Comparing Methodologies for Documenting Commingled and Fragmentary Human Remains

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Commingled and fragmentary human remains are a common occurrence in archaeological and forensic contexts, but only a few methods have been developed to record these complex assemblages. Conventional inventory methods, such as the *Standards for Data Collection from Human Skeletal Remains,* referred to from here on out as *Standards,* document the presence and completeness of specific portions of skeletal elements and the minimum number of individuals (MNI) represented by each bone portion. This rather subjective method for MNI calculation does not provide much transparency for future researchers using these data. However, new techniques for recording and analyzing commingled assemblages and for MNI calculation have been developed using zooarchaeological zonation methods, which document specific features present rather than more general measures of completeness.

This study identifies any significant differences in MNI calculation results using *Standards* versus Osterholtz's methods, through reanalysis of the assemblage of fragmented, commingled remains recovered during the 2012 season of the Petra North Ridge Project (preliminary MNI = 30). The MNI based on Osterholtz's visual-based system was notably different from that using *Standards*. Overall, the better metadata in Osterholtz's system suggests that Osterholtz's feature-based system should be the choice for individuals working with commingled and fragmentary remains.

Comparing Methodologies for Documenting Commingled and Fragmentary Human Remains

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by

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CHAPTER 1: INTRODUCTION

Commingled and fragmented skeletal assemblages are commonly encountered in both archaeological (Adams and Byrd 2008; Mack et al. 2015; Osterholtz et al. 2014a; Osterholtz et al. 2014b) and forensic anthropological contexts (Adams and Byrd 2008; Blau and Briggs 2011; Cox 2008; Mundorff 2012; Tuller 2006; Varas and Leiva 2012). Commingling of human remains, animal remains or a combination of both can result from anthropogenic and/or natural processes (Osterholtz et al. 2014a; Osterholtz et al. 2014b; Ubelaker 2002; White et al. 2011). The forces responsible for commingling often also cause bone fragmentation (Osterholtz et al. 2014a; White et al. 2011). Significant fragmentation hinders the identification of skeletal elements and, by proxy, the data collection processes necessary for extracting biological data and cultural meaning from an assemblage (Osterholtz et al. 2014a).

Despite the prevalence of commingling and fragmentation in forensic and archaeological skeletal assemblages, osteologists have had little success in establishing standard methods to analyze these assemblages. This lack of standardization derives from the variability in the condition of sites and burial practices involved in creating commingled deposits (Byrd and Adams 2009; Osterholtz et al. 2014b; Ubelaker 2008). Although no universal method can truly document commingled assemblages (Osterholtz et al. 2014b; Ubelaker 2008), there has been clear movement towards establishing best practices to aid forensic anthropologists and archaeologists in analyzing these types of samples (Adams and Byrd 2014; Osterholtz et al. 2014b). The establishment of data collection methods built specifically to record and extract maximum information from these types of assemblages could enhance the volume and quality of data derived from often neglected samples.

A key step in understanding these complex assemblages is calculating the number of individuals that comprise a skeletal assemblage. The most widely employed calculation for this purpose, Minimum Number of Individuals (MNI), represents the lowest possible number of individuals that can be accounted for by the bones within a skeletal assemblage. Multiple established methods for these calculations will be discussed and defined later in this section. Regardless of what method is used for determination, the number of individuals that contribute to a skeletal assemblage serves as the foundation for demographic analysis (Kendell and Willey 2014) and is essential for calculating male to female ratios and frequencies of pathological skeletal lesions used for establishing health and disease profiles (Osterholtz et al. 2014b). In the archaeological record, demographic information informed by the MNI aids in the reconstruction of past lifeways, and in the forensic context, demographic details aid in individuation, identification, and building evidence for criminal trials (Adams and Konigsberg 2008).

The research presented here applies a method for osteological recording and analysis developed specifically for commingled and fragmentary remains (Osterholtz et al. 2014b) to a skeletal assemblage excavated from 100 B.C. – A.D. 100 tombs from Petra, Jordan. The results of this method, including MNI and age and sex determinations, have been compared with those derived from a previous analysis using *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994), a widely-used method developed principally for primary burials. Differences in these values were documented and possible explanations for the differences explored. Discussion on variation in the two analyses focuses on the level of subjectivity during both analyses, and the digital vs. analogue nature of the methods that may have led to potential biases. The results have then been used to develop best practices for the documentation and inventory of commingled and fragmentary human remains.

Chapter 2 focuses on background information relevant to the sample being utilized for the study, a discussion of the development of the two osteological methodologies being compared, and a discussion of the different methods of calculating the number of individuals contributing to a death assemblage. Chapter 3 presents contextual information regarding the sample being analyzed and the methodology employed to conduct the reanalysis of the Petra North Ridge Project, or PNRP, 2012 skeletal sample. Chapter 4 presents the data and results of the project. Chapter 5 discusses any variations between the two analysis and possible methodological causes for variation. Chapter 6 focuses on possible future applications and developments of feature-based methodologies for the use of data collection on commingled and fragmentary human skeletal assemblages.

CHAPTER 2: BACKGROUND

THE PETRA ASSEMBLAGE

The sample used for this study comes from the ancient city of Petra in the Hashemite Kingdom of Jordan. It was excavated during the 2012 Petra North Ridge Project (PNRP) field season. This assemblage exemplifies the severity of commingling and fragmentation that can be encountered in the field and highlights the difficulties that commingling and severe fragmentation can pose for osteologists. Petra is located less than 240 km from the Jordanian capital of Amman in southwestern Jordan. It was rediscovered in 1812 by Swiss explorer Johann Ludwig Burckhardt after centuries of European obscurity (Bienkowski 1985; Bowersock 1994; Browning 1989; Joukowsky 2001; Tuttle 2013). At its height in the 1st century AD, Petra had an estimated population of 30,000 (Joukowsky 2001; Ortloff 2005), and was a bustling urban center. As the civic center of the Nabataean people, Petra was home to its tribal kings and served as a religious and administrative hub. Petra's archaeological remains encompass Nabataean, Roman, and Byzantine history (Joukowsky 2001). Archaeological research at Petra has primarily focused on the city center's monumental structures (Bedal 2001; Bedal 2002; Bedal et al. 2007; Bedal and Schryver 2007; Bienkowski 1985; Hammond 1977; Joukowsky 2002; Joukowsky and Basile 2001; Ramsay and Bedal 2015; Tuttle 2013), mansions belonging to the city's urban elite (Kolb 2002, 2001, Kolb and Keller 2001), and grand rock-cut façade tombs (Wadeson 2012a; Wadeson 2013a; Wadeson 2013b; Wadeson and Mackay 2011). For example, excavations at the Temple of the Winged Lions (Hammond 1977; Tuttle 2013), the Great Temple (Joukowsky 1998; Joukowsky 2002; Joukowsky and Basile 2001), and the Petra Pool and Garden Complex (Bedal 2001; Bedal 2002; Bedal et al. 2007; Bedal and Schryver 2007; Ramsay and Bedal 2015),

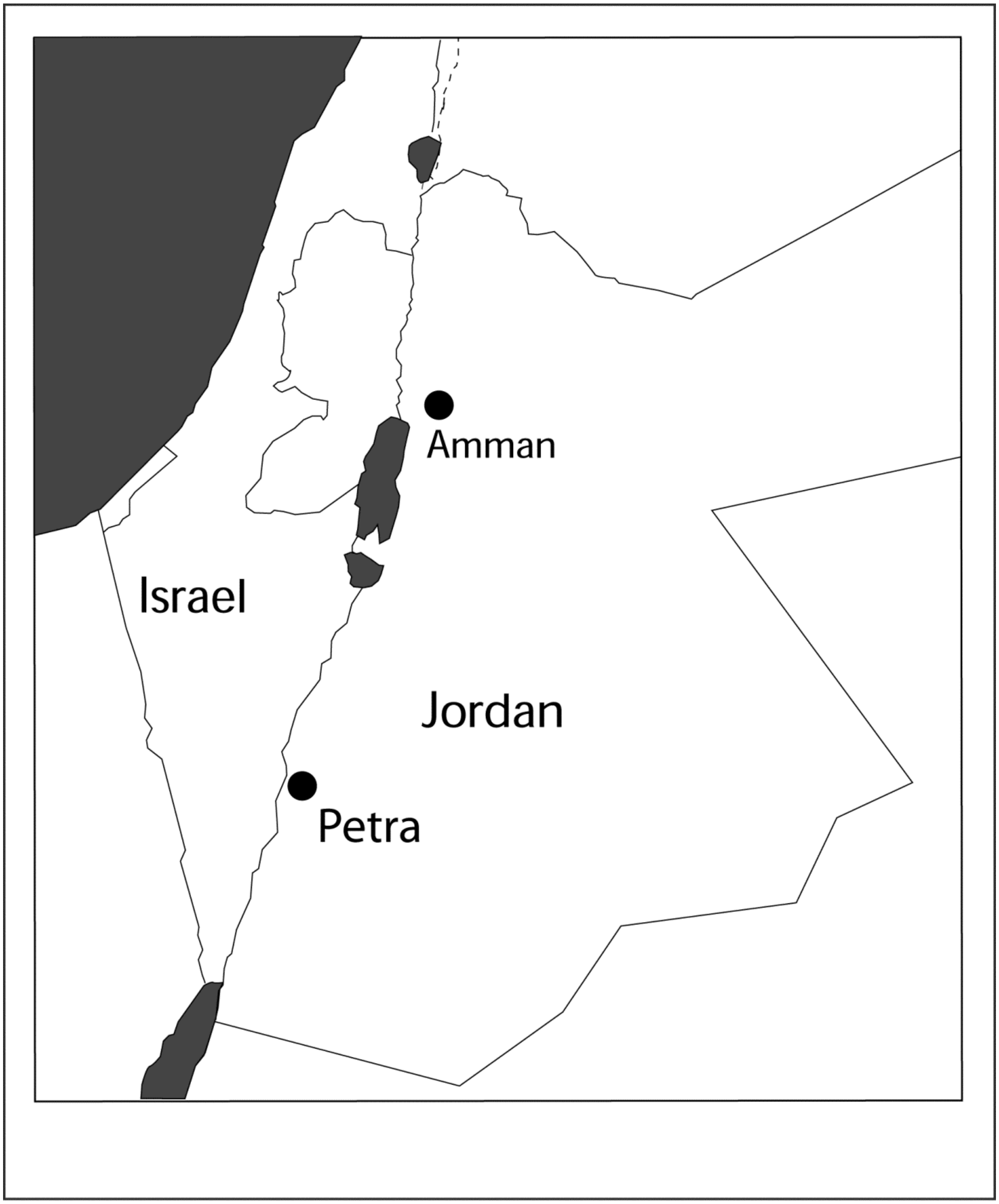

Figure 2.1. Map of Jordan

have a clear focus on Petra's public realm. There has also been a great deal of work on understanding the Nabataeans' impressive and unique skills in harnessing limited water in an arid environment (Akasheh 2002; Bedal 2002; Corbett et al. 2016; Ortloff 2005; Parr 2013).

The most famous remains of this ancient urban center are the monumental sandstone-carved tomb facades, which have been a key focus of research and excavation. Many of the façade tombs were looted and/or have been emptied for recent storage and housing purposes (Bienkowski 1985; Perry 2002; Wadeson 2012a). These often empty or heavily disturbed façade tombs have left insufficient insight into Nabataean mortuary customs, much of which has been pieced together through excavation and through careful architectural and spatial analysis of the monumental tombs and surrounding courtyards (Wadeson 2012b; Wadeson 2013a; Wadeson 2013b; Wadeson and Mackay 2011). These tombs contain almost exclusively primary burials placed in wooden coffins covered with lime and sealed with covering slabs, with no evidence of ritual commingling or secondary burial. Additionally, tombs and their courtyards could accommodate large numbers of people but through seemingly restricted access (Wadeson 2012b), who likely would have partaken in commemorative feasting and the leaving of offerings for the dead (Wadeson and Mackay 2011). However, information gleaned from the monumental tombs reflects the customs of Petra's elite residents, whose affluence was evident from resources expended in the creation of their monumental resting places (Perry 2002; Wadeson 2012b; Wadeson 2013a; Wadeson 2013b; Wadeson and Mackay 2011). The mortuary behaviors of those who were less affluent have not been fully explored due to minimal excavation and/or publication.

