, *UWM* University of Wisconsin-Madison, *LU* Lawrence University (Rudolph 2009) curated at five known locations. Locating the entire collection was made easier after Tables 1 and 2 had been assembled. From there, the repository could be traced. In one case, an undocumented loan, made decades prior, took several months of correspondence and document searching before its location was identified. Like the University of Chicago and the Moore collection, the Aztalan site had been curated at multiple locations. The separation of the skeletal and material collections across such a high number of institutions makes research challenging and sometimes impossible.

Physical Analysis

Osteological analysis of the Aztalan skeletal assemblage began with a lengthy conjoining process that was minimally useful with the exception of cranial elements. Next, all human osteological material was assessed for element identification, degree of completeness, age, sex, and pathological modification. Type, location, and quantity of cultural and natural taphonomic processes were also recorded. Results of the analysis showed patterns in deposition, processing, and taphonomic modification that provide ample evidence of interpersonal conflict (Rudolph, 2009).

Photographic Analysis

Photographs were a key resource in understanding deposition and mortuary treatment at the site as the in situ relationship of the remains to each other is only observable through photographs taken during excavation because there are no known site notes. Photographs showed that what otherwise appeared to be broken and processed remains in a museum drawer were multiple haphazard depositions. Human remains had been deposited as fragments of multiple individuals in a single pit, as whole isolated elements, and as entire articulated limbs that had been disarticulated from the rest of the body. Additionally, the use of photographs helped reestablish provenience for materials that had been separated from their original context, correct interpretive mistakes, and rearticulate individuals that had been commingled post-curation.

Methods

Photo-matching of pictures to skeletal elements was used to obtain additional information associated with the Aztalan human remains collection. A data table was designed to record the catalogue number associated with the osteological material, picture negative number, page numbers in published material if available, a digital copy of the actual photo, and any notes (Appendix B in Rudolph, 2009).

Next, over 600 photos from Barrett's excavations and from the Wisconsin Archaeological Survey excavations were examined for the presence of human skeletal material. The original photographs from Barrett's excavation were of high quality, most of them printed from glass slide negatives. Photographs from the Wisconsin Archaeological Survey excavations were printed photos of moderate quality. All photos were compared macroscopically to the physical remains. When a match was suspected, a ×10 hand lens was used to locate a minimum of two distinguishing characteristics between the picture and the specific bone. Distinguishing characteristics included fracture patterns, morphology, and pathology. There is a high level of similarity between types of morphology and between types of fracture patterns; therefore, a *minimum* of two unique characteristics were identified before a match could be made. On more than one occasion, a single trait would have led to a misidentification.

Results

Discovering the Princess

Simple methods often lead to effective results. The most important outcome of this method was the identification of the "Aztalan Princess" remains. It is unknown how she acquired this name, but it has been associated with her remains since the publication of *Ancient Aztalan* or earlier (Barrett, 1933, p. 240). The individual referred to as the Aztalan Princess is the most elaborate and publically popular individual at Aztalan. She was given an elaborate burial by those who interred her, and she is still celebrated by individuals interested in the Aztalan site. The Aztalan Princess was 20–25 years old at death and interred in a conical mound on the edge of the site. Buried supine and fully extended, she had been wrapped at the chest, hips, and lower legs in a garment made of 2,000 round and square shell beads [Barrett, 1933, pp. 241–243; MPM photo no. 60500 (Fig. 1)].

By the time of present analysis, the remains of the Aztalan Princess had become mixed between two catalogue numbers and two museum drawers. Her bones had become institutionally commingled within the depositionally commingled portion of the skeletal assemblage. This meant that identifying her remains required an advanced knowledge of osteology and the use of historical documentation.

Photos of the princess had been taken in situ (Fig. 1). Catalogue numbers and photographs were used to identify portions of the princess's remains. The skull, scapulae, humeri, ulnae, and radii were with three sets of arm bones in the drawer marked "Aztalan Queen." Photographs were used to identify which of the three sets were associated with the princess burial. Additionally, an assortment of her remains was in a bag with no catalogue number. The bones inside the bag did not have catalogue numbers either. They had been relegated to the list of "no provenience." A combination of photo-matching, articulation, morphology, and pathology allowed for the princess's remains to be rearticulated for the first time in decades.

Investigation of the Aztalan documentation file and archived museum records indicated that shortly after excavation of her remains and prior to the 1933 publication of *Ancient Aztalan,* the burial had been reconstructed and put on exhibit.

Fig. 1 In-situ photo the "Aztalan Princess." MPM photo negative no. 60500. Originally published in Barrett (1933, pp. 474–475)

The condition of the remains was too poor for exhibition, so another skeleton was used in her place. It is possible that commingling of her remains occurred at this time due to handling, although none of her remains were used for exhibit. Exhibition of the Aztalan Princess burial likely contributed to confusion about the location of her remains. Many people did not know that the individual on display was not the real princess. Professionals and causal visitors alike assumed that the princess was in a display case on the exhibit floors not still in collections storage.

The exhibit also added to the interpretive confusion surrounding the princess because the individual used in her place was a robust male which immediately provided a different visual perspective of the petite princess. For the educated eye, interpretations related to sex and gender were questioned. Exhibition designers also used the original shell beads and reconstructed the exhibit to mimic the in situ excavation photo. Although the male used in the exhibit is still available for examination, photographs of the exhibit were used to interpret the context and confusion associated with the Aztalan Princess. The exhibit was taken down in 1973 as indicated on the back of photo negative X477D, but confusion about the princess still persists.

Popularity surrounding the princess endures for many reasons. The Aztalan site has been heralded as one of the largest and most significant archaeological sites in the state of Wisconsin (Barrett, 1933; Ritzenthaler, 1958). Additionally, the relatively elaborate burial of the princess from such an important site has made her a popular topic related to Aztalan. Archaeologically, her cultural and temporal affiliation is unknown though Richards (1992) has speculated that the burial is Late Woodland because of burial location. The princess was interred nearly a quarter mile off of the main Aztalan site within one mound in a long line of conical mounds. Lines of conical mounds and other shapes overlooking waterways, such as this one, were common in the Late Woodland Effigy Mound culture (Birmingham & Eisenberg, 2000).

Alternatively, the princess may be associated with the Mississippian occupation of Aztalan. Milner (1998) observed that mounds of highly ranked Mississippian elites were placed some distance from the central focus of the site. Furthermore, the princess was buried with both freshwater and marine shell beads (Barrett, 1933). Beads of Gulf Coast Busycon and Marginella shell were often sewn into fabrics or hides of Mississippian elites (Milner, 1998). Milner graded shell beads recovered from Mississippian burial contexts by type and noted that high-, medium-, and low-grade beads were all present in burials, but that the highest grade beads were rarer and were recovered from elaborate burial contexts (Milner, 1998). The beads found with the Aztalan Princess were all of medium quality, which may be consistent with interment of an elite individual at an outpost of Cahokia.

Publically, individuals have an emotional connection to the princess. Many people would like the princess returned to her burial mound. At present, there is a non-state-park commemorative marker on the mound that she was recovered from. She is the only documented burial at Aztalan that was celebrated by the people who buried her as well as by modern peoples, most of which are of European descent. A brief search of the Internet will produce numerous and varied interpretations of the princess's burial and her role within her own culture. Many blogs reproduce the MPM exhibit photo as that of the princess (e.g., Hemp, 2013; Sutherland, n.d.). One website in particular refers to her as the "Princess/Priest King" (Sutherland, n.d.). This dual-gendered title may be a result of interpretive confusion associated with the robust male that was on exhibit as the exhibit photo is reproduced on this website. Other websites extend the lore to include friendly hauntings of the Aztalan site (e.g., Moran, 2012; Shadow State, 2013), and finally her burial mound has become a tourist attraction. RoadsideAmerica.com lists it as "the rare burial site of a princess bedecked in shell beads and atop a layer of white sand." The time-deep affection for the princess, and the lore that has become associated with her, makes the discovery and rearticulation of her remains the most important contribution this method produced.

Enhancing Interpretation

Another result of the photo-matching project is that photo-matching allowed for human elements to be put back into context. In Section II-9 of Barrett's excavation grid, Barrett found an articulated hand in what he presumed to be a baking pit. The hand in the "baking pit" is another popular topic related to human mortuary treatment at Aztalan. The combination of processed human and animal remains in the

Fig. 2 In-situ photo of human hand in "baking pit." MPM photo negative no. 60405. Originally published in Barrett (1933, pp. 452–453)

same pits at the Aztalan site led people to conclude that cannibalism had taken place (Somers, 1920). The hand in the baking pit is, to some, a specific example of cannibalism in process. The hand bones were identified via photo-matching (MPM catalogue 26957/6948, photo negative no. 60405), recovered from their storage location at MPM and rearticulated to match the photo (Fig. 2). The hand belonged to a subadult between 6 and 15 years of age. The in situ photo shows that the hand was still articulated when it was deposited. Further analysis of the hand bones revealed no burning or processing despite having been recovered from a hypothesized baking pit. The presence of a hand in a baking pit led earlier investigators to speculate about cannibalism (Barrett, 1933), saying "This, when associated with the fireplace at [feature] 8, leaves relatively little doubt as to the purpose of the pit and points very strongly to this as having been actually used as a baking pit for baking this particular hand… This further strengthens the many evidences elsewhere encountered at Aztalan of the practice of cannibalism" (Barrett, 1933, p. 114). Although the practice of cannibalism at Aztalan cannot be proven either way, it has led to years of negative speculation by people interested in the site.

Additional insight gained from matching the hand bones in the picture to the physical remains does not support the interpretation of cannibalism or heat modification at all. Interpretation is forced in a different direction. This hand could have been deposited after abandonment of the baking pit, or maybe it is not a baking pit at all. It highlights the need for better temporal control over depositional events. The subadult age associated with the hand also leads to speculation about agendas related to intergroup hostility and trophy taking.

Matching physical remains to its in situ *photo* is a relatively easy task compared to most osteological analysis, but the results are imperative to interpretation of the social behaviors that occurred prior to deposition. Photos of the Aztalan excavation show instances of complete, articulated limbs deposited with fractured and isolated skeletal elements. This indicates that human remains were processed in multiple ways and deposited in the same context. Two opposing limbs in the same context may appear in the same picture, but when the remains are matched to the photos, the opposing limbs are clearly from different individuals. When picture matching is introduced, disarticulated limbs that show no cutmarks can be interpreted as having been disarticulated prior to deposition. This is evident in photos from Aztalan of arms and legs interred with their associated scapula or os coxa but terminated at the carpals or tarsals. Conversely, other photos show articulated hands and feet isolated from the rest of the limb.

Reestablishing Provenience

The use of photographs allowed for the reestablishment of provenience information to elements with vague or no provenience. Primary burial of mostly complete individuals was rarely documented at Aztalan; only six complete burials were recovered from the midden at the site. This midden is also where the majority of the isolated and processed human remains were removed from. An example of reestablished provenience is that of an adult male. The burial is described in "Ancient Aztalan" (Barrett, 1933, pp. 143–144), but the identification within the assemblage of the skeletal remains from this burial is unclear. The catalogue book lists the provenience ambiguously as "Side of SE enclosure." Picture matching allowed for identification of this specific individual (catalogue 27250/6948, photo number 20470 and 60406) to the description in "Ancient Aztalan," thereby providing context and excavator description.

Correction of Interpretation

Interpretive information in Barrett's (1933) report can also be corrected. Barrett was an accomplished anthropologist and most of his interpretations are still supported by individuals reexamining the Aztalan collection. However, there are a few mistakes that can be corrected through photo-matching. For example, Section V, feature 23 included osteological remains underneath a potsherd. Barrett identified them as "… the fragmentary remains of an infant. Whether this was an intentional burial at this point or whether it merely represented the fragmentary remains of an infant which had suffered cannibalism, could not be definitely determined" (Barrett, 1933,

Fig. 3 In-situ photo of faunal remains under pot sherd. MPM photo negative no. 60519. Originally published in Barrett (1933, pp. 476–477)

p. 172). Reexamination of the picture revealed that that the bones are not human. Furthermore, the photo shows full epiphyseal fusion indicating that they are also not from a subadult individual (MPM photo no. 40542 (Fig. 3); Barrett, 1933). Although the osteological materials shown in the photograph were not located, the photo was used to find and match the potsherd overlying the osteological material. Using the potsherd for scale, it was determined that the bones were too small to be adult human bones and further supported an interpretation of faunal remains.

Another interpretive correction made to the report regards a human tibia modified into a hide flesher. Barrett initially identified this tibia as an elk antler dagger similar to those found amongst tribes on the North American northwest coast (Barrett, 1933; catalogue 27074/6948, MPM photo no. 70423). Close examination of the tibia revealed that it is human. It had been made into an expedient tool that was discarded when it broke (Zejdlik, in press).

Finally, two children were interred near a naturally occurring gravel knoll (catalogue 27248, 27238/40, MPM photo no. 60401): one was buried prone and facing sideways with a turtle shell on its lower legs. The other child was facing the direction opposite of the first child and had its head resting on the first child's back. Barrett estimated the ages of the children to be 10 years and 5–6 years, respectively (Barrett, 1933). Examination of mandibles and maxillae recovered from the commingled collection as a result of photo-matching showed that both of these children were 6 years old ±24 months based on dental development. The less distance between their ages may indicate that there was an additional layer of social context associated with this burial. The kinship between these two is unknown. Could these kids have been biological twins or paired in some way? Why was one child interred prone while the other child's head rested on the prone child's back? Their double interment and proximity in age pushes interpretation of this burial in new directions.

Discussion

Commingling within the context of curation is extra challenging because of the additional opportunities for commingling to occur post-recovery. The first step in working with a curated collection is identifying if it has been commingled within itself or between other collections or institutions. This requires investigation of the collection's history from excavation to present analysis. Research into the many excavations and repositories associated with the Aztalan site showed that the site had been excavated by multiple different groups of people and the materials housed at five professional institutions. Nearly half of the collection had been loaned on a "gentleman's agreement" several decades earlier and was not discovered until a thorough and detailed look at the records had taken place.

The next step in sorting out an institutionally commingled collection is to use the collection's associated documentation file. This includes site notes, photos, and any additional materials related to that collection since accession. A particularly useful resource is photos. In the Aztalan case study presented here, skeletal materials were rearticulated from the commingled remains, provenience was reestablished, and interpretations were corrected. The most successful result was the articulation and rediscovery of the Aztalan Princess, an important individual within her own culture as well as to contemporary people interested in the site. The overall outcome was increased quality of research and most importantly the ability to give back through increasing the research value of a legacy collection.

Photographs can also be useful for identification of taphonomic processes potentially affecting a collection. The background of photographs is important. It can show that burials were exposed to the sun or sitting in a wet hole. It might indicate a rodent run or use of metal tools in excavating human remains. Both processes can produce a pattern that resembles cutmarks to an untrained eye. Osteological analysis of burial 6 at Aztalan showed that the right radius and ulna were missing in an otherwise nearly complete skeleton. Examination of the in situ photo revealed that a post had been placed directly over the radius and ulna, leaving the right humerus and all of the hand bones in place. The photograph showed why the forearm bones were missing. It also indicates two temporally different uses of the site and suggests that a female, who was buried headless, was interred early enough in the occupation sequence that the location of her burial had been forgotten. Alternatively, the location of her burial had been remembered and the post was intentionally placed to destroy her arm. The additional social context information provides a richer interpretation of behavior at the site and was only available through matching of the photo with the burial.

Use of the Aztalan photographs was not limited to osteological analysis. Over 500 photographs were taken of the Aztalan excavation during Barrett's time at the site. Many more were taken during subsequent excavations by other institutions. Barrett's photographs provide site documentation more thorough than typical excavation photos. In addition to archaeology photos, he took pictures of artifact analysis, large groups that visited the site, the surrounding landscape, the living conditions of the crew, and leisure time. His photo documentary paints a picture of how an excavation was conducted in the early twentieth century. Details in these photos indicate fashion and social class, recreation activities, methods in excavation and analysis, environmental conditions, old fence lines, and trash areas. Examination of these photos was useful for the most recent excavation of the Aztalan site by the University of Wisconsin-Milwaukee in 2011. Looking at old photos provided a perspective of the site landscape very different from the present one. Much of the work for the 2011 field project involved working from maps created by Barrett during his original project. Through his extensive photo documentation of the site, Aztalan and its surroundings could be seen through his eyes.

The wide application of photographs in research at Aztalan demonstrates the use of this method for a variety of research questions. It can be used for identification, reconstruction, and organization of ceramics, lithics, and other types of easily disturbed material culture. Material culture has a greater potential for being temporally and culturally diagnostic. Reconstruction of features and associations through photo-matching of diagnostic materials can provide additional information about site use, space, and changes over time.

Conclusion

Commingled remains are methodologically and interpretively challenging. Human remains commingled post-excavation are exposed to different types and levels of commingling not encountered in a typical field or lab analysis. The importance and increasing use of skeletal collections demonstrates that these are valuable resources for obtaining new knowledge. It also provides additional opportunity for institutional commingling. Although sorting out commingled collections can be time consuming, it is a process that increases the research value of a collection and gives back to the community. Unmingling a commingled collection begins with an investigation of the collection's history. Next, site-associated documentation provides tools for additional sorting of the collection. Photographs are especially useful as they provide abundant information related to burial contents, environmental context, excavation method, and possibly analysis or curation. The photo-matching method discussed is simple but produced important results. The simplicity of the method means that it can be applied to a wide range of materials from osteology to lithics and from the lab to active field excavations. It is an inexpensive, easy, and resourceful method that can profoundly enhance interpretation so should be used whenever possible.

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Primary and Secondary Burials with Commingled Remains from Archaeological Contexts in Cyprus, Greece, and Turkey

Sherry C. Fox and Kathryn Marklein

Introduction

Commingling or mixing of human skeletal remains can take place at any stage from burial to excavation to storage of human skeletal remains and even beyond.[1] What will be presented herein are four examples of commingling or speculative commingling from sites in the Eastern Mediterranean ranging in date from the Hellenistic to the Late Byzantine periods (Fig. 1). The first site addressed, Late Roman/Early Christian Kalavasos-*Kopetra*, Cyprus, presents human remains initially interpreted as commingled following secondary burial practice. The second case discusses skeletal remains commingled from secondary burial rites at the Hellenistic and Roman sites of Paphos, Cyprus, and Corinth, Greece. The third example contains the commingled remnants of primary burials from two Late Byzantine graves at Thebes in Greece. The final study presents skeletal remains that were commingled during the excavation and exhumation of a Roman period mass grave primary burial at the site of Oymaağaç Höyük (ancient Nerik) in Turkey. Lastly, a developing methodology is proposed to maximize what can be gained from the study of commingled human skeletal remains.

This chapter ultimately focuses on a methodology conceived in Fox's dissertation research on commingled remains, *A comparative study of health based upon*

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[1] The authors thank the organizers of the SAA session from which this volume was inspired, in particular, Anna Osterholtz.

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_11,

Fig. 1 Map of Eastern Mediterranean and Black Sea with study locations highlighted: (**a**) Thebes; (**b**) Corinth; (**c**) Paphos; (**d**) Kalavasos-*Kopetra*; and (**e**) Oymaağaç Höyük

the human skeletal material from Hellenistic and Roman tombs from Paphos, Cyprus and Corinth, Greece (Fox, 2005; Fox Leonard, 1997), and greatly expanded by Marklein's efforts with recent work by the authors at Oymaağaç Höyük, Turkey.

The Commingled State of Eastern Mediterranean Bioarchaeology

Although populations are the preferred units of study in bioarchaeology, individuals characterize and define these populations. Aside from human actions, diagenesis can transform articulated individual burials into elemental components. Articulated whole skeletons can be analyzed by bioarchaeologists using relatively straightforward and time-tested methods. The state and context of these remains enable a complete, systematic analysis of the individual. In contrast, commingled remains may require considerably more time to study and yield more limited results than discrete burials from primary inhumation burials.

The unit of study among commingled human remains is not the individual per se but the skeletal element. This inevitability, however, should not preclude bioarchaeologists from devoting equivalent attention and time to commingled remains as to discrete individuals: much information can be gained from the study of commingled remains, such as demographic parameters of sex, age, and (reconstructed) statures, as well as skeletal indicators of disease and trauma. The following case studies first emphasize past and present anthropogenic factors affecting depositional and post-depositional commingling and secondly advocate paleoepidemiological studies of skeletal remains.

Because secondary burial and concomitant commingling are the norm rather than the exception in Cyprus and Greece, one would expect a wealth of information for commingling practices. The earliest case of commingling on Cyprus comes from a well dating to the Pre-pottery Neolithic B site of Kissonerga-Mylouthkia. Secondary burial and subsequent commingling also extend to the Chalcolithic period in the Paphos District of Cyprus from the site of Prastio-AgiosSavvas tis Karonis Monastery (Fox, 2005). Ubelaker and Rife (2008) present an excellent case for the preservation and study of commingled remains, notably cremated remains, at the Roman period cemetery of Kenchreai in Corinth. Unfortunately, their discussion mentions neither contemporaneous sites with commingling nor modern burial practices associated with commingled remains in the Corinthia of Greece. Overall, in Eastern Mediterranean bioarchaeology there appears to be an overarching lack of methodology, study, and publication on commingled remains.

Historical Contextualization of Commingled Burials

Modern and ancient history indicate that commingling is a conventional practice within the Eastern Mediterranean landscape, currently evidenced in the secondary burial practices within Greece and Cyprus that continue today as part of Greek Orthodox tradition (Danforth, 1982). Instances of commingled remains pervade the archaeological mortuary record geographically and diachronically from Iron Age Crete (Liston, 1993) to modern-day Arcadia (Danforth, 1982). Multiple interment tombs generally denote family affiliations, although small communities in Cyprus reportedly maintained village tombs into the modern era (A. Moustoukki, personal communication). Recent dental morphological and morphometric analyses of individuals within the Neolithic house burials at Çatalhöyük, for example, challenge speculations of a biologically associated kin group burial tradition (Pilloud & Larsen, 2011). In Roman times, burial clubs were known, somewhat akin to our modern military cemeteries (Fox Leonard, 1997). The Greek Orthodoxy tradition believes that the soul is released from the body when deposition leaves bones devoid of flesh. The remnant skeletal elements no longer represent the individual but represent the collective bones of ancestors (Danforth, 1982).

In present-day rural Greece, tombs are rented 4–7 years, allowing for decomposition to take place before the interment of another family member (Danforth, 1982). However, in actual practice (e.g., population-dense Athens), the demand for tombs is great, and the inter-burial interval may be only 3 years, with decomposition often incomplete upon exhumation (Liston 2012, personal communication). Subsequently, the body is redeposited into another grave outside the tomb later to be exhumed. Following decomposition, a secondary burial rite takes place prior to primary interment of the newly deceased. The bones of the previous individual are collected and repositioned to one side of the tomb or removed to an ossuary (Danforth, 1982).

Human skeletal remains oftentimes become commingled over time and with consistent tomb reuse. Such commingling has been documented up to 300 years, as is the case of Tomb 1 the site of Toumba tou Skourou (Vermeule, 1974).

