# EVALUATION OF THE METHODOLOGY FOR ADDRESSING COMMINGLED HUMAN REMAINS FROM THE LEWIS JONES CAVE OSSUARY (1SC42) IN ST. CLAIR, ALABAMA

by

MARIA NAIYANA PANAKHYO

KEITH JACOBI, COMMITTEE CHAIR
VERNON KNIGHT
JANE RASCO
ELIZABETH COOPER

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ABSTRACT

The commingling of human remains continues to be a problem encountered by bioarchaeologists and forensic anthropologists. Commingling is not a recent phenomenon. In fact, taphonomic processes and human activity have created scenarios of merged burials and interments throughout human history. Recent investigations into incidences of mass killings, accidents with multiple fatalities, and disturbed burial grounds within the past half century have encouraged researchers in the field of physical anthropology to develop new and better ways to gain information about the commingled human remains. With emerging developments in the methods used for addressing these unfortunate situations involving intermixed skeletal material, this research project sought to explore the available methods and evaluate their appropriateness when applied to a curated collection of commingled human remains.

To evaluate certain established methods, this project describes the application of four separate approaches to the Lewis Jones Cave Ossuary Collection (1Sc42). This collection of prehistoric Native American remains was found in northeastern Alabama, and the archaeological site from which the remains were recovered is believed to be one of the few sites demonstrating the Copena Mortuary Complex. The four methods applied to the Lewis Jones Cave Ossuary Collection include a basic Minimum Number of Individuals (MNI) calculation, comparison by osteometrics, a sorting of descriptive variables, and a correlation between a mapped excavation unit and the corresponding curated skeletal remains. Results from this evaluation indicate that while each method has strengths and weaknesses when applied alone, it is only with an amalgamation of the different methods that a researcher studying commingled human remains is

able to sort and separate intermixed skeletal material. The findings from this research project aid in the study of curated collections of commingled human remains and expand available information pertaining to the prehistoric Native Americans interred within the Lewis Jones Cave Ossuary. Furthermore, evaluation of these methodological approaches serves to assist in future investigations into incidences of genocide, man-made disasters, and other situations involving commingled human remains.

## LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| ABI | Alabama Bureau of Investigation |
| CILHI | Central Identification Laboratory, Hawaii |
| CONADEP | *Comissión Nacional sobre la Desaparición de Personas* (National Commission on the Disappearance of Persons) |
| CWA | Civil Works Administration |
| DNA | deoxyribonucleic acid |
| EAAF | *Equipo Argentino de Antropología Forense* (The Argentine Forensic Anthropology Team) |
| ft | feet |
| GIS | Geographic Information Systems |
| L | left |
| LI | Lincoln Index |
| MLNI | Minimum Likely Number of Individuals |
| mm | millimeter |
| MNE | Minimum Number of Elements |
| MNI | Minimum Number of Individuals |
| n | number of samples |
| N | number in population |
| NAGPRA | Native American Graves Protection and Repatriation Act |

| | |
|---|---|
| OAR | Office of Archeological Research |
| P | pairs (left and right) |
| ± | plus or minus |
| R | right |
| ~ | approximately |
| TVA | Tennessee Valley Authority |
| UV | Ultraviolet |
| WPA | Works Progress Administration |

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# CHAPTER 1

# INTRODUCTION

This study seeks to provide a better understanding of the methods for handling curated collections of commingled human remains by examining those excavated from the Lewis Jones Cave Ossuary (1Sc42). The human remains recovered from the Lewis Jones Cave Ossuary presented a complication for Dr. Kenneth Turner who was the investigating physical anthropologist during the 1977 excavation. This problem developed from the active taphonomic processes that caused the collection to become highly commingled. Unfortunately, cases like the Lewis Jones Cave Ossuary are not singular events. Instances of commingled human remains appear in archaeological excavations, museum-based collection studies, and contemporary forensic situations with mass graves. Although the commingling of human remains is not a recent phenomenon, current interest in forensic situations such as war crimes and clandestine mass graves has instigated the development of new and diverse approaches to handle such situations.

Initial efforts to manage commingled human remains include the development of methods that estimate the number of individuals present and separate the individuals based upon bone morphological similarities (Snow and Folk 1965). Developments in zoological and zooarchaeological studies introduced quantitative techniques that involved determining the most common bone element and creating a Minimum Number of Individuals (MNI) estimate (White 1953; Adams and Konigsberg 2004). With the growing popularity in using quantitative approaches, more advanced statistical methods using probability calculations were developed to account for the variations in bone recovery (Adams and Konigsberg 2004; 2008). Further developments in the field included the use of osteometrics and bone dimensions to separate commingled individuals and match bone elements (Byrd and Adams 2003). Lesser well-known approaches to sorting and matching skeletal material include the use of UV light, a hierarchy of subjective variables, a record of repeating bone portions, and software programs capable of providing spatial data (Eyman 1965; Church and Burgett 1996; Knüsel and Outram 2004; Herrmann 2002). The development of different approaches has created an assemblage of tools an osteological researcher may choose from to use when confronted with a situation involving commingled human remains.

In an effort to determine which approaches are most appropriate for curated collections of commingled human remains, four separate methods will be applied to the Lewis Jones Cave Ossuary. These methods include: 1) a basic MNI calculation, 2) a use of osteometrics to sort and pair-match, 3) a hierarchy of subjective variables to filter possible matches and, 4) an employment of excavation maps to determine how the collection has changed since its excavation. In applying each method separately, this research project will demonstrate how appropriate each approach is for a curated collection, how an estimation of the number of individuals is derived from the method, and how the approach fairs when evaluated based upon preset criteria. These criteria, developed for this research project, are framed around the ease with which an investigator in the laboratory can apply the method and generate a better understanding of the collection under analysis. By completing this investigation into the appropriateness of four different methods, three objectives will be met. The first objective is to review the available methods currently used for prehistoric, historic, and contemporary cases of commingled human remains. The second objective is to examine four selected methods that are used in the management of commingled human remains and make suggestions for future research that involves working with poorly preserved curated remains with limited information on the excavation context. The final objective of this research project is to create a better understanding of the biological demographics of the people utilizing Copena mortuary practices in northeastern Alabama during the middle Woodland period (100-500 A.D.) (Walthall 1980:116). With these objectives in mind, this project is structured to discuss the methodology for human osteological research and the archaeological context of the Lewis Jones Cave Ossuary.

Chapter two provides a literature review of the relevant factors in a study of prehistoric human remains including the archaeological background, information about the Lewis Jones Cave Ossuary, taphonomic processes that cause commingling, the methodology for addressing commingled human remains, and the methods specific to forensic situations. First, understanding the commingled state of the Lewis Jones Cave Ossuary Collection requires an investigation of the archaeological background and the Copena mortuary practices. Secondly, the Lewis Jones Cave Ossuary, a Copena archaeological site whose excavation was led by Dr. Kenneth Turner, provides additional information on the overall condition of the collection as a result of the 1977 excavation. Additionally, taphonomic processes in cave environments direct attention to the forces which caused the skeletal remains to become intermixed. Furthermore, in an effort to sort commingled human skeletal remains, there are a number of methods available for the task both in laboratory and field settings. The final relevant topic to be addressed involves the application of these sorting methods as well as more extensive and involved approaches to contemporary forensic situations used in cases of armed conflict and mass fatalities.

In chapter three, the four different methods chosen to be evaluated based upon their appropriateness for a curated collection of skeletal remains are split into four different phases of application. Each phase includes the process of applying the method to the Lewis Jones Cave Ossuary Collection. In addition to the steps taken toward applying each method, the required materials are detailed for each phase.

Chapter four is a discussion of the results from applying each method to the collection and the researcher's assessment of the method based upon preset criteria. As chapter three is organized into four separate phases, the organization is maintained in chapter four. Each phase describes how the collection was sorted, how an estimation of the number of individuals was obtained, and how potential pair-matches were determined. In addition to discussing the process of sorting and estimating the number of individuals for each method, this chapter also includes an assessment of each method using seven preset criteria developed for this research project.

The fifth chapter concludes with a discussion of the method evaluation results. This discussion is structured around the inherent strengths and weaknesses of each of the methods. With these attributes in mind, suggestions are made for future research concerning commingled human osteological studies both in a laboratory and field setting. Finally, a summary of the analysis of the sorting methods forwards information about the Lewis Jones Cave Ossuary, the Copena Mortuary Complex, and the people who were laid to rest within the cave ossuary.

# CHAPTER 2

## LITERATURE REVIEW

Commingled human remains are an emerging concern in recent anthropological studies and forensic investigations. In bioarchaeological studies, when a researcher examines a collection of museum curated human remains, different aspects must be taken into consideration to understand how human remains may have become commingled and how best to approach analysis of those skeletons. An initial aspect of collections-based research is creating an understanding of the temporal context for the skeletal remains. Using past archaeological records and maps allows the researcher to conceptualize the condition and situation in which the human remains were interred. In the case of this research project and the Lewis Jones Cave Ossuary prehistoric site, contextual information about the local groups in northeastern Alabama can be best derived from previous archaeological research on the Copena Mortuary Complex. Additionally, examination of the records from the original excavation of the Lewis Jones Cave Ossuary provides information about the orientation and placement of the skeletal remains. This information about the remains must be gathered from excavation records, forms, notes, maps, and personal accounts written or communicated by individuals present during the initial investigation. Alongside the information derived from records about the context of the commingled skeletal remains, a bioarchaeologist must explore the possible reasons for commingling. In many instances, causation for intermixing of multiple individuals is derived from context-specific taphonomic forces. A final aspect to bioarchaeological investigations is the method(s) chosen to approach the skeletal analysis. Recent developments in bioarchaeological and forensic studies have greatly diversified the ways in which a researcher can initiate inventorying and sorting commingled human remains.

## Copena Mortuary Complex

Archaeological investigations around the turn of the twentieth century predominately focused upon the excavations of Native American earthworks and mounds throughout the Eastern portion of the United States. As a part of this initiative, the Bureau of Ethnology employed individuals such at Cyrus Thomas to record and present the locations of the surveyed Native American mounds and archaeological sites (Walthall 1980:117). As a part of this initiative, Thomas recorded not only earthworks and mounds, but cave ossuaries as well. His survey records of the Tennessee Valley include two prehistoric cave sites, Hampton Cave in Marshall County and Cramp's Cave in Blount County, Alabama. Decades later, re-evaluation of the material remains would confirm these sites were the first archeological surveys of what is now known as the Copena Mortuary Complex (Walthall 1979:200).

While Thomas is the first known individual to record the excavations of a Copena burial site, it has only been through a century of intermittent archaeological investigations that a better understanding of the Copena Mortuary Complex has come to light. Most archaeologists will agree the Copena Mortuary Complex consists of a set of regional burial practices found within the Tennessee Valley during the Middle Woodland period (A.D. 100-500) (Cole 1981; Walthall 1980). That is not to say the term "Copena" refers to a specific group or society, but more that it is an archaeological identification used to indicate similar mortuary practices found across a geographic area (Walthall 1973). The mortuary practices most often include mound or cave site burials with any combination of flexed and extended bodies, foreign clay, copper and galena artifacts, cremated remains, and very few ceramic sherds (Cole 1981; Walthall 1973; Walthall and DeJarnette 1974). Archaeological sites identified as Copena span across northern Alabama from the Mississippi border to the edge of Georgia. The location of Copena sites heavily depends upon a proximity to water sources, including the Tennessee River and its tributaries (Webb 1939:1). The timeframe is slightly less certain as the dated material from different sites indicate various periods within the first half of the first millennium A.D. (Cole 1981). Our current understanding of the Copena Mortuary Complex and the people who utilized these mortuary practices was developed from the TVA excavation efforts in the 1930s and 1940s, and a renewed interest in the following decades in Copena mound and village sites.

Alongside the findings of Thomas, another individual credited with the initial excavations and surveys of Copena sites is Clarence B. Moore. As a part of his interest in prehistoric cultures, Moore traveled throughout the waterways of the southeastern United States exploring and excavating Native American sites (Walthall 1980:117). From 1914 to 1915, Moore excavated seven Copena mounds around the Tennessee Valley. These sites included the Roden sites (1Ms147, 1Ms150, and 1Ms152), Slaughter Place sites (1Mg43 and 11Mg44), and the Perkins Spring sites (1Lu37, 1Lu38, and 1Lu39) (Cole 1981:176-8; Webb 1939:189). Observed similarities in the artifacts found at Copena and Ohio Hopewell sites led Moore to note the possible relationship between the two complexes (Walthall 1979:200). Over a decade later, Gerard Fowke excavated two additional Copena sites including Alexander Mound and Hog Island Mound (Cole 1981:178; Walthall 1973:28). Early archaeological investigations and records by Thomas, Moore, and Fowke were based upon an exploratory analysis and mound excavation. Although early investigators noted the presence of cave burial sites and human remains within mound sites, it was not until the 1930s when archaeologists revisited the archaeological reports of Thomas and Moore that a better picture was developed of the Copena mortuary practices.

Economic and financial changes in the 1930s and 1940s spurred a growth in archaeological work throughout the United States. After the Stock Market crash in 1929, government programs such as the Tennessee Valley Authority (TVA), Works Progress Administration (WPA)**,** and Civil Works Administration (CWA) were established to aid the masses of unemployed individuals across the country to find work (Lyon 1996). Part of this initiative included the building of hydraulic dams on the Tennessee River along the border between Tennessee and northern Alabama. Damming of the Tennessee River and its tributaries ultimately led to the inundation of hundreds of prehistoric Native American sites in the Tennessee Valley (Lyon 1996). Prior to the completion of these hydraulic projects, archaeologists including William S. Webb, David L. DeJarnette, and Charles G. Wilder were employed to survey, record, and salvage excavate the prehistoric sites before they were submerged under water after dam construction (Lyon 1996).