One key dimension of the PNRP's research goals is to establish a better understanding of the health and quality of life of the city's 1st centuries B.C. and AD non-elite population. The

North Ridge tombs, such as those excavated in 2012, from which the sample for this project derives, can provide a wealth of information about non-elite Nabataean residents of Petra. A demographic profile informed and contextualized by an accurate MNI estimation, including age at death, sex, and health and disease profiles will help to truly inform us about the people who built and inhabited this magnificent ancient urban center.

DEVELOPING METHODS FOR INVENTORYING COMMINGLED DEPOSITS

In 1990, the U.S. Native American Graves Protection and Repatriation Act (NAGPRA) stimulated osteologists to create a standardized, comprehensive means for skeletal data collection. The passage of this act would result in repatriation of numerous uncatalogued or poorly studied Native American skeletal remains in a variety of different repositories. The *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994) was developed by a team of researchers to establish a standardized human osteology data collection technique. Since its publication, *Standards* has become one of the most widely used and cited methods for analyzing and recording osteological data around the world. Demonstrating its global impact, *Standards for Data Collection from Human Skeletal Remains* has been used to document skeletal collections from diverse temporal and geographic contexts such as Early Neolithic southern Syria (Santana et al. 2015), historic period England (Mays et al., 2006), Iron Age southeastern Asia (Tayles and Buckley 2004), and Classical Period Maya in Central America (Maggiano et al. 2008).

While *Standards* clearly outlines what essential skeletal data should be collected from a skeleton, it was developed primarily for work with individual skeletons rather than commingled assemblages. Less than three pages in the volume provide details on how to inventory commingled and fragmentary remains. The method utilized in *Standards* for documenting commingled remains first involves sorting the fragments by element, side (if possible or applicable), and section of the bone preserved. *Standards* groups many elements into element classes, such as Ribs 3-10, hand and foot phalanges, cervical vertebrae 3-6, thoracic vertebrae 1-12, and lumbar vertebrae 1-5 (Buikstra and Ubelaker 1994). Bone fragments from a particular segment of an element are counted or weighed, listed by percentage of completeness of that bone section, and a final MNI is produced for that element or segment (see Appendix B: Attachment 2). If fragments provide any information on skeletal age-at-death or sex, that information also can be recorded. Space is provided for age at death and sex estimates as per chapters 3-6 on a separate form. Pathology and taphonomy are also recorded on additional forms (Buikstra and Ubelaker 1994). The forms provide limited space on which to record vital data, limiting the amount of detail recorded during analysis. This is an analogue method of recording data, which can be difficult to use to determine an accurate MNI, but what is recorded can be transcribed into spreadsheet programs, such as Excel, for MNI assessment.

MNI determination based on the portions of an element determined to be present can be problematic using this system as it is subjective and can result in interobserver error. In addition, the form used for inventorying commingled and isolated bones (Attachment 2 see Appendix B) does not include space to record information about pathologies, what skeletal features are observed, information about how age and sex are determined, details about dentition where relevant, associated metrics, morphological anomalies, or taphonomy. *Standards* does provide separate forms for all this vital information, but these forms are created for individual skeletons rather than commingled samples. Commingled and fragmentary assemblages are often comprised of an extremely large number of fragments, and thus recording data on several forms complicates analysis and can disassociate vital information.

Several reviews have praised the revolutionary nature of the standardization provided by *Standards* (Baker 1995; Brooks 1996; Glassman 1996; Skinner 1995). Baker's (1995) and Glassman's reviews (1996), however, note that *Standards* provides a minimal level of data collection. Baker (1995) suggests that some of the content within *Standards* (Buikstra and Ubelaker 1994) will likely call for future revisions, and specifically comments about the issues with recording incomplete or fragmentary bones. In addition, metadata gaps exist between information recorded on the forms and interpretations made from the inventory, including ambiguity in the calculation process of MNI, inability to replicate element identification protocol, and difficulties in restudying the remains and linking element-specific data between forms.

In response to the problems with current data collection standards for commingled and fragmented remains, bioarchaeologists have turned to techniques developed in a sister discipline, zooarchaeology. Faunal assemblages regularly comprising commingled, incomplete, and fragmented remains necessitated the development of methodologies that help relate fragmentary bones to the broader assemblages they are a part of and account for a variety of taphonomic factors (Dobney and Rielly 1988; Dobney 1988; Watson 1979). Much like their faunal counterpart, the analysis of human remains relies on accurate quantification of the original death assemblage (Dobney and Rielly 1988). Thus zooarchaeological techniques have applicability for assessing commingled incomplete and fragmentary human remains.

One concept successfully borrowed from zooarchaeology is Zonation. This method focuses on documenting commonly preserved, species-specific “diagnostic” zones present on a bone fragment. Watson (1979) stipulates if more than half the zone is not present the bone should not be counted to avoid multiple counts of the same bone. In addition to incomplete zones, Watson (1979) highlights the importance of treating the same zones on opposite sided elements as entirely separate. These measures are intended to avoid inaccuracies derived from counting the same individual twice. By proxy, if an element is unsidable, it should be eliminated from the data contributing to MNI estimates. Dobney and Rielly (1988) further developed zonation by identifying and including zone designations for long bone shafts, which were not included in Watson’s methodology. Dobney and Rielly’s (1988) advancement on Watson’s methodology allows for the analysis of a larger percentage of the skeletal assemblage.

Zonation has recently been effectively adapted for inventorying human remains, to identify under-representation of elements, ritualized violence, and postmortem bone processing (Knüsel and Outram 2004; Mack et al. 2016; Osterholtz et al. 2014b). Osterholtz et al. (2014b) and Mack et al. (2016) utilize a variant of zonation that records elements based on the presence of features unique to a particular element to which the fragments belong. This study examines effectiveness of a feature-based methodology developed by Osterholtz through her work on two commingled collections, the Sacred Ridge and the Tel Abraq assemblages (Osterholtz et al. 2014b). Osterholtz adapted Knüsel and Outram’s (2004) zooarchaeological zonal method exploring meat processing to record the anatomical patterns of disarticulation and dismemberment related to a massacre in A.D. 800 at Sacred Ridge, Colorado (Osterholtz 2014; Osterholtz et al. 2014b).

The Tell Abraq assemblage in the coastal United Arab Emirates represents 100 years of complex mortuary deposition, and thus posed very different research questions than those at Sacred Ridge. Osterholtz refined her inventory system while working at Tell Abraq to not only accommodate skeletal remains from stratified mortuary contexts, but also to include a visual recording database to facilitate recording specific skeletal features present on a fragment (Osterholtz et al. 2014b). The fact that Osterholtz's feature-based recording method was developed through the documentation of two very different sites exemplifies its flexibility and applicability.

Osterholtz's revision of the zonation methodology has several improvements over traditional techniques, which are described in more detail below. Her method involves the identification of bone features, use of a visual recording system, and recommendation that a single analyst begins and completes inventory and analysis of each element sample, ensuring consistency and accuracy in recording. The inclusion of both dense and spongy bone in this inventory methodology allows for the analysis of breakage and element representation in the assemblages analyzed. Osterholtz's digital database links the bone directly to pathological observations, metric data, and other anomalies. The use of accession numbers based on context of recovery and order of analysis (Osterholtz 2014), further links the bones by stratigraphic context, increases vertical control of the material being excavated, and facilitates future spatial analysis, for example, through the creation of high resolution maps of elements linking accession numbers digitally to individual elements and their baseline data (Osterholtz et al. 2014b). Although the applications of spatial analysis will not be evaluated in this study, the inclusion of accession numbers is a notably valuable addition to the recording of any skeletal remains as it provides each fragment with a unique number. When fragments remain associated with this unique identifier, it can provide transparency in the original analysis and aid in any potential restudy by eliminating potential guess work regarding identification in the original analysis.

CALCULATING THE NUMBER OF INDIVIDUALS IN A SKELETAL ASSEMBLAGE

Much like the methods for recording and analyzing human remains, the development of methodologies for calculating the number of individuals within a commingled and fragmentary skeletal sample has increased steadily in the last two decades (Adams and Byrd 2008; Adams and Konigsberg 2004; Adams and Konigsberg 2008; Barker et al. 2008; Buikstra and Ubelaker 1994; Byrd and Adams 2009; Kendell and Willey 2014; Knüsel and Outram 2004; Mack et al. 2016; Nikita and Lahr 2011; Osterholtz 2014; Osterholtz et al. 2014b; Schaefer and Black 2007; Ubelaker 2002; Ubelaker 2008). Both archaeologists and forensic anthropologists have begun to (Adams and Konigsberg 2004, Osterholtz et al 2014) seek methods flexible enough to be applied in as varied and complex assemblages as possible (Adams and Konigsberg 2004). The most successful methods for calculating the number of individuals in an assemblage, much like the methods for recording and analyzing human remains, are rooted in zooarchaeology (Adams and Byrd 2008; Adams and Konigsberg 2004; Adams and Konigsberg 2008; Knüsel and Outram 2004; Mack et al. 2016; Osterholtz et al. 2014b).

Four specific quantification techniques have been derived from zoological standards to determine the number of specimens or individuals in skeletal samples: the Lincoln index (LI), a generalization of the LI referred to as the most likely number of individuals (MLNI), the minimum number of individuals (MNI), and the minimum number of elements (MNE) (Adams and Konigsberg 2004; Adams and Konigsberg 2008; Nikita and Lahr 2011). Each calculation technique has its own limitations and varying applicability for particular assemblages, such as level of completeness fragmentation, level of commingling, and pair-matching elements (Adams and Konigsberg 2004; Osterholtz et al. 2014b).

MNI, the most widely used method of calculation, estimates the minimum number of individuals possible in a skeletal assemblage that can account for all the elements present (White et al. 2011). Bones are first sorted by element and side and if possible, the sex and age for each element is estimated. Total counts are then produced by element and by side (if applicable), and age and sex (if possible). The highest count then constitutes the MNI of the sample. This estimation can be refined further by computing the Lincoln Index, or LI, which addresses issue with recovery bias (Lyman 1994; Waldron 1987; Willey et al. 1997). The LI utilizes known variables by element such as bone density and size to predict their chance of recovery, and thus estimates the number of individuals in the original assemblage based on only the preserved, recovered elements.

In some cases, bones representing the left and right sides of an element can be pair-matched by individual based on age, sex, and morphology. In that case, the total count is computed by adding the number of unmatched elements to the number of matched pairs. For example, if the sample has two pair-matched left and right humerii, in addition to three unmatched left and two unmatched right humerii, the total count would be seven (White et al. 2011). The ability to pair-match elements also allows the calculation of maximum likelihood estimates for samples sizes contributing to the recovered assemblage, or the MLNI (Adams and Konigsberg 2004).

Adams and Konigsberg (2004) adapted the LI to commingled human samples in the form of the MLNI, which additionally provides maximum likelihood estimates (MLEs) for different sizes of potential populations contributing to the assemblage (Adams and Konigsberg

2004). This method requires effective pair-matching of skeletal elements, this is not always practical in fragmented assemblages

The MNI calculation of fragmentary remains cannot follow the above procedures used for complete or mostly complete elements. Instead, most techniques focus on counting specific portions of a skeletal element (i.e., the distal 1/3rd of a radius) to calculate the MNI. Like the whole-bone technique, the MNI based on the fragmentary remains depicts the minimum number of individuals that could be represented by bone features in the sample (Adams and Konigsberg 2004). This feature-based method more accurately produces the MNE, or minimum number of elements, for each element based on the count of landmarks associated with each element observed in the fragments (Reitz and Wing 1999). The MNE then is used to determine the overall MNI (Osterholtz et al. 2014b).