Current debates in mortuary archaeology consider whether secondary burial practices follow similarly prescribed patterns over time. In the Neolithic burials at Ayios Charalambos, Crete, the depositional and postdecompositional recovery tradition presupposes the modern Greek ritual (Cholouveraki et al., 2008): long bones are "stacked" with crania positioned atop the long bones. This practice supposedly spanned time and sea, as evidenced in Chalcolithic burials at Souskiou-*Laona*, Cyprus (Crewe, Lorentz, Peltenburg, & Spanou, 2005). In early excavations around the Eastern Mediterranean, archaeologists initially espoused the hypothesis that secondary burial conveyed no intentionality and bones were simply haphazardly deposited within their final burial contexts. Archaeology in its present state employs an interdisciplinary approach, wherein bioarchaeologists play a crucial role in either the confirmation or denial of intentional secondary burial practices.

Kalavasos*-Kopetra*, Cyprus

The first presented example of commingling comes from the Early Christian (fifth to mid-seventh century) site of Kalavasos-Kopetra, a monastic complex comprising three basilicas, which was excavated by Murray McClellan formerly of Emory University and Marcus Rautman of the University of Missouri from 1988 to 1991 (Rautman, 2003). A preliminary study of the human remains from the site has been published since (Fox, 2005), and Kalavasos-*Kopetra* is included in a study of both Early Christian burial customs and comparative trauma (Fox, Moutafi, Prevedorou, & Pilides, 2012, 2014, respectively). Tomb 1 from *Sirmata* (Area One at Kalavasos-*Kopetra*) is one of two tombs within the basilica crypt. This tomb is oriented in a north–south direction and was excavated architecturally in 1988. The gypsum slab-built tomb was divided into quadrants upon excavation.

Preliminary analysis categorized the grave as an ossuary. As the bones were removed, they were placed in labeled boxes designated by their position in the tomb: northeast, northwest, southeast, and southwest. Study of the remains commenced the following year. Upon material inventory, it was observed that only upper body bones were represented within the northern two quadrants and only lower body bones from the southern two quadrants (Fox, 2005). A photograph of the tomb taken during excavation showed discrete, articulated remains, thereby disaffirming any previous observations that classified the grave as an ossuary.

Rather than an ossuary, the burial contained primary inhumations: four adult males extended in north–south orientation with their heads to the north. Postdepositional movement of skeletal elements undoubtedly took place from seasonal rainwater infiltration into the tomb. Spatial analysis, as elaborated by Tuller, Hofmeister, and Daley (2008), helped with the reinterpretation of this burial place. Had the tomb not been subdivided prior to excavation and removal of the human bones, this tomb would continually have been interpreted as an ossuary. Since the individuals were not exhumed intact, the remains, in essence, had become as commingled ex situ as would befit an in situ ossuary. Taphonomic conditions and

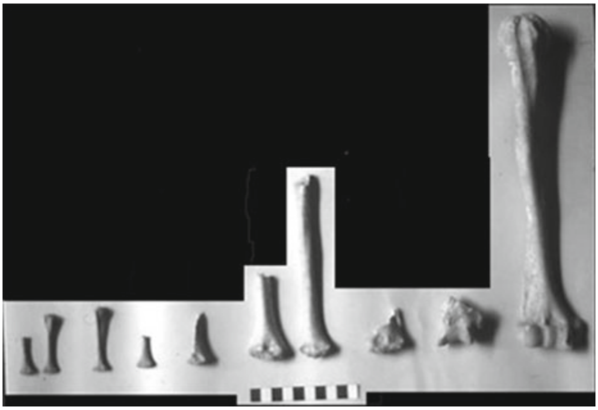

Fig. 2 Fragmentary and complete humeri from two perinatal individuals (*left*) compared with subadult and adult humeral remains

multiple reuse of the tomb may have contributed to the confusion. Unfortunately, the absence of a bioarchaeologist in the field at the time of excavation and removal has forever limited analyses of these human remains.

Alkaline soil conditions compounded by the alternating hot dry summers and cold wet winters contributed to the relatively poor state of human bone preservation at the site. Angel (1945)reported this situation for Attica in Greece, which has since been suggested elsewhere for Cyprus (cf. Harper & Fox, 2008). Certain microenvironments provide a more stable environment and ultimately better bone preservation. Such was the case within the cistern at the Sirmata locality of Kalavasos-Kopetra where originally the excavator characterized the bones as nonhuman, specifically ovicaprid. Fox (2005) was able to observe articulated human remains in situ prior to the completion of its excavation.

Although there were faunal remains recovered from this feature, the cistern was not determined to be a repository for secondary burial of human remains. Instead these remains represented a minimum of nine haphazardly deposited individuals of various ages at death who had likely been thrown into the cistern. Burial in a cistern does not constitute a normal practice for this period. Not only does this practice foul and contaminate the water supply for the monastery, but it suggests that some local catastrophe may have taken place.

However, the catastrophic circumstances leading to this mass burial deposition still remain unknown. Many of the individuals still can be partially segregated by age-at-death, for example, the two individuals of late gestational age depicted in Fig. 2. Further analysis of this material in a laboratory setting is necessary to elucidate what transpired, though plague and Arab incursions of the mid-seventh century present possible explanations for this unusual deposit. Currently known of this site is the change in settlement pattern occurring after the mid-seventh century CE, concurrent with people moving settlements from coastal Late Roman/Early Christian villages inland, with a few exceptions.

Nea Paphos, Cyprus, and Ancient Corinth, Greece

Two large cemeteries in Nea Paphos, Cyprus, date to the Hellenistic and Roman periods. The northern cemetery, known as "The Tombs of the Kings," is an elaborately constructed cemetery, with architecture strongly paralleling cemeteries from ancient Alexandria, Egypt. Although the human remains from this cemetery were not saved, it is speculated that "The Tombs of the Kings" was reserved for the social elites from the city. In contrast, the Eastern Necropolis of Nea Paphos, the largest ancient cemetery known on the island, contains hundreds of tombs which housed the dead from the nonelites. Demetrios Michaelides, former Paphos District Archaeological Officer, was able to establish a moratorium on construction for a year while this cemetery was excavated (Michaelides & Mlynarczyk, 1988). At this time, tourist hotels were being constructed over this cemetery. One of the larger tombs contained a minimum number of 82 individuals from a single tomb.

Study of the human skeletal remains from 31 rock-cut chamber tombs from the Eastern Necropolis led to a methodology for rather poorly preserved, commingled material. Pathological lesions among the minimal 275 individuals from the Eastern Necropolis were ascertained on an elemental, bone-by-bone basis. Data collection forms were developed for the long bones and crania.

The"surgeon's tomb" at Nea Paphos, one of the best-preserved Roman period tombs (Michaelides & Mlynarczyk, 1988), contained minimally 44 individuals. Although the "surgeon" may have been among one of the earliest to have been interred in the tomb, Michaelides reported that a number of individuals were interred during the mid-second century CE, and these remains had become commingled. For this reason, the identity of the speculative surgeon may never be known from the human remains.

The surgeon's tomb provides a microcosmic representation of the entire cemetery. Health profiles constructed from the commingled bones and fragments align with the discrete burials among the Nea Paphos cemeteries. Among these comparisons are the types and prevalence of pathological lesions, which display similarly between the tomb and site as a whole. For example, porotic hyperostosis has been found among individuals from the tomb and cemeteries at Paphos (Fox, 2005), but not among contemporaneous commingled remains from ancient mainland Greece, at Ancient Corinth.

Whatever the cause of the porotic hyperostosis at Paphos, differential diagnosis did not rule out vitamin B12 deficiency, folic acid deficiency, the congenital hemolytic anemias such as beta-thalassemia, or an acquired anemia, or even malaria, as contributing factors in their production (cf. Walker, Bathurst, Richman, Gjerdrum, & Andrushko, 2009). Additionally, a statistical correlation was found between two nonmetric traits, septal apertures of the humerus and tibial squatting facets, at Paphos, which were not found at ancient Corinth (Fox forthcoming). Fox speculates that women at Paphos were engaged in habitual or occupationally related postures that required constant squatting. Among many occupationally related activities, ethnoarchaeological information suggests weaving on ground looms as a potential explanation for these skeletal changes. These examples demonstrate the insight that can nevertheless be gained into the past ways of life from relatively poorly preserved, commingled remains.

Ancient Thebes, Greece

The third example provided is from two graves dating to the Late Byzantine period from the site of ancient Thebes in Greece. The site is currently under excavation by a joint project sponsored by Kevin Daly and Stephanie Larsen of Bucknell University and the Ministry of Culture of Greece.[2] There was evidence that at least one grave had been disturbed prior to excavation during the 2011 field season. Not a single intact long bone was recovered nor a single complete cranium from either tomb. The bones found within the tombs were commingled and comprised primarily of bones of the hands and feet. Preliminary field analysis of one tomb indicated minimally six individuals of various ages at death, based upon duplication of the calcaneus. These bones represent the remnants from primary burials after ritualized exhumation, removal, and transference of elements to an ossuary (cf. Ubelaker & Rife, 2008). During this secondary burial practice, the long bones and crania and larger bones were likely removed and the small bones left behind. Analysis of this material is ongoing in the Wiener Laboratory of the American School of Classical Studies at Athens.

Oymaağaç Höyük, Turkey

The final example of commingling involves a Roman mass grave (7384:009) from the Hittite site of Oymaağaç Höyük, Turkey. The site of Oymaağaç is located approximately 48 km south of the Black Sea and 75 km southwest of Samsun, within the western half of the Pontus expanse (Fig. 3). Under the aegis of the Turkish Ministry of Culture, initial surveys of the Samsun/Vezirkopru Province commenced on September 11, 2005. The project has been codirected by Jörg Klinger and Rainer Czichon of the Freie Universität in Berlin since 2007 and employs a cohesive, multidisciplinary methodological approach to excavation, analysis, and documentation. Oymaağaç, and specifically the nearby Höyük, has been proposed as the location of the ancient city of Nerik, the focal cult center for regional Hittite kings since the Middle Bronze Age (2000–1600 BCE). Archaeological investigations aim to illuminate the history of this putative city from its floruit in the Bronze Age to its gradual decline during the Roman period, when the regional focus shifted to the nearby city of Neapolis (Vezirkopru).

During the 2010 and 2011 field seasons, a reevaluation of the excavated humans remains from Quadrant 7384-Locus 009 was undertaken by Fox and Marklein. The skeletal material under consideration in this section was recovered during the 2008 season from a quadrangular (2.10 m length by 80 cm—southwest width and 90 cm—northeast width) stone-built, wall-plastered cist grave dated upon excavation to the Roman–Hellenistic period. Photographic documentation of the grave revealed a mass burial of primary inhumations wherein individuals were laid

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[2] The 2011 field season was codirected by Vasilis Aravantinos, who is now codirecting the project.

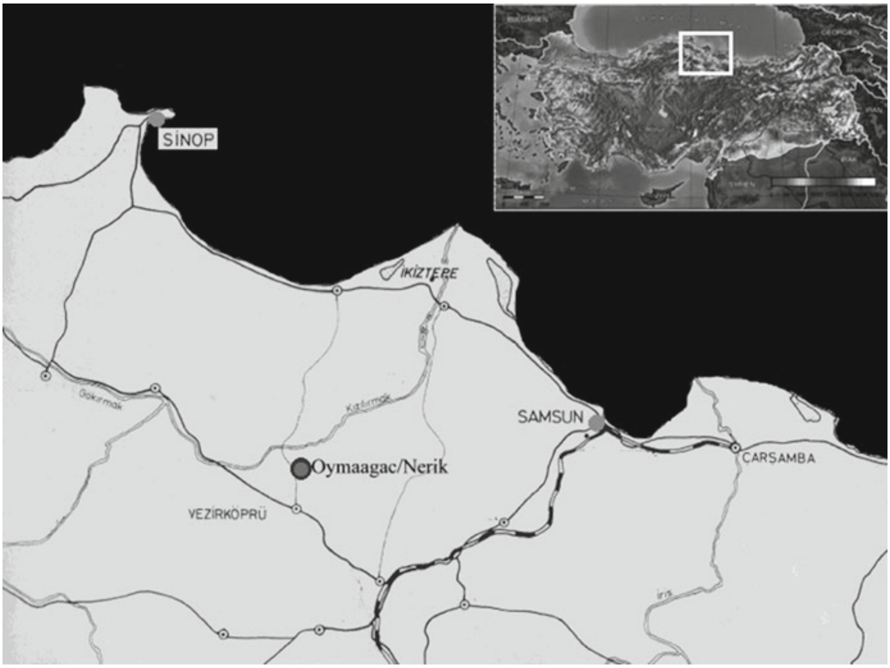


Fig. 3 Oymaağaç Höyük, Turkey

between two and four persons abreast in a consistently north-southwest orientation (Fig. 4). Exposure and recovery, furthermore, yielded a general scarcity of interred grave objects: an earring and ceramic plug (Czichon, 2007). The excavators initially assumed that over 40 individuals were represented within the mass grave, but the minimum number of individuals from the new database, based upon duplication of right calcanei (adults) and left humeri (subadults), count only 21. Individuals of all ages and both sexes were represented within the mass grave, including 14 adults and 7 subadults. Additionally, it appears that children were placed first within the mass grave, as they were removed last from the grave.

Pre- and Post-recovery Skeletal Assemblage

Despite the discrete postdepositional nature of these skeletons in situ, the bones were exhumed systematically according to anatomical region (e.g., leg, forearm), resulting in de-individualization of the remains and de-contexualization of the burial. Without the microscopic and biomolecular facilities to determine associative bone relations, Fox and Marklein endeavored “re-individualization” of remains by means of macroscopic and morphometric observations. Employing original field

Fig. 4 Roman period mass grave 7384.009 prior to exhumation of skeletal material (photo by H. Marquardt, with permission from Oymaağaç-Nerik Projekt)

reports and photographic records to identify complete skeletons, a referential minimum number of individuals were established: 12 adults. However, a preliminary assessment of the 30 bags of skeletal material indicated single-sided elemental counts beyond the expected 12 individuals. Additionally, unfused epiphyses and deciduous dentition signaled the presence of subadults within the grave which had been previously undocumented. After a consensus was reached that the discrete individuals could not be fully reconstructed, efforts were redirected toward the specific bones and diagnostic bone fragments and the subsequent information that could be gleaned from their exhaustive study.

Constructing a Commingled Methodology

When the analytical focus on individual persons was replaced by extensive and intensive evaluation of diagnostic skeletal elements, the research implications for population studies were soon realized. A contextualized and well-preserved skeletal assemblage remains the desired standard for bioarchaeological inquiry. However, direct and indirect effects of natural diagenesis and human interaction inevitably yield skeletal samples that are not wholly representative of the original interments or the entire population (Chamberlain, 2006; Waldron, 2007). By emphasizing discrete bones, this study does not equate the information obtained from one long bone with the related composite of bones from a single individual skeleton. The latter composite is always preferred as it definitively illustrates the integrative, systemic processes in action within the body.

Current standards for human skeletal remains (Bass, 1987; Buikstra & Ubelaker, 1994) concentrate on complete, or relatively complete, skeletons. The most efficacious methodology when approaching commingled remains has generally entailed the classification of elements according to side, sex, age, preservation, and MNI. Recent works in paleodemographic statistics, utilizing practices from zooarchaeological methodologies such as the Lincoln Index (Adams & Konigsberg, 2004; Winder, 1992), have sought to minimize the confounding factors that distort population profile reconstructions. While these fundamental data provide biological anthropologists with a precise paleodemographic profile of the sample (age and sex distributive patterns), demographic studies are oftentimes terminal, precluding further paleopathological and paleoepidemiological investigations (Adams & Byrd, 2008, p. v).

However, the disassociation of bones from complete skeletons should not prevent comparative studies of elements. The accuracy of population health and physiological profiles increases when equal representation of disassociated and articulated elements occurs in statistical analyses (Waldron, 2007). All of the nearly 3,000 commingled elements from Grave 7384:009 were thusly inventoried, analyzed, and labeled.

Each diagnosable bone or fragment received a unique collection number according to its specific quadrant, locus, and find number. For example, the left capitate of an adult of indeterminate sex was the 2974th bone analyzed from the grave (7384:009). As the capitate was also recorded within the find context 9, the full collection sequence for this element is 7384:009:009:2974. Similarly, the right tibial diaphysis of a juvenile, the 1739th bone from the 7384:009 grave, associated with find context 24 is recorded as 7384:009:024:1739. In total, 2986 elements were identified within the Roman grave in question and assigned collection number sequences in accordance with their burial context. These labels allow individual bones to be compared within and between quadrants, loci, finds, and elements. The first three context numbers facilitate spatial intra-grave (find and locus) and inter-grave (quadrant) distributive analyses. Additionally, these context numbers impart exact and relative chronologies upon associative skeletal remains, enabling diachronic and synchronic studies of the elemental collection.

The elemental number may exist independently from a discrete skeleton or interdependently within an individual skeleton, for example, a right lunate (7384:009:018:1602) exists outside of an individual skeleton while a right lunate (7384:009:018:1601) and scaphoid (7384:009:018:1599) articulate as components of one adult individual's hand. By allowing this dual applicability, interpreting skeletal elements apart from an individual skeleton or as part of an individual skeleton, this database is not exclusive to commingled material. In fact, since this methodology originates at the base level of the bone, this approach facilitates research between discrete and commingled burials.

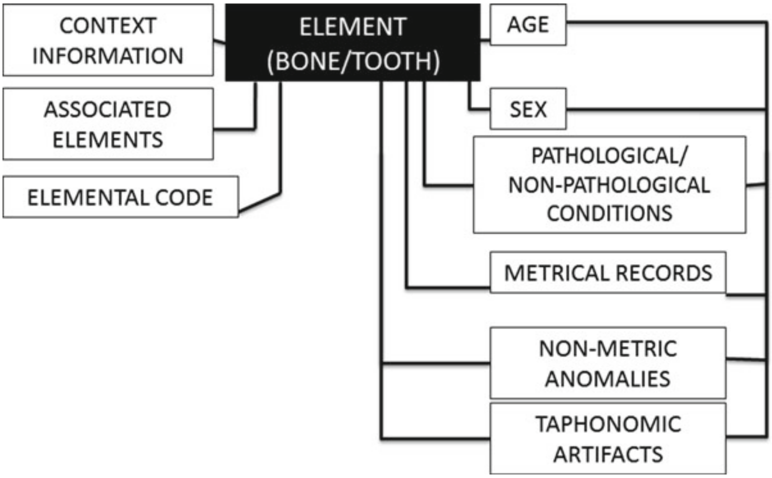


Fig. 5 Schematic representation of database coding system. Overall context and content of skeletal elements are linked with demographic, metrical/non-metrical, and pathological data

As a primary reference, the standards for documentation of commingled remains (Buikstra & Ubelaker, 1994) provided the foundational observations for each individual element: bone, side, completeness, age, and sex. To this base were added bone context and bone content observations (Fig. 5). The first component (context) addresses the burial environment, incorporating spatial, chronological, and artifactual details. Despite the disparate arrangement of the remains, there was some success correlating bones to distinct individuals. If the bone was linked to other bones (attributable to one minimum person), these connections were recorded. Unfortunately, the stratigraphic layers of skeletons were not readily visible from photographs, and these stratigraphic delineations were not maintained through the recovery practices.

The historically undisturbed nature of the mass grave places the time-of-death for these individuals within a relatively close time frame, but the exact succession of individuals into the grave was lost with excavation. Contextual finds dated this grave to the Roman period. This conclusion was then supplemented and supported by radiocarbon dating techniques; a 2.2-g sample from an adult right radius was prepared and tested at the University of Arizona AMS laboratory, positing the burial between 180 and 230 CE. The general dearth of artifacts within 7384:009 removed any issues assigning grave goods and bones.

In addition to the contextual data attributed to each bone, the bone itself provides a compelling narrative about the physical history of the individual. Although a bone or fragment may not be fully associated with an individual or multiple skeletal elements from a single individual, the information from this osseous remnant, nonetheless, exhibits a small fraction of the population profile. The current standards outline recording objectives for commingled, disparate remains/bones: elemental name, side, segment, completeness, MNI, count/weight, age, and sex (Buikstra & Ubelaker, 1994). Despite the demographic implications and interpretations generable from these observations, no means for quantifying pathological lesions and non-pathological bony responses have been standardized for biological anthropologists. For recording procedures utilized on the Oymaağaç assemblage, addenda to this initial standardized list included bony pathological manifestations, non-pathological osseous reactions, metric recordings (including stature estimates), nonmetric anomalies, and taphonomic artifacts.

Pathological diagnoses, though variable across time and geography, were categorized as joint diseases, infectious diseases, metabolic diseases, dental diseases, trauma, tumors, and atypical skeletal growth and development (Waldron, 2009). One of the issues surrounding paleopathological theory is the application of a standardized methodology to skeletal analyses (Ubelaker, 1998, p. 178). Multivariate environmental and sociobiological factors determine the occurrence and virulence of diseases throughout peoples and populations, thereby resulting in variable manifestations of conditions (Roberts & Buikstra, 2003). Unfortunately, paleopathological studies often resign to florid descriptions. While florid descriptions are preferable to binary "present"–"not present" records, intra- and interpopulation paleoepidemiological reviews expect and demand some standardization in disease manifestations over the course of the disease's [human-associated] history.

In line with the extensive work being conducted through The Ohio State University and "Global History of Health Project" (Steckel, Larsen, Sciulli, & Walker, 2005; Steckel, Rose, Larsen, & Walker, 2002), Fox and Marklein similarly established pathognomonic criteria for pathological conditions (Aufderheide & Rodriguez-Martin, 1998; Ortner, 2003; Steckel et al., 2005; Waldron, 2009). However, the observations that led to these diagnoses were descriptively documented in order to assess variability in bony manifestations. For example, osteoarthritis was determined by either the presence of eburnation or the combination of two skeletal phenomena: marginal osteophytes, alteration of the joint shape, new bone growth on the surface, and joint surface pitting (Waldron, 2009, p. 34). If the joint of a bone or fragment exhibited these characteristics, a diagnosis of osteoarthritis was made, yet these characteristics were maintained for the record for further investigations into the disease's etiologies and pathophysiology.