With the increase of workers and excavations, archaeologists turned to a more systematic approach in recording prehistoric cultures. A systematic approach, usually in the form of trait lists, necessitated more attention to the quantities and dispersion of artifacts and characteristics from each site. Cole (1981) has described trait lists as, "itemized lists of traits and characteristics assumed to be more or less typical of the culture being defined" (Cole 1981:161). The management of different characteristics, artifacts, and their respective quantities allowed archaeologists to establish general descriptions about cultures and use them as a comparison tool for future excavations. In the case of the Copena Mortuary Complex, the creation of a cultural trait list would theoretically allow an archaeologist to compare different sites to a Copena trait list to see if they are a part of the complex (Cole 1981:162). Surveys and excavations at the Wheeler, Pickwick, and Guntersville Basins allowed for the formation and refinement of a cultural trait list for the Copena Mortuary Complex.

Excavations of the Wheeler Basin helped create a better understanding of prehistoric peoples living in the Tennessee Valley and the Copena Mortuary Complex. Situated along the Tennessee River, the Wheeler Basin is predominately in Lauderdale and Limestone Counties, Alabama. Beginning in 1934, Webb was assigned as the director of archaeological projects in the Tennessee Valley. He was involved in the surveying and excavating of many prehistoric sites throughout the region (Webb 1939:2). Of the nineteen excavated sites described in the Wheeler Basin survey, only the Lauderdale site (1La37) and the Tick Island site (1La14) were determined to be a part of the Copena Mortuary Complex (Webb 1939; Walthall 1973:52). These sites were determined to be examples of the complex predominately by the unique mortuary practices and material remains similar to those found noted by Thomas and Moore.

Creation of a cultural traits list from the excavations of the Lauderdale site and Tick Island site, Moore's 1914-1915 excavations, and Fowke's 1928 surveys, led to the initial concept of the Copena Mortuary Complex. Webb (1939) compared the artifact finds from the Lauderdale and Tick Island sites to the two Copena mounds surveyed by Fowke and the seven sites excavated by Moore. Similar traits that were found across these sites included conical mound structures, "inclusive" burials, subsoil burials with minimal artifacts, stone celts and pipes, galena deposits, copper artifacts including beads and bracelets, killed copper artifacts (an artifact intentionally made unusable), shell objects, and flexed burials (see Appendix A for the complete trait list) (Webb 1939:189-190, 194). Webb (1939) states:

> "It is at once apparent from this tabulation that this cultural complex involving the use of copper and galena in this way is a very compact and definite group of traits. This group

> of traits, which for purpose of description herein has been called the copper-galena complex, though small, contains many quite unusual traits, and its homogeneity on these seven areas seems to justify setting it apart as distinctly different from other cultural complexes in the southeastern area, at least for the time being." (Webb 1939:191)

Although raw counts for the observed traits were not extensive, Webb (1939) believed the site similarities and the prominent presence of copper and galena artifacts signified these sites were similar but a separate entity from the Ohio Hopewell complex (Webb 1939). The extent to which the Copena complex differs from the Ohio Hopewell had not been fully examined at this point in archaeological research. By the end of the Wheeler Basin salvage excavations, Webb had a potential trait list and name for the complex: Copena (**Cop**per and Gal**ena**) (Webb 1939). The trait list was only the beginning as Webb was still unclear of the temporal placement, the extent to which the Copena complex spanned within the southeast United States, and the relationship between societies employing Copena mortuary practices in and around the Tennessee Valley (Webb 1939:200-201).

Soon after the completion of the Wheeler basin survey, the TVA employed archaeologists to survey and excavate prehistoric Native American sites around an area that would become the Pickwick basin. Of the nineteen excavated sites in the Pickwick Basin, five mounds and two village sites were Copena in nature (Webb and DeJarnette 1942). The mounds sites, Wright Mounds #1 and #2 (1Lu63 and 1Lu64), Colbert Creek Mound (1Lu54), Boyd's Landing Mound (1Hn49), and Fisher Mound (44Hn4), were compared with and confirmed as Copena by the trait list developed by Webb (1939) during the Wheeler Basin excavations. The Wright Village site (1Lu65) and the Fisher Village site (44Hn4) were the first Copena village sites to be excavated and a separate trait list of 45 traits was created for them (Webb and DeJarnette 1942). Mortuary characteristics and artifacts from the mound sites led to a refinement of the Copena mortuary trait list. From the original trait list, two traits were removed because of inapplicability, and eleven were added based upon the characteristics and artifacts found at the Pickwick Basin excavations (Webb and DeJarnette 1942). Although the excavation of Copena village sites provided additional information about everyday activities, Webb and DeJarnette (1942) were still unable to place the Copena mortuary practices within a temporal placement beyond a relative proximity to the neighboring Hopewell and Adena influences. These influences included Hopewell tendencies in trade goods (i.e., importation of copper) and Adena use of foreign clay in the burial process. Furthermore, the presence of small amounts of limestone tempered pottery would suggest Copena was temporally situated towards the creation and use of pottery (Webb and DeJarnette 1942:303).

In addition to the Pickwick basin excavations, archaeological work in the Guntersville Basin provided additional evidence toward framing a cohesive understanding of the Copena Mortuary Complex. Although the Guntersville Basin was surveyed and excavated soon after the Pickwick Basin, the onset of WWII halted the publication of the archaeological findings until 1951 (Webb and Wilder 1951). A total of five Copena sites were excavated during the Guntersville survey including the Rose site (1Ms134), Samuels sites (1Ms136 and 1Ms137), Columbus City site (1Ms91), Roden Mound sites (1Ms48, 1Ms49, 1Ms51, 1Ms53, and 1Ms53A), and the Hampton Cave (1Ms145) (Webb and Wilder 1951). The Hampton Cave was of particular interest to Copena research as it was a revisit to Thomas' records and the first Copena cave burial site to be excavated under the TVA projects (Walthall and DeJarnette 1974). The cave itself was unique in that even though the entrance high above the valley floor, there was still an extensive deposit of human remains indicating continual use as a burial location (Walthall 1973:66). Additionally, the excavation of these sites led to two more traits being added to the Copena trait list bringing the total to 47 (Walthall 1973:65). The result of the Guntersville

Basin survey included an addition to the diagnostic Copena traits and the inclusion of cave sites as Copena burial grounds.

Archaeological excavations of the TVA basins led Webb and his associates, DeJarnette and Wilder, to create a summation of diagnostic traits for the Copena Mortuary Complex. During and immediately after the publications of the TVA excavations archaeologists sought to create a cohesive description of the Copena Mortuary Complex. This objective included the efforts of Harold V. Anderson, who according to Cole (1981), sought to coalesce traits from all Copena excavations into one list. Unfortunately, his data and review was not put into publication and only seen by a few (Cole 1981:169; Knight 1990:xiii). DeJarnette (1952) took a slightly different approach in that he described the practices associated with the Copena complex. For example, Copena mounds had subsoil or intrusive burials in which the individuals were either bundled or in flexed or extended positions. An individual usually had very few, if any at all, accompanying burial goods. More unusual mortuary characteristics included the intentional presence of nonlocal clay in the burial, clay headrests and/or footrests, and log or bark lined burial pits (DeJarnette (1952) in Cole 1981:169).

In addition to amassing Copena cultural traits, mid-century archaeologists sought to determine the Copena complex origins. Initial disagreements over the origins of Copena burial practices were focused on the multiple similarities in mortuary traditions between neighboring complexes, most especially Hopewell and Adena influences to the north. While there were similarities between Copena burial goods (although not in quantity) and the Hopewell complex, the burial patterns were similar to Adena (Webb and Snow 1974). Some archaeologists argued that the Copena complex was the result of people migrating south from Adena or Hopewell areas (Webb and Snow 1974; Dragoo 1963). Others argued that the Copena complex developed as a local practice and similarities with regional cultures were due to trade interactions (Faulkner 1970; Walthall 1973; Walthall 1980). Although both points of view were logical assumptions, the latter is the assumption archaeologists tend to accept with increasing knowledge of trade patterns and origins of raw materials.

In Seeman's (1979) analysis of the Hopewell Interaction Sphere, he illustrates the extent of trade networks within the Midwest. "The current picture is one of a highly complex trading system existing among cultural units with different adaptations, but at roughly equivalent levels of cultural development" (Seeman 1979:248). Seeman (1979) describes the Hopewell Interaction Sphere as an overarching system in which smaller cultural units produce goods and/or raw materials which are then traded and exchanged to geographically different groups. The value of the goods and materials extends beyond the object to the distance in which it was transported (Seeman 1979:311). Seeman (1979) was able to support his findings about the trade network by the determination of the origins of raw materials. In the case of Copena, galena and copper were not locally present in the raw quantities needed for the amount of worked artifacts excavated from the burial sites (Seeman 1979:292-293). By looking at the composition of the copper and galena, researchers were able to determine the copper was most likely being traded down from its source area of Lake Superior and galena was being transferred in from its source near Joplin, Missouri (Seeman 1979:292-295). With a more precise understanding of artifact origins and the regional interactions, recent Copena research has shifted towards synthesizing data from prior excavation data.

A contributor to the synthesis of Copena knowledge is John A. Walthall, who published not only his dissertation but numerous articles and book chapters on the Copena complex. In Walthall's (1973) dissertation, he provides a detailed account of the history of archaeological excavations and surveys of the Copena complex. His synthesis includes not only an account of the excavations of mounds and villages, but of cave sites as well. Analysis of prior Copena publications allowed Walthall (1973) to present a comprehensive narrative of the Copena complex to date. His findings and clarifications led the way toward expanding our knowledge of the Copena Mortuary Complex beyond trait lists and trade regions. Part of the development of Copena knowledge included Cole's (1981) and Knight's (1990) site analyses, and Beck's (1990, 1995) regional analysis.

Since the time of Walthall's (1973) revisit of the Copena complex, there have been very few publications concerning archaeologists locating or revisiting Copena sites. One such study is Gloria Cole's (1981) excavation and analysis of the Murphy Hill site (1Ms300). The undisturbed state of the mounds, especially mound A, provided ample material to analyze the social structure of the social structure found within the Copena mortuary practices (Cole 1981). She found that mound A fit with previous Copena excavations because the ceramics and artifacts corresponded with the trends in the middle Woodland period. Furthermore, the presence and distribution of exotic goods (i.e., copper) reaffirmed Copena was a regional complex that was contemporaneous with Hopewell and a participant in the Hopewell Interaction Sphere (Cole 1981:295-296). In addition to Cole's (1981) analysis of the Murphy Hill site, Vernon Knight (1990) revisited the Walling site which included middle Woodland mounds and a village. Re-excavation of the truncated mound indicated that people were not only using these earthworks for burial use, but as a place for production and exchange (Knight 1990:113). From the ceramic artifacts and those found at other Copena sites, Knight (1990) suggested there were three regional variations within the complex. In line with Knight's (1990) comments on the regional variation, Lane Beck (1990; 1995) found that Copena regional mortuary practices had a distinctive split between the east and west portions of the Tennessee Valley. The difference between the east and west was noted predominately through grave good association with age in the east and a higher frequency of grave goods for all interred in the west (Beck 1995:180-181). The findings of Cole (1981), Knight (1990), and Beck (1990; 1995) were able to strengthen our knowledge of the Copena Mortuary Complex through re-analysis of prehistoric finds in mound and village sites.

In addition to Walthall's (1973) reanalysis of the Copena mound and village sites, he compiled the available information on Copena cave ossuaries. Of these cave ossuaries, he mentions Hampton Cave (1Ms145), Rockhouse Spring Cave (1Li1), McCalla Cave (1Je30), Ed Smith Cave (1Mg76), Cave Springs (1Mg65), and Kymulga Cave (1Ta105) (Walthall 1973). While varying geographically, these caves were determined to be part of the Copena Mortuary Complex based upon the interment method and associated grave goods. Similarities between burial mounds and cave ossuaries included copper and galena artifacts, the use of burial furniture (i.e., clay headrests), wrapping the bodies in bark then covering with clay, and the inclusion of cremated remains (Walthall 1973:561-563; Walthall and DeJarnette 1974). An aspect of cave ossuaries that was not possible to completely study in mound burials was the wrapping process of individual interments. Due to the enclosed and sheltered atmosphere in a cave environment, botanical remains were better preserved (Walthall 1973:525-561). Walthall (1973) found in the excavation notes from Cave Springs that some bodies had a more involved burial preparation including a shroud of a woven textile, then a layer of bark matting, and finally a covering of clay (Walthall 1973:538-540). In addition to the body preparation process, placement within the cave varied between natural troughs and ledges along the walls (Walthall 1973:539-540). It is important to note that while the Cave Springs site did shed light on the actual interment processes, this type of information is rare and not found elsewhere primarily because of modern pot hunter looting and animal scavenging of prehistoric cave ossuaries (Walthall 1973:558). Walthall (1973) notes that while there are twelve known Copena cave ossuaries (thirteen with the Lewis Jones Cave Ossuary), only six of the aforementioned caves he studied provided any insight into prehistoric activity (Walthall 1973:516). The six left unmentioned were in too poor of preservation to provide information on Copena cave ossuaries (Walthall 1973:515-516). Although cave environments can supply valuable information about the Copena mortuary practices, the acts of vandals and looters hinder an archaeologist's ability to learn about the past.