The question being asked in this study is does the newer feature-based method retain the same amount of data as the widely-used percentage-present approach? My study seeks to compare and contrast a traditional percentage-based method, *Standards (Buikstra and Ubelaker 1994)*, for inventorying commingled and fragmented remains with the newly developed feature-based method discussed above (Osterholtz et al. 2014b). The original MNI of the PNRP 2012 skeletal assemblage was determined in 2013 and 2014 by Dr. Megan Perry and a group of her graduate students at East Carolina University following the specifications for analysis in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994). In the previous *Standards* analysis, bones were recorded by the element, side where applicable, segment (i.e. distal 1/3 of diaphysis, proximal epiphysis), relative completeness, minimum number of individuals (MNI), count/weight, age, and sex (Buikstra and Ubelaker 1994). Additional forms were completed for the PNRP 2012 skeletal assemblage for dentition, pathologies, age and sex, and complete skeletons where individuals were identified (Adult Sex/Age Recording Form, Attachment 11, Paleopathology Recording Forms I and II, Attachments 25 and 26, Dental Inventory Recording Form, Attachments 16 and 17, Inventory Recording Form for Complete Skeletons, Attachment 1). The heavily fragmented and commingled remains excavated during the PNRP 2012 field season, previously recorded using *Standards*, have been reanalyzed using Osterholtz's feature-based inventory database. Due to the inability to pair match within this sample, the inventoried data were than used to calculate the MNI.

I hypothesized that Osterholtz's method for the analysis of commingled and fragmentary human remains would produce comparable data to those produced *by Standards for Data Collection from Human Remains*. The basis of the analysis was similar, the same questions are being asked of the same material, so the results would likely mirror one another. As with the original *Standards* analysis I was also seeking to determine what skeletal material was present and how many individuals were indicated by the material recovered? The data produced using the digital feature-based method would be easier to synthesize due to organization within a computerized database, and would not be complicated by disassociation of pathological and taphonomic data caused by the use of multiple forms. The visual nature of Osterholtz's system would aid in feature identification and allow even a less experienced osteologists to record and analyze remains accurately, through the requirement of visual confirmation and reconciliation for each feature recorded.

CHAPTER 3: MATERIALS AND METHODS

DESCRIPTION OF TOMB CONTEXTS

The sample utilized for this methodological comparison originates from Petra, Jordan, and was collected during the PNRP2012 field season. The PNRP consists of 50 rock-cut shaft tombs dating to first centuries BC and AD. Excavations in 2012 included three shaft tombs on the North Ridge located inside the city wall, 80 m east of the Ridge Church. One tomb, B.4 was completely excavated by the end of the 2012 season, while tombs B.5 and B.6 were only partially excavated due to time constraints.

Tomb B.4 was accessed by a shaft measuring 2.13-m-x-0.99-m wide and 2.54-m deep which opened into a 6.45-m-x-6.20-m chamber that contained two receptacles for human remains. The first receptacle was a burial niche (locus B.4:11) located lengthwise along the eastern wall that contained the remains of at least four partially complete articulated burials, although five mandibles were recovered from partially disturbed soil related to the niche (locus B.4:10, niche fill). The second receptacle for the deceased in Tomb B.4, which bordered the western and northern walls of the chamber, was a channel edged by a 0.12-0.18-m high lip. The western (locus B.4:21) and northern (locus B.4:20) portions of this receptacle were excavated separately. No intact remains were discovered in the northern portion of the channel (locus B.4:17, channel fill). However, it appeared that the remains from the northern trough had been washed out of the channel and into the surrounding fill, extending approximately 50 cm to the south. This continuation of B.4:17 contained the very poorly preserved remains of one individual. Excavation continued with the western portion of the channel, locus B.4:21, where a partially articulated burial (locus B.4:18, channel fill) was recovered at its southern end. Like the

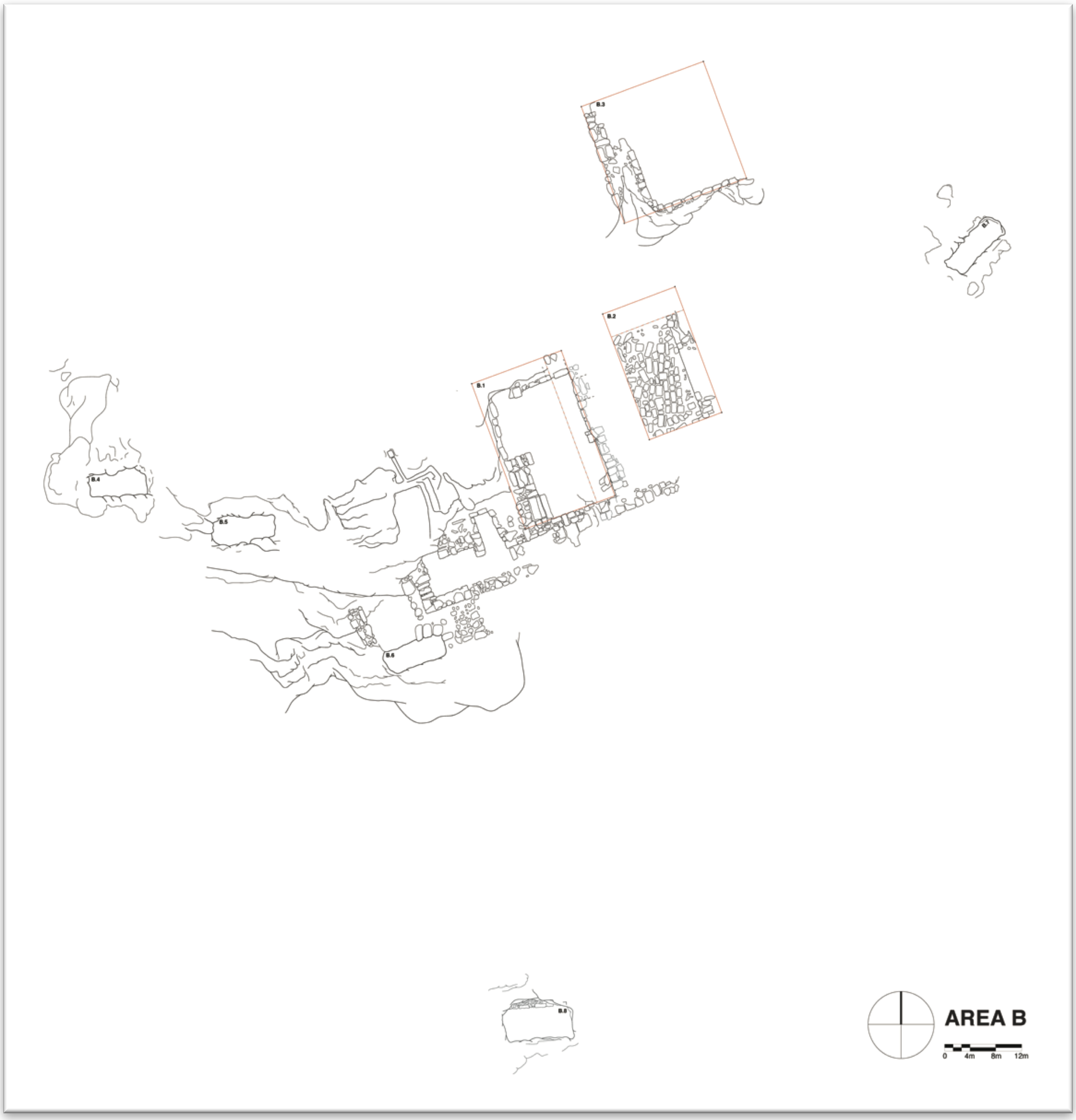

Figure 3.1. Map of Area B Trenches 2012

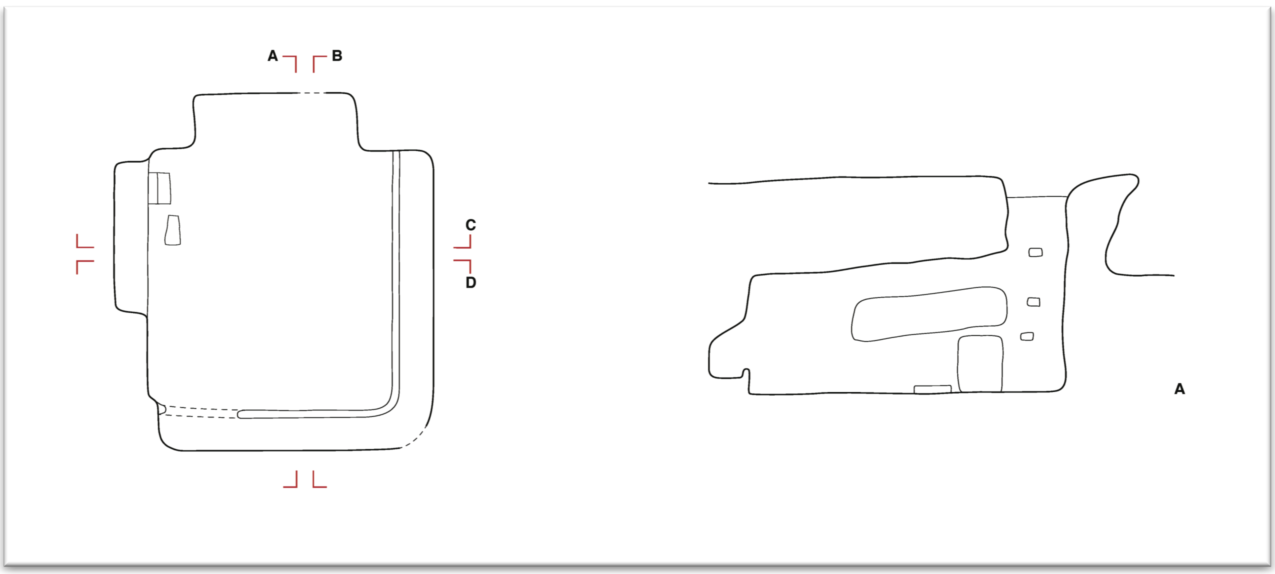

Figure 3.2. Top and Side Plans of Tomb B.4.

Figure 3.3. Burial B.4:10 in Tomb B.4.

northern trough, it appeared that some remains from the western trough had washed to the floor below in an area extending approximately 30 cm to the east. Just east of the western portion of the channel, an articulated burial as well as a few commingled remains were recovered and designated locus B.4:22.

The floor of the Tomb B.4 chamber (locus B.4:16 and locus B.4:22) contained completely and partially disarticulated remains. The original location of these remains is not clear, and while they may also have been placed in the western and northern troughs, the presence of at least one mostly articulated skeleton placed in silt near the floor in B.4:22 may indicate they originally were placed on the floor. One area of the chamber floor sediment (locus B.4:23) contained a higher concentration of commingled remains and three partially articulated burials were unearthed in this locus. Finally, the incomplete remains of an infant (locus B.4:13) were found in the tomb shaft, which, due to its context, may have been an opportunistic burial placed into the tomb at a later date.

The north-western corner of B.4 contained an oval ‘window’, with obvious tool markings, that had been covered with molded flat glass. An additional oval opening was discovered in the south wall of the shaft and is likely due to the bedrock sharply dropping off directly to the south and east of the shaft entrance. Unlike the ‘window,’ this oval showed no evidence of tool marks and may be a product of natural weathering or the tool marks may have disappeared over time due to surface erosion. The window in the northwestern corner was situated at the points where the northern and western troughs intersected, and thus would have allowed water to flow directly through the troughs and into the chamber during winter rains.

Much of the commingling of the floor deposits and displacement of the skeletal remains original in the troughs likely resulted from this fluvial disturbance.