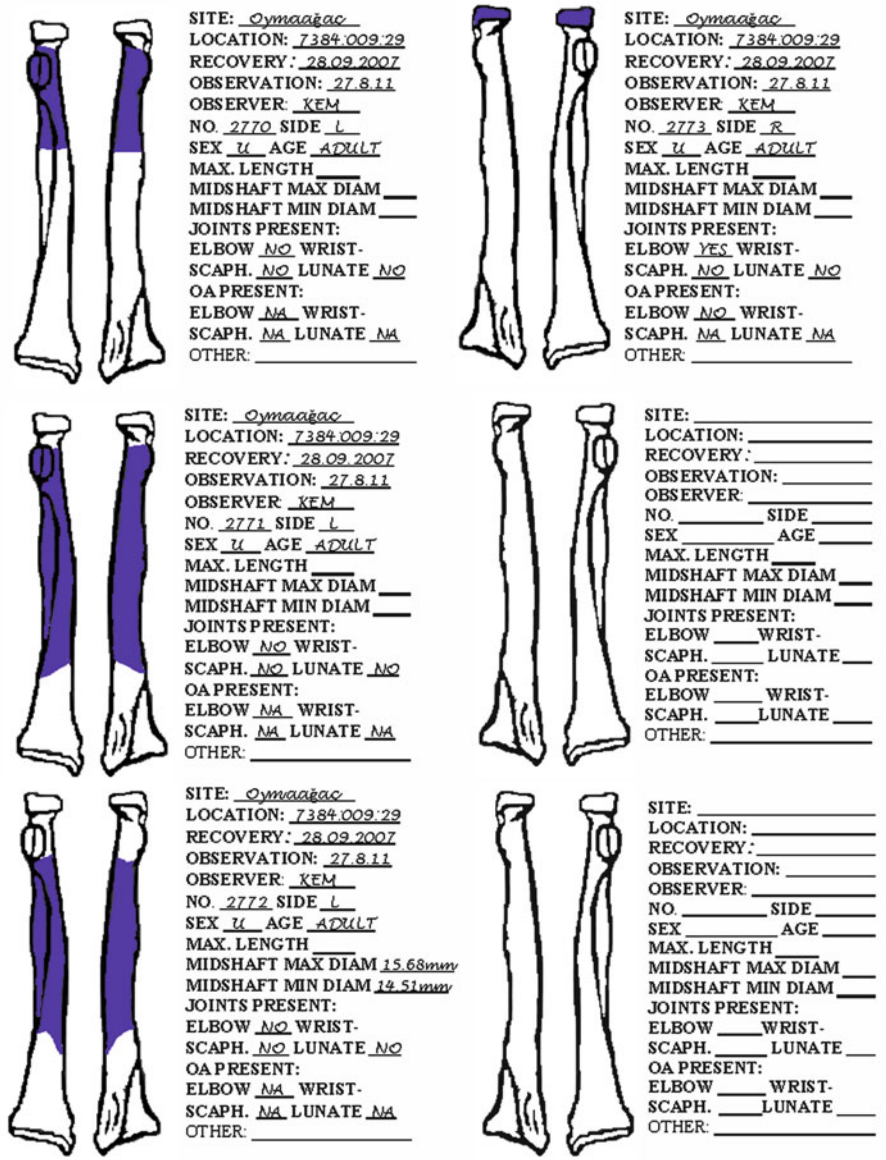
However, an inherent effect of commingled assemblages and the de-individualization of remains is the limitation of diagnostic accuracy. Without associative elements, a bone expressing reactive skeletal tissue cannot be indisputably correlated with a systemic condition. Until the other associative elements are recognized as concomitant to an individual, pathological lesions will remain generalized for a commingled collection. The ratio of non-pathological to pathological conditions within the de-individualized samples may be, as a presently irreconcilable reality, higher than the actual prevalence.

Inferences about past pathogenic and pathological events can also be determined through metric observations. Cueing from the *standards*, longitudinal and transverse measurements were taken for long bones, while the distances between osteometric points were determined for intact crania. Additional metrics (e.g., subadult metaphyseal breadths) were recorded in the database. As metric analyses, notably in forensic anthropological studies (e.g. Black & Ferguson, 2011), are producing results that continuously reformat understandings of genetic and epigenetic factors in development, the authors acknowledge the preliminary incompleteness of metric standards. With the expansion of the database, more metric data will gradually be incorporated. As with certain pathological lesions allowing for certain reassociation of skeletal elements, it is furthermore anticipated that metric data will reunite once individual-associated, now disparate, elements.

While nonmetric, discontinuous skeletal traits on discrete bones and fragments may link commingled elements to one individual, these traits frequently link multiple individuals to a biogeographical unit (Brothwell, 1981, p. 90). Cranial (e.g., metopic suture, extrasutural bones) and postcranial (e.g., os tibiale externum) skeletal variations that are asymptomatic or largely quiescent during life provide macroscopic starting points for research into genetic affiliations and family groups. The latter variation, os tibiale externum, will be evaluated in relation to the Oymaağaç population and database.

Finally, pre- and postdepositional structural alterations to the bone have been incorporated into the essential observations. Taphonomic patterns, foremost, may help with reassigning bones to discrete individuals. From death and past excavation, the body is subjected to myriad natural and human diagenetic influences (White & Folkens, 2005). These data also reveal the final stage of an individual's physiological life history (Stodder, 2008), the stage wherein self-agency is no longer a factor in skeletal changes. Therefore, in undisturbed or contextualized assemblages, mortuary practices can be extrapolated from the living population's treatment or disregard of their dead. From a perspective of preservation, information can provide precise results about the resilience of certain elements to burial conditions. The forms (Fig. 6) developed for the metric records of long bones provide additional visual representations of elemental preservation. This information not only adds to the growing taphonomic literature (Djuric, Djukic, Milovanovic, Janovic, & Milenkovic, 2011) but constructs an expected preservation distribution to which future recovered remains can be compared and contrasted. For example, if a high percentage (relative to the MNI count) of vertebrae survive within a cemetery, deviations from this distribution may indicate differences in vertebral preservation or reflect purposeful mortuary traditions.

The previous section dissects the methodological framework and justification of a developing database designed for accommodating data from individual and commingled human skeletal remains. Such preliminary procedures for observing and recording hope to maximize the interpretative potentialities from otherwise problematic commingled remains. The four-component coding system allows for associations between bones (on a comparative, elemental level), between bones and artifacts, within graves, and across quadrants. The data can then be viewed spatially and temporally according to age, sex, metric and nonmetric measures, pathological lesions, nonspecific bone anomalies, and taphonomic characteristics.



SITE: Oymaağaç
LOCATION: 7384:009:29
RECOVERY: 28.09.2007
OBSERVATION: 27.8.11
OBSERVER: KEM
NO. 2770 SIDE L
SEX U AGE ADULT
MAX. LENGTH ____
MIDSHAFT MAX DIAM ____
MIDSHAFT MIN DIAM ____
JOINTS PRESENT:
ELBOW NO WRIST-
SCAPH. NO LUNATE NO
OA PRESENT:
ELBOW NA WRIST-
SCAPH. NA LUNATE NA
OTHER: ____

SITE: Oymaağaç
LOCATION: 7384:009:29
RECOVERY: 28.09.2007
OBSERVATION: 27.8.11
OBSERVER: KEM
NO. 2773 SIDE R
SEX U AGE ADULT
MAX. LENGTH ____
MIDSHAFT MAX DIAM ____
MIDSHAFT MIN DIAM ____
JOINTS PRESENT:
ELBOW YES WRIST-
SCAPH. NO LUNATE NO
OA PRESENT:
ELBOW NO WRIST-
SCAPH. NA LUNATE NA
OTHER: ____

SITE: Oymaağaç
LOCATION: 7384:009:29
RECOVERY: 28.09.2007
OBSERVATION: 27.8.11
OBSERVER: KEM
NO. 2771 SIDE L
SEX U AGE ADULT
MAX. LENGTH ____
MIDSHAFT MAX DIAM ____
MIDSHAFT MIN DIAM ____
JOINTS PRESENT:
ELBOW NO WRIST-
SCAPH. NO LUNATE NO
OA PRESENT:
ELBOW NA WRIST-
SCAPH. NA LUNATE NA
OTHER: ____

SITE: ____
LOCATION: ____
RECOVERY: ____
OBSERVATION: ____
OBSERVER: ____
NO. ____ SIDE ____
SEX ____ AGE ____
MAX. LENGTH ____
MIDSHAFT MAX DIAM ____
MIDSHAFT MIN DIAM ____
JOINTS PRESENT:
ELBOW ____ WRIST-
SCAPH. ____ LUNATE ____
OA PRESENT:
ELBOW ____ WRIST-
SCAPH. ____ LUNATE ____
OTHER: ____

SITE: Oymaağaç
LOCATION: 7384:009:29
RECOVERY: 28.09.2007
OBSERVATION: 27.8.11
OBSERVER: KEM
NO. 2772 SIDE L
SEX U AGE ADULT
MAX. LENGTH ____
MIDSHAFT MAX DIAM 15.68mm
MIDSHAFT MIN DIAM 14.51mm
JOINTS PRESENT:
ELBOW NO WRIST-
SCAPH. NO LUNATE NO
OA PRESENT:
ELBOW NA WRIST-
SCAPH. NA LUNATE NA
OTHER: ____

SITE: ____
LOCATION: ____
RECOVERY: ____
OBSERVATION: ____
OBSERVER: ____
NO. ____ SIDE ____
SEX ____ AGE ____
MAX. LENGTH ____
MIDSHAFT MAX DIAM ____
MIDSHAFT MIN DIAM ____
JOINTS PRESENT:
ELBOW ____ WRIST-
SCAPH. ____ LUNATE ____
OA PRESENT:
ELBOW ____ WRIST-
SCAPH. ____ LUNATE ____
OTHER: ____

Fig. 6 Sample recording form for radial metrical and non-metrical observations

Application of the Proposed Commingled Database: Prevalence of *os tibiale externum* and Osteoarthritis

In order to evaluate the effectiveness of our database, a brief case study was conducted to calculate the prevalence of a congenital foot condition, *os tibiale externum* (OTE), discovered within grave 7384:009. Briefly, OTE, or os naviculare, presents an accessory bone medial to the navicular. Although three types have been identified in clinical literature, the occurrence of OTE within the Roman grave sample was exclusively Type II (Fig. 7), wherein the accessory bone is connected to the navicular through a cartilaginous bridge; this bridge often ossifies to become the Type III variant (Offenbecker & Case, 2012, p. 159), but no such occurrences were detected in the grave assemblage.

During the analysis of the skeletal remains, the Fox and Marklein observed five (3 left, 2 right) cases of OTE from a total of 17 (10 left, 7 right) adult naviculars and an MNI adult count of 13 individuals. These specimens were found disassociated from individuals, so the sexes were indeterminate and the age limited to an adult classification. However, the available data allowed the researchers to determine a minimum prevalence of individuals affected with the condition: 30 % (left affected naviculars/total left naviculars) occurrence in the 7384.009 grave, in comparison to the 4–21 % incidence documented in clinical cases (Coskun, Arican, Utuk, Ozcanli, & Sindel, 2009, p. 675). Although these bones were not directly linked with individuals, this prevalence nonetheless supposes a genetic association (Kiter, Erduran, & Günal, 2000) between nearly one-third of the interred adults represented by naviculars.

Another application of the database addresses paleoepidemiological studies of commingled remains. However, since multiple bones are frequently involved in pathological conditions, disease profiles must be cleverly approached through statistics. Osteoarthritis (OA), for instance, may be identified at the intersection of the joints, between 2 and 3 bones. While the shoulder is a composite of humeral and scapular components, the elbow comprises humeral, radial, and ulnar elements. Therefore, when determining the prevalence of osteoarthritis at specific synovial

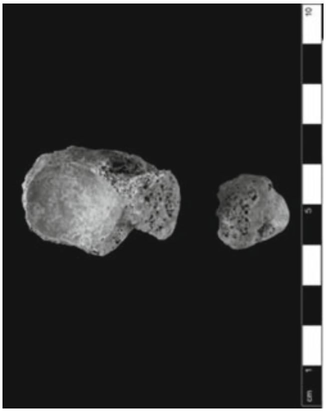


Fig. 7 Left navicular manifesting *os tibiale externum* (photo by H. Marquardt, with permission from Oymaağaç-Nerik Projekt)

Table 1 Prevalence of osteoarthritis in the left and right knee joints according to femoral, tibial, and fibular elements

	Right				Left			
Knee skeletal components	Number of present joint surfaces	Number of joints with OA	Prevalence of OA according to element	Maximum affected prevalence	Number of present joint surfaces	Number of joints with OA	Prevalence of OA according to element	Maximum affected prevalence
Femur	13	0	0.00	0.077	13	1	0.077	0.077
Tibia	5	0	0.00		13	0	0.00	
Patella	9	1	0.11		10	1	0.10	

joints, an inventory of all preserved joint elements is required. For the current chapter, Fox and Marklein will demonstrate a step-by-step analysis of OA at the knee joint.

The knee is a composite joint consisting of femoral, tibial, and patellar components, so these joint surfaces were recorded for their completeness as well as pathognomonic indicators of OA (Table 1). For the right knee the joint surfaces were present on 13 femora, 5 tibiae, and 11 patellae; complementarily, the left knee was expressed by 13 femora, 13 tibiae, and 10 patellae. Observations of OA were noted on the joint surfaces of one right patella, one left femur, and one left patella. Like the ratios calculated for the occurrence of *os tibiale externum*, these "commingled joints" were also analyzed for the maximum prevalence of affected individuals. This was attempted by creating a ratio between the highest number joint elements with OA and the highest number of elements present for the joint. For the right knee, 13 individual joints are represented by the 13 femora, but only one of the individuals exhibited evidence of OA, as shown on the articular surface of one right patella. Consequently, the maximum prevalence of OA in the right knee equates to 7.7 % (1/13). For the left knee, the prevalence also equals 7.7 % (1/13). Since the $\mathrm{MNI}_{\mathrm{adult}}$ for this grave is 14, these prevalence results yield relatively accurate profiles of OA occurrence at the knee within the specific Roman sample. Where joint preservation is poor or joints are poorly represented in the grave (e.g., temporomandibular joint), it is difficult to extrapolate accurate prevalence.

In the last decades, paleoepidemiological research has sought to illuminate possible genetic and environmental factors engendering and impacting osteoarthritis (Waldron, 2009). Expression of OA changes across time and populations. These skeletal records, therefore, provide previous insight into the pathogenesis and potential etiology of OA. Studies across different populations have emphasized age as a significant variable impacting OA (Chung et al., 2010; Kramer, 2006). As individuals age, articular chondrogenesis decreases, and joints experience heightened susceptibility to normal biomechanical stress (Anderson & Loeser, 2010). Furthermore, the number of inflammation-inducing cytokines increases, coupled with poorly reactive, aged chondrocytes, upsets synovial homeostasis (Anderson & Loeser, 2010). Physical activity (chronic and repetitive) weighs on joints, especially during later years, contributing to the pathogenesis of OA (Anagnostopoulos et al., 2010; Larsen, 1997; O'Neill et al., 1999).

Despite the extensive, meticulous, and time-laden nature of this commingled data collection and documentation model, the authors have conveyed the invaluable research possibilities for de-contextualized remains. Forensic anthropology has assumed primary responsibility for developing methodologies that address commingled remains while bioarchaeologists have deterred from constructing methodological standards for commingled, de-individualized remains. Unfortunately, this negative bias toward commingled remains eliminates vast quantities of data from previously and poorly excavated archaeological sites. Since every individual, in life, impacted and factored into the overall sociocultural and sociobiological constructions of the population, would it not be remiss to overlook all the individuals who are incompletely and indiscreetly represented in death?

Conclusions

Commingling can take place at any stage from burial to the removal of human skeletal remains and beyond, and although time-consuming, much can be gained from studying commingled remains. This chapter has exhibited different contexts in which commingling has occurred, from depositional to excavation and recovery practices. These instances of commingling have inspired a developing methodology, which expands future analysis and research potential for commingled human skeletal remains. While commingling inevitably engenders research limitations, these limitations need not dissuade skeletal population comparisons. Implementing a cohesive methodology across sites will facilitate immediate dialogue between researchers in Turkey, Greece, and Cyprus. The Eastern Mediterranean region, as a notable byway between Europe and Asia, provides a remarkable palette on which human interactions have be continuously portrayed, and with standardized methods these interactions can be further realized and clarified in bioarchaeological studies.

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Commingled Bone Assemblages: Insights from Zooarchaeology and Taphonomy of a Bone Bed at Karain B Cave, SW Turkey

Levent Atici

Introduction

Paleontology, forensic anthropology, human osteology, and zooarchaeology may differ greatly in terms of their research questions, topical foci, and theoretical agendas, but their research interests may strongly intersect when it comes to their methodological engagement with the most fundamental question: "what are these bones doing here?" Modern taphonomic research aids all these researchers and sheds light on the processes that accumulate, modify, and destroy bones. Ubelaker (2002, p. 332) describes commingling as mixing together of remains of different origins and usually of more than one individual. Zooarchaeologists commonly deal with exhaustively fragmented animal bone assemblages that are scattered and commingled. The same can also be said of human osteologists when they encounter archaeological contexts that do not present primary and undisturbed contexts with complete human bodies neatly entombed. Commingled human remains from such contexts are usually interpreted in terms of a series of antemortem, perimortem, postmortem, and postrecovery events (Sorg & Haglund, 2002). The degree of fragmentation and commingling, thus complexity, varies from context to context, depending upon taphonomic histories of human bone assemblages. Catastrophic events leading to mass graves, funerary rites, defleshing, trophy collection, secondary burials through post-burial cultural intervention, or intervention of nonhuman biotic or abiotic agents generate disarticulated, scattered, and fragmented human skeletal remains

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_12,

(e.g., Buikstra & Ubelaker, 1994 and references therein; Haglund & Sorg, 2002 and references therein; Knüsel & Outram, 2004).

Along the same lines, the formation of faunal assemblages is usually the result of a combination of complex, interacting factors including human activities, nonhuman animal ravaging, and diagenetic processes. These taphonomic filters do not necessarily operate simultaneously and may affect an assemblage differentially, increasing the preservation potential of some bones while destroying others. Some bones may escape the destructive effects of one or more filtering agents but may succumb to others, thus coming to be deleted from the archaeological record. The impact of these destructive processes will also vary in accordance with the chemical, morphological, and mechanical attributes of different skeletal parts. Therefore, before making inferences about cultural or natural phenomena, paleontologists, forensic anthropologists, human osteologists, and zooarchaeologists face the same challenging task of developing appropriate analytical protocols to sort out and identify signatures left by various agents. Yet, the task may not be a simple one, as the signature(s) of one agent sometimes may mimic the signature(s) of another. Thus, a major challenge for all the analysts is to deal with issues of apparent equifinality and to conclude which taphonomic process or processes created the patterns seen in archaeological bone assemblages (e.g., Bar-Oz & Munro, 2004; Lyman, 2004; Marean, Dominguez-Rodrigo, & Pickering, 2005; Rogers, 2000).

I echo Lee Lyman's assertion that methods and techniques of all these disciplines can significantly overlap (Lyman, 2002). To affirm my commitment to the same agenda, I borrow conceptual and methodological frameworks developed and used by vertebrate paleontologists and embed them within a taphonomy- and zooarchaeology-oriented explanatory framework. I do so by presenting a multivariate taphonomic approach and a comprehensive quantitative matrix using an Epipaleolithic archaeological bone bed from Karain B Cave, Turkey, as a case study. This methodological framework can be applied to both animal and human bone assemblages, can reveal assemblage formation processes, and can identify natural and cultural agents of bone accumulation, modification, and destruction.

It is anticipated that the methodology presented here will also aid those who encounter commingled and fragmented human bone assemblages. This chapter, however, represents an individual approach rather than a blueprint universally used by all researchers. Zooarchaeologists may significantly differ in the complexity of their recording protocols and number of quantitative variables and amount of primary data they choose to record (sensu Atici, Kansa, Lev-Tov, & Kansa, 2012). Despite this, the ultimate goal of this chapter is to initiate a dialogue between paleontologists, forensic anthropologists, human osteologists, and zooarchaeologists and to explore a shared methodological framework.

The rest of this chapter is structured as follows: First, a conceptual framework reviewing paleontological approaches to the study of bone beds is presented. Then the necessary archaeological background is briefly provided for Karain B Cave and the Epipaleolithic bone bed used as a case study in the chapter. Last is an elaboration of the taphonomic and zooarchaeological methodology followed by analysis, results, and discussion.

Paleontological Approaches to Bone Beds

Behrensmeyer (2007, p. 66) defines bone bed as "…*a single sedimentary stratum with a bone concentration that is unusually dense (often but not necessarily exceeding 5 % bone by volume), relative to adjacent lateral and vertical deposits*." According to Eberth et al. (2007, p.106) a bone bed consists of the "…*complete or partial remains of more than one vertebrate animal in notable concentration along a bedding plane or erosional surface, or throughout a single bed*." Although there are nuances in the ways vertebrate paleontologists define the term "bone bed," the emphasis lies on rich, localized concentration of hard tissues representing multiple individuals of a single taxon or multiple taxa within a clearly defined and discrete depositional context.

In order to probe formation of bone beds and their taphonomic histories, vertebrate paleontologists often examine two lines of specific evidence. First, they classify bone beds according to element and animal size and taxonomic representation including relative abundance, diversity, richness, and evenness of taxa (Rogers, Eberth, & Fiorilla, 2007). Vertebrate paleontologists recognize two distinct categories of bone beds: *macrofossil* and *microfossil*. The former is thought to yield abundant skeletal elements that are greater than 5 cm in maximum dimension and that are from two or more animals, whereas the latter yields abundant hard tissues from animals with an average body mass of 5 kg or less (Behrensmeyer, 1991; Rogers & Kidwell, 2007). As far as taxonomic representation is concerned, *monospecific/monotaxic/monodominant* bone beds with low taxonomic diversity vs. *multispecific/multitaxic/multidominant* bone beds with high taxonomic diversity provide an explanatory framework. A low diversity, monospecific, or monotaxic bone bed consists of multiple skeletal elements originating from multiple individuals of a single, dominant taxon, whereas a high diversity, multispecific, or multitaxic bone bed mostly consists of remains of two or more dominant taxa (Behrensmeyer, 2007; Rogers & Kidwell, 2007; Weiss, 2012). It is essential, however, to also factor in the evenness (i.e., relative abundance) of each taxon in the event of multitaxic and high taxonomic diversity bone beds. The following hypothetical scenarios with two opposing taxonomic composition can best exemplify this point: the first assemblage comprises four taxa represented equally (25 % each) as opposed to an assemblage with three taxa represented by 65 %, 20 %, 10 %, and 5 %, respectively. The richness or the number of taxa represented for both assemblages is the same (4), while evenness or the relative abundance of each taxon is significantly different in the two assemblages. The first assemblage can be said to have a rich and even taxonomic representation, whereas the second assemblage can be said to have a rich but uneven taxonomic representation. Diversity statistics can be utilized to develop an absolute measure of dominance, richness, and evenness (Hammer, Harper, & Ryan, 2001). Eberth, Shannon, and Noland (2007) expand the discussion on taxonomic representation and propose causal relationships between temporal origins and diversity. According to these authors, monotaxic/monodominant bone beds can be associated with catastrophic, short-term, mass-death events and multiple death events resulting from a narrower set of agents and processes such as predation, trapping, and disease, whereas multitaxic/multidominant bone beds can be linked to time-averaged, reworked assemblages resulting from a wide array of agents and processes (Eberth et al., 2007, pp. 120–121).

Second, vertebrate paleontologists seek to reveal taphonomic histories of bone beds through investigating and identifying the biological and physical taphonomic agents and processes responsible for accumulation, modification, and destruction of vertebrate hard parts. Bone assemblage formation is often associated with natural processes that include biological/biogenic/biotic and physical/geological/abiotic taphonomic agents. The biological category involves intrinsic biogenic accumulations that result from activities of accumulated animals themselves and extrinsic biogenic accumulations that result from activities of predatory and nonpredatory bone-collecting animals (e.g., Behrensmeyer, 2007; Lyman, 1994b; Rogers & Kidwell, 2007; Shipman, 1981). As far as the physical category is concerned, there are numerous factors including fluvial hydraulic activities; sedimentologic activities, such as erosion, sedimentary omission, pedogenesis, deposition, abrasion, attrition, and sediment compaction; and atmospheric activities such as wind and weathering (e.g., Behrensmeyer, 1991; Lyman, 1994b; Rogers et al., 2007; Shipman, 1981). By investigating bone beds and revealing their taphonomic histories, vertebrate paleontologists gain insights into paleontological, paleoecological, paleobiological, and geological phenomena.