**Lewis Jones Cave Ossuary (1Sc42)**

The Lewis Jones Cave Ossuary is one of the less well-known Copena sites. Records of the cave ossuary are scant in detail about the circumstances surrounding the cave's identification and its subsequent excavation. Information that was obtained came from Dr. Kenneth Turner's personal notes, his progress reports submitted to the University of Alabama, and newspaper clippings. Additional information came from personal correspondence with Mr. Eugene Futato at the Office of Archaeological Research (OAR) who volunteered during the excavation of the site. The surviving records housed at the Laboratory for Human Osteology coupled with memories from a volunteer archaeologist, provided details of how the skeletal and material remains were excavated from the cave site. Additionally, Dr. Turner's progress reports described the preservation techniques he employed for the removal and curation of the human remains from the Lewis Jones Cave Ossuary. It is with these records and memories that a story unfolds of the rediscovery and salvage excavation of the Lewis Jones Cave Ossuary that occurred nearly 36 years ago.

Figure 2.1 Entrance to the Lewis Jones Cave Ossuary (1Sc42). Photographer unknown.

On July 1, 1977, a bulldozer operator uncovered the entrance to a limestone cave located near the border of St. Clair and Etowah counties in northeastern Alabama (Figures 2.1-2.3). At the time, land owner Lewis Jones was clearing the hillside for road construction and development of the Canoe Creek Country Club (Bryant 1980:5-A). When human remains were discovered within the cave, he notified authorities at the St. Clair Sheriff's Office who contacted the Alabama Bureau of Investigation (ABI). Unsure if the remains where contemporary in nature, Captain James A. Davis and Sergeant L.P. Wetzel of the ABI requested the aid of Dr. Kenneth Turner who was in charge of the Human Osteology Laboratory at the University of Alabama in Tuscaloosa, Alabama (Brogdon 1977:1).

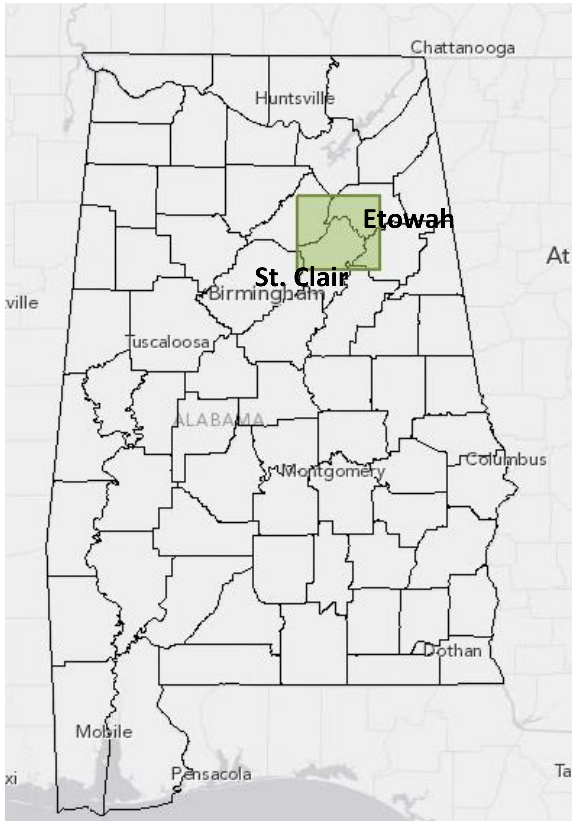


Figure 2.2 Location of St. Clair and Etowah counties in northeastern Alabama.

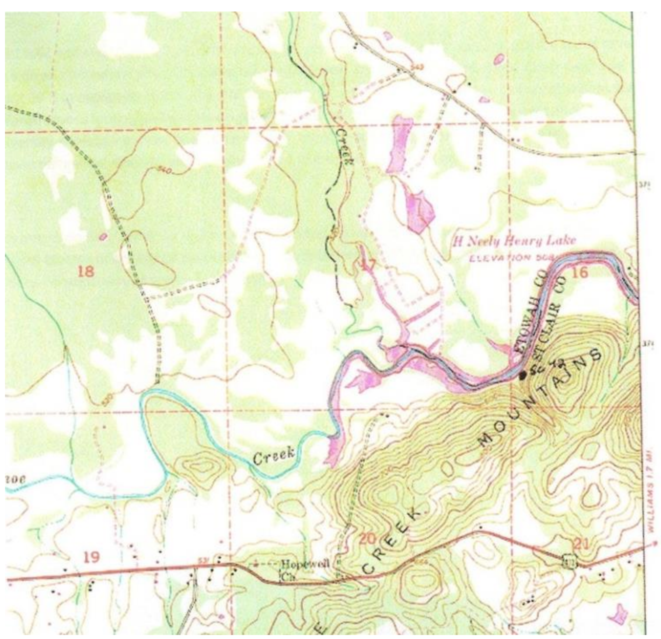


Figure 2.3 State Site File map indicating the location of the Lewis Jones Cave Ossuary (1Sc42). Courtesy of Mr. Futato, UA Office of Archaeological Research.

In the following days, Dr. Turner and C. Earle Smith Jr. visited the site to determine if it was a modern forensic case and to judge the context of the human remains. Dr. Turner identified the skeletal remains and associated artifacts as prehistoric in nature. Turner's notes from the time and subsequent newspaper articles indicated there were beads, worked metals, shells, "Copena darts," and other artifacts present indicating the cave's prehistoric use (Bryant 1980:5-A). The presence of copper and galena artifacts led Dr. Turner to conclude that the Lewis Jones cave was a Copena cave ossuary. The partial articulations and dispersal of bones led Dr. Turner to believe that the site had been undisturbed by human activity since its prehistoric use. With the exposure of the Copena ossuary cave site, Dr. Turner pursued an excavation of the archaeological material and human skeletal remains for preservation purposes.

A day after the rediscovery of the Copena ossuary site, vandals broke past the temporary entrance blockades and looted both the skeletal and material remains. The county sheriff's office and the ABI worked to recover the stolen remains while Lewis Jones posted signs and off-limits borders around the site to deter further looting (Futato 2013). Of the many skulls found the first day, a majority of them were broken or stolen by the vandals. Alongside stolen and broken skulls, the vandals had taken an unknown quantity of long bones and material artifacts (Brogdon 1977:1). While authorities sought to recover the stolen remains, Dr. Turner requested aid and funding from the University of Alabama for a salvage excavation of the site in order to recover what remained before there was further damage by looters and vandals. While some of the stolen remains were returned, it is currently unknown how much of the human remains are still missing.

Over the course of a few days, Dr. Turner enlisted the aid of archaeologists, students, and volunteers associated with the University of Alabama and OAR to assist in the salvage excavation of the Lewis Jones Cave Ossuary. Due to time constraints, the size of the cave (the main passageway was reported to be 150ft long by 30ft wide), and the dispersion of the skeletal material, the excavation proceeded as a combination of bone collection and planned excavation units (Futato 2013). While much of the skeletal material was collected sans provenience information, the remaining bones were excavated from areas where there were bone concentrations. These concentrations included the backroom (room II), frontroom (room I), entrance, crawlspace, unit 121L3, unit 114.5L2, and unit 116R3 with an one meter extension (114R2) (Figure 2.4). While the two larger rooms, entrance, and crawlspace are without excavation maps, illustrations were partially completed for the four planned excavation units (see appendix B for original unit excavation maps). Excavation also included removing containers of mud from the cave to the entrance for screening (Brogdon 1977:1). Quarter inch mesh screens and water pumped from Canoe Creek were used to water screen buckets of mud to separate human and material remains from the soil/clay matrix.

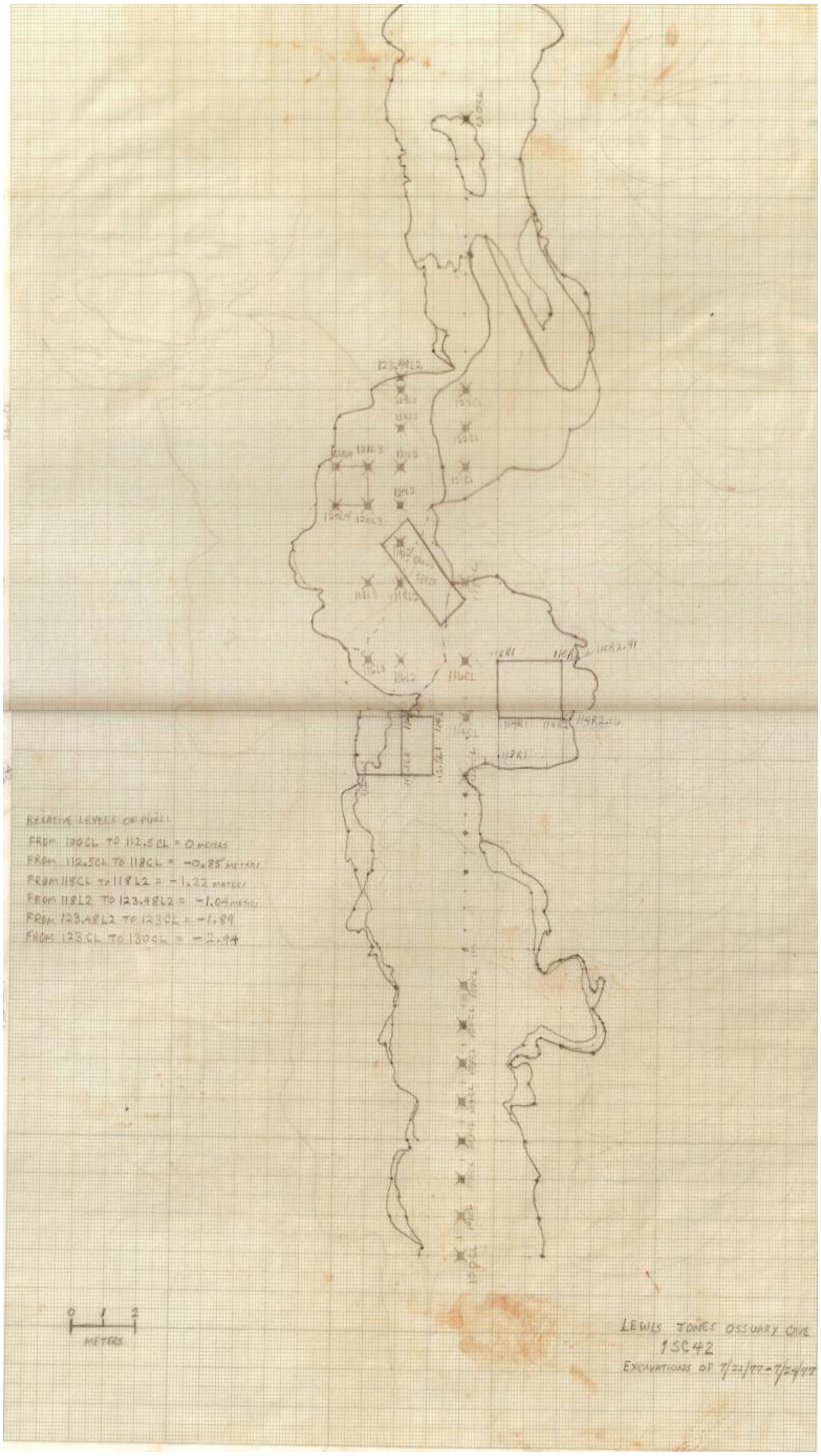


Figure 2.4 Base map of the Lewis Jones Cave Ossuary. Cartographer unknown.

Upon completion of the cave excavation, the skeletal remains were brought to the University of Alabama's Human Osteology Laboratory for washing, reconstruction, and preservation. Curation processes included reconstructing the bones by adhering segments of disarticulated bones back together and setting teeth back into the maxilla and mandible. Due to workspace limitations in the laboratory, the human remains did not receive a full preservation treatment. The collection identification number ("1Sc42") was written on all bone elements and, when the provenience number was maintained, it was added to the notations on the bone. With identification notations on the bones, Dr. Turner separated the bones by element and segment (left, right, and unidentifiable), and bagged the collection into brown paper bags for storage in the Human Osteology Laboratory at the University of Alabama.

In 1980, Dr. Turner revisited the Lewis Jones Cave Ossuary Collection for a genetic distance analysis using non-discrete traits present on the temporal bone. Turner (1980) sought to demonstrate a population change in northern Alabama during the shift from the Woodland to the Mississippian cultural period (Turner 1980:26). In an effort to demonstrate the population change and the usefulness of non-discrete traits, Turner compared five collections including the Lewis Jones Cave Ossuary (1Sc42), Vienna Landing site (1Pi61), Koger's Island site (1Lu92), Harris site (1Ms80), and Lubbub Creek site (1Pi33) (Turner 1980). These sites were from either the Woodland or Mississippian periods, and were located in western and northern Alabama. Turner found the observations of non-discrete traits to be of use when studying poorly preserved remains and he sought to demonstrate their effectiveness in genetic distance analysis (Turner 1980). After Turner's (1980) analysis of non-discrete traits, the collection was inventoried in 1994 for the Native American Graves Protection and Repatriation Act (NAGPRA). Beyond the NAGPRA inventory, this current research project concerning commingled human remains is the first study since 1994 to investigate the Lewis Jones Cave Ossuary Collection for information about the people who were buried in this Copena mortuary cave.

**Causations for commingled human remains**

The commingling of skeletal remains is a result of the burial context and the active taphonomic processes acting on the burial and its remains. That is to say, the location of a burial will determine the taphonomic processes/agents that change and commingle those skeletal remains. Taphonomic agents can best be described as either physical entities or natural processes that help transition the human body after death from above ground to the ground layer (Ubelaker 1997:77). Agents of taphonomy include insects, scavengers, wind, fluvial transport, geologic changes, and human activity, to name a few (Ubelaker 1997). The Lewis Jones Cave Ossuary is a good backdrop for investigating taphonomic agents and the commingling of skeletal remains. In this prehistoric burial context, taphonomic agents will include scavenging by carnivores and rodents, water transport, and human activity. While each of these forces can lead to the transport of skeletal remains from one part of the cave to another, it is when they work in conjunction with each other that the cave ossuary creates a highly commingled collection of skeletal remains.