Tomb B.5 was a 3.54-m-x-2.80-m chamber entered via a 2.4-m-x-0.07-m shaft that was 3.1-m deep. The chamber contained niches in the western, northern, and eastern walls and three complete rectangular floor shaft graves for the interment of corpses. The western wall niche (locus B.5:25) contained a nearly complete articulated burial (locus B.5:12), although, poor preservation of the skeletal material made recovery of a large portion of the remains impossible. The northern wall niche (locus B.5:18) also contained the remains of one individual (locus B.5:17), this burial was less than 25 percent complete, and fragments of bone encased in a clay matrix on the edge of the niche indicated that the missing skeletal elements likely fell to the chamber floor during looting or natural disturbances. Additional skeletal material was recovered from the chamber floor near the northern wall niche designated "west of skull 10" within Locus B.5:15. The eastern wall niche (locus B.5:23) did not contain any skeletal remains (locus B.5:22, fill).

Three completed, rectangular, shaft graves were carved into the chamber floor aligned north to south. The opening of the grave shafts had originally been covered with large capstones, but only the eastern-most shaft (locus B.5:26) still had them *in situ*. This was the only shaft grave excavated by the end of the 2012 field season. The upper stratum, locus B.5:11, had a few commingled remains, along with an articulated but displaced femur and pelvis (that may have originated from the commingled deposit located on top of the capstones. The bottom-most stratum (B.5:31) was a poorly preserved, incomplete primary burial, along with an extra mandible belonging to another individual.

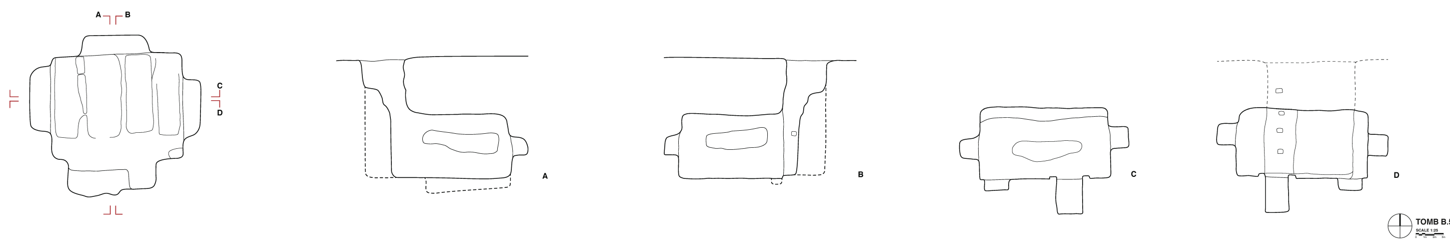

Figure 3.4. Top and Side Plans of Tomb B.5.

Figure 3.5. Articulated burial in western niche in Tomb B.5 (B.5:12).

Above the capstones and across the eastern end of the chamber in B.5 was a large assemblage of commingled remains in loci B.5:9, B.5:11, B.5:13, B.5:15, and B.5:19. This context contained one almost completely articulated skeleton, one partially articulated skeleton, and at least 10 skulls along with commingled post crania. The two articulated or partially articulated individuals were discovered lying on top of the commingled deposits.

Tomb B.6 was entered via a 3.1-m-x-0.80-m shaft that was approximately 2.7-m deep, and was comprised of two chambers. One chamber was located north of the shaft measuring 2.27 m x 3.10 m, and to the south of the shaft a smaller chamber was discovered measuring 0.85 m x 2.75 m. Excavation of Tomb B.6 had only reached the early stages by the end of the 2012 field season, and limited skeletal material was recovered from shaft and chamber fill. These remains were not included within the inventory after the 2012 season, so they were not included in this study.

Each of the three tombs chosen for excavation in 2012 represent different degrees of looting and disturbance. Tomb B.5 was the least disturbed, the absence of grave goods with primary burials and the empty eastern wall niche may be evidence of disturbance during antiquity. The presence of modern trash in the loose and disturbed soil in the upper fill of B.4 indicated recent looting, although, only one-third of the shaft appeared to have been disturbed. The patterning of commingling on the tomb chamber floors and disturbed nature of the soil containing most of the skeletal elements and artifacts are postulated to be selective disturbance, possibly caused by looting in antiquity. However, they also may indicate secondary burial practices, such as Strabo suggests of the Nabataeans in *Geography*, in which bodies were left to decompose either in the tomb or at another location before final interment (Blackburn 2010; Perry 2002; Wenning 2007).

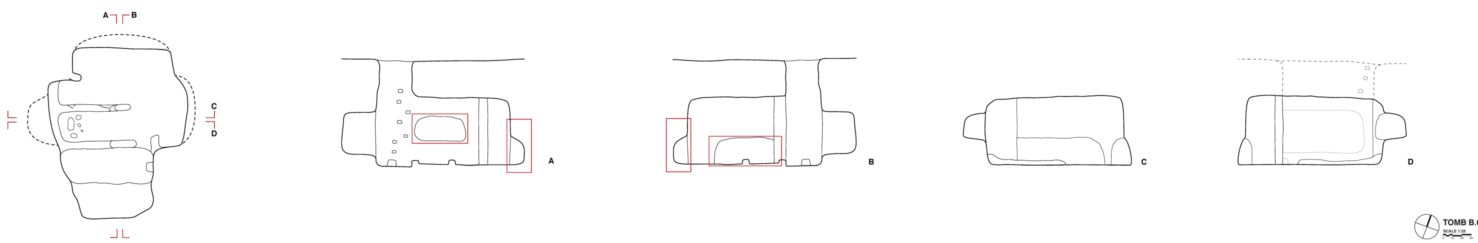

Figure 3.6. Top and Side Plans of Tomb B.6.

The remains recovered from these tombs experienced severe fragmentation, weathering, and cortical and trabecular bone exfoliation and cracking, likely due to a combination of looting and seasonal flooding. That was compounded by little to no drainage in the tombs. Fragmentation and commingling presents one of the primary issues discovered in tombs in the Near East, and explains the need for a rigorous, detailed inventory method.

INVENTORY PROCESS

The Microsoft Access database and visual recording system, developed by Anna Osterholtz (Osterholtz et al. 2014b) was employed to find a system more suitable for commingled and fragmented remains than Buikstra and Ubelaker's *Standards*. The recording forms were created using Microsoft Access a Database Management System (DBMS) that integrates the functionality of a relational database with a visual interface. Osterholtz's database is comprised of 14 separate forms that record presence/absence of specific element features and other general data (age/sex observations, pathologies, taphonomy, and so on). Specific forms include those for the clavicle, cranium, foot, femur, forearm, hand, humerus, lower leg, os coxa, patella, rib, scapula, sternum, and vertebral column (see Appendix A).

Each fragment is provided a unique accession number and entered separately into the database. When a refit of two or more fragments could be made, the fragments were recorded as a single entry into the database and the number of fragments in the refit noted in the memo field. These bone fragments were then bagged together and labeled as refits. The accession number was comprised of the area letter, the tomb number, the locus number, and finally a unique number determined by the sequence of recording. In the cases of remains labeled with details about the context, such as, articulated skeletal material where fragments were previously labeled as individuals, labeled as commingled, or numbered skulls this data was included in the accession number by including a forward slash and relevant label. The unique sequential numbers for these fragments were also chosen differently, for example, in B.5:15 where some of the remains were bagged specifically as commingled, a fragment was given a unique number that started sequentially at 100 instead of at 1 to eliminate overlapping numeric designations. So, a fragment collected from area B, tomb 5, locus 15, commingled remains, would appear as follows, B (area).5 (tomb):15 (locus).101 (unique number)/COM (context information).

If the fragment does not include one of the recorded features, it still receives an accession number but a box indicating that the fragment is not contributing to MNI is checked. If the fragment contains indicators of age or sex, those data are recorded including a description of how the estimate was achieved. Other observations can be noted on the form, such as if the fragment shows evidence of pathologies, mineral staining, burning, or osteoarthritis. A memo box can also be used to make general notes about how a fragment was identified, relevant contextual information, or any other valuable observations. The Access database is then exported into Excel for calculation of MNI and age and sex profiles of the sample, which is described further below.

In the reanalysis, fragments with identifications from the original analysis that could not be substantiated in this analysis were labeled UID (unidentified) and placed back in the bag associated with their original identification. In cases where bone fragments received an identification in this analysis different from the first inventory, the variation from the original analysis was noted in the memo field on the Access recording form. Any fragment that could not be attributed to a particular element was not included in the database. Finally, 35 elements had been sampled for carbon and nitrogen isotope analysis before their reanalysis in this study. In those cases, the sections preserved was ascertained as best as possible from the original *Standards* analysis.

DEMOGRAPHIC ANALYSIS

The database includes age and sex estimation information for skeletal fragments that contain diagnostic indicators of age and sex. In most cases, fragments could only be identified as belonging to an adult or a subadult. Occasionally, fragments could provide a more detailed age estimates primarily based on the pubic symphysis, auricular surface, or epiphyseal union. In these instances, observations and any relevant measurements were included in the "Notes" box on the form. General age categories laid out in the database are as follows: Fetal (< birth), Infants (birth - 3 years), Children (3 - 12 years), Adolescents (12-20 years), Young Adult (20-35 years), Middle Adult (35-50 years), Old Adult (50+years). An additional space for a refined age was also provided and these details were included when possible.

Adult remains recovered from PNRP 2012 were analyzed by the methods described by Buikstra and Ubelaker (1994). Adult age determinations were established primarily using the pubic symphysis and the auricular surface as per Lovejoy et al (1985), Brooks and Suchey (1990), and Todd (1921). In addition to the use of the os coxa, fusion of cranial sutures based on the scholarship of Meindl and Lovejoy (1985) as laid out by Buikstra and Ubelaker (1994) was used to establish the age of the remains from locus B.5:17.

Age determinations established for the 46 subadult database entries were based on standards in Developmental *Juvenile Osteology* and *Juvenile Osteology: a laboratory and field manual* (Schaefer et al. 2009; Scheuer et al. 2000). Measurements were taken from subadult tibia, humerii, ulna, radius, zygomatic, ilium, ischium, and pubis and age refinements were made using skeletal measurements originally devised by Fazekas and Kósa (1978).

Determination of the biological sex of subadult remains has not been met with sufficient standardized methods (Cox and Mays 2000) so only the adult remains were analyzed to determine biological sex. Determining the sex of the adult individuals who contributed to the PNRP 2012 death assemblage met similar limitation to determining age due to severe fragmentation and poor preservation of the remains. Scoring for the morphological traits of the crania and os coxa as established by Buikstra and Ubelaker (1994) were utilized to determine the biological sex of adult remains where possible. In addition, morphological features on the humerii, such as the shape of the olecranon fossa and trochlear extension, as specified by Vance (2011) were used to determine sex. Measurements of the metatarsals as per Mountrakis et al. (2010), and metacarpals as per Manolis et al. (2009) and Stojanowski (1999) were also used where possible to determine biological sex. Sex was then recorded in the Estimated Sex field and relevant measurements and scores were recorded in the Sex Notes field when applicable.

MNI CALCULATION

Calculating the MNI for my analysis required exporting the data from Microsoft Access into Microsoft Excel. Each form includes a drawing of the element with checkboxes over the element features to be documented. Checking the box indicate the presence of that particular feature as "true" and all unmarked boxes will be marked as "false". To sum the number of times the presence of a feature was marked "true," all "true" responses were recoded as "1" and the "false" responses recoded as "0." Data from each tomb were compiled on a separate spreadsheet, and within that spreadsheet, the entered elements were group separately by "adult" and "subadult." Each row of the imported spreadsheets contained information related to an entry identified by a unique accession number. The columns contained information about each entry, such as element type, side, age and sex information, and the true/present (1) or false/absent (0) features of the element represented by the fragment or fragments recorded.