Zooarchaeologists engage with a similar taphonomic agenda with the exception that they aim to identify the role played by cultural processes and human agency as primary taphonomic factors accumulating, modifying, and destroying bones. Humans, as a sort of extrinsic biogenic bone-accumulating agent or a predator, have interacted with animals throughout history in a myriad of ways from hunting to scavenging to taming to domesticating to large-scale industrial production. Humans have used animal hard parts not only for consumption but also for other postmortem utilizations such as toolmaking. Although animal hard tissues are found at almost every archaeological site in various quantities, archaeological bone beds are not that numerous (e.g., Dewar, Halkett, Hart, Orton, & Sealy, 2006; Frison, 1974, 1991; Frison & Todd, 1986; Gadbury, Todd, Jahren, & Amundson, 2000; Haynes, 1991; Hill, 2002; Hoffecker et al., 2010; Hofman & Todd, 1997; Meltzer, Todd, & Holliday, 2002; Todd, Hofman, & Schultz, 1990). Furthermore, the preponderance of archaeologically known bone beds comes from North American sites associated with Paleo-Indian large-game hunters, and bone beds from the Old World in general and from Southwest Asia in particular are scarce. As such, the taphonomic and zooarchaeological study of the Epipaleolithic bone bed at Karain B, Turkey, adds new data to research in bone beds.

Site Description and History of Research at the Site

Karain ("Black Cave") is located in the foothills of the Taurus Mountains, some 30 km northwest of Antalya and of Mediterranean coast in southwest Turkey (Fig. 1). The site is a complex of several interconnected chambers (A–G currently known)

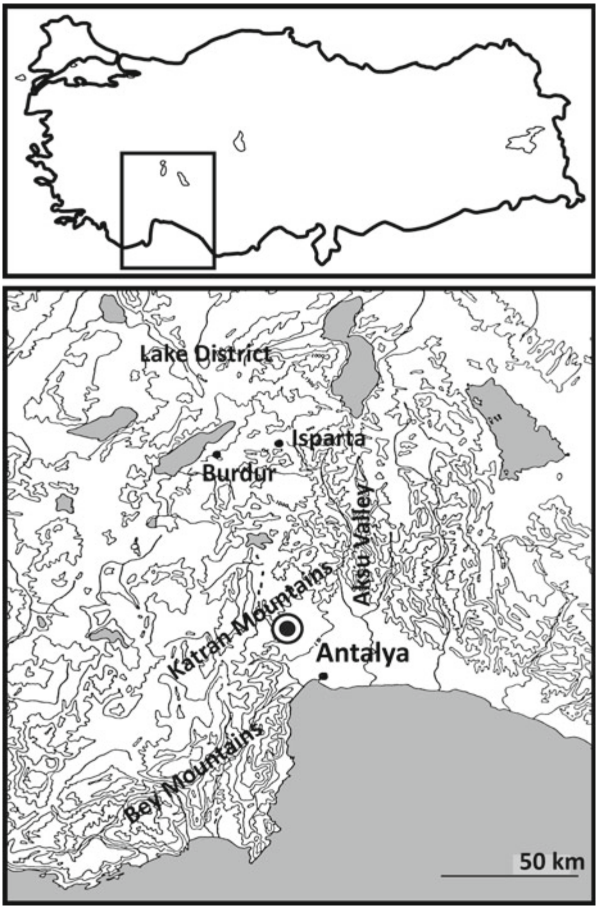

Fig. 1 Location of Karain B Cave

that are located 450 m above the sea level and 150 m above the travertine plain. The cave is situated in an ecotonal zone having access to a wide range of microenvironments including steep mountains cut by short valleys; broad, flat, travertine plain and open grassland with shrubs, marshes, and gallery forests; and pine forests limited to high altitudes.

Karain Cave was discovered in 1947 by Turkish prehistorian Kılıç Kökten who conducted excavations in B chamber between 1955 and 1973 (Yalçınkaya, 1995). After Kökten, excavations at Karain B intermittently continued by different teams. First, his successor Işın Yalçınkaya of Ankara University and a German team from Tübingen University excavated the cave between 1985 and 1988 (Albrecht, 1988b). Then, in 1996, a large interdisciplinary team restarted excavations that are still ongoing (Yalçınkaya & Otte, 1999, 2000).

Stratigraphy and Chronological Setting

The area excavated at Karain B covers 22 m^2 and includes both Holocene and Pleistocene strata. The Holocene component is divided into four geological horizons (GH): the Middle Ages, Roman Period, Iron and Bronze Ages, and Chalcolithic and Neolithic. Underlying deposits have yielded a Pleistocene component divided into three GHs: Epipaleolithic (PI.1 and PI.2), Upper Paleolithic (P.II), and Middle Paleolithic (P.III) (Yalçınkaya, Taşkıran, Kösem, Özçelik, & Atici, 2002) (Fig. 2).

A series of 29 radiocarbon dates form the basis for an absolute chronological framework at the site. Here, only the earlier phase of the Epipaleolithic strata, PI.2, the bone bed is detailed as the other strata are beyond the scope of this chapter. Radiometric range for PI.2 is ca. 19,950–19,250 calibrated years BP, and the bone bed appears to have accumulated rapidly during a short period from primarily of anthropogenic agents (Atici, 2011).

The Bone Bed at Karain B and Previous Zooarchaeological Work

The earlier phase of the Epipaleolithic at Karain B yielded faunal assemblages of extraordinary preservation and richness, warranting the label "bone bed." The Turkish-German excavations at the site in 1985 unearthed approximately 70,000 bones from the Pleistocene strata, mostly from the Epipaleolithic layers (Albrecht, 1988a). These faunal assemblages were studied by Hubert Berke who expressed his fascination with the richness of the Epipaleolithic bone assemblages in the following words: "…it was possible in horizons 23 to 18 to identify 1000 to 1500 bones from only one square meter and 5 cm depth. In this part of the profile the sediment is almost totally built of bones!" (Berke, 1988, p. 38).

Subsequent excavations have also yielded extraordinarily rich and well-preserved faunal assemblages, verifying Berke's preliminary diagnosis and increasing the sample size enormously. GH PI.2 at Karain B extends horizontally across the cave surface and forms a 30-cm-thick bone-rich layer that warrants the label bone bed. That a single layer in a square meter area, G12/18, yielded over 10,000 bone fragments weighing 25 kg in 2002 could best demonstrate the riches of the cave (Fig. 3). Epipaleolithic archaeofaunal assemblages from Karain B and nearby Öküzini caves have recently been analyzed with a special emphasis on Epipaleolithic forager economic adaptations by the present author (Atici, 2007, 2009a, 2009b, 2011).

Methodological Framework

As the success of zooarchaeological and taphonomic analyses will depend upon employing best practices in recovery, sampling, sorting, recording, identification, and quantification, I briefly describe the methodology before moving on to the taphonomic approach which is the major focus of this chapter.

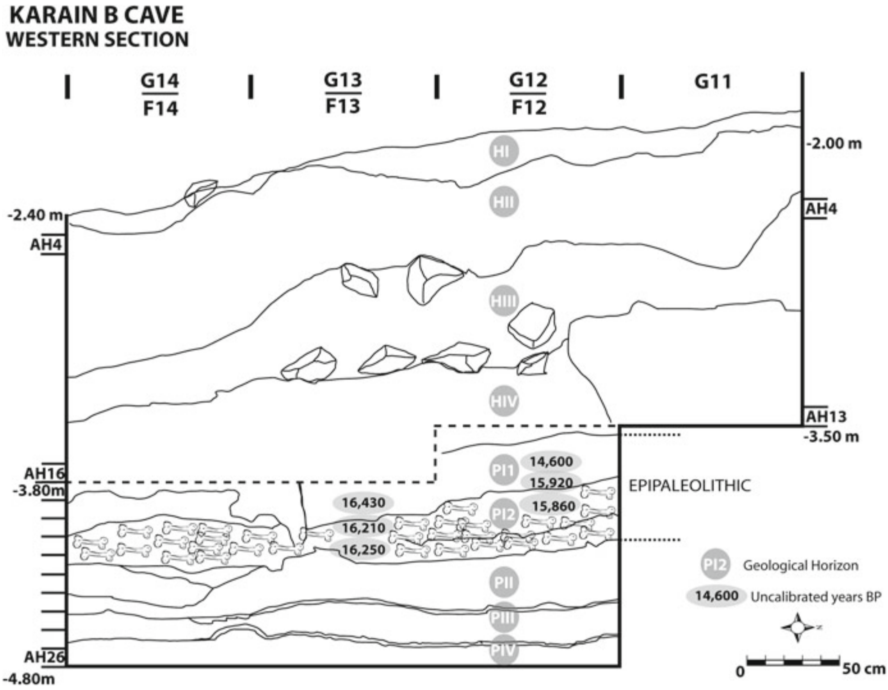

Fig. 2 The stratigraphy of Karain B Cave

Recovery

All deposits from the cave were systematically processed using bucket flotation during the excavation for full recovery of macro- and microfaunal remains. All the excavated sediments were wet screened using a set of nested sieves consisting of 4-, 2-, and 1-mm mesh size. Thus, there is no or minimal bias involved in the recovery of the assemblage. The author actively participated in every stage of the excavation and recovery of the faunal material from the site in an effort to minimize the effects of "controllable factors" (sensu Meadow, 1980).

Sampling

The basic excavation units—arbitrary archaeological horizons (AH)—formed the basis for sampling at Karain B (sensu Gamble, 1978). AHs were combined into GHs to generate larger and comparable analytical units. A total of 228 archaeological units were excavated in 22 m^2, equaling to a volume of 24.3 m^3

Fig. 3 A close-up of the bone bed (upper) and animal bones sorted into skeletal element/portion (lower)

of sediment. From this overall assemblage, 60 archaeological units—6.3 m^3—are associated with the Epipaleolithic. From this Epipaleolithic assemblage, 17 AHs from 7 m^2, making up 1.7 m^3 of sediment, were randomly sampled and analyzed for the bone bed. Thus, 31.8 % of the horizontal space and 28.3 % of the Epipaleolithic layers have been covered for this work. This sampling strategy is adequate to generate statistically viable samples and significant and robust results.

Recording

The recording protocol employed in this work entailed general documentation of the entire assemblage for the purpose of assemblage characterization and included every element, element portion, and nonidentified splinters recovered ($N = 18{,}916$). A small subsample ($N = 225$) of targeted, data-rich skeletal elements and portions were excluded to ensure consistency and to eliminate and/or minimize analyst-introduced biases. No presorting was practiced and all of the bones were packed and stored together in the storage area of the Karain dig house. Every fragment was scrutinized first by naked eye under strong light and then examined with a ×10–15 hand lens again under strong light for bone surface modifications, while subsamples were randomly chosen for recording variables such as fracture platform angle and percussion and notches. All the fragments were identified to the maximum degree possible, refitted and mended when possible, weighed, counted, labeled, assigned unique individual specimen numbers, measured when appropriate, and entered into an automated FileMaker database (Atici, 2011). When individual recording of fragments was not necessary, grouped specimens were counted, weighed, and entered into the database as a single entry under the same specimen number (e.g., nonidentified long bone shaft fragments, nonidentified skull fragments, and splinters). Postcranial bones were entered into a postcranial layout, cranial bones were entered into a cranial layout, and taphonomic attributes were entered into a modification layout. Recording took place at the project's facilities near the site in Antalya, at the Prehistory Laboratory at Ankara University in Ankara, and at the Zooarchaeology Laboratory of Harvard's Peabody Museum in Cambridge, MA, between 2002 and 2007.

Identification

Taxonomic and skeletal element identifications were carried out partly using a modern comparative reference collection assembled by the author and partly using published manuals and articles describing identification criteria. When the degree of certainty of identification was high, specimens were identified to the highest taxonomic category, i.e., species, possible. When identification to a higher taxonomic category such as species, genus, or family was not possible, *methodological categories*, such as "medium artiodactyl" or "medium bovid," commonly used by zooarchaeologists were employed. In other cases, for the purpose of statistical viability, the bones from wild sheep and goats were combined into an "O/C" ("caprine") category and treated as a single analytical unit. According to Shipman (1981, p. 106), the microscopic bone structures and size of animals determine how their bones break. As such, combining the bones of medium-sized bovids such as sheep and goats for taphonomic purposes should not impact the validity of the taphonomic analysis and results presented here.

Quantification

Number of fragments (NF) (Lyman, 1994a, 2008), number of identified specimens (NISP) (Cannon, 2012; Dominguez-Rodrigo, 2011; Grayson, 1984; Lyman, 1994a, 2008), and minimum number of elements (MNE) (Bunn & Kroll, 1986; Dominguez-Rodrigo, 2011; Lyman, 1994a, 2008; Morlan, 1994) were quantitative measures employed in this chapter. NF was used to document entire assemblages including nonspecific skeletal part categories such as nonidentified bone splinters and long bone shaft fragments, and NISP was used when fragments could be identified to skeletal element and at least to a general taxonomic or size category. Comprehensive MNI (Chaplin, 1971; Dominguez-Rodrigo, 2011; Klein & Cruz-Uribe, 1984) estimations took into account several relevant biological variables such as individual animal body size, ontogeny, and biometry.

For the estimation of MNE—the minimum number of skeletal units required to account for all of the fragments in an assemblage that are identifiable as each skeletal category or skeletal portion—a combination of discrete features or landmarks and manual overlap approach were used. Besides eyeballing overlap, degree of completeness for all the specimens was recorded to achieve a certain degree of standardization and to avoid double counting and inflating the element numbers. Among other quantitative measures used were average bone weight for all fragments and average specimen size for long bone shaft fragments. A recent experimental study has confirmed that these measurements can shed light on the degree of fragmentation (Cannon, 2012).

Minimum animal unit (MAU) was calculated by simply dividing MNE of a skeletal element/portion by the number of times that skeletal element occurs in a complete skeleton (Binford, 1978, 1981). For example, if the MNE for distal humerus is 200, then the MAU value will be 200 ÷ 2 = 100. %MAU is calculated by finding the element/portion with the highest MAU values, then setting %MAU value for it as 100 %, and ranking the remaining %MAU by dividing each MAU value by the highest MAU value (Binford, 1978; Lyman, 1994b).

In addition to MAU and %MAU, other derived measurements such as the ratio of MNI to NISP and MNE to NISP are presented to assess the degree and rate of fragmentation, specimen reduction, and deletion. Conventional zooarchaeological wisdom has held that NISP should increase with greater fragmentation, while MNI and MNE should not, and a negative relationship should be observed between MNI and NISP ratio and bone fragmentation. Cannon (2012), however, challenges this assumption and argues that MNI/NISP ratio does not vary with fragmentation.

I would like to refer more curious readers to Dominguez-Rodrigo's (2011) recent experimental work where he critically reviews these quantitative units and shows that NISP and MNI can actually produce independent errors of estimation, unlike previously thought. Similarly, Michael Cannon (2012) also sheds light on the relationships between NISP and bone fragmentation by providing new experimental data in a recent paper. Table 1 details some of the attributes of the quantitative measures adopted in this research.

Table 1 Potential limitations of the basic quantitative units used

Quantitative unit	Potential issues	References
NF: number of fragments	Differential fragmentation and identifiability	Lyman (1994a, 2008)
NISP: number of identified specimens	Differential fragmentation and identifiability; duplicate counts for same specimen, element, and individual	Cannon (2012), Dominguez-Rodrigo (2011), Grayson (1984), Lyman (1994a, 2008)
MNE: minimum number of elements	Duplicate counts for same individual; aggregation; dependency	Bunn and Kroll (1986), Dominguez-Rodrigo (2011), Lyman (1994a, 2008), Morlan (1994)
MNI: minimum number of individuals	Duplicate counts for same individual; aggregation; dependency	Chaplin (1971), Dominguez-Rodrigo (2011), Klein and Cruz-Uribe (1984)

Zooarchaeological and Taphonomic Concepts and Methodology

The multivariate taphonomic approach presented here is similar to the one pioneered by Shipman (1981) and Behrensmeyer (1991) and to the more detailed, extended version of the one that has been extensively and particularly applied to Levantine faunal assemblages by Bar-Oz and colleagues (e.g., Bar-Oz, 2004; Bar-Oz & Dayan, 1999, 2003a, 2003b; Bar-Oz & Munro, 2004, 2007) and to Anatolian assemblages by the present author (Atici, 2009a, 2009b, 2011).

I formulate a quantitative matrix that includes 66 variables organized in two separate tables (Tables 2 and 3). Following the foregoing paleontological framework, I draw upon two lines of specific evidence and group variables into the following analytical categories to analyze the bone bed at Karain B:

1. *Taxonomic composition*, which entails relative abundance, diversity, richness, and evenness of taxa.
2. *Assemblage composition and formation*, which investigates taphonomic history of the bone bed. Specifically, assemblage composition and formation, fragmentation, differential preservation, skeletal completeness, and bone surface modifications were investigated. A stepwise analytical procedure determines the next set of questions and narrows the focus to isolate signatures left by primary bone collector(s), modifier(s), and destroyer(s).

Taxonomic Composition: Diversity, Richness, and Evenness

Trends in taxonomic diversity through time, and richness and evenness in animal species composition were examined based on NISP counts. All potentially intrusive taxa and species represented by individual specimens, however, were excluded.

Table 2 Variables used in the analysis of taxonomic representation

Variable	Analytical category	Specific observation	Values
1	Taxonomic representation	Number of taxa	13
2	Diversity, richness, evenness	%Number of fragments (NF) large game	98.7 %
3		%Minimum number of elements (MNE) large game	96.5 %
4		%Bone weight (BW) large game	98.2 %
5		%NF caprines of large game	99.9 %
6		%MNE caprines of large game	99.7 %
7		Minimum number of individuals (MNI) caprines	85
8		Small game/large game MNE	0.030
9		Dominance index	0.557
10		Simpson's diversity index	0.443
11		Evenness index	0.202
12		% Young (based on epiphyseal fusion stage >12 but <18 m)	12.8
13		% Young (based on the count of dP4 first 12 wear stages)	40.9

I computed several diversity indices to be able to detect a clear and consistent pattern of richness and evenness in the analyzed assemblage. Taxonomic richness refers to number of species present, whereas evenness examines relative abundance of species identified. The specific diversity statistics used include the following:

1. *Dominance index* (D): ranges from 0 (all taxa are equally represented) to 1 (one taxon dominates the assemblage) (Hammer et al., 2001).
2. *Simpson's index of diversity* ($1 - D$): ranges from 0 to 1; the greater the value, the greater the diversity (Hammer et al., 2001).
3. *Shannon diversity index* (H): ranges from 0 for assemblages with only single taxon to higher values for assemblages with many taxa that are more evenly represented (Hammer et al., 2001).

Assemblage Composition and Formation

Carnivore Ravaging

Actualistic studies show that there can be considerable differences in pre-carnivore ravaged and post-carnivore ravaged assemblages. NISP counts for epiphyses in post-ravaged assemblages are dramatically lower than in pre-ravaged ones, and post-ravaged shaft NISP counts are significantly higher than pre-ravaged ones (Travis Rayne Pickering, Marean, & Dominguez-Rodrigo, 2003, p. 1473). This is

Table 3 Variables used in the analysis of assemblage composition and formation

Variable	Analytical category	Specific observation	Values
1	Assemblage composition	NF	18,916
2		Number of Identified Specimens (to skeletal element and taxon)	10,425
3		MNE	4,298
4		MNI	85
5		BW	44,646
6		NF per unit volume (m^3)	239.26
7		Average fragment weight in grams (AFW)	2.46
8		Average fragment length in centimeters (AFL)	3.6
9		NISP/MNE	2.42
10		NISP/MNI	122.6
11		Nonidentified bone splinters	5,464
12		Long bone shaft fragments	3,586
13	Assemblage formation	%Identified	55.1 %
14	Fragmentation	%Nonidentified fragments <1 cm	29 %
15		%Epiphyses	5 %
16		%Long bone shaft fragments	19 %
17		%Shaft fragments identified to element	16 %
18		%Excavation breaks	21.3 %
19		%Cylinders of long bones	2.09 %
20		%Acute/obtuse fracture angles (<85 and >95 degrees)[a]	89.40 %
21		%MAU-bone density significance (2-tailed) $p>0.01$	Insignificant
22		%MAU-economic utility significance (2-tailed) $p>0.01$	Insignificant
23		Cranial bone MNE:loose tooth MNE	0.063
24	Differential preservation	Shaft:epiphysis	3.8
25	Upper vs. lower limb	Humerus:radius	0.9
26		Femur:tibia	0.5
27	Proximal vs. distal limb bones	Proximal humerus:distal humerus	0.2
28		Proximal radius:distal radius	1
29		Proximal metacarpus:distal metacarpus	0.2
30		Proximal metatarsus:distal metatarsus	0.5
31		Proximal femur:distal femur	2
32		Proximal tibia:distal tibia	0.2

(continued)

Table 3 (continued)

Variable	Analytical category	Specific observation	Values
33	Articulating ends	Distal scapula:proximal humerus	7.4
34		Distal humerus:proximal radius	1.4
35		Distal femur:proximal tibia	1
36		Distal tibia:astragalus	1.1
37		Distal metapodia:proximal phalanx 1	0.7
38		Phalanx 1:phalanx 2	1.2
39	Skeletal evenness	Shannon's skeletal evenness	0.975
40	Skeletal completeness	% Axial completeness (all axial elements; large game)	23.50 %
41		% Carpal completeness (all carpals; large game)	100 %
42		% Tarsal completeness (all tarsals; large game)	85.10 %
43		% Phalanx completeness (all phalanges; large game)	37.30 %
44	Bone surface modification	%Weathering > stage 2	0.27 %
45	Erosion, abrasion and transport	%Trampling/sediment scratch marks	0.01 %
46		%Eroded edge/rounding	0.49 %
47		%Abraded/pitted/polished bone surfaces	0.00 %
48	Bioerosion	%Root etching/insect boring	0.01 %
49	Biotic modification	%Rodent gnawing	0.02 %
50		%Carnivore marks (gnaw, score, puncture)	0.08 %
51	Cultural modification	%Percussion marks/notches[a]	18.24 %
52		%Cut marks	1.08 %
53		%Burned bones	2.19 %

[a] Only applies to the randomly-selected shaft sub-samples

because carnivores attack first the more cancellous (spongy), less resistant, and greasier axial elements and long bone articular ends.

Tooth marks were recorded in order to determine the impact of nonhuman biotic agents on assemblage formation and modification. This is particularly important, as evaluation of the effects of potential taphonomic filters and identification of the major bone-modifying and bone-accumulating agent(s) are the major foci of taphonomic studies. Blumenschine (1995, p. 29) describes tooth marks as follows: “Carnivore tooth marks contain bowl-shaped interiors (pits) or U-shaped cross-sections that commonly show crushing that is conspicuous under the hand lens, and which, macroscopically, gives the mark a different patina than the adjacent bone surface.” For this study, tooth marks were scrutinized first by the naked eye under strong light and then examined with a ×10 hand lens again under strong light. Each located mark was examined and its features carefully considered in the light of experimentally derived tooth and percussion marks.