Scavenging by larger animals, especially those of the canine variety can lead to a wide dispersal of skeletal remains. Haglund (1997a) notes that while in the pursuit of food, dogs and coyotes will modify and consume soft tissues, disarticulate skeletons, break-down bone elements, and scatter skeletal material (Haglund 1997a:367). Additionally, Haglund (1997a) has determined there to be five phases of scavenging which intensify the disarticulation of a body over time. The first phase is early scavenging where there is only the consumption of soft tissues within the first few hours to days. The second phase is a break-down of the thorax and disarticulation of the upper extremities (arms and shoulders) anywhere up to two months. The next phase is the disarticulation of the lower extremities which takes anywhere from two to four months (Haglund 1997a:368-369). This type of disarticulation is more involved in that the lower extremities have more fibrous material, such as ligaments and tendons connecting the lower limb bones. The fourth phase concerns the disarticulation of the vertebral column and can occur anytime between two and eleven months. The final phase of scavenging includes the total disarticulation of a body and can take anywhere between five and twenty-five months (Haglund 1997a:368-369). The duration of each phase greatly depends upon the other active taphonomic agents, degree to which animals are using a corpse for a food source, and the density of muscle tissue (Haglund 1997a:377). In the case of an active cave ossuary site, carnivores visiting the site will have a partially enclosed space in which to scavenge.

Lewis Jones Cave Ossuary illustrates the extent to which carnivores can scavenge buried human remains. Depending upon the pre-burial treatment and the season in which the bodies were interred at the cave ossuary, the first few phases described by Haglund (1997a) would have progressed quickly. In the Lewis Jones Cave Ossuary there is complete disarticulation meaning the remains have surpassed the last stage of Haglund’s (1997a) scavenging descriptions. With little to no muscle mass left and the joints disarticulated, both large and small scavengers could have transported bone elements within the cave and possibly carried them outside of the cave. With the ability to move bone elements and the space to accomplish it, carnivorous scavengers were prominent contributors to the commingling of the multiple individuals interred in the Lewis Jones Cave Ossuary. In addition to carnivore scavengers, rodents also have been noted to move bones throughout an archaeological site (Brain 1980; Haglund 1997b).

Although rodents are not carnivores in the traditional sense, they are known for scavenging and bringing objects back to their niches (Brain 1980). Within the cave environment, rodents including rats, mice, and porcupines scavenge for both food and chewing materials. The scavenging for chewing items, especially hard objects like wood and bone, is a unique trait in some species of rodents. This type of behavior stems from the need to wear down their central incisors for optimum functionality (Haglund 1997b). According to Brain (1980) and Haglund (1997b), a prime example of rodent activity in cave environments are porcupines and their accumulation of hard objects within their lairs. Once porcupines have possession of a hard object like human bone, they will take it back to their lair or niche and continually gnaw on it to grind down their central incisors (Haglund 1997b; Brain 1980). Haglund (1997b) also notes that rodents will not only scavenge for bone to gnaw upon, but also use it as a food source (Haglund 1997b:408-411). Whether rodent activity is due to gnawing or feeding, it can best be observed by the presence of parallel striations on bone elements. The importance of rodent activity in an archaeological site is their ability to transport bone (within a reasonable weight) to different areas away from the primary interment site and destroy skeletal remains through consumption (Haglund 1997a).

In the case of the Lewis Jones Cave Ossuary, rodent activity was a significant contributor to not only transporting bone elements but in consuming portions of bone. According to Dr. Turner's records and new articles, the skeletal remains collected from the cave ossuary were highly commingled and in poor preservation (Brogdon 1977:1). As the cave environment is a prime location for rodent habitats, the commingling of skeletal material may, in part, be due to rodents living in the cave and scavenging for gnawing material and food. Additionally, the designation of poor preservation usually is attributed to human remains that have been under the force of taphonomic agents for an extended period of time. While scavenging by carnivores and rodents is a primary taphonomic process, fluvial transport also contributes to the commingling of skeletal material.

Fluvial transport, or flowing water in streams and rivers, is a significant geological manifestation that can cause commingling. According to Hanson (1980) and Nawrocki et al. (1997), the movement of bones in water depends heavily upon the bone in question, speed of water flow, depth of water, and geological formations under the water. Aspects of the bone's size and density will determine how far a bone will travel from the primary interment to its secondary location. Likewise, the speed and flow of the water will also assist in how well the bone will move from one location to another. Bone transport by moving water was first tested in an experiment by Voorhies (1969), and then by Boaz and Behrensmeyer (1976). While Voorhies (1969) found there to be a reasonable division between bone elements that would move well in water and those that would drag behind, Boaz and Behrensmeyer (1976) found that bone morphology better determined how well a bone element would move in a waterway (Micozzi 1991:69; Nawrocki et al. 1997:534). For instance, Boaz and Behrensmeyer (1976) found that increased density and flat surface dimensions would cause a bone to lag behind rather than travel (Nawrocki 1997:534). Fluvial transport was an instrumental mover of bone material because of the presence of a wash channel within the Lewis Jones Cave Ossuary.

A topographical map of the Lewis Jones Cave Ossuary indicates a wash channel may have contributed to the movement of skeletal material throughout the cave. In the process of excavating the cave ossuary, volunteers mapped the cave to scale and indicated the presence of a wash channel that ran from the Backroom to the entrance of the cave (figure 2.5). Futato (2013) further noted that at different points in the cave, especially near the walls, there were places with high elevations and ledges. If there was seasonal change in the water levels of the nearby Canoe Creek, then the water levels in the wash channel could have fluctuated as well. This fluctuation in moving water along the main passageway would have assisted in the transportation and commingling of the skeletal remains throughout the Lewis Jones Cave Ossuary. In addition to fluvial transport, human disturbance can also cause an extensive amount of change to the primary interment places of human remains.

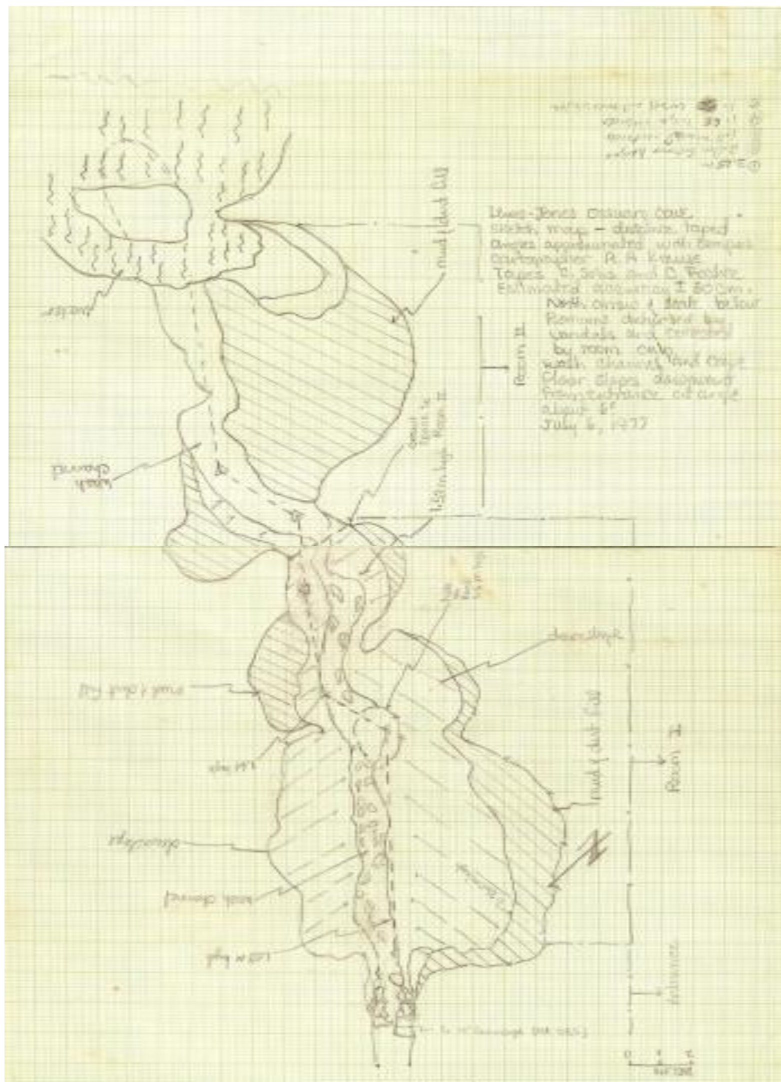

Figure 2.5 Topographical map of the Lewis Jones Cave Ossuary illustrating the directionality of the wash channel. Cartographer R.A. Krause.

Besides naturally occurring taphonomic agents, there are those of an unnatural nature. According to Holland et al. (1997), taphonomic processes affecting bone include not only naturally occurring phenomenon (i.e., streams and rodent scavenging), but human activity as well. In some circumstances the handling of human remains or reburial of interred remains can be a part of a mortuary practice. For instance, some cultures practice bundle burials in which the remains of the deceased are left to decompose in charnel houses then the bones are gathered and interred in a wrapped bundle (Curry 1999). In more malicious examples, Holland et al. (1997) discuss American soldiers who die overseas and the individuals, referred to as bone traders, who locate and turn-in skeletal material thought to be of American servicemen for monetary gain (Holland et al. 1997:266-267). Holland et al. (1997) describe a case in which a physical anthropologist working for the Central Identification Laboratory, Hawaii (CILHI), encountered people attempting to pass-off native human remains as American soldiers by pulling their central incisors (an attempt to deter identification of ethnicity) (Holland et al. 1997:266-269). A far more common avenue of human taphonomic activity involves vandalism and looting for artifacts in graves which disturbs and jumbles the skeleton(s). These types of activities are found worldwide and destroy the skeletal remains and burial inclusions from prehistoric and historic populations.

In the case of the Lewis Jones Cave Ossuary, the extent of destruction by vandals and looters is unknown. What can be determined, and what is obvious about the Lewis Jones Cave Ossuary skeletal material is that vandalism and looting significantly increased the degree to which the remains were commingled. Movement of skeletal material from its original position, thus losing original provenience, disrupts the context of the cave site and original orientation of the skeletal remains. Natural taphonomic processes tend to have a bit of a pattern to the dispersal of human remains (especially fluvial transport). With human taphonomic agents any sort of pattern or hope of determining the original position of remains is left to the abilities of the physical anthropologist and archaeologist.

## Methodology for commingled human remains

The methods for addressing commingled human remains can vary greatly depending upon the approach of the physical anthropologist. The underlying goal, or inherent objective of commingled human remains studies, is to create a best estimate of the number of individuals present within the collection. This estimation is often referred to as the Minimum Number of Individuals (MNI). As an additional step beyond determining the MNI, researchers also seek to sort and separate the intermixed individuals back into separate skeletal entities. To achieve these objectives, physical anthropologists will often take different routes to sort the collection of commingled human remains, estimate the number of individuals, and separate the commingled individuals into separate entities. In some instances these different approaches are based upon the building blocks of past research. In other circumstances, the approach utilizes new technology or an innovative concept in the field of physical anthropology. The result of these different approaches is an extensive body of literature which spans the development of physical anthropology throughout the latter part of the twentieth century.

Logically speaking, the methods and techniques administered to commingled human remains initially began with quantifying the assemblage of skeletal remains. This included examining morphological differences on skeletal elements and pair-matching bilateral elements. A modification to the quantification of commingled skeletal collections was the addition of statistical measures to determine the likelihood of obtaining an accurate estimate of the individuals present. As Byrd and Adams (2003) took the developing methodology for commingled human remains towards osteometrics, or the measurement of skeletal remains, other less well known methods that were developed included using ultraviolet light, applying a set of identifying variables, and employing a recording system of bone element zones to sort skeletal material. More recent developments in the study of commingled human remains include gathering data while leaving the skeletal material in situ. These techniques use computer software such as Geographic Information System (GIS) to digitally record the frequencies of bone elements and their dispersion pattern across any known site (Hermann 2002). While there have been numerous methods developed for handling commingled human remains, the decision of which method to use depends largely upon the situation and the objectives of the osteologist.

While quantitative methods were initially used to address skeletal commingling, they remain to this day viable options. Quantifying an assemblage is still a necessary tool in both archaeological and modern situations concerning commingled remains. According to Adams and Konigsberg's (2004) publication, the individual recognized for developing the Minimum Number of Individuals (MNI) method is Theodore White (1953) in his work on prehistoric animal bones and dietary patterns (Adams and Konigsberg 2004:138). White refined the MNI by using the most common bone element and the most abundant side (left or right) to determine the number of individuals (White 1953). For example, if one were to encounter a burial cache of deer bones and the most abundant bone element was the femur with twenty rights and twenty-five lefts, the MNI would be twenty-five. The logic supporting this method is that the most common element, the femur, is going to provide the lowest possible number of individuals present (Adams and Konigsberg 2004:139). By identifying the sides and ignoring the less abundant side, one may decrease the possibility of over estimating the number of individuals by avoiding repeat counting (counting both the left and right femur as two separate individuals)

(Adams and Konigsberg 2008:243). Whether the situation concerns archaeological collections of deer bones like the example above or a mass grave site yet to be excavated, the MNI method is simplistic in use and flexible enough to be applied to nearly every situation with commingled skeletal remains (Adams and Konigsberg 2008:243).