Once separated by tomb, elements were grouped together by element and then by side. Left and right elements were treated as entirely separate to limit miscounts, and elements that could not be sided were excluded from the calculations. The adult remains were then analyzed for MNI by calculating the maximum number of times any one feature, accounting for the side and element where applicable, was observed by tomb. The "sum" function in Excel was used to calculate the number of times within each context that a feature was recorded. The recorded feature with the maximum count established a baseline MNI for that tomb. Any additional demographic data collected as outlined above was then utilized to build limited demographic profiles by tomb. The results were than compared with the original MNI that was calculated from the analysis conducted using *Standards,* and any discrepancies were noted.

CHAPTER 4: RESULTS

The inventory process of the 2012 PNRP sample resulted in the entering of 3,259 fragments into the database, of which 1,238 (38%) contained diagnostic features that could be used for MNI calculation. The fragments are almost equally distributed between the two tombs, with 54% coming from Tomb B.4 and 46% from Tomb B.5. Tomb B.4 had 1762 fragments recorded, of which 639 (36%) retained identifiable diagnostic features, and 13 that contributed to the final B.4 MNI of 13 (Figure 4.1). The section of Tomb B.5 excavated by the end of the 2012 season contained 1,497 fragments, 569 (38%) of which retained identifiable diagnostic features, and 17 that fragments contributed to the B.5 MNI of 17 (Figure 4.2). The similar percentages of diagnostic features in each tomb may suggest that preservation conditions were similar as well.

COMPARISON OF THE RESULTS FROM BOTH ANALYSES BY TOMB

B.4 MNI

The feature-based technique recognized four additional adults in the B.4 samples compared to the *Standards* analysis. Two elements, the right clavicle and the right medial first cuneiform, established the *Standards*-based MNI of nine adults. The reanalysis of the assemblage identified thirteen right patellar lateral articular facets, two of which were missed in the inventory using *Standards*, and four of which were missed during calculation of the MNI.

B.4 SEX DETERMINATION

Sex determination for the B.4 adults varied only slightly from the original analysis. One female was determined to actually be male during reassessment, and one additional male that

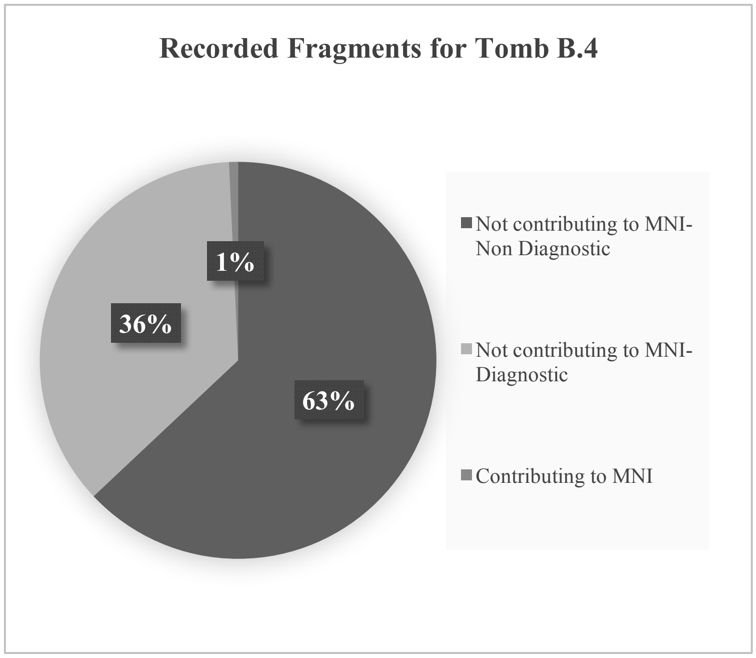

Figure 4.1. Tomb B.4 Fragments Contributing or Not Contributing to MNI Calculation: Not Contributing to MNI- Diagnostic (639), Not Contributing to MNI - Non-Diagnostic (1110), and Contributing to MNI (13)

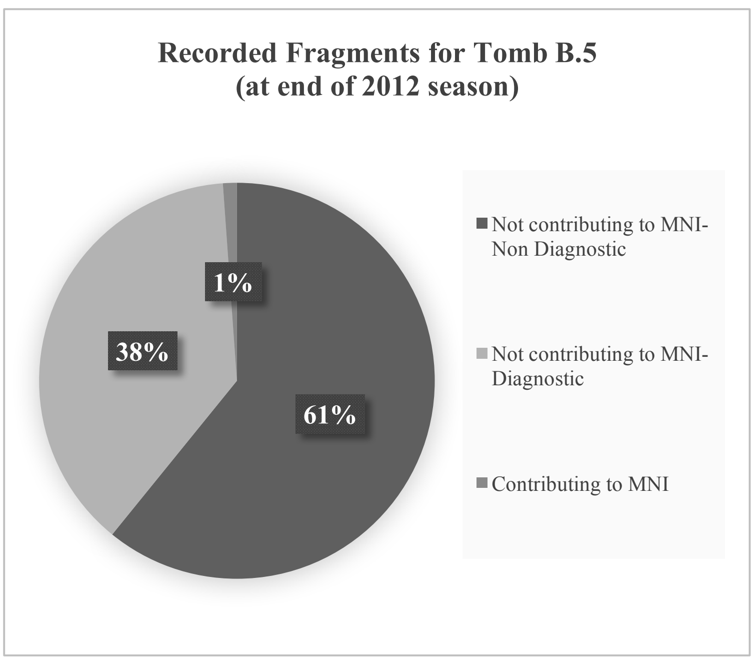

Figure 4.2. Tomb B.5 Fragments Contributing or Not Contributing to MNI Calculation: Not Contributing to MNI- Diagnostic (569), Not Contributing to MNI - Non-Diagnostic (911), and Contributing to MNI (17).

Table 4.1. Comparison of Results from Both the Original and Feature-Based Analysis, Including Age and Sex Demographics.

Age	Sex	Tomb B.4		Tomb B.5 (at end of 2012 season)	
		Standards	**Osterholtz**	***Standards***	**Osterholtz**
Adult (Indeterminate Age)	Indeterminate	4	6	1	1
	Male	3	5	5	4
	Female	3	2	1	7
Old Adult (50+years)	Indeterminate	--	--	1	1
	Male	--	--	--	--
	Female	--	--	--	--
Middle Adult (35-50 years)	Indeterminate	--	--	--	--
	Male	--	--	1	1
	Female	--	--	1	1
Young Adult (20-35 years)	Indeterminate	--	--	2	2
	Male	--	--	--	--

Table 4.1 Continued

Age	**Sex**	**Tomb B.4**		**Tomb B.5 (at end of 2012 season)**	
		Standards	**Osterholtz**	***Standards***	**Osterholtz**
	Female	--	--	1	--
Adolescents (12-20 years)	Indeterminate	--	1	--	--
	Male	--	--	--	--
	Female	--	--	1	1
Children (3 - 12 years)	Indeterminate	1	1	1	1
Infants (birth - 3 years)	Indeterminate	1	1	--	1
Fetal (< birth)	Indeterminate	1	1	--	1
Total		13	17	15	21

may have been overlooked during the original analysis was identified (Table 4.1).

B.4 AGE DETERMINATION

The subadult MNI in B.4 did not differ between the two methods. However, the *Standards*-based adult MNI included an 18-22-year-old, who through reassessment was assigned an age of 16-18 years old. This resulted in one additional subadult and one less adult in the reanalyzed sample compared to the *Standards* results. Both methods counted a ~38-week-old, a 2- to 3-year-old, and a ~10- to 12-year-old in Tomb B.4 (Table 4.2.).

B.5 MNI

The reanalysis of the Tomb B.5 sample identified four additional adults with the feature-based technique versus *Standards*. The original analysis determined the MNI by of a count of 13 left scapulae. The reanalysis identified 17 adults, and this was determined from a count of 17 mandibular mental eminences (Table 4.1).

B.5 SEX DETERMINATION

The number of females identified in the original analysis was three and the number of males was six. The reassessment, however, identified eight females and the number of males decreased to five. Both inventories included four adults of indeterminate sex. The additional adults recognized in the reanalysis therefore were all female

B.5 AGE DETERMINATION

Age refinement during the B.5 reanalysis produced some variations in age estimations.

Table 4.2. Tomb B.4 Age Refinement.

B.4 Age Refinement	
Original age	Refined Age
18 to 22-year-old	16 to 18-year-old
~10 to 12-year-old	No Change
2-3-year-old	No Change
~38 weeks	No Change

One female whose age had been determined to be 35-45 years old during the original analysis has been refined to 45-49 years old with reanalysis. In addition, a male whose age had been determined to be 45-50 years old during the original analysis has been refined to 30-39 years old during reanalysis. The age of one old adult of indeterminate sex was refined from 50 + to 60+ years of age. The four additional females identified in the sample are of indeterminate age, and one adult female of 20-35 years identified during the *Standards* inventory was not identified during reanalysis (Table 4.3). The reassessment of the B.5 subadults using the feature-based method also discovered additional individuals. The reanalysis of the skeletal sample discovered two additional subadults: an infant between 2 and 3 years of age, and the remains of a preterm fetus of ~38 weeks. In addition, reanalysis resulted in the changed age estimate of a 12- to 13-year-old to ~ 10 to 12 years of age.

MNI CALCULATION SUMMARY

Therefore, Osterholtz's feature-based technique resulted in the calculation of a total of eight additional adults and two additional subadults, with an overall MNI across both tombs of 38. Four additional adults were calculated in the B.4 sample and four additional adults in the B.5 sample. Two additional subadults also were calculated in B.5. However, any age and sex refinements, as well as the addition of the two subadults, are products of reanalysis and are not likely a reflection of variance between the two methods

ELEMENT REPRESENTATIVENESS

The basic average MNI of all elements in Tomb B.4 is 5.5, which is far lower than the MNI of 13, established by the presence of 13 right patellar lateral articular surfaces. The average MNI in Tomb B.5 only including the 2012 excavated sample is 7.1, also far lower than the MNI

Table 4.3. Tomb B.5 Age Refinement.

B.5 Age Refinement		
SEX	Original Age	Refined Age
Female	35-45-year-old	45-49-year-old
Male	45-50-year-old	30-39-year-old
Indeterminate	50+ year old	60+ year old
Not Applicable	12-13	10-12 year old
Not Applicable	Not Found	~38 weeks
Not Applicable	Not Found	2-3 year old

of 17, established by the presence of 17 mental eminences. A Chi-square analysis with a Bonferroni correction for multiple comparisons was created in SPSS and identified which elements has an MNI was significantly smaller the actual tomb MNI, thus highlighting elements significantly underrepresented in each tomb. In Tomb B.4 the second cervical vertebrae, humerus, radius, fibula, temporal, ulna, femur, tibia, maxilla, os coxa, parietal, occipital, scapula, rib 1, frontal, sphenoid, and sternum returned p-values of < 0.05 indicating they were significantly underrepresented in the assemblage when compared to the patella-based MNI. In Tomb B.5 the frontal, parietal, temporal, Patella, clavicle, second cervical vertebrae, radius, talus, first cervical vertebrae, femur, fibula, sphenoid, scapula, metacarpal 3, os coxa, sternum, and rib 1 returned p-values of < 0.05 indicating they were significantly underrepresented in the skeletal assemblage when compared to mandible-indicated MNI (Figure 4.3-4.).