Table 4 Skeletal elements in anatomical order and their idealized %Survivorship values in "one" complete skeleton (MNI = 1)

Skeletal element	MNE expected	MNE observed	MAU	%MAU	%Survival	Density[a]	MGUI[b]
Horncore	2	2	1	100.0	100.0	NA	1.03
Skull	2	2	1	100.0	100.0	NA	12.87
Mandible	2	2	1	100.0	100.0	0.55	43.6
Atlas	1	1	1	100.0	100.0	0.11	18.68
Axis	1	1	1	100.0	100.0	0.14	18.68
Cervical vertebra	5	5	1	100.0	100.0	0.13	55.33
Thoracic vertebra	13	13	1	100.0	100.0	0.24	46.49
Lumbar vertebra	6	6	1	100.0	100.0	0.22	38.9
Rib	26	26	1	100.0	100.0	0.25	100
Sternum	1	1	1	100.0	100.0	0.22	90.52
Scapula	2	2	1	100.0	100.0	0.33	45.06
Humerus proximal	2	2	1	100.0	100.0	0.13	37.28
Humerus distal	2	2	1	100.0	100.0	0.34	32.79
Radius proximal	2	2	1	100.0	100.0	0.36	24.3
Radius distal	2	2	1	100.0	100.0	0.21	20.06
Carpals	12	12	1	100.0	100.0	0.48	13.43
Metacarpus III + IV proximal	2	2	1	100.0	100.0	0.55	10.11
Metacarpus III + IV distal	2	2	1	100.0	100.0	0.44	8.45
Pelvis	2	2	1	100.0	100.0	0.26	81.5
Femur proximal	2	2	1	100.0	100.0	0.28	80.58
Femur distal	2	2	1	100.0	100.0	0.22	80.58
Tibia proximal	2	2	1	100.0	100.0	0.16	51.99
Tibia distal	2	2	1	100.0	100.0	0.36	37.7
Astragalus	2	2	1	100.0	100.0	0.63	23.08
Calcaneus	2	2	1	100.0	100.0	0.58	23.08
Metatarsus III + IV proximal	2	2	1	100.0	100.0	0.68	15.77
Metatarsus III + IV distal	2	2	1	100.0	100.0	0.39	12.11
Phalanx anterior/posterior 1	8	8	1	100.0	100.0	0.55	8.22
Phalanx anterior/posterior 2	8	8	1	100.0	100.0	0.4	8.22
Phalanx anterior/posterior 3	8	8	1	100.0	100.0	0.3	8.22

[a] Lyman (1994b)

[b] Binford (1978)

Also presented are the MGUI of Binford (1978) and bone mineral density values of Lyman (1994b) for sheep, Ovis aries

Documenting the degree of carnivore ravaging on the assemblages and/or excluding them as potential bone collectors can enable the zooarchaeologist to focus on human behavior as a major bone-accumulating and bone-modifying agent. To this end, the present taphonomic analysis first examines and measures the impact of nonhuman biotic and abiotic agents.

Other Nonhuman Bone Accumulators and Modifiers

Predatory birds, small and large rodents, and artiodactyls have been reported as other major biotic bone-collecting and bone-modifying agents (Shipman, 1981). In particular, rodent gnawing of epiphyses and shafts of long bones may significantly alter bones. In so doing, rodents leave conspicuous traces easily identified with the naked eye.

Weathering

Weathering is the exposure of skeletal elements to the potentially destructive mechanical, physical, and chemical effects of weather, including fluctuating temperatures, humidity, and solar radiation. Behrensmeyer (1978) states that weathering is a continuous process taking place during both pre-burial and post-burial stages as well as in both aboveground and underground contexts. When bones are exposed to the physical and chemical effects of weathering, they can become mechanically and structurally altered to the point of disintegration (Lyman, 1994b). Investigation of weathering stages provides insight into duration of exposure and history of accumulation for bone assemblages and thus into the tempo and timing of depositional processes (Lyman, 1994b). If bones display traces of heavy weathering, this would indicate that they may have been remained on the surface for a long time before burial. If the weathering is minor or absent, we may assume rather rapid burial. Recording and analysis of weathering for the bone bed at Karain B used the six stages described by Behrensmeyer (1978).

Trampling and Abrasion

Surface scoring and scratch marks on bone surfaces may provide insights into depositional environments, sedimentary matrix (i.e., sediment grain size), size of bioturbators, the intensity of loading and mass of trampler, and the duration of trampling (Behrensmeyer, Gordon, & Yanagi, 1986; Eberth et al., 2007; Lyman, 1994b). Abrasion refers to mechanical removal of bone surfaces by sedimentary, hydraulic, chemical, and biological processes. Polish on bone surfaces, pitting of bones, and overall rounding of elements with broken crests and edges combine to aid the analyst distinguish mixed assemblages and identify the duration and velocity of bone transport (Eberth et al., 2007; Shipman, 1981). Following Shipman, trampling and abrasion were recorded using broad categories and relative states such as slight, moderate, and heavy trampling and abrasion.

Root Etching

The wavy, "dendritic," "sinuous," and "spaghetti-like" patterns of plant roots etch into the bone surface as a result of dissolution by acids associated with growth or decay of roots or fungi before or after burial (Lyman, 1994b, pp. 375–376 and references therein). This process stains the bone surface and creates very conspicuous and easy-to-identify patterns. Traces of root etching have been recorded for the bone bed at Karain B when present.

Skeletal Part Abundance, Bone Survivorship, and Bone Density

The preservation potential of skeletal elements and their portions is primarily a function of the combined variables of age, size, morphology, composition, and other chemical and physical characteristics of the bones (Shipman, 1981). Documenting frequencies of skeletal parts in relation to bone mineral density has increasingly become more popular among zooarchaeologists as one of the most effective analytical techniques to examine completeness of faunal assemblages and to identify taphonomic agents responsible from their accumulation and modification. The relevance of bone density studies to zooarchaeology is in that many researchers have identified significant correlations between bone mineral density and abundance of skeletal elements. This association is typically referred to as "density-mediated attrition," "postdepositional destruction," or "in situ attrition" of bones (Binford, 1978; Brain, 1967, 1969; Klein, 1989; Lyman, 1982, 1984, 1985; Marean, 1991; Marean & Kim, 1998; Marean, Spencer, Blumenschine, & Capaldo, 1992; Stiner, 2002).

In examining skeletal part abundance, zooarchaeologists often focus either on the articular (epiphyseal) ends of long limb bones, with the assumption that these parts can be more reliable indicators of original skeletal part distributions, or put greater emphasis on the use of shaft fragments to obtain more reliable skeletal part profiles due to their mechanical resistance to cultural and natural taphonomic processes. The few archaeological assemblages to which both approaches have been applied show dramatic differences in the representation of the least dense elements and, consequently, in behavioral reconstructions with the "shaft approach" being particularly potent when carnivores are documented to have severely impacted the assemblages (Costamagno, 2002; Marean et al., 2005; Pickering, Dominguez-Rodrigo, Egeland, & Brain, 2005; Pickering & Egeland, 2006; Pickering et al., 2003; Yeshurun, Marom, & Bar-Oz, 2007). For the sites where carnivore ravaging can be ruled out, however, the time-consuming and labor-intensive analytical procedures that require the scrutiny of all shaft fragments can be deemed redundant to estimate MNE values and to construct skeletal part profiles. For such sites, a focus on the application of "epiphysis approach" or "rapid counting" (sensu Marom & Bar-Oz, 2008) would be more viable and can easily be justified, as experimentally demonstrated by Capaldo (1998). For the Karain B bone bed, shafts were not ignored; they were routinely sampled and analyzed in order to document bone surface modifications and fragmentation patterns. Furthermore, long bone MNE values were calculated separately for shafts and epiphyses to independently test whether these two approaches agree or generate comparable values and to verify other researcher's observations.

Evaluating differential survivorship of skeletal parts for this chapter was approached by comparing expected and observed MNE values. Expected MNE values were estimated based on MNI values. Thus, for example, if the MNI for wild sheep has been calculated to be 100, then we expect to observe MNE for mandibles = 200, for atlas = 100, for other cervical vertebrae = 500, for thoracic vertebrae = 1,300, for ribs = 2,600, and so forth. From these expected MNE values, the percentage survival for each skeletal part (e) is calculated as (MNE observed e ÷ MNE expected e) × 100. Supposing that the expected MNE for distal humerus is 200 and only 79 distal humeri have been documented, the resulting %Survival value for the distal humerus is (79 ÷ 200) × 100 = 39.5. Table 4 exemplifies skeletal elements and portions and their %Survival values in "one" hypothetical, complete sheep skeleton, with skeletal parts listed in anatomical order. The table includes expected and observed MNE values (observed = expected in this case) and %Survival values (=100 % in this case) along with their density values and economic utility indices. These data form the basis for calculations made for the Karain B bone bed. In contrast to the listing order in Tables 4, 5 and Fig. 4 show idealized bone mineral density values of skeletal portions in ascending order from the least dense to the densest using Lyman's (1994b) density values for sheep. Skeletal parts are divided into three categories with respect to their bone mineral density values: *low*, *medium*, and *high density* or "*high-survival elements*" (Faith & Gordon, 2007). Bone mineral density values and %MAU values were also used to test the correlation between density and bone survival. In addition, Spearman's rank correlation statistic (Spearman's rho) and the statistical significance of the correlation coefficient were provided. Ultimately, the assumption being tested here is that if bone destruction is density dependent, the skeletal part abundance pattern will be dominated by high- and medium-density bones, and a clear bias against low-density bones will be detected.

Skeletal Completeness and Differential Preservation

To assess degree of bone loss and differential bone preservation, the following variables were quantified: (1) percentage upper to lower limb, (2) percentage proximal to distal bones, (3) percentage articulating ends, (4) percentage cranial bones to loose teeth, (5) percentage complete to incomplete axial skeletal elements, (6) percentage complete to incomplete carpals and tarsals, and (7) percentage complete to incomplete phalanges (see Table 3). Completeness is defined as the ratio between broken/incomplete and unbroken/complete specimens. In so doing, one uses the binary opposition of "complete" to "incomplete." Degree of "brokenness" or "completeness" is not evaluated for these statistics. To deal with

Table 5 Skeletal parts and their density values in ascending order from least dense to densest

Skeletal element	Density	Category
Atlas	0.11	Low density
Humerus proximal	0.13	
Cervical vertebra	0.13	
Axis	0.14	
Tibia proximal	0.16	
Radius distal	0.21	
Lumbar vertebra	0.22	
Sternum	0.22	
Femur distal	0.22	
Thoracic vertebra	0.24	
Rib	0.25	
Pelvis	0.26	
Femur proximal	0.28	Medium density
Phalanx anterior/posterior 3	0.30	
Scapula	0.33	
Humerus distal	0.34	
Radius proximal	0.36	
Tibia distal	0.36	
Metatarsus III + IV distal	0.39	High density
Phalanx anterior/posterior 2	0.40	
Metacarpus III + IV distal	0.44	
Carpals	0.48	
Mandible	0.55	
Metacarpus III + IV proximal	0.55	
Phalanx anterior/posterior 1	0.55	
Calcaneus	0.58	
Astragalus	0.63	
Metatarsus III + IV proximal	0.68	

this shortcoming, one or more of the several indices widely used by zooarchaeologists to assess completeness of skeletal elements can be employed (e.g., Marean, 1991). The carpal/tarsal completeness index of Marean measures completeness by using the following algorithm: average percentage completeness = 100 [(comp 1 + comp 2 + comp 3 +… comp n)/n], where comp = proportion of the element present with a whole bone = 1. A hypothetical example might be average percentage completeness = 100 [(1 + 0.75 + 0.50 + 0.25)/4] = 62.5 %. In contrast, the binary method yields a result of 25.0 % (one out of four elements is complete). I prefer the latter approach because average percentage completeness (also used by Bar-Oz, 2004) inflates bone completeness in a situation where, particularly for compact bones and phalanges, what is taphonomically important is whether a bone is complete or not complete.

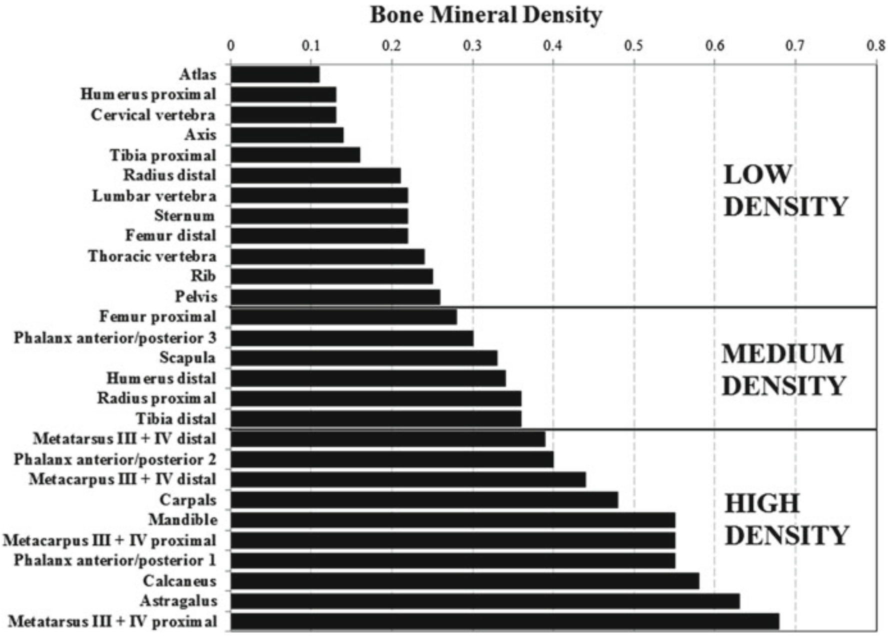

Fig. 4 Skeletal elements in ascending order according to their bone mineral density values

The frequency of body parts is often used by zooarchaeologists to assess bone loss and carcass processing (e.g., butchery) and transport patterns. This approach usually entails grouping skeletal elements into specific body parts or “anatomical regions” (e.g., Stiner, 2002). Decisions regarding grouping individual skeletal elements into anatomical regions or body parts vary from analyst to analyst. Here, frequency of body parts was analyzed by assigning skeletal elements into the following six body part categories:

1. *Head*: horn cores, cranial fragments, maxillar and mandibular teeth
2. *Axial*: all vertebrae, ribs, and sternum
3. *Forelimb*: scapula, humerus, radius, ulna, carpals
4. *Hind limb*: pelvis, femur, tibia, patella, fibula, tarsals
5. *Limb*: nonidentified long bone shafts and nonidentified carpals and tarsals
6. *Distal extremity*: metapodials, anterior and posterior phalanges, and proximal and distal sesamoids

The skull is not included in the axial skeleton because taphonomic processes affect the skull and axial skeleton differentially (Capaldo, 1998). The metapodials are included in the distal extremity group based on their low nutritional values and butchery practices. By lumping nutritionally disparate elements such as humerus, radius, and metacarpus or femur, tibia, and metatarsus together, meaningful variation in the dataset can be obscured (Pickering et al., 2003, p. 1472).

Carcass Processing, Economic Utility, and Skeletal Evenness

The presence of cut marks provides the most direct evidence for human modification of bones. Examination of cut marks and butchering practices reveals modes of prey procurement and of carcass processing and consumption. Zooarchaeologists record, count, and report cut marks and butchery practices in numerous ways, resulting in non-comparable data. Abe et al. (2002) provide a detailed discussion of the diversity of approaches for recording, counting, and presenting cut marks. Some analysts apply "fragment-count data" (counting the fragments with cut marks, not the cut marks), whereas others use "cut mark-count data" (frequency of individual cut marks on specimens within a skeletal element, e.g., proximal humerus or mid-shaft) (see Abe et al., 2002 and references therein). Blumenschine (1988) and Capaldo (1995, 1998) also produced NISP and MNE cut mark-count data and NISP and MNE fragment-count data. It is also known that cut mark counts can be affected by fragmentation.

For this chapter, I used the "fragment-count" approach and counted fragments with cut marks, not cut marks themselves. I also recorded depth and anatomical location and position of cut marks. Ultimately, I associated cut marks with three possible consumption patterns: skinning, disarticulation, and filleting or meat removal. As a function of the anatomy of butchering, cut marks that are on the mid-shaft and epiphyses of metapodials or on the skull and mandible are associated with skinning. Cut marks that are on or near epiphyses and vertebrae are interpreted as resulting from disarticulation, whereas multiple, parallel, and oblique cut marks that are not typically associated with other categories are interpreted as evidence for filleting. Filleting marks are usually found on ribs, on the medial side of scapulae, and on limb bone shafts.

One of the fundamental goals of skeletal element abundance and body part profile analyses in zooarchaeology is to investigate human decision-making processes regarding carcass process and transport. Experimentally generated data for some taxa commonly documented in archaeofaunal assemblages (e.g., gazelle, sheep, and deer) provide zooarchaeologists with a methodological and explanatory framework as to the quantity of food—meat, marrow, and bone grease—different parts of carcasses yield, and their zooarchaeological implications (Bar-Oz & Munro, 2007; Binford, 1978; Blumenschine & Madrigal, 1993; Lyman, 1994b; Madrigal & Holt, 2002; Marshall & Pilgram, 1991; Metcalfe & Barlow, 1992; Metcalfe & Jones, 1988; Morin, 2007; Outram, 2001). Toward this end, Binford's (1978) modified general utility index (MGUI) values and %MAU values are often used to see the degree and significance of correlation between economic utility of portions (i.e., amount of attached meat) and their survival rates. In this chapter, correlation between %MAU was tested using Spearman's rank correlation statistic (Spearman's rho) and the statistical significance of the correlation coefficient was provided.

As an alternative to using MGUI, Faith and Gordon (2007) introduced a new analytical technique, *skeletal evenness index*, to probe carcass processing, transport, and consumption. This approach predicts that there is a direct and proportional relationship between skeletal element abundance and field processing. Thus, increase in abundance over time would indicate lower levels of field processing and increased rate of nonselective carcass transport to include low-utility elements and parts, while decreased field processing would result in increased skeletal element evenness. An even distribution of skeletal elements results in an evenness of 1, with values approaching 0 as evenness declines. Following Faith and Gordon (2007), skeletal element evenness is measured in this research using the Shannon evenness index.

Bone Fragmentation Patterns

To analyze fragmentation patterns, shaft specimens were randomly sampled for the fragment size grouping, for the element identification, and for the analysis of percussion, notches, and the fracture platform angles. All sizes of long bone shaft fragments were represented, with the exception of those smaller than 3 cm and those with modern/excavation breaks. Specimens larger than 6 cm and smaller than 10 cm were sampled for analysis of platform angles and of percussion and notches since this size category best represents the breakage patterns affecting whole collections (Alcántara et al., 2005). MNE values based on shaft fragments were estimated by combining information from the following: (1) shaft section shape, (2) shaft thickness, (3) presence or absence of surface landmarks (i.e., muscle insertions or foramina), and (4) the texture of the surface of the medullary cavity.

The mode of bone fragmentation was assessed by the frequency of breakage planes and the angle range for longitudinal and especially oblique breakage planes. The way that a bone breaks follows basic physical principles (as also for notches). Dynamic loading (i.e., hammerstone percussion) creates more acute or obtuse angles than does static loading (i.e., carnivore gnawing), whereas the latter shows more right angles than the former (Alcántara et al., 2005; Pickering & Egeland, 2006; Pickering et al., 2005). Dynamic loading through hammerstone percussion creates an impact on the bone that expands according to the density of the bone and the force of the impact, detaching a fragment with an angle that tends to be either acute or obtuse. This is the same phenomenon as that occurring when a lithic flake is detached through percussion. In contrast, carnivore broken bones tend to have breakage planes more at right angles, just as do pressure-flaked lithics (Alcántara et al., 2005).

Burning

The presence of burned bones does not necessarily indicate cooking or food preparation activities. Bones may be burned as fuel, disposed into the fire for cleaning purposes, accidentally burnt near fireplaces, or indirectly affected by the heat when buried (e.g., Payne, 1983; Schiegl, Goldberg, Pfretzschner, & Conard, 2003; Shipman, Foster, & Schoeninger, 1984; Stiner & Kuhn, 1995; Thery-Parisot, 2002). As such, degree of burning should be evaluated, not simply the presence or absence of burned bones. Intensely burned bones that are grayish or white in color suggest deliberate or accidental burning, not cooking (Payne, 1983, p. 151). Having conducted experimental studies on burning, weathering, and trampling, Stiner

(2005, p. 48) has documented that burning causes a loss of organic matrix, increasing the fragility of bones and the degree of fragmentation, while reducing the size of fragments. Accordingly, Stiner (2005) also reports that the size of the carbonized bone fragments rarely exceeds 1 or 2 cm. The results of Stiner's experiments have interesting implications for interpreting archaeological burned bones. She shows that even buried bones can be altered when exposed to heat and that calcined bones are usually found in the form of powder due to crushing and sediment compaction (Stiner, 2005, pp. 48–50). Goat bones buried 5 cm below a firebed displayed conspicuous morphological and structural modifications, whereas bones 10 cm below the heated zone showed no change (Stiner, 2005, p. 50).

Along the same lines, burned bones from Karain B were counted, weighed, measured, and color coded following Nicholson's (1993) scheme for burned sheep bones. Fragment size categories for burned bones were tabulated to test whether Stiner's findings hold for the bone bed.

Results

Taxonomic Composition

The Epipaleolithic bone bed at Karain B is dominated by the remains of two principal taxa: wild sheep (*Ovis orientalis*) and wild goat (*Capra aegagrus*). Their bones combine to comprise 98.7 % of the entire assemblage, making caprines the exclusively targeted taxa of the Epipaleolithic inhabitants of Karain B. The contribution of the secondary taxa is marginal and insignificant (Tables 2 and 6). Thus, as a first step, it is a straightforward task to establish the stratum PI.2 at Karain B cave as a macrofossil bone bed in terms of element and animal size categorization.