Adams and Konigsberg (2004) also use modified versions of the MNI method which adds pair-matching into the equation. For example, this modified version of the MNI involves counting both sides of the most abundant bone element, then subtracting the number of paired bones (Adams and Konigsberg 2004:139; Adams and Konigsberg 2008:244).

$$MNI = L + R - P$$

Pair-matching prompts the researcher to analyze the bone elements and to determine if there are any matches of left and right sides of the same individual (i.e., the left and right tali of individual #1). Adams and Konigsberg (2008) have noted the importance of accurate pair-matching for formulae using pair-matching to have greater accuracy over the standard MNI method (Adams and Konigsberg 2008:247). While there have been modifications to the MNI method and it remains widely used in its earliest form, critics argue that this method focuses on the recovered remains and not the original population (Adams and Konigsberg 2004:138-139). In most instances, critics refer to the original population as the total number of individuals who were interred at the site, not the individuals recovered by physical anthropologists or archaeologists after taphonomic processes have influenced the site (Adams and Konigsberg 2008:245). Adams and Konigsberg (2004) argue that attainment of the original population at the site aids in demographic and forensic studies (Adams and Konigsberg 2004:138).

Building upon the notion of MNI estimations, more theoretically oriented models have been developed for estimating the number of individuals in the original population (Adams and

Konigsberg 2004:138). In addition to the MNI method, Adams and Konigsberg (2004) discuss a variety of statistical methods which include the Petersen/Lincoln Index (PI or LI) and Chapman's (1951) work with the Most Likely Number of Individuals (MLNI) method. The Petersen or Lincoln Index was developed from external research in animal capture and recapture studies conducted by C.G.J. Petersen in 1889 and F.C. Lincoln in 1930 (Adams and Konigsberg 2004:139). Similar to the MNI, the LI utilizes the most common bone element found in the collection, counts of both the right and left side, and pair-matching. The LI formula is (Adams and Konigsberg 2008:246):

$$LI = \frac{LR}{P}$$

For example, if there are 10 lefts, 7 rights, and 2 pair-matches:

$$LI = \frac{10(7)}{2}$$

$$LI = 35 \text{ Individuals}$$

This method differs because the number of lost elements due to taphonomic processes can be obtained as well as the total number of individuals present at the time of death and/or burial (Adams and Konigsberg 2004:140).

A statistical variation to the MNI and LI calculations is to take into account the recovery probability and sample size bias. Taking into account how the sample size will affect the population estimation and the likelihood of recovering all of the skeletal remains from a site requires a stronger mathematical formula than the MNI or LI. Chapman's (1951) statistical addition to the LI approach was to incorporate a hyper-geometric distribution (a statistical function to find probabilities of non-reoccurring elements) (Adams and Konigsberg 2004:142-3).

This addition led to the Most Likely Number of Individuals (MLNI) formula which is (Adams and Konigsberg 2004:141):

$$MLNI = \frac{(L+1)(R+1)}{(P+1)} - 1$$

For example, using the same counts from above:

$$\text{MLNI} = \frac{(10+1)(7+1)}{(2+1)} - 1$$

$$\text{MLNI} = \frac{85}{3} \text{ or } 28.3$$

$$\text{MLNI} \sim 29 \text{ Individuals}$$

This statistical approach can be further quantified by determining the degree of confidence that the estimation is an accurate representation of the original population (Adams and Konigsberg 2008:246). Adams and Konigsberg (2004 and 2008) argue that although the MLNI may underestimate the population if there is a small sample size, it has greater applicability and relevance to quantifying the results of collecting commingled human remains from an archaeological site.

A strong component to the usefulness of the LI and MLNI method includes the accuracy in reporting pair-matches (Adams and Konigsberg 2008:247; Nikita and Lahr 2011). In some instances, pair-matching is not possible either due to a high degree of bone fragmentation or the large size of the collection. Nikita and Lahr (2011) attempted to solve the issue of pair-matching and finding the original number of individuals by creating two computer algorithms in Microsoft Excel that are able to estimate both quantities. To demonstrate the effectiveness of their method, Nikita and Lahr (2011) applied their algorithms to a collection of 152 skeletons from Jebel Moya, Sudan that are part of the Duckworth Collection housed at the University of Cambridge.

The first algorithm required recording of osteometrics, muscle attachment sites, and levels of arthritis and the second algorithm necessitated recording of bone loss and alteration (i.e., breakage) (Nikita and Lahr 2011:630). With some qualifications as to how each criteria is scored and measured, Nikita and Lahr (2011) found their algorithms to produce population estimates close to the known population (i.e., N=148 ± 15) (Nikita and Lahr 2011:635). Although their computerized method has expedited the mathematical aspect of these statistical methods, there are still concerns over obtaining accurate pair-matches for the second algorithm to function correctly (Nikita and Lahr 2011:635).

Another contribution to the quantitative approach in handling commingled remains is the work of Snow and Folk (1965). Snow and Folk (1965) provide an algorithm to find the probability of more than one individual being present in a collection. An important aspect of their work is the mention of using skeletal morphological features to differentiate the individuals (Snow and Folk 1965). Morphological differences, whether they are based on sex, age, stature, or robusticity are critical characteristics for identifying skeletal remains and pair-matching like bone elements (Snow and Folk 1965:423-4). When there are very few morphological differences, the determination of an MNI relies upon the presence of repeating skeletal elements. For example, if there are four similar, nearly complete right femora in a collection of human remains, then there are at least four individuals present. The assumption is that each right femur belongs to a separate individual and the similarity in bone morphology may be due to the individuals being of a similar build (Snow and Fold 1965). Similar to Snow and Folk's (1965) use of morphological similarities and statistics, Byrd and Adams (2003) present another approach which focuses on similarities in bone dimensions.

As with the development of statistical approaches, researchers have utilized osteometrics and sorting by morphological characteristics to handle commingled human remains. The premise of osteometric sorting is that by organizing different bone elements by their metric likeness, the researcher will eventually be able to segregate each individual present within the skeletal collection (Snow 1948). According to Byrd and Adams (2003), the first to be recognized for using this type of method was Charles Snow (1948) who segregated commingled human remains generated from the first and second World Wars. Snow's work is based upon separating commingled individuals by their bone morphological differences (i.e., robusticity, length, etc.) (Byrd and Adams 2003:1).

In the 1980s, Buikstra et al. (1984) and London and Curran (1986) isolated specific bone elements and articulations for osteometric analysis. Buikstra et al. (1984) initiated the use of a null hypothesis to determine if a bone element belonged to a specific individual. Their method emphasized the use of measurements at bone articulation points to provide objective evidence for re-articulating separated bones (Byrd and Adams 2003:1-2). Aside from Buikstra et al.'s (1984) work, London and Curran (1986) and London and Hunt's (1998) subsequent work utilized patterns in the articulation of the femoral head and acetabulum (ball-and-socket joint in the pelvis) to pair-match long bones of the same individual (Adams and Byrd 2003:2). The work of Buikstra et al. (1984), London and Curran (1986), and London and Hunt (1998) advocate the matching of adjacent bones. Adams and Byrd (2003) demonstrate a similar method advancing the use of matching bone elements on a larger scale.

Adams and Byrd's (2003) own work involved creating a reference sample and comparing bone elements on a regression of the reference sample (Adams and Byrd 2003). The reference sample was created by collecting osteometric measurements taken from an array of collections including those at the Central Identification Laboratory, Hawaii (CILHI) and the Smithsonian Institution's Terry Collection. Developing this reference sample employed both standard osteological measurements used for complete bone and additional measurements applicable to archaeological collections with broken and incomplete bone (Adams and Byrd 2003:3). The actual statistical analysis involves hypothesizing the relationship between two bone elements. If the two bone elements (thought to be from the same individual) fall within the prediction interval along the regression, then it is probable they are from the same individual (Adams and Byrd 2003:3-4). The basis for this type of statistical use of a regression is the fact that bone size will correlate with body proportion (Adams and Byrd 2003).

Alternatives to osteometric and morphological bone differences for sorting commingled skeletal remains include new technology and recording systems. While not overly used, they involve the use of ultraviolet light, a coding system with a hierarchy of variables, and a bone element zone recording used with commingled human remains in a laboratory setting. In one such instance, Finnegan (1976) used multiple methods in an attempt to separate and to identify the individuals sent to him from the Walnut Creek Massacre that occurred in Barton County, Kansas. He was provided with photos of the excavation as well as the skeletal remains of an unknown number of individuals. The human remains were in various states of fragmentation and overall were poorly preserved due to weather, haphazard periods of excavation, and poor attempts at preserving bone (i.e., a mixture of water and craft glue applied to the bones) (Finnegan 1976:737-8). To separate the commingled individuals, Finnegan applied McKern's (1958) and Eyman's (1965) method that uses ultraviolet light. This approach employs ultraviolet light to sort the bone elements based upon their reflective color (Finnegan 1976:738). After this method and additional attempts as matching bone elements by stature estimations proved to be unsuccessful, Finnegan (1976) was left with comparing the bone elements to the photographs taken during excavation and using historic records research.

Another less well-known approach concerns the use of an identification hierarchy system developed by Church and Burgett (1996). Discussed in Herrmann (2002), Church and Burgett's (1996) system includes recording descriptive characteristics for every bone element in a commingled and/or fragmented collection. Characteristics would include area of the bone present (i.e., midshaft, distal end, and proximal end), bone coloration, robusticity, identifying features, pathologies, and taphonomic changes (Herrmann 2002:19). Locating matches between bone elements can be accomplished by using the hierarchy to identify similarities between bones within the collection. The more similarities between bone elements, the more likely they are pair-matches (if comparing bilateral elements). The basis for the identification hierarchy is to observe and record subjective variables in the hopes of finding potential matches of bilateral elements.

Aside from the integrated identification system, Knüsel and Outram (2004) have proposed a recording system for commingled human remains which focuses on the repeating portions (zones) of bone elements. Knüsel and Outram's (2004) recording system is based upon the concept of the Minimum Number of Elements (MNE) and the precursory work of Dobney and Rielly (1988). By recording a skeletal collection by a standardized system of labeling bone elements by zone, a researcher can create an estimation of the MNE. The number of elements present can then be converted into an MNI (Knüsel and Outram 2004:86). For instance, if an entire collection of commingled remains were recorded with Knüsel and Outram's (2004) system and the most recorded zone was the iliac crest of the pelvis (#12 in their recording system) with a total of ten, then the MNI would be ten (Knüsel and Outram 2004:91). Similarly, Stanton and Herrmann (2013) have been working on a similar concept in which they examined commingled, fragmented remains and recorded the repeating portions of bone digitally by scanning images (Stanton and Herrmann 2013). The recording of bone portions, or zones, enables the researcher to gain a better idea of the individuals present within a collection of commingled human remains when there is poor preservation and highly fragmented remains. While these methods are not discussed in great detail in the literature, they remain viable options for analyzing commingled human remains.

Thus far, discussion has focused predominately on the methods developed for analysis of skeletal remains within a laboratory setting. While these methods are diverse in their approach, there are also ways to analyze commingled human remains while in situ. In most cases, physical anthropologists have a burial context to excavate because they are called to assist at a forensic scene or archaeological site. When this is the case, there are methods which utilize Geographic Information Systems (GIS) software and other computer programs that have the capability to spatially map the site. Herrmann (2002) and Herrmann and Devlin (2008) are proponents of GIS based applications to address commingled human remains. Herrmann (2002) demonstrated how GIS can be used to locate and map all of the skeletal remains within a cave ossuary site in Honduras while the remains were left in situ. An obvious benefit to this method is that the remains are left in the burial context and data can be analyzed away from the site (Herrmann 2002:17). Herrmann and Devlin (2008) demonstrated the use of GIS and ArchView in reconstructing and identifying bone elements from highly fragmented remains. By mapping each fragment digitally, they were able to configure through GIS the most likely matches and pair elements within the collection of skeletal remains (Herrmann and Devlin 2008). Although the use of GIS provides a new direction for bone analysis and handling commingled human remains, any use of this method requires a researcher to have access to GIS in the field or laboratory and knowledge of its capabilities.

A similar program was developed by Richard Wright (2003), and discussed by Tuller et al. (2008), which uses Microsoft Access to map mass graves by using the articulation points within the human body (i.e., the distal femur and proximal tibia ends) (Tuller et al. 2008:14). Tuller et al. (2008) describe the coding system used to note each articulation point observed while excavating a mass grave in Belgrade, Serbia. They found that with consistent and strict use of a coding system, they were able to map the position of each body and rearticulate the bone elements of the individuals present (Tuller et al. 2008). As with Herrmann's work using GIS, these methods require the physical anthropologist to be on-site during the excavation process, have access to mapping programs, and have working knowledge of how to use these programs.

For the most part, the described methods and approaches to commingled human remains can be applied to archaeological, historical, and contemporary investigations. The methodology and objective will change when more information about the interred individuals is needed. For instance, contemporary investigations of commingled human remains found in a mass grave will need to be sorted and identified so the remains can be returned to family members. The application of commingled methodology must change and adapt to what is required in forensic case studies of intermixed skeletal remains.

**Forensic methods**

While many of the methods discussed thus far have been developed to address both modern forensic and archaeological cases, there are specific methods available strictly for those modern situations. It has been within the past few decades that physical anthropologists and forensic specialists were forced into finding methods to address the issue of contemporary occurrences of commingled human remains. One method that is widely used is the identification by material remains found with the body. For some investigations, especially those of an historical nature, personal items found with the body such as dog-tags, clothing, and other personal items can be used for identification. Another method discussed in literature is the use of deoxyribonucleic acid (DNA) to match bone elements with reference samples (Yazedjian and Kešetović 2008). DNA samples must be provided by genetically related family members or collected from the individual's personal belongings antemortem, or prior to death, and compared to DNA from the bone element. While there are some situations that only permit identification by personal items found with the body, most contemporary cases necessitate multiple methods to confirm identification.