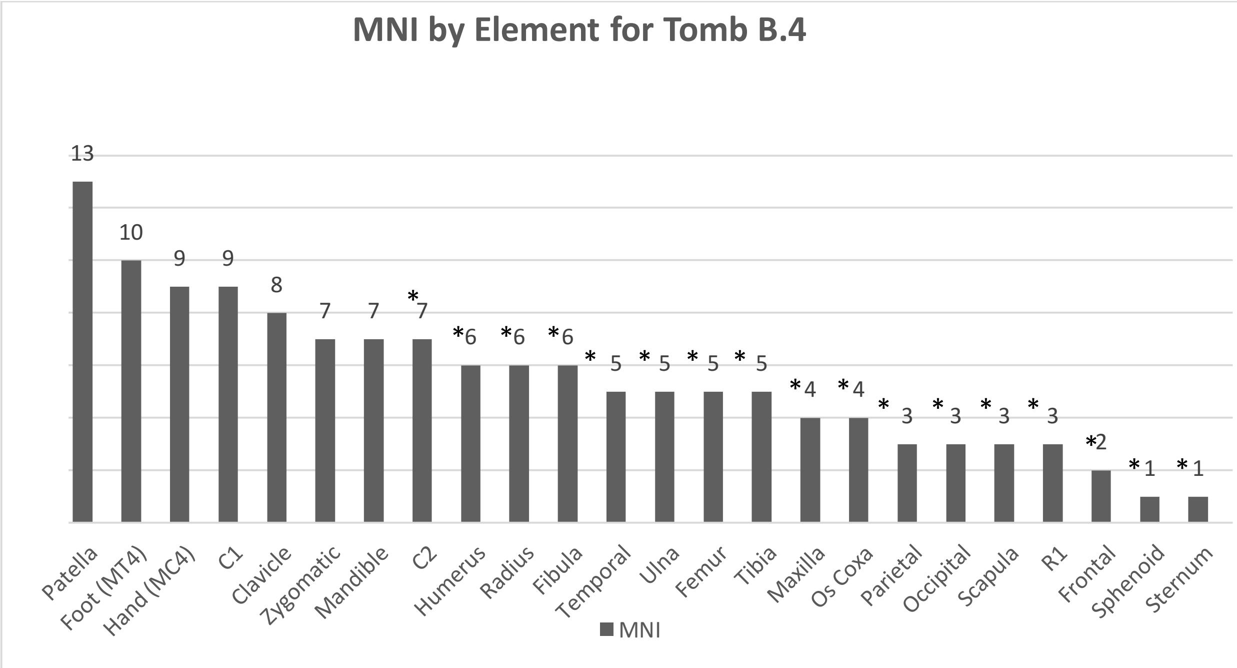

Figure 4.3. Element Representativeness for Tomb B.4 using results from the feature based analysis (asterisks indicate statistical significance)

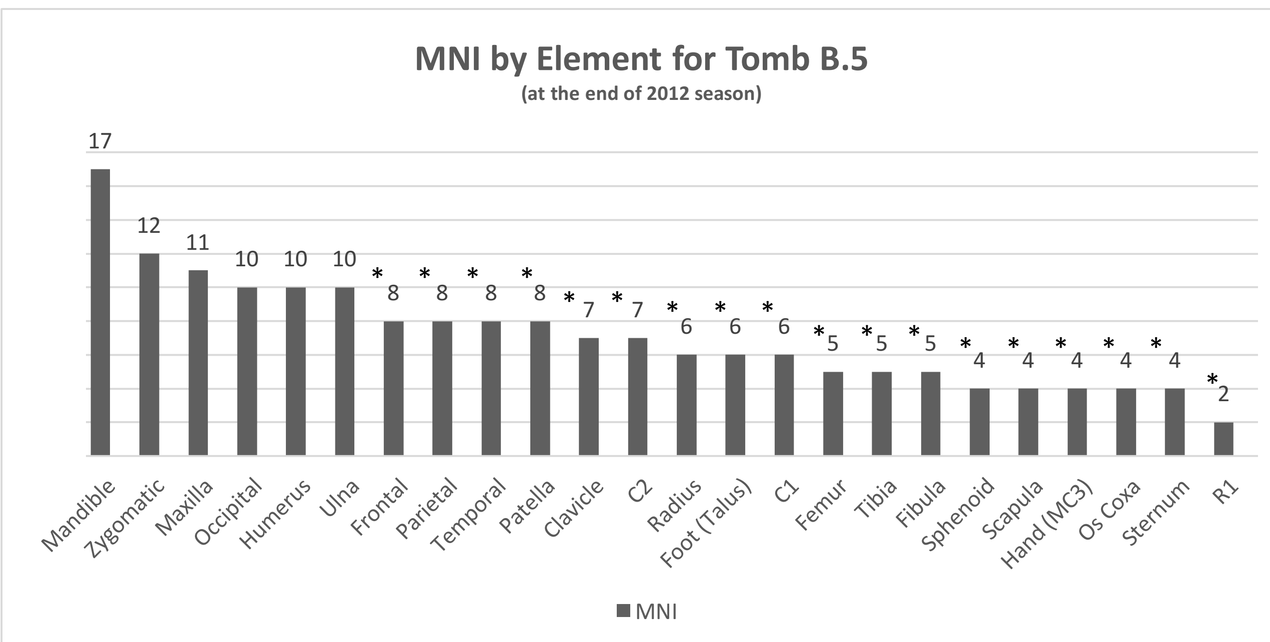

Figure 4.4. Element Representativeness for Tomb B.5 using results from the feature based analysis (asterisks indicate statistical significance)

CHAPTER 5: DISSCUSION

Both the feature-based and percentage-based methods sought to inventory the skeletal remains and compute MNI, and each method answers these research questions with varying levels of success. The percentage-based method provided more subjective and disjointed results. The feature-based method, however, enhanced the previously established MNI through the recording of specific features, and allowed the recording of relevant pathological, age, and/or sex related observations on the same form. Osterholtz's feature-based technique resulted in the calculation of four additional adults in the B.4 sample and four additional adults and two additional subadults in the B.5 sample, as well as variation in the demographic analysis.

The *Standards* inventory of the B.4 sample demonstrates mistakes that can occur with analogue recording techniques, analytical mistakes that can occur with multiple contributors to the analysis, and problems when recognizing whether or not elements actually overlap on the *Standards* forms. The reanalysis of the B.4 assemblage identified an additional four adults based on a total of thirteen right patellar lateral articular facets. Two elements, the right clavicle and the right medial first cuneiform, established the *Standards*-based MNI of nine adults. However, upon reassessment of the original analysis, the *Standards* inventory forms actually included eleven patellae, with four right patellae being overlooked during tabulation of MNI. This illustrates that data oversight can be a key issue with non-digital recording techniques.

The sex and age determination in the B.4 tombs varied only slightly, with one female being reanalyzed and determined to be male, the new identification of one male, previously categorized as of indeterminate sex, and the calculation of three additional adult individuals of indeterminate age and sex. An individual who was estimated as 18 to 22 years old in the first analysis was reassessed as 16 to 18 years old in this analysis. These variations are likely a result of consistency in observation and restudy. The reanalysis was completed by a single individual during the second analysis, limiting potential observation inconsistency between recorders. In addition, restudy allows for the observer to focus more specifically on the inventory itself, as opposed to the sorting and labeling of the entirety of the sample and these variations were likely not a direct product of the method by which the data was recorded.

The reanalysis of Tomb B.5 identified four additional adults and the subadult MNI increased by two. The original analysis determined the MNI by of a count of 13 left scapulae, which seems problematic as the scapula is very delicate and easily fragmented with the exception of the glenoid fossa. The reanalysis identified only 4 adults based on the recorded scapula features. This discrepancy highlights a key issue with the percentage-based *Standards* method for data collection - the inability to clarify the estimated MNI using *Standards* and the subjectivity involved in determining a percentage-based MNI. The feature-based method in this case more clearly identified exactly which parts of the bone are represented in an assemblage, providing a stronger foundation for calculating MNI. The reanalysis identified 17 adults, and this was determined from a count of 17 mandibular mental eminences, a much more robust feature on the mandible more likely to survive intrinsic and extrinsic factors that impact the survivability of bone.

Variations in age and sex determinations in tomb B.5 likely reflect more careful age and sex estimation, and like tomb B.4, are likely a reflection of the merits of restudy and the consistency of a single observer. Sex determination of the B.5 sample decreased the number of males of indeterminate age established in the initial analysis by one, as one assessment of a male individual could not be substantiated during reanalysis, and increased the number of females of indeterminate age by six, through identification features overlooked in the original analysis.

The reassessment of the tomb B.5 age determinations did not identify the one female aged 25-45 years of age that had been identified in the first analysis. Additionally, reassessment of age determinations found that a female aged 35-45 years old should be 45-49 years old, and a male originally aged 45-50 years old was misclassified as 30-39 years old, and one old adult of indeterminate sex originally identified as 50 + years of age was refined to 60+ years of age. The B.5 subadult MNI increased by two and identified a ~38-week-old and a 2- to 3-year-old not included in the previous analysis, and changed the age of a previously identified 12- to 13-year-old to ~ 10 to 12 years of age.

Discrepancies in MNI between the two methodologies for both tombs result from a better reflection of the MNI through feature-based methods in addition to correction of oversights from the first inventory through reanalysis. For instance, demographic variations and the increase in the number of subadults are as stated most likely the result of restudy. The first inventory of the PNRP 2012 assemblage included both sorting of commingled bones by element in addition to their inventory, while the second analysis could focus only on the inventory itself. As a result, incorrect categorizations of bone fragments or other oversights from the first assessment could be identified and corrected.

However, it is clear that locating and documenting the exact part of a bone that is present when using the feature-based system results in better, more objective inventories. The *Standards* inventory relies on a subjective assessment of the percentage of bone or bone segment that is present. Sometimes during analysis one can over- or under-estimate the amount of bone present.

For instance, assessment of scapulae using *Standards'* mode of percentage complete did not catch feature overlap in this element. The over-counting of left scapulae established the adult MNI of Tomb B.5 as 13. However, recording the scapulae using the feature-based method accounted for the overlap, and reduced the scapula-based MNI to four individuals (see Figure 5.1.). Therefore, feature-based method records a finer level of detail allowing for more accuracy in both the analysis and the calculation of the MNI.

In addition, the use of a digital method, in this case a database, made it easier to synthesize data and reduced error in relevant calculations. The *Standards* method relies on manual calculation of the MNI (or theoretically could involve the transcription of data into Excel for calculation), both potential areas that can introduce error. The feature-based digital method allowed the recording of all information on any given fragment, such as observations of pathological lesions or age and sex indicators, in one form, and these observations remained associated via accession number to the fragment identification. This also increased the potential for accuracy when doing further analysis on the remains, preventing disassociation of valuable demographic, taphonomic, or pathological information. The visual nature of Osterholtz's database aided in visual feature identification allowing even a less experienced osteologist to record and analyze remains with confidence and accuracy. The requirement of visual confirmation, where possible, and reconciliation of identification for each feature recorded helped to clarify each determination made during the analysis.

Additionally, the specificity of the feature-based method creates a higher level of data transparency, allowing any observer to understand how MNI has been calculated and what feature has been recorded and used to determine element identification. Feature-based systems provide exact counts of diagnostic bone features to determine MNI. For example, an observer could possibly record five distal epiphyseal ends of a humerus as each bone having <25% present, but they can see that three of these features overlap. In that case, the MNI will be three, not five, since the overlapping parts of the distal humerus cannot be from the same person (and the other two possibly could be associated with any of those three individuals). When using *Standards*, this observation of overlap would not be recorded and the decision to calculate the MNI of three based on five humerii fragments from the same section of the bone would not be obvious to someone using the inventory for further analyses. However, the digital method makes immediately obvious the feature that indicated overlap and contributed to the MNI.

The MNI tabulated once the analysis is complete is therefore based on which diagnostic feature shows the greatest repetition. This seems to limit not only interobserver biases in determining MNI during the recording process, but also human error in calculating a final MNI. Methods such as *Standards,* which record portions of bones and percentages of completeness limit the amount of fine-grained data that is recorded during analysis. Additionally, as previously stated, the first inventory was carried out by many individuals, and the relative subjectivity of the method employed meant that determination and documentation of MNI could vary. While the second analysis was completed by a single individual, the precision of the method itself, as described above, would likely reduce any interobserver discrepancies.