Taxonomic Diversity, Richness, and Evenness

Table 6 lists taxonomic categories with 13 taxa listed at the genus level. The representation of large game (wild sheep and goat, fallow deer, wild boar, and aurochs) is 98.7 % in the bone bed. Of the bones identified to large game, caprines account for 99.9 %, while 11 other taxa collectively account for only the remaining 0.1 %. Thus, despite a rich and diverse taxonomic composition, the assemblage lacks evenness in proportions as only two taxa contribute over 99 % of the bones analyzed. The high dominance index (D) (0.5572) as opposed to low Simpson's index of diversity ($1-D$) value (0.4428) as well as low evenness (H/S) value (0.2017) converge to indicate a diverse but uneven taxonomic composition for the bone bed at Karain B. As such, the Epipaleolithic bone bed at Karain B can be said to have a multispecific, multitaxic, or multidominant taxonomic representation since the

Table 6 Relative abundance of taxa

Taxonomic ID	NF	MNE	Weight (g)	%NF	%MNE	%Weight
Small bird	13	4	11	0.1 %	0.1 %	0.0 %
Medium bird	30	7	32	0.2 %	0.2 %	0.1 %
Large bird	41	24	121.6	0.2 %	0.6 %	0.3 %
Columba sp. (pigeon)	3	3	3	0.0 %	0.1 %	0.0 %
Alectoris chukar (partridge)	36	35	40	0.2 %	0.8 %	0.1 %
Accipitridae (eagle/hawk)	20	19	62	0.1 %	0.4 %	0.1 %
Otis tarda (great bustard)	17	15	68	0.1 %	0.3 %	0.2 %
Lepus europaeus (hare)	71	30	116	0.4 %	0.7 %	0.3 %
Lynx lynx (lynx)	2	2	22	0.0 %	0.0 %	0.0 %
Vulpes vulpes (red fox)	6	5	15	0.0 %	0.1 %	0.0 %
Canis lupus (wolf)	8	4	16	0.0 %	0.1 %	0.0 %
Sus scrofa (wild boar)	7	7	52	0.0 %	0.2 %	0.1 %
Dama dama (fallow deer)	10	5	115	0.1 %	0.1 %	0.3 %
Bos primigenius (aurochs)	7	3	294	0.0 %	0.1 %	0.7 %
Capra aegagrus (wild goat)	280	251	2,449.51	1.5 %	5.8 %	5.5 %
Ovis orientalis (wild sheep)	621	600	4,758.3	3.3 %	14.0 %	10.7 %
Ovis/Capra	17,744	3,284	36,470.32	93.8 %	76.4 %	81.7 %
Grand total	18,916	4,298	44,645.73	100.0 %	100.0 %	100.0 %

remains of two dominant, medium-sized bovids, caprines to be more specific, exclusively dominate the assemblage.

Assemblage Composition and Formation

The analysis of 18,916 bone fragments weighing over 44 kg indicates that degree of fragmentation is high, and nonidentified bone splinters and long bone shaft fragments dominate the assemblage. Table 3 details the bone surface modification data and shows that traces of weathering, trampling, abrasion, erosion, root etching, and rodent gnawing are very sporadic and extremely rare in the bone bed. This indicates a lack of vegetation growing in the cave, and perhaps, could form an independent line of evidence for intensive occupation, site maintenance, sweeping, or cleaning floors and burning the vegetation inside the cave by the occupants. Alternatively, the data may also suggest a stable depositional environment and rapid burial of bones, eliminating the chance for nonhuman biotic and abiotic agents to access the bones. Given that overall bone surface preservation is good and that traces of abrasion, rolling, edge erosion, hence bone transport, are also marginal, rapid burial scenario seems to be more plausible and congruent with the bone surface modification data. The proportion of carnivore ravaging is below 1 %, while the proportion of cylinders or long bone diaphyses, which are considered as the indicator of carnivore activity, is 2.09 %. Yet, when cylinders are associated with carnivore ravaging, they are most likely to be accompanied by heavy gnawing, biting, and tooth marks. At Karain B, however, no such traces were observed. The presence of cylinders cannot be attributed to carnivore ravaging either, ruling out a role for carnivores in assemblage accumulation, modification, and destruction. During this first stage of taphonomic analyses, thus, a role for carnivores and other biotic and abiotic taphonomic filters in the accumulation, modification, and destruction of bones from the bone bed at Karain B can be ruled out safely.

Figure 5 shows the presumed inverse relationship between NF, NISP, MNE, and MNI on a logarithmic scale given the large range of values. The figure also shows a high degree of fragmentation and the subsequent preponderance of nonidentified splinters and shaft fragments ($N = 8{,}491$ or 45 % combined). Figure 6 visualizes various variables pertaining to fragmentation. Worthy of note are the relatively high degree of identifiability ratio with a proportion of 55.1 %, average fragment length (3.6 cm), and high number of bones with excavation breaks (21.3 %). The high ratio of modern breaks is related to the packed and dense nature of the bones in the bone bed.

Skeletal Part Abundance, Bone Survivorship, and Bone Density

A glance at the log-scale line graph in Fig. 7 reveals that all skeletal elements and portions are represented in varying proportions. When expected vs. observed MNE estimates (derived from MNI of 85 for caprines based on combined mandibular dP4 and M3) are compared, however, a rather clear pattern is detected: a conspicuous bias against some axial elements in general and long bone epiphyses in particular (see Table 7). There is a big plateau between the expected vs. observed rib, sternum, thoracic vertebra, lumbar vertebra, proximal humerus, proximal metacarpus, carpals, distal femur, proximal tibia, proximal metatarsus, and third phalanx MNEs. These element portions are severely underrepresented by the magnitude of many times as the plateau covers a full logarithmic interval. Figure 8 provides further insights into the above-mentioned mixed patterning and manifests that bone density is a significant factor as to whether a bone element or portion succumbed to or survived the effects of combined destructive forces. It is clear that skeletal parts were differentially destroyed by various forces. Thus, processes governing bone destruction should be further explored to examine how much bone loss could be linked to bone mineral density.

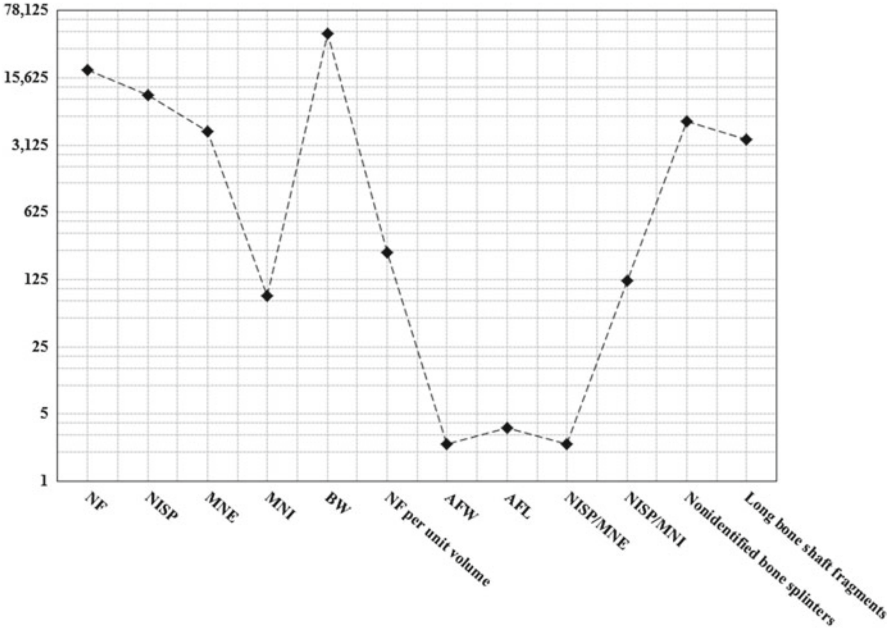

Fig. 5 The relationship between basic and derived quantitative units using log scale

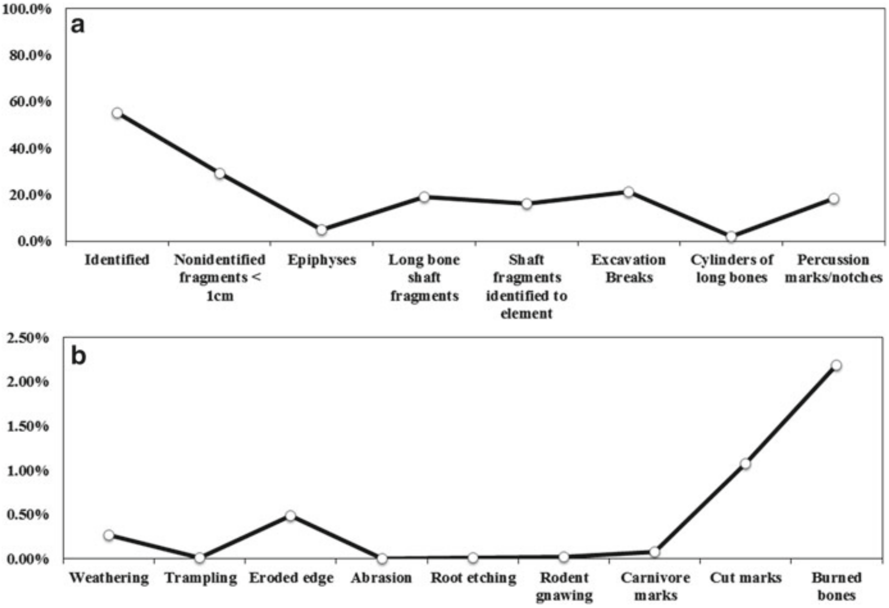

Fig. 6 Some of the basic taphonomic variables used to characterize the assemblage

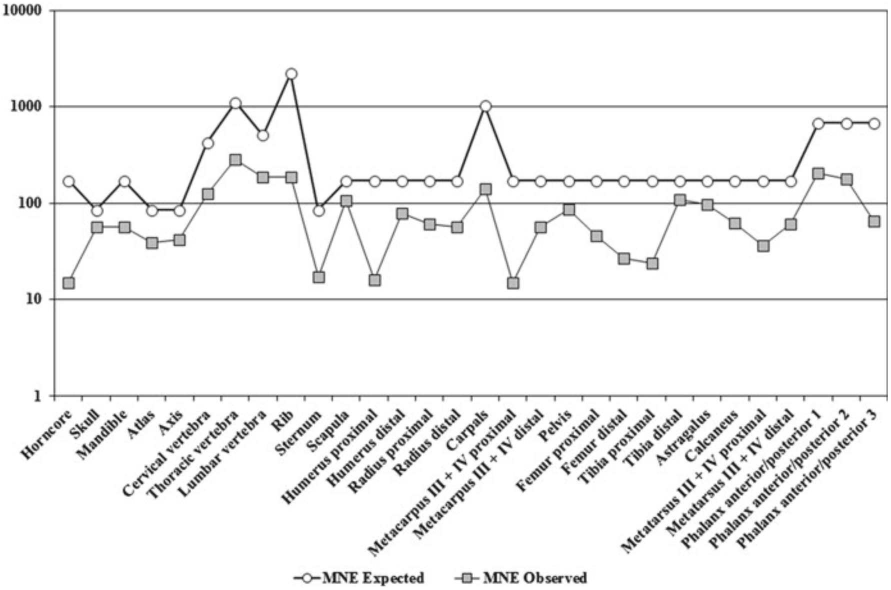

Fig. 7 Expected vs. observed MNE values to probe skeletal part abundance using log scale

In order to determine whether there is a real correlation between %MAU and density and to verify its statistical significance, Spearman's rank order correlation (Spearman's rho) was computed and significance test for the correlation coefficient was generated. The correlation is only slightly positive but statistically not significant ($r=0.080$; $p=0.711$).

Skeletal Completeness and Differential Preservation

In order to examine the degree of bone loss and differential bone preservation, I measure the preservation of upper vs. lower limb pairs, proximal vs. distal limb bone pairs, and skeletal completeness for body parts (Fig. 9). For the humerus-radius pair, the log-scale graph shows good and nearly equal representation, whereas there is a clear bias against femur in femur–tibia pair. Because the values for both pairs were generated by lumping proximal and distal portions together and taking the average, the biased patterns may be a result of differential preservation of proximal and distal portions due to their different density values or other reasons. This possibility is explored next through examination of ratios between proximal and distal portions of various bones.

Proximal humeri, proximal tibiae, distal femora, and distal radii are among the low-density skeletal parts in contrast to proximal and distal metapodia which are high-density parts, while distal humeri, proximal radii, proximal femora, and distal

Table 7 Expected vs. observed MNE, MAU, %MAU, and %Survivorship values

Skeletal element	MNE expected[a]	MNE observed	MAU	%MAU	%Survival
Horncore	170	15	7.5	13.2	8.8
Skull	85	57	57	100	67.1
Mandible	170	57	28.5	50	33.5
Atlas	85	39	39	68.4	45.9
Axis	85	42	42	73.7	49.4
Cervical vertebra	425	126	25.2	44.2	29.6
Thoracic vertebra	1,105	285	21.9	38.5	25.8
Lumbar vertebra	510	186	31	54.4	36.5
Rib	2,210	186	7.2	12.6	8.4
Sternum	85	17	17	29.8	20.0
Scapula	170	107	53.5	93.9	62.9
Humerus proximal	170	16	8	14	9.4
Humerus distal	170	79	39.5	69.3	46.5
Radius proximal	170	60	30	52.6	35.3
Radius distal	170	56	28	49.1	32.9
Carpals	1,020	140	11.7	20.5	13.7
Metacarpus III + IV proximal	170	15	7.5	13.2	8.8
Metacarpus III + IV distal	170	56	28	49.1	32.9
Pelvis	170	87	43.5	76.3	51.2
Femur proximal	170	46	23	40.4	27.1
Femur distal	170	27	13.5	23.7	15.9
Tibia proximal	170	24	12	21.1	14.1
Tibia distal	170	110	55	96.5	64.7
Astragalus	170	97	48.5	85.1	57.1
Calcaneus	170	62	31	54.4	36.5
Metatarsus III + IV proximal	170	36	18	31.6	21.2
Metatarsus III + IV distal	170	61	30.5	53.5	35.9
Phalanx anterior/posterior 1	680	205	25.6	45	30.1
Phalanx anterior/posterior 2	680	177	22.1	38.8	26.0
Phalanx anterior/posterior 3	680	65	8.1	14.3	9.6

[a] Based on MNI = 85

tibiae are considered to be medium-density skeletal parts. This way of looking at the data provides us with a means to further evaluate the role of structural bone density on differential survivorship and destruction of bones. Figure 9 demonstrates the log-scale relationships between long limb bone parts. The lower panel of the graph (i.e., below 1) shows typical bias against low-density portions such as proximal humeri, proximal femora, proximal radii, and proximal tibiae. Exception to this pattern is radius for which proximal and distal ends are equally represented. Thus, for these elements, it appears that density-mediated attrition was important. This contrasts with the situation for metapodia. There is a conspicuous bias against proximal metacarpi, one of the densest elements with a density value of 0.55 g/cm^3 (e.g., compared to the proximal humerus value of 0.13), and against proximal metatarsi, the densest bone portion of those considered, with a value of 0.68. This situation underlines the

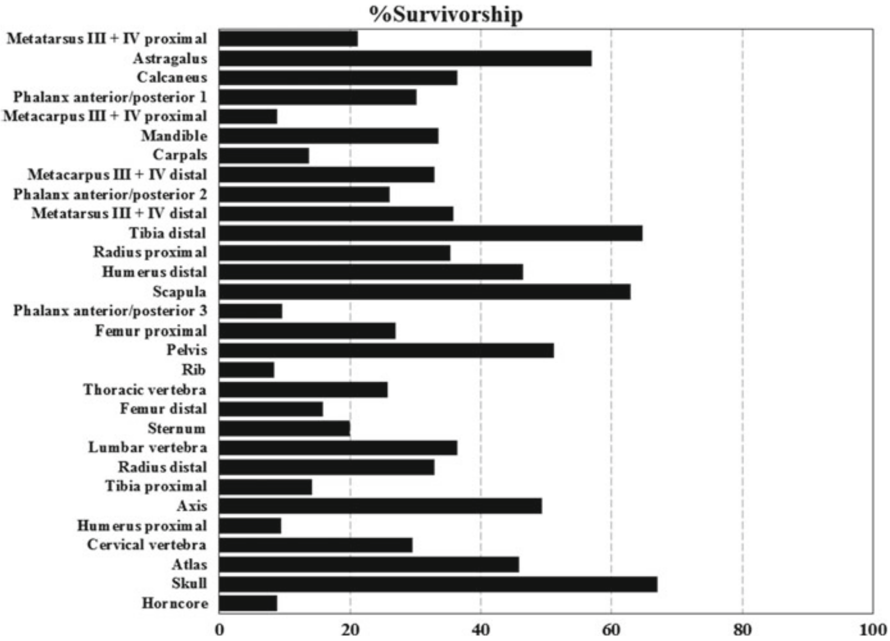

Fig. 8 %Survivorship of skeletal parts in the bone bed assemblage

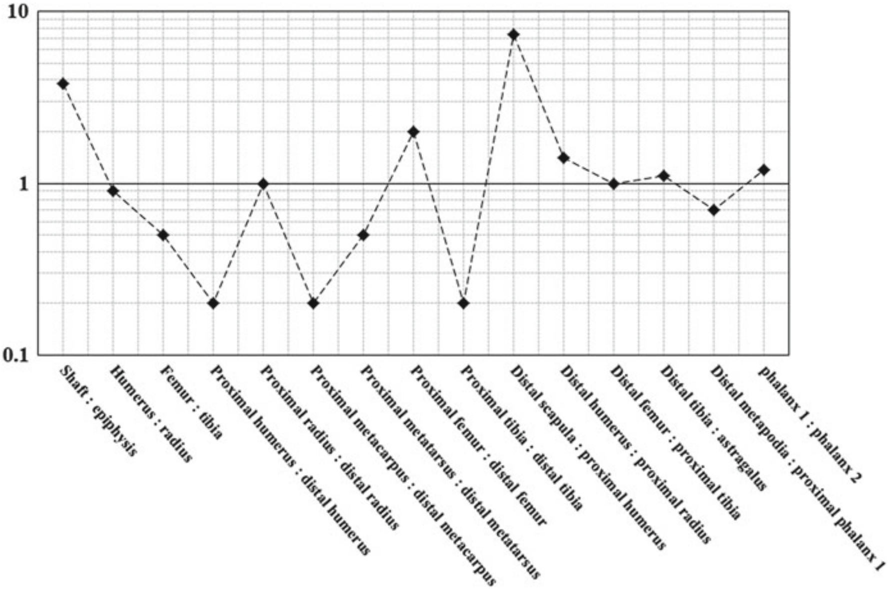

Fig. 9 Ratios of upper to lower and proximal to distal limb elements on a log scale

fact that bone loss was not exclusively density-mediated even though low-density parts overall were destroyed more frequently than high-density parts. Had bone destruction been only density dependent, these two high-density skeletal parts would have been among the best-represented portions of the skeleton. Underrepresentation of these two high-density parts attests to selective predepositional removal or destruction, for use as tools, not by in situ or density-mediated postdepositional attrition.

In addition to comparing proximal vs. distal portions of long bones, a ratio between shafts and epiphyseal fragments was also established. A shaft to epiphysis ratio of 3.8 is very similar to the ratio (5 to 1) obtained through actualistic and experimental research concerning the average number of fragments per limb bone (Capaldo, 1998). Along the same line, Table 8 offers an independent and verifying line of evidence as to how MNE estimates based on epiphyses and shafts yielded either similar results, or articular ends yielded greater MNE values, suggesting that this time-consuming and labor-intensive analytical procedure is not really necessary to estimate MNE values for the Karain B bone bed. This last affirmation also lends support to proponents of "rapid count" or "diagnostic zones" approach if and when carnivore ravaging can be securely ruled out as in the case presented here.

According to the body part profiles generated for the bone bed, forelimb, hind limb, and distal extremities are outnumbered by axial and cranial elements. This is an abnormal pattern particularly for the axial elements (21.7 %) which are more prone to destruction and underrepresentation in archaeofaunal assemblages because of their low-density values. Skull fragments (including teeth and mandibular fragments) comprise 28.6 % of the assemblage followed by the distal extremity, hind limb, and forelimb, respectively (Table 9). This trend does not change when NISP values are used, with the exception of decreased skull MNE values. This is an artifact of much higher skull fragmentation rates as attested by cranial bone MNE to loose tooth MNE ratio of 0.063 (Table 3). Among the axial elements, rib fragments comprise the largest group with a proportion of 20.7 %, whereas all other axial elements contribute 16 % of the total number of bones in the assemblage.

Given that very little impact from carnivore ravaging and other biotic factors has been demonstrated for the bone bed, the completeness of small, compact, and high-density bones such as carpals, tarsals, and phalanges should further illuminate the taphonomic processes that created observed patterns in the assemblages. Low degree of completeness for these bones would indicate intensive carcass processing or predepositional breakage. In contrast, axial skeletal elements with low density, inherent fragility, and high nutritional values are more susceptible to fragmentation. Thus, higher axial completeness values may indicate less intense processing and relatively low-level postdepositional bone loss. Figure 10 shows that axial elements are heavily fragmented, since their degree of completeness is low, with a proportion of 23.5. This pattern can be an artifact of bone density or more intensive processing and selective destruction of axial elements. Carpals have a completeness proportion of 100 %, whereas tarsals have a somewhat lower completeness degree in 85.1 %. The relatively lower completeness of tarsals may be due to the larger sizes of astragali and calcanei. In addition, their shape and anatomical position between marrow-rich tibiae and metatarsi make them susceptible to damage during butchery. The low

Table 8 MNE values for long bone shafts and epiphyses

Element	Portion	NF	MNE
Humerus	Proximal	37	16
	Distal	84	79
	Shaft	71	12
Radius	Proximal	80	60
	Distal	59	56
	Shaft	67	0
Ulna	Proximal	69	64
	Distal	15	15
	Shaft	41	0
Metacarpus III + IV	Proximal	30	15
	Distal	66	56
	Shaft	34	2
Femur	Proximal	55	46
	Distal	70	27
	Shaft	117	26
Tibia	Proximal	33	24
	Distal	118	110
	Shaft	162	18
Metatarsus III + IV	Proximal	89	36
	Distal	70	61
	Shaft	32	0
Grand total		1,399	723

Table 9 Body part frequencies

Body part %MNE	KB1
Head	28.6
Axial	21.7
Forelimb	13.3
Hindlimb	15.6
Distal extremity	20.8
Total	100

completeness of phalanges, with a proportion of 37.3 %, indicates heavy fragmentation of these parts. These elements are relatively small and poor in nutrients. Only the first and second phalanges contain small amounts of marrow. Thus, their deliberate fragmentation would point to a level of prey procurement intensity compatible with predictions of optimal foraging models.

Carcass Processing, Economic Utility, and Skeletal Evenness

A detailed look into butchery and carcass processing might offer further insights into skeletal completeness. The bone bed has 201 specimens with cut marks with almost all skeletal elements bearing traces of butchery (Table 10). It is also worth

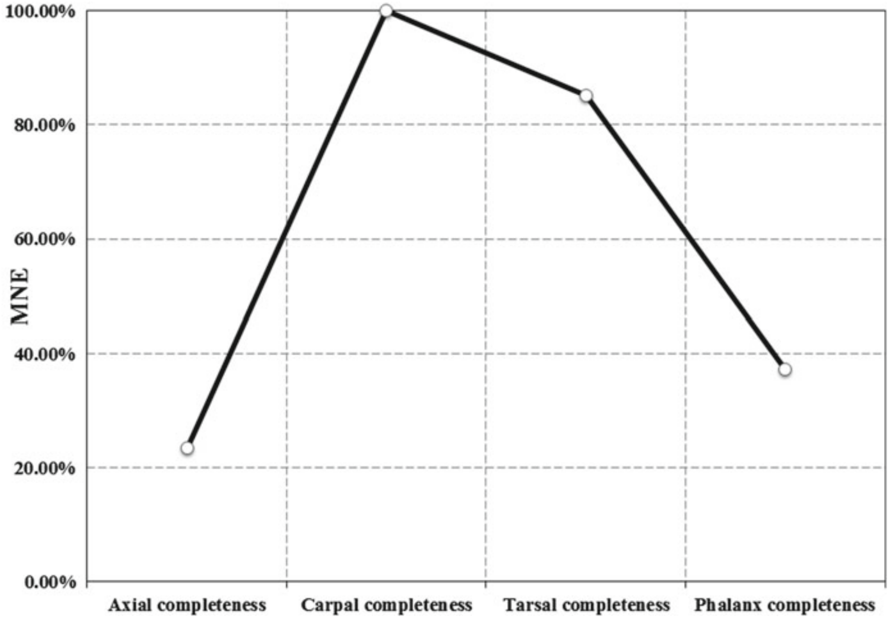

Fig. 10 Completeness of skeletal elements and body parts based on MNE

mentioning that majority of cut marks are on long bone shafts and ribs (45.8 %). This preponderance of cut marks on shafts and ribs may be symptomatic, an extremely important, and fundamental methodological issue in zooarchaeology. Many zooarchaeologists adopt a "diagnostic zones" approach; choose to record only more easily identifiable skeletal elements, such as teeth and articular ends; and exclude elements such as vertebrae, ribs, and long bone shaft fragments. Therefore, justification of ignoring long bone shaft fragments and other not so easily identifiable bones becomes even more problematic.