One of the most widely recognized situations that require identification by personal items is the commingling of human remains during historic wartime activities. During armed conflict, there are chances for mass fatalities to occur within a short amount of time and often across a limited geographic area. During World War II when armed conflicts arose across many different nations from 1939 to 1945, there were indeed incidences of mass fatalities. One occurrence involved the end of the war in 1945 when Allied forces took city of Berlin (Hollmann et al. 2008:420-421). During this time, Berlin was repeatedly bombed causing buildings to collapse upon both civil and military personnel. Decades later, demolition of the old bombed buildings and reconstruction of new ones uncovered caches of commingled human remains found within the rubble. Hollmann et al. (2008) conducted a review of the collections of human bones discovered during demolition and construction from 1997 to 2006 in Berlin. They found that of the 290 collections, which include over 40,000 bone elements, only 44 individuals have been identified (Hollmann et al. 2008:423). Identification of these individuals has predominately been by the personal affects that were found with the skeletal material. Helmets, “identity disks,” uniforms, and identification papers assisted in not only indicating possible identifications, but assisted in differentiating civilian from military remains (Hollmann et al. 2008:423-424). In this situation, in which DNA samples are unlikely and sorting of individuals is near impossible with the overwhelming numbers of remains, the most that can be accomplished is identification by personal artifacts and burial of the human remains (Hollmann et al. 2008). While historic cases are limited by identifying personal effects, contemporary cases of commingled human remains may present the opportunity to employ multiple methods to ascertain identity and sorting.

Cases which utilize multiple methods to determine identification often include DNA testing, identification by personal effects, and local knowledge of the incident. These types of methods, especially DNA, have only come into recent use in physical anthropological investigations of commingled human remains. Furthermore, while the use of one approach may provide a means to identify someone, using multiple methods provides supportive evidence towards a correct identification. One such instance in which forensic anthropologists and emergency response teams will utilize multiple methods to ascertain identification is in the case of contemporary incidences of mass casualties due to plane crashes and collapsed buildings. Mundorff et al. (2008) cite the September 11, 2001 plane crashes into the World Trade Center as a situation in which protocols needed to be established for victim identification. The forensic response teams to the World Trade Center relied upon traditional identification methods and DNA comparison to identify the remains recovered from the explosions (Mundorff et al. 2008). The use of DNA specifically allowed forensic anthropologists and the medical examiner’s office to match fragmented human remains from the World Trade Center so that families could bury their family members (Mundorff et al. 2008). Similar to these circumstances and planes crashes are incidences of mass fatalities due to political conflict and war crimes.

Recently, there has been a growing need for forensic anthropological and archaeological knowledge in investigations of political conflicts (Ubelaker 2008). The use of forensic and archaeological techniques has been important to recent events including the investigations of mass and/or clandestine graves in countries such as Argentina, Zimbabwe, El Salvador, Yugoslavia, and Bosnia-Herzegovina, to name a few (Egaña et al. 2008; Haglund 2002; Simmons 2002; Tuller et al. 2008). In each of these regional conflicts, forensic and archaeological techniques were utilized to locate and exhume mass graves. Due to the growing global concern and interest with mass graves, a general definition was standardized for legal applications. Haglund (2002) notes that a mass grave refers to a burial with more than one individual and contact between the individuals has been maintained (Haglund 2002:244-245). The point at which a mass grave becomes commingled is due to both the decomposition of multiple individuals and the efforts of those burying the victims (Haglund 2002). These efforts, whether they are natural events or attempts to destroy the evidence of a crime, create a challenge for forensic anthropologists who seek to locate and identify the interred individuals. Such changes can best be demonstrated by the 1970s political unrest in regions of South America.

One may examine the political conflicts arising in 1970's Argentina to illustrate the forensic aspect of commingled human remains studies in mass grave situations. During this time, both militant and guerilla groups were active in the abduction and persecution of individuals from the opposing side.  It is believed that from 1976 to 1983, militant groups were the cause of over 10,000 individuals becoming one of the "disappeared" (Egaña et al. 2008:67). Those who disappeared were thought to have been abducted, interrogated, and fatally persecuted for their political views. After Argentina regained democratic leadership in 1983, commissions and civil human rights groups were formed to locate and identify those who had become one of the "disappeared" (Egaña et al. 2008:67). Two of these commissions included the *Comissión Nacional sobre la Desaparición de Personas* (National Commission on the Disappearance of Persons: CONADEP) and *Abuelas de Plaza de Mayo* (Grandmothers of the Plaza de Mayo) (Egaña et al. 2008:677-68). Local knowledge and witness accounts led regional authorities to the possible locations of mass burials of the disappeared. Soon after the initial ineffective excavations by local authorities, CONADEP and the *Abuelas de Plaza de Mayo* requested the assistance of forensic anthropologists from the United States (Egaña et al. 2008:68-69). Forensic anthropologists including Dr. Clyde Snow trained personnel and helped establish the *Equipo Argentino de Antropología Forense* (The Argentine Forensic Anthropology Team: EAAF) (Egaña et al. 2008:69). The EAAF utilizes local accounts of the abductions, witness testimonies, forensic archaeological techniques, and traditional MNI methods to sort and identify the commingled human remains recovered from mass graves. Although DNA comparison was not available when EAAF investigations first began, it is now being employed in current cases in Argentina (Egaña et al. 2008:72). The political conflict in Argentina not only demonstrates some of the challenges inherent in commingled individuals in mass graves, but also the multiple methods which are employed to handle such a situation.

As one may see in the available literature concerning commingled human remains, there are a variety of methods that have been developed. Which method a physical anthropologist utilizes depends largely upon the situation and the appropriateness of the method. For instance, DNA testing is limited to contemporary situations where there is a strong likelihood of an available reference sample; this would not be possible with burials from an archaeological site.

Likewise, one may use a traditional method such as an MNI determination in a cave where the remains have yet to be excavated, but the availability of the burial context provides an opportunity to gain much more information about the individuals interred. So, the issue remains as to which sorts of methods are available and are appropriate for collections of commingled human remains excavated with very minimal records or notations.

# CHAPTER 3

# MATERIALS AND METHODS

Evaluation of the methods used for addressing commingled human remains included four separate phases of data collection. At the conclusion of all four phases, conclusions were made in regards to the experiences of applying each method to the Lewis Jones Cave Ossuary Collection. These deductions aided in the determination of the overall appropriateness and applicability of each method under assessment.

Prior to initiating the data collection phases, procedures were developed for handling the human remains and evaluating the methods throughout the data collection process. Procedures for managing the Lewis Jones Cave Ossuary Collection included the managing of poorly preserved and fragmented remains. A part of these procedures involved non-invasive and non-destructive handling of the remains during the analysis of the bone elements. Skeletal material that was broken during excavation and the subsequent curation processes was not re-articulated. In instances where rearticulation was necessary, the fractured bone elements were temporarily held together for analysis and measurement was extrapolated.

Additional procedures were developed for recording the evaluation of each method that was assessed in this research project. After each day of data collection, notes were taken on the progress and overall experience of applying each method. Evaluation was focused on seven areas including: 1) duration of method application, 2) necessary tools, 3) bone components, 4) skills, 5) areas of subjective judgment, 6) problems encountered during the application of the method, and 7) clarification issues in the literature. To record these evaluation categories, a chart was maintained documenting how each method faired (see Appendix C). These categories will be the basis for the method evaluation in this research project.

Phase one was the application of the MNI method to the Lewis Jones Cave Ossuary Collection. The MNI method included the creation of an inventory of all bone elements in the collection for quantitative purposes. Using a Microsoft Excel spreadsheet, the contents of each collection bag was recorded for bone element, side, segment, and collection bag identification (Table 3.1).

| | **Bone Element** | **Side** | **Segment** | **Bag ID** |
|---|---|---|---|---|
| | | | | |
| | | | | |

Table 3.1 Example of the MNI inventory spreadsheet

The bone element refers to the specific bone in the human body. For bone elements that were unidentifiable or too fragmented to be analyzed, a descriptive notation was made about the condition. The side variable referred to the left, right, or midline portions of the body. The segment category indicates the dimension of the bone element. Segments were primarily descriptive and included identifiers such as “complete,” “partial-proximal,” and “partial-midshaft.” For incomplete bone elements that were subject to more severe taphonomic processes, additional descriptive terms were used for the segment identification (i.e., less than 1 inch midshaft fragment). In some instances the bone elements were fragmented beyond side and segment identification. The bone fragments were labeled as fragmented and not included in determination of the MNI. The final category in this inventory included the collection bag identification system created by Dr. Turner. Observation of these categories led to a basic calculation of an MNI.

Phase two utilized osteometrics as the means to determine the MNI and potential bone pair-matches.  A duplicate of the entire MNI inventory (both bone elements and variables) was placed into a new Microsoft Excel spreadsheet. Columns were created for each osteological measurement applicable to the Lewis Jones Cave Ossuary Collection. Buikstra and Ubelaker (1994) provided the standard points of measurement used in osteological studies (see Buikstra and Ubelaker 1994:75-84). Each measurement was taken with a Mitutoyo 500 digital sliding caliper with ± .02 mm accuracy. An osteometric board was used for the rare cases of bone elements exceeding the 300mm limit of the digital sliding caliper. When the osteometrics board was used, the measurement was estimated to the closest millimeter. After each measurement was taken, the units were recorded in the Microsoft Excel spreadsheet according to Buikstra and Ubelaker's (1994) numerical system.

The third phase of this research included the creation of a hierarchy of variables. A copy of the MNI inventory was placed into a new Microsoft Excel spreadsheet. Following the work of Church and Burgett (1996), the subsequent variables were used in analysis: age, size, sex, fusion, development, pathology, trauma, weathering, burning, gnawing, and breakage (see Herrmann 2002:19). Due to differences in research topics and collection conditions, the variables that were used in this research project were modified or added to Church and Burgett's (1996) suggested categories. The resulting hierarchy of variables included bone element, segment, portion, bag identification, age, size, sex, fusion/development, pathology, weathering, gnawing, breakage, trauma, genetic/non-metric discrete traits, bone architecture, and location of the excavation site.

Each variable was entered as either a categorical or descriptive value. For bones that were age-determinable, they were categorized into age groups based upon suggestions by Buikstra and Ubelaker (1994) (see Buikstra and Ubelaker 1994:9). These groups included subadult (infant), subadult (adolescent), and subadult (child). In the cases where age was indeterminable beyond the delineation of subadult, the classification “subadult” or “possible subadult” was applied. The subadult category included bone elements that showed signs of incomplete fusion of epiphyseal ends and small and gracile bone structures. When possible, bone elements were placed into one of the three adult categories (young (20-35 years old), middle (35-50 years old), and old (50+ years old)) if they exemplified complete fusion and signs of bone deterioration (i.e., porosity and lipping) (see Buikstra and Ubelaker 1994:9).

As with age observations, bone element size and sex were both categorical variables. The size of the bone element was coded with one of three different values: robust, normal, and gracile. Likewise, sex determination (when possible) was separated into male, possible male, female, possible female, unknown, or indeterminate. The unknown value was applied to bone elements when there was insufficient evidence to determine the sex. Similarly, bone elements were coded as indeterminate when they were found to be subadults. As in all osteological studies, sex cannot be determined from subadult remains because these individuals have yet to develop sex characteristics within their bone structures.

The fusion/development category was coded into three separate groups: complete, incomplete and unknown. The complete value referenced bone elements that had no trace of ossification activity at fusion centers. The incomplete group included bone elements that exhibited some form of ossification activity, incomplete lines of fusion, or undeveloped epiphyseal ends. This group was composed of subadults and the obscure group of individuals that can be considered subadult or adult (i.e., teenagers). Bone elements fell into the unknown group when there was not enough present to determine if the ossification process was complete. In a majority of cases, a judgment call was made based on the robusticity and wear patterns of the bone element. For example, a midshaft fragment less than four inches of length with heavy muscle attachment was classified as complete even though ossification centers were not present. This category differs from age estimations in that fusion and development is a more robust variable whereby a general statement can be made about the individual's age instead of determining specific age ranges.

As pathological conditions and skeletal traumas manifest differently for each individual, these two variables were observed and coded as separate descriptive values. Consequently, each bone was examined and a description of the location and the specific pathological manifestation were documented. The trauma variable was treated in the same manner. Every bone element that exhibited evidence for trauma was described, noting the location as well as documenting its extent.

Due to diversity in both the weathering and gnawing variables, observations of these taphonomic processes were coded into categories. The weathering category referred to the coloration of the bone elements. For bones that exemplified the expected coloration for prehistoric skeletal remains, they were coded as within normal range. This range included hues of beige, light brown, and off white. Abnormal coloration included hues of black, red, and grey, in addition to black speckling, and green, black, and brown stains. Further weathering included instances of striations and bleaching of bone commonly found with skeletal remains that have been exposed to the elements (i.e., sunlight). Similar to the weathering variable, the observed animal gnawing was categorized into five categories: none (0%), minimal (1-25%), average (26-50%), above average (51-75%), and nearly complete (76-100%). These groups were largely subjective in nature and refer to the percentage of the periosteum, or outer cortical bone, absent because of chewing by scavengers.

The breakage variable refers to the bone element fractures caused by postmortem taphonomic processes. This variable provided a more precise description of the bone portion and gave more detailed information than the segment variable. Descriptive terms were used to document what remained from the poorly preserved collection of skeletal material. Similar to the breakage variable, the genetic/non-discrete and bone architecture variables were also descriptive in nature. These two variables differ from one another in that genetic/non-discrete traits are a part of the genetic composition of each individual. If the genetic trait is known to occur bilaterally, then it can be used to pair-match bone elements. Differences in bone architecture may be due to genetics, but are most commonly seen as responses to phenomenon such as developmental or occupational stresses. For example, robust muscle attachments in the posterior portion of the proximal tibia are an abnormality in the bone architecture because they are a probable sign of strenuous muscle use in the lower extremities. Observations of non-discrete traits and bone architectures were documented descriptively in the hierarchy of variables inventory.