Despite the precision of the feature-based method and the ease of digitization through use of a database there are some issues and limitations to this system. The database, as developed by Osterholtz, is not a relational database. This means a great deal untapped analysis potential is not being realized with the database. The database could and eventually should be utilized to capture complete data from a site. The inclusion of data about each stratum as well as recovered artifacts could allow for a variety of contextual-based analyses. Being able to relate these different data sets, such as skeletal remains, soil matrix, and pottery recovered would aid in post data collection analysis. For example, one would be able to determine the number of individuals and

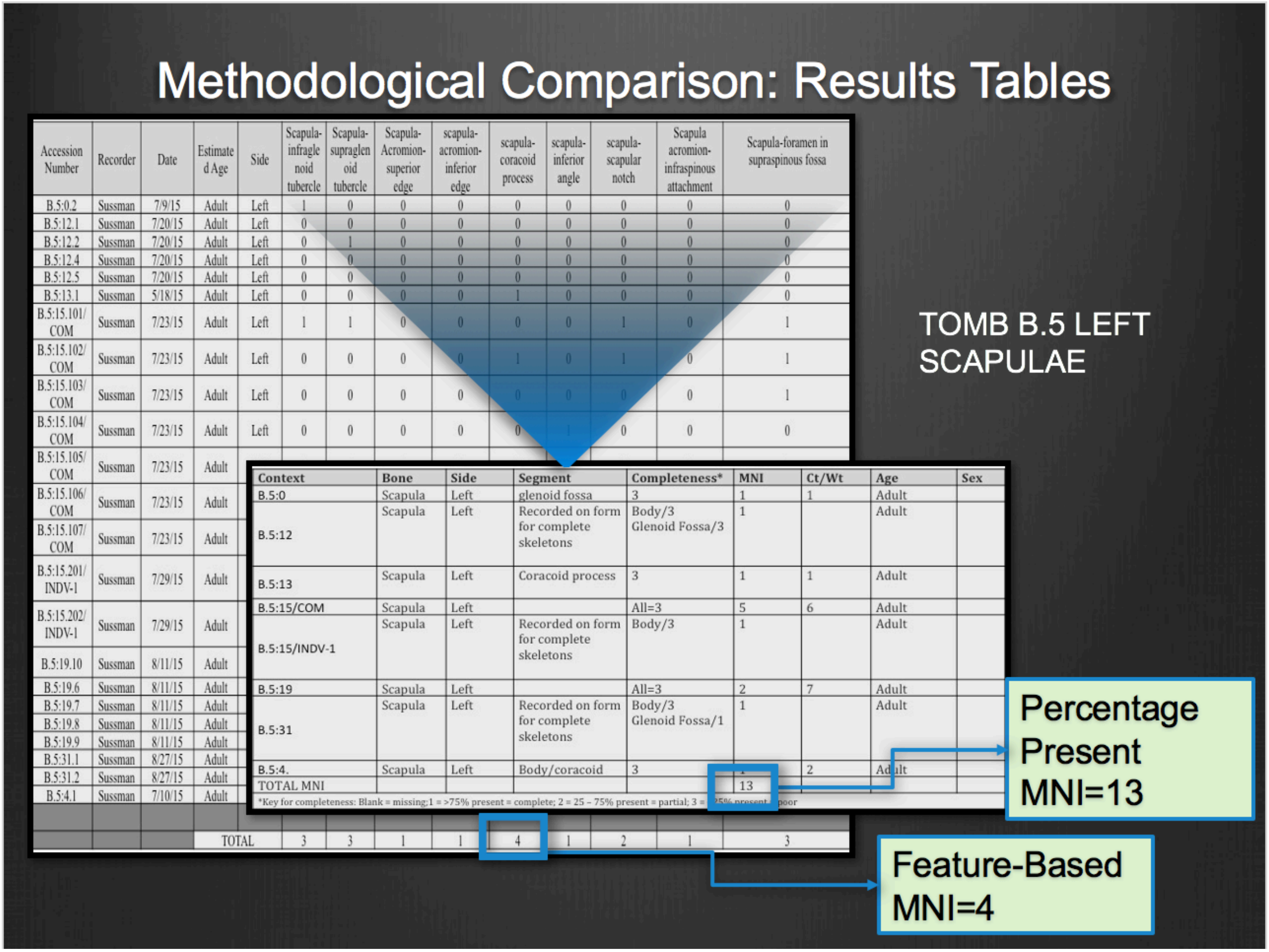

Figure 5.1. Comparison of Resulting Data by Method: These two tables demonstrate the differences in depth of data and detail between the results from both methods. The column for information on the segment of the bone in Standards is expanded upon in the feature-based method and allows for recording a high degree of detail during data collection.

demographic profile of a particular excavation area, but also build a socio-economic and possible cultural profile of the people in the tomb by understanding what artifacts are associated spatially with which burials. Additionally careful development and use of what is described in database design as natural keys, which are identifiers comprised of real world attributes, like the accession numbers used for this study, which could account for contextual data such as order of removal during excavation, would aid in a broader understanding of the depositional factors, and provide more vertical control of excavated materials, possibly allowing researchers to understand the movement of remains and artifacts through soil over time. A vital next step in the development of this database should be to work to redesign the database structure and convert it into a relational database.

Another shortfall of this system can be found in one of its strengths. This method is so effective because it has been developed specifically for use on commingled and fragmentary remains, but could be even more broadly applied if it also included the ability to record biological information from articulated skeletal remains or commingled assemblages containing mostly complete bones in addition the commingled and fragmentary remains. As at Petra, commingled and fragmentary human remains frequently can be accompanied by articulated and partially articulated remains. Further development of the database forms to include similar data collection for more complete and articulated remains will increase the capability for complete collection of all relevant data from any type of assemblage. Recording the variable types of burials together as they occur together in the same place would be of great value to researchers.

The use of a feature-based method also produces data sets that enable the researcher to better understand the taphonomic processes that contribute to elemental representativeness. The analysis of what elements are underrepresented with in a sample can aid in understanding the processes that have impacted the remains. The PNRP tombs can be considered their own microclimates and the items recovered from the soil will reflect the unique conditions of the tomb from which they were recovered (Behrensmeyer 1978). Bone is specifically sensitive to changes in the soil. Fluctuations in humidity and wetness can leach bones of collagen and cause bone deterioration (Henderson 1987) and these bones will also be likely to flake and crack when drying, causing degradation of the cortical bone (Dent et al. 2004), while low pH can impact the mineral matrix of bone also leading to deterioration (Gordon and Buikstra 1981; Henderson 1987). Specific elements are intrinsically more at risk for fragmentation than others, such as skulls and os coxae, which can fragment as a result of pressure from soil and compaction of soils caused by humans and/ or animals (Henderson 1987; Behrensmeyer et al. 1986). Additionally, bone density and the ratio of cortical to trabecular bone can impact the survivability and condition of skeletal elements (Henderson 1987; Kendell and Willey 2014). For example, Tomb B.4 some of the underrepresented elements such as fourth metatarsals and metatarsals, the C1, the zygomatic, and the mandible are small and robust, and should survive taphonomic process. In fact, the mandible preservation in Tomb B.5 is such that it had the highest count and established the MNI. In tomb B.5 the only elements that are not significantly underrepresented when compared to the MNI indicator are the zygomatic, maxilla, occipital, humerus, and ulna. The elements that seem to be significantly underrepresented are elements susceptible to moisture fluctuations and/or are more delicate with a low ratio of trabecular bone. The biggest factor effecting the recovery of the remains from the PNRP 2012 field season are environmental in nature.

Precision combined with the completeness of data in Osterholtz's feature-based system suggests that this type of method should be the choice for individuals working with commingled and fragmentary remains. Use of more precise methods developed and specifically designed for dealing with commingled and fragmentary human remains has wide-reaching applications in bioarchaeology and forensic anthropology. This feature-based system can open the study of large commingled skeletal samples previously neglected due to the time-consuming process of their analysis and may aid in the collection of evidence in forensic cases.

CHAPTER 6: CONCLUSION

This research project was undertaken with the intent to better understand possible improvements in the methodologies utilized to analyze complex commingled and fragmentary human remains. The expectation was that reanalysis of the PNRP 2012 skeletal assemblage using a newly developed feature-based method would produce better inventory results. Understanding the differences of these two types of methodologies would then better inform future data collection endeavors when determining which methodology for analysis would be most accurate for analyzing commingled and fragmentary remains. Demonstrating the success of this technique would not only stimulate the further development of these methodological tools, but also generate more research on traditionally neglected or troublesome assemblages.

The differences between methods for the analysis of commingled and fragmentary human remains reanalyzed a sample previously analyzed using a percentage-present methodology (*Standards,* Buikstra and Ubelaker 1994) using a feature-based method (Osterholtz 2014). The MNI was tabulated from the data recorded using the feature-based methodology and the results were compared to those from the original percentage-based analysis. This comparison of the results from both methods of data collection indicated that the data from feature-based method increased the overall MNI by 10 individuals. The feature-based method and reanalysis produced some variation in demographic analysis and a calculation of a total of eight additional adults, four per tomb, and two additional subadults (in Tomb B.5) when directly compared to the original *Standards* method. The two subadults added to the MNI as well as the demographic variation is unlikely to have been directly connected to the differences in the two methodologies, however the eight additional adult individuals are a direct reflection of methodological differences. The specificity in identification of diagnostic features on skeletal elements allows researchers an exact and quantifiable measurement through which MNI calculations can be determined and substantiated.

Streamlined and standardized methodologies designed to analyze commingled and fragmented remains are of broad importance in both the archaeological and forensic fields, and are of particularly timely importance in the context of the current political environment in the Middle East. The media has widely covered the extent of looting and destruction of antiquities by the Islamic State in Syria. Many are being killed and disposed in mass graves as a product of continuous unrest in both Iraq and Syria. By empirically establishing the merits of a simplified and standardized feature-based methodology utilizing a database system, osteologists with varied levels of experience would be better able to thoroughly and efficiently document at-risk collections and preserve them for posterity, aid in the collection of evidence in human rights atrocities, and help anthropologists advance methodologies for the analysis of commingled and fragmentary remains.

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APPENDIX A: ENTRY FIELDS AND FEATURE LIST FOR OSTERHOLTZ'S DATABASE

General Data Fields

RECORDER

- Field for the name of the individual analyzing and recording the entry into the database

DATE

- Date that the entry was made into the database

ACCESSION NUMBER

- This number is a unique identifier for the item being entered into the database that contains contextual information. For this analysis, this was recorded in this form: Area.TombNumber.LocusNumber.NumberOfFragment e.g. B.4:10.1

LAB NUMBER ASSIGNED

- Check box for use in lab analysis, not used for this study.

ESTIMATED AGE- (Drop Down Menu)

- Pre-term = Before Birth
- Infant = Birth – 2 Years
- Child = 2 -12 Years
- Adolescent = 12-18 Years
- Adult = 18 + Years
- Young Adult = 18 – 35 Years
- Middle Adult = 35 – 50 Years
- Old Adult = 50 + Years
- Adolescent + = 12 + Years
- Subadult = < 18 Years

- Child or Younger = < 12 Years
- Indeterminate = ???

REFINED AGE

- Data field for more specific age if able to be estimated

ESTIMATED SEX (Drop Down Menu)

- Not Applicable
- Female
- Male
- Ambiguous
- Indeterminate
- Female Possible
- Male Possible

SEX NOTES

- This data field allows for the recorder to note any morphological scores or metrics used to determine sex.