To further illuminate butchery, carcass processing, and bone transport, Spearman's rank order correlation was performed for the %MAU and MGUI pair. A slightly positive but statistically insignificant correlation ($r=0.044$; $p=0.819$) determines that there does not seem to exist a statistically meaningful and significant relationship between skeletal part abundance and the nutrients element portions contain. Moreover, using the standardized MAUs ($N=292$) for only high-density and high-survival elements (i.e., skulls, mandibles, humeri, metapodia, radii, femora, and tibiae), a Shannon evenness index of 0.975 was generated. Since skeletal evenness values very close to 1 indicate extremely even distribution of skeletal elements, a nonselective carcass transport includes low-utility elements (i.e., bones with low meat, marrow, and grease content) and parts, and no field processing would be inferred. In other words, carcasses were brought to the cave without field processing and without selective transporting of the parts with higher nutritional content and value.

Table 10 Frequency of butchered specimens

Skeletal element	NISP	%NISP
Mandible	14	7.0
Atlas	2	1.0
Cervical vertebra	1	0.5
Rib	32	15.9
Scapula	9	4.5
Humerus proximal	1	0.5
Humerus shaft	7	3.5
Humerus distal	16	8.0
Radius proximal	3	1.5
Radius shaft	5	2.5
Radius distal	4	2.0
Ulna	2	1.0
Metacarpus proximal	0	0.0
Metacarpus shaft	4	2.0
Metacarpus distal	2	1.0
Pelvis	3	1.5
Femur proximal	1	0.5
Femur distal	1	0.5
Femur shaft	16	8.0
Tibia proximal	1	0.5
Tibia shaft	25	12.4
Tibia distal	4	2.0
Astragalus	6	3.0
Calcaneus	2	1.0
Metatarsus proximal	4	2.0
Metatarsus shaft	3	1.5
Phalanx 1	1	0.5
Phalanx 2	2	1.0
Nonidentified shaft	30	14.9
Grand total	201	100

Bone Fragmentation

The relative frequencies of long bone shaft fracture angles coupled with the presence or absence of notches and percussion marks permitted identification of deliberate breakage of bones for marrow extraction and bone grease rendering. The fracture angle data coupled with percussion marks and notches suggest that most bone breakage was the result of dynamic loading or hammerstone blows when the bones were in a fresh state. Such green breakage is likely to have been the result of human demarrowing. The fragment size distribution in this assemblage shows that 84.2 % of shaft fragments ($N=3{,}019$) fall in the size range of 1–5 cm (Fig. 11). Acute and obtuse angles were observed in the randomly sampled shaft assemblage with a

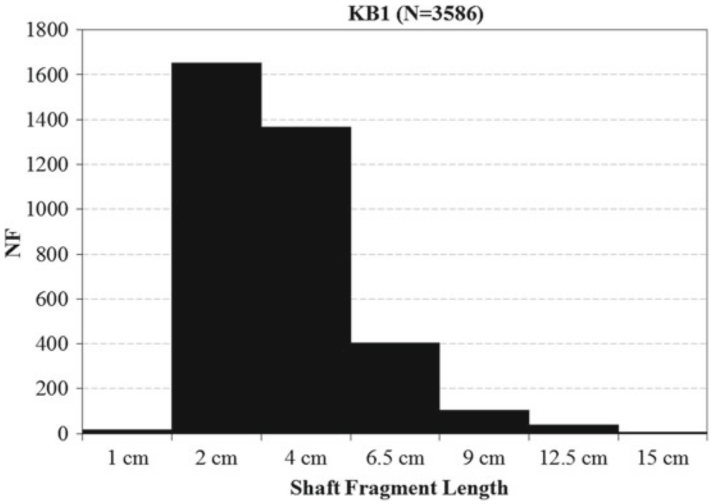

Fig. 11 Long bone shaft fragment size frequencies

proportion of 89.4 %. This interpretation is further supported by direct evidence for dynamic loading, i.e., by percussion marks and notches. In the absence of carnivore ravaging, the data clearly point to human modification and reduction of marrow bearing long bones.

Burning

Of the 419 burned bones from the bone bed, 45.6 % represent fragments smaller than 1 cm. Another 35.8 % make up the burned long bone shaft fragments within the 1–3 cm category. Burned long bone epiphyses or articular ends, which can be exposed directly to fire and heat when meat is cooked, account for only 12.4 % of the total number of burned bones. Thus, the high ratio of burned splinters and minute long bone shaft fragments suggest burning associated with either fuel management or site maintenance and not necessarily with cooking. A substantial portion of the burned bone sample, when it could be identified, consists of cancellous fragments. Use of cancellous bones as fuel may account for the large number of missing axial skeletal elements, whereas overrepresentation of other potentially combustible bone portions still begs for an explanation. Furthermore, the fact that other dense and less greasy bone portions (i.e., proximal metacarpals) are underrepresented exacerbates this issue. Given the size distribution among burned bones, burning may account for a part of the bone loss and might have facilitated, accelerated, or increased the number of nonidentified bones. It is also highly likely that burning may have deleted, altered, or masked some bone surface modifications (e.g., cut marks) that could have been conspicuous otherwise.

Discussion and Conclusions

Drawing upon two lines of specific evidence, taxonomic composition and assemblage formation, the present work shows that the Epipaleolithic stratum PI.2 at Karain B is a macrofossil bone bed with multispecific, multitaxic, or multidominant taxonomic representation, since the remains of two caprine species exclusively dominate the assemblage.

As far as the genesis and formation of the bone bed is concerned, the first stage of the taphonomic analyses revealed that the actions of nonhuman biotic or abiotic agents may not account for bone accumulation, modification, and destruction, leaving human behavior as the primary taphonomic filter. The archaeofaunal assemblage from the Epipaleolithic bone bed at Karain B provides a good example of human-accumulated and human-modified assemblage exhibiting differential bone preservation.

Despite the complete lack of carnivore ravaging and impact of other noncultural processes, a commonly observed trend toward underrepresentation of the most cancellous portions of limb bones (i.e., proximal humerus, proximal tibia, and distal femur) in archaeofaunal assemblages is also identified in this assemblage. This is a most striking aspect of the bone bed given that structurally weak and least dense axial elements, which are usually severely underrepresented in archaeofaunas, are relatively well represented in the bone bed. Because cancellous axial elements and articular ends contain tissues rich in fat and lipids and thus calories, they are the most likely targets for marrow and grease rendering processes that result in the smashing up of these elements (Speth, 1991). Defleshing meat from bones, cracking open long bones to extract marrow, and pounding and boiling axial bones and cancellous articular ends to render grease result in the loss of these skeletal elements and/or portions. Bar-Oz (2004) documented several Levantine Epipaleolithic assemblages with similar patterning and interpreted this as a product of intensified human exploitation of within-bone nutrients, in particular bone grease. At Karain B, there is no clear evidence for bone grease rendering nor is there much evidence for the practice of extensive butchery.

The taphonomic evidence indicates that meat and marrow extraction were the primary economic activities and thus primary cause of long bone fragmentation. Brain (1981) asserts that length of bone fragments tends to be remarkably consistent having a mean length of about 5 cm, probably as an artifact of efficient marrow extraction. A similar fragment size distribution in the bone bed reinforces the idea of an efficient marrow extraction. A secondary cause of bone fragmentation would be use of bones for combustion. A substantial portion of the burned bone sample, when it could be identified, consists of cancellous fragments. Use of cancellous bones as fuel may account for the large number of missing axial skeletal elements, whereas overrepresentation of other potentially combustible bone portions still begs for an explanation. Furthermore, the fact that other dense and less greasy bone portions (i.e., proximal metacarpals) are underrepresented exacerbates this issue. Still, the scarcity of cut marks may be a product of the combined marrow extraction processes and accidental burning of bones or their use as combustibles. This means that most of the shaft fragments underwent a size reduction that could have led to a poor visibility for cut marks or even to their total deletion.

A second most striking aspect of the bone bed assemblage is the lack of correlation between bone density and skeletal part representation and between MGUI and skeletal part representation. The analysis that was carried out by Bar-Oz (2004) on the five Levantine Epipaleolithic assemblages shows that humans were the major bone-accumulating and bone-modifying agents with minimal or no carnivore impact. This is an aspect shared by both the Levantine and the Karain B assemblages. The Levantine assemblages, however, show a strong correlation between bone density and skeletal part representation, suggesting a pronounced density-mediated bias in gazelle skeletal part profiles (Munro & Bar-Oz, 2005). This is in sharp contrast to the Karain B Epipaleolithic assemblage in which density-mediated attrition is not so evident. Therefore, pre-burial bone destruction must have occurred in addition to, or instead of, postdepositional bone loss. The Levantine assemblages are similar to those from Karain B also in that there does not seem to be a significant relationship between bone preservation and food utility index. This is interpreted to represent an absence of the selective transport of high-utility body parts. This difference is of paramount significance and has broader theoretical implications. There may be significant differences in results even when using very similar or identical analytical approaches. These differences may be due to the variation in behavior of bone-accumulating and bone-modifying agents. Therefore, generalizations and universal laws concerning past human behavior should be reconsidered.

A third most striking aspect of the bone bed assemblage has broader theoretical and methodological implications concerning the hotly debated research paradigm that entails the “shaft only”/“epiphysis only” binary. The bone bed at Karain B provides a good example of the sort of site that is free of carnivore impact, increasing the preservation potential of cancellous epiphyseal fragments for equally accurate, consistent, and representative MNE estimates. This also justifies a scenario if and when a zooarchaeologist chooses to skip time-consuming and labor-intensive shaft approach in favor of rapid-counting or data-rich diagnostic zones.

To conclude, the multivariate taphonomic approach and comprehensive quantitative matrix used in this work can be applied to all types of bone assemblages, and will help develop high-resolution picture of taphonomic histories—cultural, natural, or a combination of both. This methodological framework enables both intrasite and intersite probing at a local scale or at a higher, regional scale.

Acknowledgement I would like to extend a special thank you to Anna Osterholtz, Kathryn Baustian, and Debra Martin for organizing a very stimulating symposium, where I presented an earlier version of this paper at the 77th Society for American Archaeology (SAA) annual meeting in Memphis, TN, on April 19, 2012, and for putting this exciting special volume together.

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Normal Goat or Diseased Human? Disciplinary Boundaries and Methodological Traps in the Analysis of Fragmentary Remains at Franchthi Cave, Greece

Della Collins Cook

Previous Analysis

Franchthi Cave is a deep, stratified rock-shelter (the cave) and associated open-air site (the Paralia) on the shore of the Gulf of Argolis, the Peloponnese Peninsula, Greece. Thomas W. Jacobsen directed excavations there from 1967 through 1979 as a joint project of Indiana University's program in Classical Archaeology, the University of Pennsylvania, the Greek Archaeological Service, and the American School of Classical Studies at Athens. The excavation yielded Upper Paleolithic, Neolithic, and recent remains, the most extensive and complex pertaining to the several Neolithic components. The project was a landmark in Greek archaeology for its scale, its interdisciplinary focus, and its innovations in field methods (Cullen, 1995; Jacobsen, 1976; Jacobsen & Cullen, 1981) As is true of most large field projects in archaeology, analysis and publication have been slow, and both are still incomplete.

The late J. Lawrence Angel (1915–1986), a physical anthropologist associated during most of his career with the Smithsonian Institution, established the physical anthropology of ancient Greece as a modern discipline. He studied the human remains from many sites in the eastern Mediterranean (Buikstra & Prevedorou, 2012). Jacobsen invited Angel to describe the Franchthi human remains, and Angel spent several weeks in August 1969, September 1972, and June 1975, working with the collection (Angel & Bisel, 1985). During these few weeks, he reconstructed crania and long bones, measured both, took photographs, and wrote descriptions.

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_13,

In his manuscript on skeletal remains from Franchthi Cave, finished shortly before his untimely death, Angel described three groups of small vault fragments as highly unusual. In 1987, after Angel's death, Jacobsen asked this author to review Angel's manuscript with my eye toward revising it for publication; questions arose while reviewing the manuscript that could not be resolved without reanalysis of the skeletal material. Of particular interest were the similarities in three descriptions of cranial fragments recovered from different excavation units: whether they were pathological and whether they might represent a single individual who had been fragmented and distributed widely through the cave. Angel describes the fragments as:

> "64 Fr (Q5S#73) is an occipital skull fragment. It includes a +++ inion at a very sharp angle where internally the torcular herophili occurs (venous dural sinus turning and meeting), and a right cerebral fossa with a thickness of only 3.5–4 mm. This could be a male young adult. Brain digitations are striking" (Angel & Bisel, 1985, p. 43).
>
> "74 Fr (Q:77) is the right upper occipital of a child of about 10–14 years, perhaps from the same skull as 72 Fr. It includes 36 mm along the open lambdoid suture, extends 32 mm forward, includes the right lateral sinus (the groove for the major dural sinus carrying venous blood from the brain) and shows ++ brain gyri digitations" (Angel & Bisel, 1985, p. 43).
>
> "75 Fr (Q6N#25) is the anterior left parietal, posterosuperior right parietal, and upper left occipital of a female (?), probably middle-aged on the basis of + closure of the lambdoid suture. The meningeal grooves are average, but the occipital brain digitations are very marked. The occipital crest is mound-shaped and + size. Thicknesses…are average with no hint of anemia" (Angel & Bisel, 1985, p. 44).
>
> "82 Fr (P5#162) is a 32 × 28 mm piece of upper right frontal bone, possibly from a young adult female, with open coronal suture and sharp curvature. The thickness near the boss is 6.5 mm with diploë 4.9 mm, suggesting anemia. Brain digitations are very marked and sharp" (Angel & Bisel, 1985, pp. 46–47).

Angel's term for the confluence of the sagittal and transverse venous sinuses on the inner surface of the occipital bone may be unfamiliar to some. "Torcular herophili" is an obsolete anatomical term meaning "the wine press of Herophilus" (Dortland, 1948). His use of this term is an example of Angel's immersion in classical studies and his wit regarding anatomical science. Herophilus was a Greek physician (335–280 B.C.) born in Asia Minor, who was the first anatomist to dissect humans, and perhaps someone we ought to remember with an eponym. Note that Angel's language verges on suggesting that these cranial fragments are pathological. He points out what he calls "brain gyri digitations" or falciform impressions. These are ridges on the internal surface of the skull vault that correspond to the convolutions on the surface of the brain. He also points out unusual suture margins (Fig. 1).

Reanalysis

I was immediately interested in Angel's descriptions, because gyral or falciform impressions recording the surface detail of the brain are very unusual in these locations in humans, and if they are present, they point to increased intracranial pressure

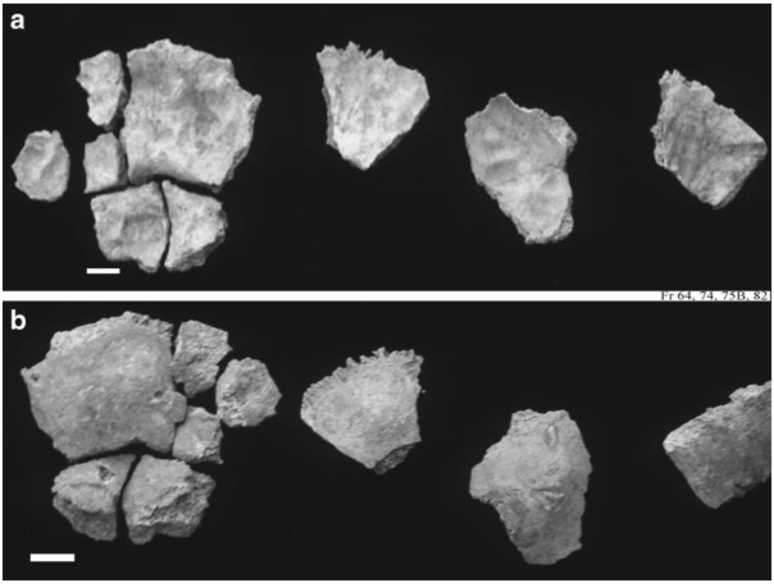

Fig. 1 Faunal cranial elements mistaken for human, (**a**) endocranial surfaces, (**b**) ectocranial surfaces

or other grave abnormalities. Only 74 Fr falls within what one might consider a normal location for falciform impressions in humans. My guess was that these fragments might all be from a single individual, albeit one distributed very widely through the excavations. Since I am interested in paleopathology, I was perhaps too eager to discover whether these fragments might constitute an earliest case of hydrocephalus, an ambition since bested by other researchers (Tillier, Arensburg, Duday, & Vandermeersch, 2001), or the perhaps first case in paleopathology of polymicrogyria (Flotats-Bastardas et al., 2012). When Jacobson and Tracey Cullen invited me to examine the Franchthi collection and and add to Angel's manuscript, these fragments were the ones I was most anxious to see.

A refresher course may be helpful for readers who may not look at ungulates every day. Common ruminants differ from humans in having paired os frontale that includes the horn core or the antler base. The metopic suture between the two persists into adult life. The sagittal suture fuses early so that the single os parietale is a narrow band of bone extending from orbit to orbit. The os occipitale is relatively large, and the interparietal suture (or sutura Mendoza) closes late, so that the squamous occipital in humans is represented by two bones: the interparietal and the occipital proper. Fusion of the squamous occipital with the lateral occipital elements around the foramen magnum is also late in comparison with the suture closure pattern typical of humans. All the vault bones in smaller ungulates routinely show falciform impressions.

In 1989, reanalysis undertaken by Tracey Cullen and the author showed that several cranial fragments had been misidentified as human, and following the practice previously established for Franchthi, these were removed from the list of human specimens. The discovery that a group of Mesolithic burials had been burned and that many bones in this group had freshly broken edges led us to look at the corresponding faunal units, refitting of many unrecognized fragments of human bone fragments made possible the recognition that two bodies had been burned while fully articulated (Cullen, 1995). More faunal units were searched in 1990 and 1992 for more human bone. Any skull fragments identified as faunal were reassigned to the appropriate part of the collection. However, small vault fragments lacking suture margins or named features were sorted as possibly human consistent with the earlier practice. For example, Sebastian Payne, the faunal specialist who took on the Franchthi bones, reassigned 97 mostly cranial fragments from the faunal series to the human bone series between 1975 and 1982 (Angel & Bisel, 1985).

A noteworthy characteristic of the Franchthi cranial fragments is that they are small, all less than 5 cm, and thus too small for one to appreciate the much tighter radius of curvature in the vault bones of small-brained mammals. Leonard Radinsky pointed out long ago (1974) that humans are unusual among mammals in not having marked falciform impressions, a consequence of our large body size exacerbated by our exceptionally large brain size. That is to say that what is normal in a goat—well-marked, small falciform impressions in a brain case less than 10 cm in diameter—is quite abnormal in a human.

My purpose here is not to make posthumous fun of Larry Angel. He was an accomplished osteologist and anatomist with much experience in distinguishing human remains from nonhuman remains (Angel, 1974). His time with the Franchthi collection was short and disjointed, and he did a great deal of skull reconstruction and measurement during his short stays. He wrote his manuscript in ill health and without opportunity to revisit the collection. In addition, he had a great deal of company in these mistakes. Records are incomplete, but physical anthropologist Yaşar Işcan participated in Angel's later seasons at Franchthi, and may have seen these fragments or pulled them from the faunal remains. Sara Bisel saw them and took trace element samples from three of the four (Cook, 1999). Embarrassingly, it took this author two examples to realize what was being examined was nonhuman bone, perhaps because of a preexisting theory regarding the discrepant features as pathology.

Lessons Learned

There are several lessons here. Franchthi Cave was the first site in Greece to be systematically screened. It yielded enormous quantities of animal bone that have yet to be fully analyzed. Sorting of ceramics, lithics, shell, faunal bone, and human bone was a labor-intensive task. Records were not kept on the training or identity of the sorters, but this job goes to junior members of most field projects. An interesting

Fig. 2 Nondescript cranial elements from a single excavation unit differing in taphonomic features that suggest differing histories

consequence at Franchthi is that bone elements reassigned from ceramics after sherds were washed with acid look as if they have passed through a carnivore digestive system (compare Payne & Munson, 1985). A methodological issue arises here: best practices would require records of reassignment of these bones from one portion of the collection to another. Also, acid treatment should be avoided to protect against future misinterpretation of their taphonomy.

Human bone at Franchthi is relatively sparse compared with the enormous quantities of faunal bone that were recovered. The Mesolithic inhabitants of the cave are represented by nine individuals consisting of, at worst, five elements from an excavation unit and, at best, complete skeletons recognized as burials during excavation, as well as 49 isolated bones or teeth (Cullen 1995). The Neolithic occupation is represented by 41 partial or complete skeletons and 269 fragments. Only four of the Mesolithic isolated bones are vault fragments, whereas 86 of the isolated bones in the Neolithic components are vault fragments.

Small skull fragments are vastly overrepresented in the fragmentary remains. The cranial fragments in Fig. 2 are from a single excavation unit. The different colors and textures suggest quite different taphonomic histories, including in this example burning, weathering, and surface abrasion. The identifiable sheep or goat fragments in Fig. 1 are similar to the Fig. 2 vault fragments in their small size. They are well preserved at a tissue level despite their fragmentation, as are all but a few of the human burials from Franchthi. They differ from the sheep–goat vault fragments in that they lack diagnostic features such as suture margins. Indeed, the whole Franchthi human bone fragment collection is notably lacking in the elements that one would use for a minimum number of individuals count: petrosals, parietal notch, occipital condyle, zygomatic process of frontal, external occipital protuberance, mental eminence, etc. These portions of the skeleton are denser than cranial vault and hence more likely to resist fragmentation. They are paired and can be readily sided, or they are midline structures. The Franchthi vault fragments are nondescript in the sense that they lack features that lend themselves to unambiguous species identification. It seems very likely that the nondescript vault fragments that Angel and others—including myself—have identified as human may include many other ungulate fragments. Because faunal bone is much more common at Franchthi than human bone and because many of the faunal crania are highly fragmented, likely for culinary purposes, any ungulate skull might leave behind several such nondescript fragments. Consequences for estimates of the number of persons buried at Franchthi, for arguments about secondary burial or ritual use of human bone, and for the numerator in statements about anemia and trauma are substantial.