The final variable observed in the hierarchy inventory was the bone element's location within the cave. Review of Dr. Turner's field notes and those recorded on the bone elements indicate only a partial recording of provenience. He included identifiers for the different areas in the cave and the three excavation units dug in the main passageway. Each bone element's location was coded as backroom, front room, crawlspace, unit A, unit B, unit C, or no provenience. The backroom and frontroom, also written on the collection bags as "B" and "F", were Dr. Turner's terms for room I and room II. This assumption was based on an illustrated topographical map of the cave layout. The collection bags labeled crawlspace were able to be matched with the crawlspace drawn on Dr. Turner's site map. The different excavation units included 121L (unit A), 114.5L2 (unit B), and 114R2-116R3 (unit C). These three excavation units were relabeled by the researcher to accommodate inconsistencies in collection bag labels. All collection bags that did not have a location identifier, or were identified as no provenience, were coded as having “no provenience.” After all the bone elements were analyzed and the observations recorded in the inventory, the data was sorted to determine an estimation of the number of individuals present and analyzed for any additional information pertaining to the number of individuals.

The fourth phase of this research project included a comparison between the skeletal remains from unit C (114R2-116R3) and the excavation maps from 1977. It was thought that contextualization of the excavation, through the digitization of the maps, would provide a better means to finding an estimate of the number of individuals in unit C. Digitizing the excavation from unit C included scanning the sectioned pieces of the excavation map and piecing them together prior to transferring the files into a PDF format for Adobe Illustrator CS4 (see appendix B). Once the unit C base map was uploaded to Illustrator, a separate digital layer was created for each bone and its side in the case of bilateral elements. While working in each layer, a bone element was traced and filled-in with an assigned color.

In addition to digitizing the excavation map of unit C, all skeletal material was analyzed for an MNI comparison. The bags labeled “116R3” and “114R2” were inventoried for bone element, side, segment, and provenience. In this phase, the provenience was limited to the original two by two excavation unit (116R3) and the one meter extension (114R2). Observations of the bone elements from unit C were placed into a Microsoft Excel spreadsheet for further sorting and analysis.

During the application of each method to the Lewis Jones Cave Ossuary Collection of skeletal remains, observations were recorded according to the seven preset assessment criteria.

Upon completion of all four phases, the population estimations and evaluation results were accumulated and reported in the Results chapter of this research report.

# CHAPTER 4

# RESULTS

First and foremost, the objective of this research project is to evaluate four different approaches to commingled human remains and determine the appropriateness of these methods when they are administered to a curated collection of skeletal remains. To accomplish this endeavor, each method was applied to the Lewis Jones Cave Ossuary Collection of human remains in a separate phase. The results of these four phases included an estimation of the number of individuals present, determination of potential pair-matches, and an evaluation of each method. While the estimation of the number of individuals provides an idea of the population, the determination of the potential pair-matches contributes to the researcher's effort to separate the commingled individuals into independent entities. The evaluation was a result of the researcher's experience and observations of how appropriate the method was when applied to the Lewis Jones Cave Ossuary Collection. Evaluation was based upon seven different criteria including the time spent completing the method, required tools, needed bone components, necessary skills, areas of subjective judgment, problems, and clarification issues in the literature. Based upon the evaluation of each method, suggestions can be made for future research and curation studies involving commingled human remains.

## Phase I: Basic MNI approach

An MNI of the Lewis Jones Cave Ossuary skeletal collection was determined by sorting the newly created collection inventory and locating the bone element with the highest frequency (see page 46). The entire inventory was first organized alphabetically by bone element. A formula was added to calculate the frequencies of each bone element. With the femora being the most common element (n=207), this figure was further refined by isolating the most common side. The MNI was further filtered by using the filter tool in Microsoft Excel and removing all fragments and small partial bones in the bone segments column. Partial bones, which could not be ascertained as non-repeating were removed so the MNI was not overestimated. By filtering this information in an inventory created in Microsoft Excel, an estimate of at least 62 individuals was found from nonrepeating, complete or nearly complete right femora. As the MNI method is the most basic of approaches to addressing commingled human remains, further analysis and attempts at pair-matching bilateral elements was left to the remaining phases of this research project.

In conducting this phase of research, seven different criteria were assessed for the appropriateness of the basic MNI method when it is applied to a curated collection of poorly preserved human remains. The following are the evaluation results of the basic MNI technique.

1. **Time:** The total time span of this method was approximately 30 hours. Included within this time frame was the pulling of the collection from curation storage, organizing the collection bags by bone element, analyzing the bone elements, entering data into a Microsoft Excel spreadsheet, filtering the spreadsheet, and returning the bone elements to collections.
2. **Tools:** The only tool required during this method was Microsoft Excel. In future applications of this method, a different data entry software program or even standardized paper forms may also work.

3. **Necessary bone components:** Identification of bone elements was based upon the presence of one or more landmarks (morphological features normally found on the bones of the human skeleton). Additionally, landmark orientation allowed for the siding of each bone element. In cases where bone elements did not exhibit enough indicators for bone identification or for siding, they were excluded from analysis.
4. **Skills:** Skills needed for the basic MNI approach included in-depth knowledge of human skeletal anatomy and Microsoft Excel data entry. Working with human bone required the abilities to identify the bone elements, differentiate fragmented remains, and separate nonhuman from human skeletal material. This method also required a moderate competence in Microsoft Excel. Using Microsoft Excel necessitated the ability to enter large quantities of data and use the program's tools to organize the spreadsheet for quantitative purposes. One area that may extend beyond common knowledge in Microsoft Excel was inputting specific formulas to determine the frequencies of non-numerical data. For example, the formula to calculate the frequencies of bone elements necessitated the modification of an existing standard formula used for numerical data.
5. **Subjective judgment:** An area of subjective judgment was the identification of subadult long bones. As with the Lewis Jones Cave Ossuary Collection, subadult bones present a challenge when they have yet to develop the landmarks used for siding and they are in poor preservation. With incomplete fusion and development, a judgment call was made when siding and/or identifying young subadult skeletal material.
6. **Problems:** One of the most notable problems was maintaining consistency in vocabulary usage and segment description. Although there are procedures and standardized

techniques for describing fractured bones (see Buikstra and Ubelaker 1994), these techniques are not always applicable to every fragmented bone element.

7. **Literature clarification issues:** Based upon Adams and Konigsberg (2004), the only problem with clarification was the descriptive terms and techniques used for differentiating bone segments. Much of the literature on the basic MNI method does not clearly state what to do with partial and fragmented bones. To solve this problem in this research project, the non-repeating partial bones (with approximately half of the bone present) were included in the MNI calculation.
8. **Comments:** Although pair-matching bilateral elements was not an focus of this research phase, there are clarification issues within the literature on how one would go about determining pair matches. Many of the basic MNI methods found in literature indicate a necessity for pair-matching for MNI calculations.

**Phase II: Osteometric analysis and comparison**

The second phase involved an osteometric analysis to estimate of the number of individuals and determine potential pair-matches based upon measurement similarity. Application of this method included inventorying the collection and recording the bone element, side, segment, and measurements of standardized distances for each bone. In this research project, the standard measurements were derived from Buikstra and Ubelaker's (1994) publication on osteological research (see Buikstra and Ubelaker 1994:74-84). An estimate of 62 individuals (non-repeating right femora) was determined by organizing the inventory by bone element, side, and segment. The determination of 20 potential pair-matches was found by using the collected measurements from the most common bone element (femora) and comparing them through an intraobserver error range.

In further detail, pair-matching bilateral bone elements was achieved by examining the propinquity of the osteological measurements. The use of osteometrics is an important aspect of Adams and Konigsberg's (2004) research concerning contemporary and forensic cases of commingled human remains. Their use of a linear regression and hypothesis testing were not used in this project because of the time requirements of applying hypothesis testing to a very large collection of skeletal material. Techniques drawn from Adams and Konigsberg's (2004) work included the use of osteometrics as a tool for bilateral comparison and the application of statistical analyses for probability testing.

While a metric comparison of the entire Lewis Jones Cave Ossuary Collection was not possible within the timeframe of this project, collected measurements were used to detect potential matching femora. In an effort to pair-match femora and account for intraobserver error, an intraobserver error range was established to assist in determining potential pairs of femora. This range provided a way to take into account the researcher's measurement error, asymmetry of bilateral elements, and poor preservation of the collection.

Creation of an intraobserver error range was developed by calculating the average standard deviation in a test-retest scenario. A sample (n=30) was taken of the femoral subtrochanteric medial to lateral measurement. The next day, the measurement was retaken and recorded. One standard deviation was calculated between each of the femoral measurements. The standard deviations for each femur were then averaged and the result was rounded to the nearest whole number to obtain an intraobserver error range of ± 1 mm (Table 4.1). Although using one standard deviation from the mean would imply a low degree of confidence in the range, increasing the standard deviation may cause the narrow distribution of femoral measurements to be enveloped. For example, if a standard deviation of two was used instead of one, the range may become too wide and would indicate there were more matches than desired.

| Test | Retest | One Standard Deviation |
|---|---|---|
| 24 mm | 24 mm | 0 |
| 25 mm | 23 mm | 1.414214 |
| 25 mm | 26 mm | 0.707107 |
| 26 mm | 27 mm | 0.707107 |
| 27 mm | 27 mm | 0 |
| 21 mm | 22 mm | 0.707107 |
| 27 mm | 27 mm | 0 |
| 25 mm | 26 mm | 0.707107 |
| 27 mm | 29 mm | 1.414214 |
| 22 mm | 21 mm | 0.707107 |
| 21 mm | 23 mm | 1.414214 |
| 25 mm | 28 mm | 2.12132 |
| 24 mm | 28 mm | 2.828427 |
| 24 mm | 25 mm | 0.707107 |
| 21 mm | 21 mm | 0 |
| 25 mm | 25 mm | 0 |
| 24 mm | 25 mm | 0.707107 |
| 24 mm | 24 mm | 0 |
| 30 mm | 32 mm | 1.414214 |
| 24 mm | 23 mm | 0.707107 |
| 24 mm | 24 mm | 0 |
| 24 mm | 24 mm | 0 |
| 27 mm | 27 mm | 0 |
| 25 mm | 25 mm | 0 |
| 27 mm | 29 mm | 1.414214 |
| 24 mm | 23 mm | 0.707107 |
| 23 mm | 22 mm | 0.707107 |
| 26 mm | 27 mm | 0.707107 |
| 23 mm | 27 mm | 2.828427 |
| 23 mm | 26 mm | 2.12132 |
| | average of standard deviation= 0.824958 | |

Table 4.1: A sample (n=30) of medial to lateral measurements of the femoral subtrochanteric distance used for a test/retest scenario to develop an intraobserver error range.

With an intraobserver error range of ± 1 mm, matching left and right femora was based upon a 1 mm difference between both the medial to lateral and anterior to posterior measurement (Tables 4.2-4.6). To further narrow down potential matches, the femora were separated into their respective locations. Within each location, possible pair-matches were highlighted with yellow. In cases of multiple groupings, or more than one potential pair-match, additional colors were used (green, blue, purple, and orange).

| **Backroom right femora** | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 30mm | 26mm |
| 30mm | 26mm |
| 30mm | 24mm |
| 29mm | 27mm |
| 28mm | 27mm |
| 27mm | 25mm |
| 25mm | 27mm |
| 25mm | 22mm |

| **Backroom left femora** | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 36mm | 28mm |
| 34mm | 25mm |
| 33mm | 29mm |
| 33mm | 24mm |
| 32mm | 26mm |
| 29mm | 27mm |
| 29mm | 26mm |
| 28mm | 23mm |
| 28mm | 21mm |
| 27mm | 23mm |

Table 4.2 Measurement comparison of femora excavated from the Backroom

| 116R3 right femurs | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 32mm | 27mm |
| 32mm | 27mm |
| 32mm | 25mm |
| 31mm | 24mm |
| 29mm | 25mm |
| 28mm | 26mm |

| 116R3 left femurs | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 34mm | 27mm |
| 33mm | 28mm |
| 32mm | 29mm |
| 30mm | 28mm |
| 30mm | 28mm |
| 28mm | 27mm |
| 26mm | 21mm |

Table 4.3 Measurement comparison of femora excavated from unit 116R3

| 114R2 right femurs | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 29mm | 29mm |

| 114R2 left femurs | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 32mm | 25mm |
| 29mm | 27mm |
| | |
| 29mm | 27mm |

Table 4.4 Measurement comparison of femora excavated from unit 114R2

| No provenience right femora | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 34mm | 32mm |
| 34mm | 29mm |
| 33mm | 28mm |
| 32mm | 25mm |
| 31mm | 29mm |
| 31mm | 29mm |
| 31mm | 26mm |
| 30mm | 28mm |
| 29mm | 24mm |
| 28mm | 27mm |
| 28mm | 22mm |
| 27mm | 23mm |
| 26mm | 27mm |
| 26mm | 23mm |

| No provenience left femora | |
|---|---|
| **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 32mm | 24mm |
| 32mm | 24mm |
| 31mm | 26mm |
| 30mm | 24mm |
| 30mm | 24mm |
| 29mm | 27mm |
| 29mm | 25mm |
| 27mm | 23mm |
| 26mm | 24mm |
| 24mm | 22mm |

Table 4.5 Measurement comparison of femora with no provenience

| | Right | |
|---|---|---|
| | **Medial to lateral subtrochanter measurement** | **Anterior to posterior subtrochanter measurement** |
| 121L3 | 29mm | 25mm |
| frontroom | 30mm | 24mm |

Table 4.6 Measurement comparison of femora from unit 121L3 and the Frontroom

With the backroom femora, there are potentially eight matches. There are six bones (four rights and two lefts) that are within range (± 1 mm) of each other (Table 4.2). The 116R3 excavation unit holds three potential pairs: two rights with a possible left (see yellow highlights), and a left and right (see green highlights) (Table 4.3). The 114R2 excavation does not have any potential matches when applying the intraobserver error range (Table 4.4). Within the collection of femora with no provenience, there are nine possible pairs. These potential pairs are separated into five different groups with one pair (see green highlights) having both dimensional measurements matching (Table 4.5). The final two femora from excavation unit 121L3 and the frontroom do not have corresponding bilateral elements for matching (Table 4.6).