SIDE (Drop Down Menu) excluding Cranium, Sternum, and Vertebra

- Indeterminate
- Left
- Right
- Midline

BURNING, PATHOLOGY, OSTEOARTHRITIS, MINERAL STAINING

- These are checked to indicate presence of the above

MEMO FIELD

- Any additional or vital information about the fragments such as if they are refits, or anything of interest can be recorded here

CLAVICLE FORM

- Medial Epiphysis
- Costoclavicular Impression/Tubercle
- Middle 1/3 Shaft
- Conoid Tubercle
- Deltoid Rugosity
- Acromial End

Additional Data fields

- Max Length
- Midshaft Circumference

CRANIUM FORM

FRONTAL

- Left Zygomatic Process
- Right Zygomatic Process
- Glabella
- Bregma
- Frontal Not Contributing to MNI

NASAL

- Left Nasal
- Right Nasal

MAXILLA

- Left Nasal Process
- Right Nasal Process
- Left Palatine Process
- Right Palatine Process
- Left Canine Prominence
- Right Canine Prominence
- Left Zygomatic Process
- Right Zygomatic Process

MANDIBLE

- Left Mandibular Condyle
- Right Mandibular Condyle
- Left Coronoid Process

- Right Coronoid Process
- Left Gonial Angle
- Right Gonial Angle
- Left Mental Foramen
- Right Mental Foramen
- Left Mental Tubercle
- Right Mental Tubercle
- Mental Eminence

MALAR (ZYGOMATIC)

- Left Frontal Process
- Right Frontal Process
- Left Maxillary Process
- Right Maxillary Process
- Left Temporal Process
- Right Temporal Process

PARIETAL

- Left Bregma
- Right Bregma
- Left Origin of Meningeal Groove (anterior)
- Right Origin of Meningeal Groove (anterior)
- Left Lambda
- Right Lambda
- Left Obelion
- Right Obelion
- Left Parietal Notch
- Right Parietal Notch
- Parietal Not Contributing to MNI

TEMPORAL

- Left Zygomatic Process
- Right Zygomatic Process
- Left EAM (External Auditory Meatus)
- Right EAM (External Auditory Meatus)
- Left Mastoid
- Right Mastoid
- Left Squama
- Right Squama
- Left Occipito-Mastoid Ossicle/Suture
- Right Occipito-Mastoid Ossicle/Suture
- Left Temporal Not Contributing to MNI
- Right Temporal Not Contributing to MNI

OCCIPITAL

- Left Superior Nuchal Line
- Right Superior Nuchal Line
- Left Pars Lateralis
- Right Pars Lateralis
- Left Occipital Condyle
- Right Occipital Condyle
- Lambda
- Pars Basilaris
- Occipital Not Contributing to MNI

SPHENOID

- Left Lesser Wing
- Right Lesser Wing
- Left Greater Wing
- Right Greater Wing
- Left Pterygoid Plates
- Right Pterygoid Plates
- Chiasmatic Groove
- Sella Turcica
- Sphenoid Not Contributing to MNI

HYOID

- Body
- Wing (left)
- Wing (right)

Additional features for Cranium

- LTMJ (Left Temporomandibular Joint)
- RTMJ (Right Temporomandibular Joint)

FEET FORM

Element Drop Down Menu

- Talus
- Calcaneus
- Foot Navicular
- Cuboid
- First (Medial) Cuneiform
- Second (Intermediate) Cuneiform
- Third (Lateral) Cuneiform

- Metatarsal 1
- Metatarsal 2
- Metatarsal 3
- Metatarsal 4
- Metatarsal 5
- Proximal Phalanx
- Intermediate phalanx
- Distal Phalanx
- Metatarsal Indeterminate

TALUS

- Head
- Superior Articular Surface
- Flexor Hal Long Groove
- Lateral Process

CALCANEUS

- Sustantaculam Tali
- Calcaneal Tuberosity
- Facet for Cuboid
- Posterior Talar Facet
- Fibular Tubercle

METATARSAL 1

- Head
- Base

METATARSAL 2

- Head
- Base

METATARSAL 3

- Head
- Base

METATARSAL 4

- Head
- Base

METATARSAL 5

- Head
- Base

Additional Data

- Whole Bone

FEMUR FORM

- Fovea Capitis
- Superior Portion of Greater Trochanter
- Inferior Portion of Greater Trochanter
- Midpoint of Intertrochanteric Crest
- Lesser Trochanter
- Poirier's Facet
- Allen's Facet
- Third Trochanter
- Midpoint of Intertrochanteric Line
- Linea Aspera Where Lines Coalesce
- Linea Aspera Where Lines Diverge
- Adductor Tubercle
- Medial Epicondyle
- Lateral Epicondyle
- Intercondylar Fossa
- Medial Portion of Patellar Surface
- Lateral Portion of Patellar Surface
- Medial condyle
- Lateral Condyle
- Popliteal Surface
- Fragment of Head Not Contributing to MNI
- Fragment of Shaft Not Contributing to MNI

Additional Data Field

- Diameter of Femoral Head

FOREARM FORM

ULNA

- Olecranon (Superior Portion)
- Coronoid Process
- Radial Notch
- Interosseous Border (Volar Region)
- Styloid Process
- Ulnar Shaft Not Contributing to MNI

RADIUS

- Radial Head
- Neck
- Tuberosity
- Ulnar Notch
- Lister's Tubercle
- Styloid Process
- Radial Shaft Not Contributing to MNI

Additional Data fields

- Diameter of Radial Head

HANDS FORM

Element Drop Down Menu

- Scaphoid
- Lunate
- Triquetral
- Pisiform
- Trapezium (Greater Multangular)
- Trapezoid (Lesser Multangular)
- Capitate
- Hamate
- Proximal Phalanx
- Intermediate phalanx
- Distal Phalanx
- Metacarpal 1
- Metacarpal 2
- Metacarpal 3
- Metacarpal 4
- Metacarpal 5

METACARPAL 1

- Head
- Base

METACARPAL 2

- Head
- Base

METACARPAL 3

- Head
- Base

METACARPAL 4

- Head
- Base

METACARPAL 5

- Head
- Base

Additional Data

- Whole Bone

HUMERUS FORM

- Head
- Greater Tubercle
- Lesser Tubercle
- Deltoid Tuberosity
- Lateral Supracondylar Crest
- Medial Supracondylar Crest
- Olecranon Fossa
- Lateral Epicondyle
- Medial Epicondyle
- Trochlea
- Capitulum
- Coronoid Fossa
- Indeterminate Shaft Fragment
- Distal Shaft – Between Deltoid Tuberosity and Supracondylar Area

Additional Data fields

- Vertical Diameter of Humeral Head

- Biepicondylar Breadth

LOWER LEG FORM

Element Drop Down Menu

- Tibia
- Fibula

TIBIA

- Anterior Intercondylar Area
- Tibial Tuberosity
- Medial Border of Medial Condyle
- Lateral Border of Lateral Condyle
- Medial Intercondylar Tubercle
- Lateral Intercondylar Tubercle
- Fibular Articular Surface
- Fibular Notch
- Medial Malleolus
- Nutrient Foramen
- Point Where Anterior Crest Crosses Midline
- Squatting Facet
- Shaft Not Contributing to MNI

FIBULA

- Styloid Process
- Proximal Fibular Articular Surface
- Lateral Malleolus
- Malleolar Articular Surface
- Shaft Not Contributing to MNI

OS COXA FORM

Additional Data fields

- GSN Score (Greater Sciatic Notch)
- Ventral Arc Score
- Subpubic Concavity Score

- Ischiopubic Ramus Score

ILIUM

- Auricular Surface – Superior Demiface
- Retro Auricular Surface
- Posterior Superior Iliac Spine
- Iliac Spine Near Anterior Gluteal Line
- Anterior Superior Iliac Spine
- Anterior Inferior Iliac Spine
- Iliac Fossa
- Anterior Gluteal Line
- Posterior Gluteal Line
- Greater Sciatic Notch
- Fragment Not Contributing to MNI

ISCHIUM

- Ischial Spine
- Lesser Sciatic Notch
- Ischial Tuberosity
- Ischial Ramus
- Fragment Not Contributing to MNI

PUBIS

- Iliopubic Ramus
- Pubic Tubercle
- Symphysis
- Ischiopubic Ramus
- Fragment Not Contributing to MNI

ACETABULUM

- Ilial Surface
- Ischial Surface
- Hiatus
- Fragment Not Contributing to MNI

PATELLA FORM

- Apex
- Medial Articular Surface
- Lateral Articular Surface
- Quadriceps Attachment

Additional Data fields

- Max Width
- Max Height
- Max Breadth

RIB FORM

RIB 1

- Head
- Tubercle
- Scalene Tubercle
- Sternal End

SCAPULA FORM

- Infraglenoid Tubercle
- Supraglenoid Tubercle
- Acromion Process – Superior Edge
- Acromion Process – Inferior Edge
- Coracoid Process
- Where Acromion Meets Medial Border
- Inferior Angle
- Scapular Notch
- Acromion Process- Infraspinous Attachment
- Foramen in Suprapinous Fossa
- Blade Not Contributing to MNI

STERNUM FORM

- Xiphoid Process

- Sternal Foramen
- General Fragment Not Contributing to MNI

MANUBRIUM

- Jugular Notch
- Left Clavicular Notch
- Right Clavicular Notch
- Second Costal Notch

BODY

- Second Costal Notch
- Distal Border

VERTEBRAE FORM

Element Drop Down Menu

- C1 (Atlas)
- C2 (Axis)
- C3-C7
- T1
- T2-10
- T11
- T12
- T Vert (General)
- L Vert (General)
- L5
- Vertebral
- Sacrum
- Coccyx

VERT GENERAL

- Spinous Process
- Left Superior Articular Facet
- Right Superior Articular Facet
- Left Inferior Articular Facet
- Right Inferior Articular Facet

- Left Transverse Process
- Right Transverse Process
- Body
- Body Fragment Not Contributing to MNI
- Laminar Fragment Not Contributing to MNI

THORACIC ONLY: RIB FACETS

- Left Superior Demifacet (T only)
- Right Superior Demifacet (T only)
- Left Inferior Demifacet (T only)
- Right Inferior Demifacet (T only)
- Left Full Facet
- Right Full Facet

C1 (Axis)

- Facet for Dens
- Left Superior Articular Facet
- Right Superior Articular Facet
- Posterior Tubercle
- Left Inferior Articular Facet
- Right Inferior Articular Facet

C2 (Atlas)

- Dens
- Body (Inferior Surface)
- Left Superior Articular Facet
- Right Superior Articular Facet
- Left Inferior Articular Facet
- Right Inferior Articular Facet
- Spinous Process

APPENDIX B: ATTATCHMENT 2 FROM *STANDARDS*

INVENTORY RECORDING FORM FOR COMMINGLED REMAINS AND ISOLATED BONES

Site Name/Number ____________________ / ____________________ Observer ____________________

Feature/Burial Number ____________________ / ____________________ Date ____________________

Burial/Skeleton Number ____________________ / ____________________

Present Location of Collection ____

Report all cranial bones separately. Group Cervical Vertebrae 3-6; Thoracic Vertebrae 1-9; Ribs 3-10; Carpals; Metacarpals; Tarsals (other than Talus and Calcaneus); Metatarsals; Hand and Foot Phalanges. Vertebrae other than those grouped above should be reported individually. Identify **bones** by name, indicate **L** (left); **R** (right); **B** (Both); **M** (Midline); **?** (Unsidable). Code articular regions, long bone diaphyses, and vertebrae by **segments**: **PE** (proximal epiphysis), **P1/3** (proximal third of diaphysis), **M1/3** (middle third of diaphysis), **D1/3** (distal third of diaphysis), **DE** (distal epiphysis); **B** (vertebral body or centrum), **NA** (neural arch). Otherwise, leave this category blank. Code **Completeness** according to the following: **1** = >75% present; **2** = 25% - 75% present; **3** = <25% present. MNI reflects the minimum number of individuals recorded on this line. **Count/Wt** refers to the number/weight of fragmented materials. **Age** and **Sex** determinations should be entered as counts (see text for codes).

Bone	Side	Segment	Completeness	MNI	Ct/Wt	Age	Sex