An important consequence for interpreting Franchthi is that at least three of the supposedly human bones included in Sara Bisel's pioneering trace element analysis were demonstrably nonhuman (Cook, 1999), and so many more of the small vault fragments she sampled must be suspect. More recent stable isotopic studies have sampled only the complete and partial skeletons at my advice (Papathanasiou, 2003). A remaining puzzle is the failure of either the trace element or the isotopic research to demonstrate the high variability in marine versus terrestrial resource use documented in studies of the fauna (Payne, 1975; Stiner & Munro, 2011). A small number of ungulates would contribute importantly to the picture of Franchthi's inhabitants as terrestrial C3 plant consumers.

Franchthi fauna is diverse in body size and differentially distributed across the stratified components of the cave and the Paralia. The Mesolithic fauna includes wild goat and boar, auroch, red deer, and wild ass (Stiner & Munro, 2011), while the Neolithic fauna is predominantly domestic sheep and goat (Jacobsen, 1976; Payne, 1975). This shift in subsistence and the relocation of domestic activities in the open-air site rather than the cave may account for differing frequencies of vault fragments relative to other body parts without resort to ritual activities as an explanation (Cullen, 1999).

In hindsight, a more rigorous criterion for identifying vault fragments as human should have been set. Nondescript vault fragments that this author could not identify were retained as nonhuman because that had clearly been the previous field method, because my colleague was committed to manipulation of remains as ritual practice (Cullen, 1995), and because a primary research goal was the refitting of skull fragments into larger units for analysis. The search for joins was disappointing, and that disappointment may be instructive. It suggests that the fragments do not originate from crania broken in situ to gravel size and moved over short distances as deposits were reworked. The ratio of easily identified teeth to skull fragments has been used to argue against an identification of vault fragments as human in other contexts (Palmqvist et al., 2005) and would similarly cast doubt on whether most of the nondescript vault fragments at Franchthi are human.

On the one hand, a more formal approach to minimum number of individuals analysis would have been useful early in the process rather than after the fact. On the other hand, this zooarchaeological method would substantially underestimate the number of Neolithic burials recognized as such in excavation. There have been few tests of the efficacy of MNI methods on human remains, and most have been done on specialized cemetery sites (Bello, Thomann, Signoli, Rabino-Massa, & Dutour, 2002; Waldron, 1987) rather than on habitation sites that include burials plus enormous quantities of faunal bone. These studies have not quantified relative fragmentation, as several contributors to the zooarchaeology literature have done. Franchthi is not the place for such a study in retrospect, but one is needed.

Implications for Future Research

Why is this little group of mistaken identifications important? This problem is not limited to Franchthi Cave, to Greece, or to Old World osteology. White tailed deer, llamas, and many other medium-sized ungulates will yield similar fragments in stony, unstable deposits that result in considerable breakage. In addition, there are issues within our training and literature that need to be addressed. There is relatively little discussion in the bioarchaeological literature of the problem of distinguishing human from nonhuman bone. Ubelaker has published on hydrocephalic calves mistaken for normal human children in forensic contexts (Ubelaker, Berryman, Sutton, & Ray, 1991). This particular mistake is even more common than he demonstrates. Until 1986, Beloit College Museum had catalogued a hydrocephalic calf vault as an archaeological example of human hydrocephalus from the Northwest Coast until this author noted the error. Note that in these cases a pathological animal is mistaken for a normal human, the inverse of the Franchthi case, where my enthusiasm for finding a pathological human led me to normal goats and sheep!

Our colleagues in human paleontology are much more likely than are those of us who work with more recent remains to air their dirty laundry in print. Wildscheuer Cave right parietal fragments purported to be Neanderthal are, in Fred Smith's opinion, not human (1984). At least two groups of researchers have resorted to histological techniques to distinguish hominid from cave bear teeth (Gantt, Xirotiris, Kurten, & Melentis, 1980; Vlček, 1978), and there are many other examples. Probably the most vituperative recent case is Orce Man—or Orce Horse—or Orce Deer (Campillo, 2002; Gibert et al., 1998, 2002; Moya-Sola & Kohler, 1997). The controversy over this fragment has been ongoing since 1985 and has outlived several of the initial participants. The fragment has been most recently identified as a ruminant (Martinez-Navarro, 2002), and there is a convincing argument for the statistical improbability of recovering several bone fragments but no teeth (Palmqvist et al., 2005), the teeth being far more diagnostic of species than bone fragments. Orce is quite similar to the Franchthi cranial fragments in that much of the debate involves anomalous falciform impressions and contested suture identifications.

As a discipline, paleopathology lies betwixt and between many others: archaeology, physical anthropology, medicine, human anatomy, comparative anatomy, and paleontology, among them. Adequate training of physical anthropologists or paleopathologists in the osteology of faunal remains is vital. My own training included courses in mammalogy, primate comparative anatomy, and mammalian comparative anatomy, but no courses in ethnozoology or zooarchaeology. In contrast, zooarchaeologists almost always have some training in human osteology. The University of Tennessee's program is one of the few good models for equal emphasis on human and animal osteology. Indiana University has always had a zooarchaeologist on our faculty, and the curriculum encourages study across subdisciplinary boundaries. The Franchthi case study is used as an example in encouraging physical anthropology students to take zooarchaeology courses.

Specialization is the norm in science, but overspecialization has its own perils. One psychologist interested in scientific thinking has labeled one of the important hazards *instrumentalism*: "I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail" (Maslow, 1966, p. 15). Paleopathologists and bioarchaeologists should borrow a tool or two from our colleagues in zooarchaeology. It is sometimes better to focus on elements that can be identified reliably and unequivocally, rather than straining to recover every possibly or plausibly human fragment.

Acknowledgements A version of this chapter was presented at the Fifteenth Annual Paleopathology Association Meetings, Durham, England, in 2004. I thank Thomas W. Jacobsen for inviting me to look at the Franchthi collections. Tracy Cullen and Susan Kirkpatrick Smith collaborated in the labor of searching the faunal bone units for human elements, and Tracy Cullen oriented me to the collection and negotiated permits.

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Taking Analyses of Commingled Remains into the Future: Challenges and Prospects

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Cultural Context and Commingled and Disarticulated Human Remains

A well-known axiom in bioarchaeology is that the dead do not bury themselves (Parker Pearson, 1999, p. 3), and so burial practices will disclose as much about the living who perform the burials as the dead who are buried. Often these assemblages represent secondary burial practices or the continued reuse of burial sites, and for this reason they are linked to mortuary behavior and beliefs that involve manipulation and cultural modification. When examining commingled or disarticulated burials, it is almost impossible not to draw associations with van Gennep (1972 [1960]) and Hertz's (1960) work regarding liminality and rites of passage. Hertz (1960) in particular notes that the manipulation of the body is a mechanism for the creation of group identity and reintegration of the dead individual back into the community as an ancestor. This places the physical body of the deceased in a state of balance between life and death, danger and safety, and chaos and order. During the processing of the body, whether that be through active manipulation of the body (see Osterholtz's discussion of Sacred Ridge, 2013), or variable taphonomic changes as seen for La Plata and Op. 1000 (Martin, Akins, & Toll, 2013; Duncan & Schwarz, 2013), or through natural decomposition of the body in the tomb of Tell Abraq

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6_14,

(Osterholtz, Baustian, Martin, & Potts, 2013), the remains represent a "… state of mediated equilibrium between order and vitality …" that "… has become a state of pure, fatal order" (Metcalf & Huntington, 1991, p. 115). Only through a successful completion of the entire process of death, transition, and final disposal of the body is the "… proper relationship between the worlds of the ancestors and the living… reestablished" (Metcalf & Huntington, 1991, p. 130).

Commingled and disarticulated burials can also be seen as social currency. Sofaer (2006, p. 20) notes that "… the dead body was flagged as a highly visible social resource that could be appropriated to act as a focus for the communication of intended meanings related to the social perception of the deceased by others" and cites the work of Shanks and Tilley (1982) to support this argument. Commingled assemblages (however created) can be a mechanism for developing cohesive group identity. Cauwe (2001) ties an association between the collectivizing of burials and agriculture, noting that in Europe and Southwest Asia, the number of collective graves increases with the Neolithic period during periods of aggregation and agricultural development. Keswani (2004) draws an association between collective tombs and maintenance of tradition, particularly during times of economic change. In this way, the dead are used as a touchstone for the living and a mechanism for the maintenance of underlying social structure in changing economic conditions. In a larger sense, an example from the island of Cyprus shows that the relationship with the dead and the houses of the dead have been used as community touchstones since at least the Late Bronze Age (ca. 1750 BCE) (Fisher, 2007). Once interred in a collective manner, the individual disappears and is subsumed under into the identity of the ancestors (Hertz, 1960). This relationship can then be used to cement social ties or assert economic rights over specific resources or land (Keswani, 2004; Saxe, 1970).

Intentionally commingled burials indicate that strong cultural mortuary rituals may have been important to those burying the dead at sites employing long-term commingling (e.g., chapters covering Çatalhöyük, Tell Abraq, and Op. 1000). This may not always be the case, however, because of sites where episodic commingling occurs (e.g., chapters covering Crow Creek and Sacred Ridge). When commingling only involves isolated bones, it is crucial that the bioarchaeologist/archaeologist gather as much contextual information as possible. This is important to explain the process by which the bones became mixed. If it is determined that the admixture was due to cultural modification, then the objective shifts to understanding the cultural significance of such actions.

This last exercise is also relevant for understanding intentional dismemberment, reduction, and fragmentation of human bodies. In recent years, the concepts of fragmentation and enchainment have permeated discussions of burial practice in Neolithic and Mesolithic Europe (Chapman, 2000, 2010; Chapman & Gaydarska, 2007). Appleby (2010) notes that the primary impact of fragmentation in archaeology is the acknowledgement that archaeologists do not always work with whole objects. A modern anatomical understanding of fragmentation and enchainment theories sees the body as a part of a machine, "… a whole but with definable parts each with a specific function" (Brittain & Harris, 2010, p. 586). Thus, the retention of specific body parts (e.g., adult male skulls) can be seen as a continuation of their specific function in society. Breakage may be deliberate and the pieces may be dispersed in meaningful ways (Appleby, 2010; Chapman, 2000) and lead to the renegotiation of the dead person's role in society.

Conceptualization of these theoretical perspectives regarding commingled and disarticulated assemblages allows greater interpretation of human behavior and cultural practices for past societies. This cannot be done without extensive detailed analyses of the human remains. The following section addresses the most optimal techniques for approaching commingled skeletal remains.

Best Practices and Approaches to Commingled Skeletal Remains

One of the primary objectives of the original SAA-organized session and this volume is to coordinate the work of numerous scholars and collectively present their approaches to analyzing commingled and disarticulated skeletal remains. The variation in technique in each of the projects demonstrates that every assemblage requires flexibility and innovation. We suggest that the case studies in this volume be considered best practices that can be adapted and modeled in future bioarchaeological work involving commingled and/or fragmentary remains.

When a commingled assemblage is encountered, the methodological approach impacts what kinds of information can be obtained from the sample. A great deal of planning and organization is often necessary from the beginning of excavation through analysis of the remains and into the data synthesis stage. The methods exemplified in this volume illustrate various ways in which assemblages are investigated. While guidelines for the estimation of sex and age at death can be given along the lines of White, Black, and Folkens (2011), the analysis of commingled remains calls for a large degree of flexibility for two reasons. First, the way an assemblage was created will impact how it can be analyzed and the types of research questions that can be asked. The analytical approach must also be tailored to accommodate the circumstances of formation processes, preservation, taphonomy, and curation. Second, bioarchaeologists are influenced by their research agendas and questions regarding the population of study. Without defined research goals (i.e., the determination of MNI and the identification of a demographic profile), the sheer amount of data that can be collected on commingled remains can become overwhelming. Preservation and context of a sample may mandate amendment of these research goals, however, and changes may occur at many stages of inquiry.

Beyond innovation in methodology, the research findings in this volume demonstrate a need for organization in data management systems. Commingled and/or fragmented assemblages require aggressive organization from the start of analysis through presentation of results. This is particularly an important step in the construction of data forms and databases. With a well-designed and organized process for data collection, researchers can dramatically accelerate analysis, interpretation, and presentation of data.

The establishment and maintenance of a data management system is also important for accommodating the amount of data that can be gathered with fragmented and commingled remains. Analysis of commingled remains should begin with an eye towards the ultimate quantitative and qualitative analysis of the remains by periodic checks for data hygiene. This may entail keeping daily logs with more detail than would be required for standard burial analysis. When conducting a large-scale commingled project, consistency in data collection can be a challenge. A minimum of confusion and maximum of consistency is optimal; therefore, a small team completing the analysis is helpful. Also, the use of dropdown menus and attention to consistency in computerized data entry will ensure that quantitative analysis of categorical data can be conducted without significant error. The amount of data that can be generated during a large-scale analysis of commingled and fragmented remains can be overwhelming. A plan should be in place prior to the beginning of any such analysis to accommodate large data sets.

There is no *right* way to approach the analysis of a commingled and/or fragmentary assemblage. Three studies that exemplify the vast differences in methodological approaches include those by Zejdlik, Osterholtz, and Atici. Zejdlik's use of photographic evidence helped to reestablish provenience of Aztalan remains that had become commingled after excavation. The methods in this project demonstrated the value of using all documentation from the field and the repository when analyzing commingled assemblages, particularly those with less than optimal curation. Osterholtz (drawing on White's analysis of a similar assemblage) showed that the intense process of refitting fragments into conjoins offers an opportunity to discuss perimortem processes and trauma patterns that would otherwise be missed almost entirely. And lastly, Atici's discussion of taphonomy and representativeness of elements among faunal remains illustrated that zooarchaeological techniques can be useful in analysis of commingled human assemblages as well.

The use of modern technology is especially highlighted by the chapters by Hermann and colleagues, Fox and Marklein, Atici, Osterholtz, and Osterholtz and colleagues. Each of these projects utilized modern technology and sophisticated identification of elements from the beginning of the analytical process so that organization was maintained. This was vital in their approach to their large assemblages. Numerous authors also used technology and organization to present their data in easy-to-interpret ways. The amounts of data collected in some of the studies reported here are quite substantial. The task of interpreting such data without sufficient organization would likely have been unmanageable. Readers should thus learn from the examples of this volume and keep organization at the forefront of their own research.

Common Themes in Commingled Analysis

The themes that run through the various chapters demonstrate that commingled skeletal assemblages are capable of providing extensive and valuable data to archaeological interpretations. Four common themes stand out as relevant to analysis and interpretation of commingled assemblages: overcoming fragmentation, identifying taphonomy, understanding complicated mortuary practices, and revealing symbolism and agency. Each theme is closely tied to others and this is observed frequently in the contributed case studies. The following sections highlight these themes.

Fragmentation

Commingling can occur in a variety of ways but is most complicated when bones are not in their original and complete state. The processes by which bones become fragmented can dramatically impact the degree of commingling. As research at the Sacred Ridge and Mancos sites demonstrated, perimortem dismemberment and processing of the body caused significant fragmentation of elements (Osterholtz, 2013). Exposure to the elements and animal scavengers likely contributed to fragmentation among the dead at Crow Creek (Kendell and Willey, 2013). The researchers in that project focused on bone mineral density and its effect on element representation and preservation among commingled assemblages. The breakdown of the cellular structure of bone is a natural process, so natural taphonomic fragmentation is expected for any human remains given a long enough period of interment and appropriate conditions around the remains. When fragmentation of skeletons occurs, the proximity of individuals to each other will greatly influence how much commingling is possible.

Cross-disciplinary training is very important for the identification of fragmentary bone, particularly the ability to differentiate between faunal and human bone fragments. This is not always an easy or straightforward task, as noted by Cook (2013). She describes a previous analysis conducted by J. Lawrence Angel where cranial fragments were identified as belonging to a pathological human cranium. Upon reanalysis, the fragments were correctly identified as caprid remains. The establishment of MNI based on a feature-based approach (Osterholtz et al., 2013) is essentially an adapted zooarchaeological technique (based primarily on the work of Knüsel and Outram (2004)), as is the concept of the likely minimum number of individuals (LMNI) as used by Kendell and Willey. Atici (2013) provides an in-depth exploration of how zooarchaeological analytical methods can impact the study of human remains from a collective setting. We suggest that these be incorporated into the best practices for studying commingled and fragmented skeletal assemblages.

Taphonomy

By definition, taphonomy is any process that affects the body of an individual after life has ceased. These processes may be intentional, natural, or accidental, but the disturbances to the human remains can cause significant shifting and mixing of body parts. One prominent similarity among all of the commingled assemblages discussed in this volume is that taphonomy is a major factor in commingling.

Studies in this volume demonstrate how to recognize taphonomic processes in commingled assemblages and what methodological approaches are most appropriate for dealing with them in analysis.

Taphonomy can be both postdepositional within an interment and related to curation and lab analysis. The case studies in this volume exemplify great variation in the processes that contribute to fragmentation and commingling of bodies. On one end of the spectrum, post-excavation curation and lab taphonomy (Zejdlik, 2013) resulted in commingling of remains from Aztalan. At the other end, extreme processing of human bodies at Mancos and Sacred Ridge (Osterholtz, 2013) created very complicated assemblages requiring extensive refitting. Through a careful analysis of the distribution and nature of tool marks, fracture patterns, and burning, a reconstruction of the choices made during dismemberment and processing could be compared between two assemblages exhibiting extreme processing.

Identifying processes that have affected human remains can be vital to reconstructing events at the times of death and burial. Case studies in chapters by Kendell and Willey, Osterholtz, and Martin and colleagues demonstrate how peri- and postmortem activities can be revealed by understanding taphonomic processes. Having a better understanding of taphonomy can also assist in delineating cultural values of the population being studied. For example, Herrmann, Devlin, and Stanton (2013) explore the complexity of mortuary activity among the Adena by comparing the degree of burning during cremation and element distribution. In a similar way, Osterholtz and colleagues (2013) were able to hypothesize mortuary scenarios at the site of Tell Abraq by identifying differential preservation and representation of skeletal remains. Lastly, Martin and colleagues (2013) demonstrated that taphonomic processes such as carnivore activity may reveal a lack of mortuary significance rather than consideration of dismemberment as a mortuary treatment. As these examples illustrate, taphonomy and interpretation of mortuary practices can be inextricably linked which blends the identification of these two themes in this volume.

Mortuary Practices

Commingling is frequently the result of mortuary treatments and the ideologies that guide them. Both primary and secondary mortuary practices can lead to commingling, particularly if the body is decomposed at the time of interment. The disposition of the body in a grave is the primary informer of mortuary context; however, analysis of the human remains themselves can provide an incredible amount of data regarding mortuary ritual. Boz and Hager (2013), for example, described how social factors affected the ways in which bodies were treated at death and body parts became dispersed in intramural settings. Glencross (2013) also demonstrates that differential mortuary treatments and skeletal evidence can inform the analyst about the role of individuals during life. Her discussion showed how Yandasqua prisoners/enemies could be identified among commingled assemblages.

Mortuary practices are not always the primary cause of commingling, however. In one of the case studies provided by Fox and Marklein (2013), the authors discovered that the commingled remains at Kalavasos-*Kopetra* were not actually commingled at the time of interment. Through the use of photographic comparison of human remains during excavation, they were able to unmingle the remains and reinterpret the mortuary practices accurately. While many commingled assemblages can at least be partially explained by mortuary treatments, Fox and Marklein caution against assumptions that assume intentional mortuary treatment.

Symbolism and Agency

What is *not* recovered is also important to exposing symbolic meaning and agency on the part of the community burying the dead. Analyses that discover differential representation of elements reveal more about the culture of the people that are still living than the dead themselves. This was apparent in the study of the remains from Tell Abraq (Osterholtz et al., 2013), in which the underrepresentation of male crania in the tomb indicated significance of some individuals or skeletal elements.

Symbolism and agency are discussed by Duncan and Schwarz (2013) in their research investigating Postclassic Maya embodiment of elements. In their study, the intentional removal of specific areas of the body for use elsewhere was presented in an alternative approach to understanding assemblage formation processes. This was also the case at La Plata (Martin et al., 2013) where the placement of long bones in a skull cap was found to be ritually symbolic rather than a discard associated with cannibalism. Lastly, Glencross (2013) discussed the Feast of the Dead in Ontario and the mixing of bones in “the kettle” as a symbol of community membership.

Thus, symbolism is richly interpreted in many of the studies in this volume. Consideration of such cultural motivations is vital to more nuanced explanations for commingling and disarticulation of human bodies. An excellent example of this is how Duncan and Schwarz use ethnographic examples to show that land tenure and corporate control was gained by an incoming group by the desecration of a large grave assemblage. So, the question of *who* is manipulating the remains and for *whose* benefit the manipulation is being performed should also be considered. Analyses of commingled and fragmentary remains must take place within cultural contexts as ignorance of possible factors presents a great potential for the misunderstanding of unrecognized processes and cultural practices in past communities.

Future Directions for Bioarchaeologists Analyzing Commingled Remains

This volume pushes the bioarchaeological analysis of fragmentary and commingled remains in a new direction. The case studies presented emphasize the importance and significance of commingled skeletal assemblages in research that contributes to our understanding of past human cultures. Although often a great deal more complicated, commingled remains are valuable data sets and should not be ignored. The contributors to this volume have demonstrated the variety of information that can be interpreted and some of the best approaches to accomplishing data collection.

But where do bioarchaeologists go from here when encountering commingled human remains? Innovation in methodology will continue to be important in analysis, and new kinds of information will be gleaned from these techniques. These methods will become increasingly more advanced and provide new directions for the interpretation of the assemblages. It is also imperative that researchers strive to account for all taphonomic processes and causes of fragmentation as these data have proven to be excellent in assisting interpretation of mortuary practices and cultural reconstructions. Furthermore, the contributions from the field of zooarchaeology should be recognized as valuable assets to commingled analysis. Having at least minimal exposure to zooarchaeological analysis and techniques could greatly assist bioarchaeologists as they assess MNI and taphonomy of commingled assemblages.

Analysis of commingled human remains provides extensive biological data yet interpretation of cultural practices and values is not always a priority for researchers. We recommend that researchers take a biocultural approach incorporating multiple disciplines so that social aspects of a population may be better understood. Bioarchaeology as a discipline has moved to be more anthropological and holistic in recent decades; however, analysis of commingled assemblages has taken this approach inconsistently. The inclusion of other kinds of data can also be valuable to interpretation. Specifically, ethnographic comparisons and linguistic evidence could provide additional data to prompt new theoretical models.

It is our hope that this volume pushes bioarchaeologists and archaeologists to recognize the value of commingled and disarticulated human remains, particularly when more contextual information is available. Numerous commingled assemblages exist in repositories across the world and have remained unanalyzed due to misconceptions that they are too difficult to analyze and are unable to provide valuable data. Bioarchaeological method and theory continually evolve to provide better interpretation of past communities. As has been discussed in the introductory chapter of this volume, there is no one *correct* way to analyze commingled assemblages.

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A.J. Osterholtz et al. (eds.), *Commingled and Disarticulated Human Remains: Working Toward Improved Theory, Method, and Data*, DOI 10.1007/978-1-4614-7560-6,