The final results from this research phase indicate an estimate of 62 individuals from the right femora, and potentially 20 pair-matches of femora using metric similarity of the subtrochanteric medial to lateral and anterior to posterior measurements. A figure of 20 potential pair-matches of the most common bone element in the collection (femur) is a starting point for separating the commingled skeletal remains into individual entities. Furthermore, the evaluation of the appropriateness of an osteometric analysis is as follows:

1. **Time:** The application of this method included creating the inventory (~ 30 hours), taking measurements of the bone elements (27 hours), and comparing measurements of the femora (7 hours). The total time it took to complete this phase of research and the osteometric method was approximately 64 hours.
2. **Tools:** Several instruments were required for collecting measurements of the skeletal remains. A plastic measuring tape was needed for circumference measurements of long bones. Sliding calipers were used extensively in taking precise measurements of vertical and horizontal bone dimensions. In cases where the sliding calipers were not long

enough, an osteometric board was used for long bone vertical measurements. The final tool necessary for osteometrics was a published standard for measurement points. Buikstra and Ubelaker's (1994) osteological standards were used as points of reference for the osteometric measurements.

3. **Necessary bone components:** Identification of bone elements necessitated the presence of one or more landmarks. Correct siding of every bone element also required landmarks. For measurements to be accurate, the bone element needed to be whole at the location of where the measurement was taken. In many cases, the bone elements were severely gnawed by animals or eroded away by time. With this level of bone deterioration, some of the measurements were extrapolated around gnaw marks and bone deterioration. For many of the bone elements the preservation was too poor for metric analysis.
4. **Skills:** In order to complete this phase, the researcher needed a working knowledge of human osteology. More specifically, the ability to identify bone, determine the side, locate major landmarks, and find points on each bone that required measurement. Further skills were needed in taking measurements with specialized tools meant for osteometrics. For example, if taking the medial-lateral measurement of the tibia shaft required locating the nutrient foramen (which is the landmark where the measurement is taken) and using a sliding caliper to take the measurement. Additional skills required in this type of analysis include the ability to enter data into Microsoft Excel and knowledge of statistical formulae for the creation of an intraobserver error.
5. **Subjective judgment:** An area of osteometrics that necessitated subjective judgment was locating a long bone midpoint. With complete bone, the midpoint is found by using an osteometric board in conjunction with sliding calipers. With poorly preserved remains

where the bone elements are fractured, highly fragmented, and incomplete, the midpoint had to be estimated to the researcher's best ability using a comparison with like femora that were complete.

6. **Problems:** The first problem encountered with the osteometric approach was the condition of the collection which hampered the collection of measurements. Fractured bone elements, severe gnawing, deterioration, and curation re-articulation (gluing) all were factors that hindered bone measurement. Another problem encountered during this phase was maintaining consistent measurement locations at the standardized points used in osteometrics. Although Buikstra and Ubelaker (1994) provide a general description of the measurement points, differences in bone morphology and preservation created a challenge in finding the same measurement point on every bone element. This was especially true with gnawed areas of the long bones in the lower extremities. A final problem was the limitations of the osteometric method. Without complete bone elements, a longer timeframe, or a reference data set, the method put forth by Adams and Konigsberg (2004) was not completely applicable to this collection. Instead of a complete application of Adams and Konigsberg's (2004) method, the bone elements used for the MNI were pair-matched based upon measurement propinquity. This alternative in itself contained a problem. In the case of the Lewis Jones Cave Ossuary Collection, many individuals had similar body proportions. This similarity in femoral dimensions created a narrow range of variation. Matching bilateral elements became a challenge because of the natural asymmetry in an individual's bone structure and the narrow range of variation within the collection of human remains.

7. **Literature clarification issues:** A clarification issue with this type of approach is its appropriateness with poorly preserved skeletal remains. Highly fragmented and deteriorated skeletal material severely hampers the effectiveness of using metrics to sort the remains of multiple individuals. Without complete bone and a surface on which the measurements can be taken, measurements must be extrapolated and estimated.
8. **Comments:** Preservation of the collection limited the application of an osteometric approach. Even with these unavoidable changes to bone, the measurements that were collected were useful in locating potential pair-matches of femora.

**Phase III: Hierarchy of variables**

The third phase of analysis included the creation of an inventory and observation of multiple morphological and taphonomic variables to determine an estimation of the number of individuals and generate potential pair-matches. The hierarchy of variables consisted of observing each bone element for side, segment, age, sex, size, fusion/development, pathology, weathering, gnawing, breakage, trauma, genetic/non-discrete traits, bone architecture, and location. Analysis of the hierarchy of variables indicated an estimation of 62 individuals based upon non-repeating right femora. Analysis also indicates six potential pair-matches based upon similarity in the observed morphological and taphonomic variables.

While determination of an estimate of the number of individuals present was accomplished by sorting the inventoried bone elements by side and segment, locating potential pair-matches was accomplished by expanding the inventory sorting to include the morphological and taphonomic variables. For example, sorting the age variable demonstrated the separation of subadult and adult populations. Matching bilateral bone elements was accomplished by identifying similarities between morphological characteristics of both the left and right femur. Locating similarities between right and left femora included analyzing bone elements for age, development, and bone architecture. Although additional variables were observed during this phase (i.e., pathology, trauma, and weathering), they were not helpful in pair-matching femora due to asymmetry in manifestation. To record potential matches based upon similarities in age, development, and bone architecture, a check list was utilized to track the results (Table 4.7). From this check list, a series of potential pair-matches was determined by the similarities found in observable taphonomic and morphological characteristics.

| **CRITERIA** | **Potential Pair-Matches** | | | | | |
|---|---|---|---|---|---|---|
| | Pair #1 | Pair #2 | Pair #3 | Pair #4 | Pair #5 | Pair #6 (subadult) |
| Approximate age | X | X | X | X | X | X* |
| Provenience | X | X | X | X | X | X |
| Approximate length | X | X | N/A | N/A | X | X |
| Muscle attachment at the linea aspera | X | X | X | N/A | X | N/A |
| Discoloration at the subtrochanteric muscle attachment site | N/A | X | X | X | X | N/A |
| Curvature of the subtrochanter | X | X | X | X | X | N/A |
| Spiral line along medial portion | N/A | N/A | X | X | X | N/A |
| Presence of third trochanter | N/A | N/A | X | X | X | X |
| Midshaft curvature | X | X | X | X | X | X |
| Distal arch | X | X | N/A | N/A | X | X |

An “X” indicates a similar feature between a potential left and right pair. “N/A” signifies there was insufficient evidence to confirm the bones were the same. An asterisk (*) notes the bone elements had the same provenience but were mislabeled.

Table 4.7 Criteria for matching left and right femora.

Based upon an analysis of the entire collection of femora, there are potentially six pair-matches. Of the six potential pairs, five were adults and one subadult. The adults each had identifying features that led to pair matching. In the case of pair #5, the left and right femora were of a highly robust nature and were easily pair matched. Pair #6 provided some difficulty in that the subadult long bones were thought to be mislabeled. Without epiphyseal ends or development of key landmarks, the shafts of the long bones looked strikingly similar. Analysis of the available features, especially the age and development, indicated that the bones were most likely from the same individual.

Further analysis indicated a diverse set of individuals within the collection. The age variable demonstrated that the Lewis Jones Cave Ossuary was the interment place of infants, children, young and middle aged adults, and the elderly. The pathological features were diverse and indicated a wide variety of illnesses manifested on the bones of the individuals buried in the cave. Noted pathologies range from remodeling at muscle attachments to severe periosteal reaction (infection). In more than one instance, nearly the entire bone was encased in bone remodeling due to periosteal reaction. Two additional uncommon pathologies that were observed in the Lewis Jones Cave Ossuary Collection were saber shin and external auditory exostoses. Saber shin is an indicator of treponemal infection and is identified by the anterior bowing of the tibia. Within the collection of tibae, there are approximately ten cases of saber shin. In contrast, the presence of external auditory exostoses, which is a bone growth in the external auditory meatus, can be an indicator of an environmental stress (Kennedy 1986). Contemporary clinical research and bioarchaeological studies have concluded that the presence of exostoses is an indicator that the individual was involved in cold water activities (Kennedy 1986). In addition to pathologies, there are a few bone elements that show evidence of truama. These bone elements include a skull with a healed depression on the left parietal, possibly from a blow to the side of the head, and a healed fracture in the proximal portion of the ulna also sometimes referred to as a parry fracture. All signs of truama, whether accidental or the result of personal conflict, showed evidence of recovery after infliction. Although further analysis of the Lewis Jones Cave Ossuary Collection's demographics is out of the timeframe of this research project, the gathered pathological information did contribute to the sorting of the commingled collection. Overall, the results of this phase indicate an estimation of 62 individuals within the collection and 6 potential pair matches of femora. Consequently, the locating of these six pair-matches can initiate the process of separating the commingled individuals into separate entities. As with the previous phases, this method was assessed upon seven different criteria.

1. **Time:** If this method of commingled human remains research was the only approach applied to the Lewis Jones Cave Ossuary, the total time taken would have been approximately 70 hours. This included pulling the collection, creating an inventory, observing and recording all variables, and analyzing the inventory of variables.
2. **Tools:** Instruments used in this phase of research included a software program for data collection (Microsoft Excel), goniometer for sex determination of the mandibles, and sliding calipers for sex determination of all possible long bones.
3. **Necessary bone components:** There needed to be at least one landmark present for identification and siding (when applicable) of each bone element. When the identification and siding were not possible, the bone elements were labeled as fragments.
4. **Skills:** Extensive osteological skills were needed in the application of this method. Necessary abilities included identification of poorly preserved bone elements, pathologies, traumas, age, sex, and non-metric discrete traits. Determining age and sex

required considerable knowledge of the morphological characteristics inherent in stages of bone development and also those differences between males and females. Additionally, this phase of research required a strong comprehension of the differences between non-metric discrete traits and their expression, as well as pathologies, and trauma. Observed pathologies provided a particular challenge because of the degree of variation in the appearance of reactive bone change.

5. **Subjective judgment:** An area of particular subjective judgment was the determination of which categories were appropriate for the Lewis Jones Cave Ossuary. In this instance, some of the suggested variables by Church and Burgett (1996) were merged with more appropriate categories for the Lewis Jones Cave Ossuary. For example, Church and Burgett's (1996) category of burning was subsumed into the weathering variable. Another area of subjective judgment was the descriptions of values for each variable. For the hierarchy of variables to be sorted, the variables used for pair-matching needed to be classified as categorical variables. In situations where this was not possible, descriptions were taken of each observed value (i.e., indicators of trauma). The final area of subjective judgment was in pair-matching bilateral femora by similarities in bone architecture.
6. **Problems:** A problem encountered during this phase in was the matching of bilateral elements. When matching left and right femora, there were too many similarities in morphology and taphonomic alterations to completely delineate which bones were pair-matches and which were similar because of a narrow range of variation. In order to resolve this problem, the femora were analyzed and differentiated by the observable differences in bone architecture. Another problem with this analysis was maintaining consistent reporting of the variables' values and descriptions. The challenge came from

having an extensive collection of skeletal material and having to return to the analysis over many days to complete the inventory.

7. **Literature clarification issues:** An issue that would have benefited from clarification was the value descriptions for each variable. If each bone element was described in a unique fashion with specific wording, then the sorting of the inventory, which is based upon similarities in wording, would suffer. For example, take five radii that have been described as complete, partially complete, distal portion, vertical fragment of midshaft, and fragment less than 2 inches in the breakage variable. Sorting these bone elements by their similarities during the analysis stage would be particularly difficult as they are descriptive but not cohesive in their description. Possible clarification in creating categories or descriptive terms could be in the form of Church and Burgett's (1996) original work being published in a public forum as an example of this type of approach to commingled remains.
8. **Comments:** Use of this method made it possible to gain a better understanding of the Lewis Jones Cave Ossuary Collection. Biological profile information such as age and sex provided demographic information. Observed evidences of trauma and pathologies led to a better understanding of the health and challenges the people interred in this cave encountered in life.

**Phase IV: Excavation map comparison**

For the final phase of this project, an excavation map of unit C (114R2-116R3) was digitized and then compared to the skeletal remains for a more contextualized estimation of the number of individuals present and a better determination of bone clusters indicating separate individuals. Digitizing the excavation map of unit C involved piecing together the original base map drawn during the 1977 excavation (see appendix B, first figure) and redrawing the bone elements in overlapping digital layers with Adobe Illustrator (Map 4.1). Each bone type was assigned a color and in the case of bilateral elements, the left was a darker hue and the right was a lighter hue. Within the final digitized map the following colors were used to indicate each bone type: humerus- orange, radius- brown, femur- green, tibia- blue, hands and feet- purple, cranial-red, mandible- fuchsia, clavicle- black, and ulna- pink. Two special cases were the articulated right leg which was filled in with a purple gradient to indicate the articulation, and unidentifiable bone elements that were filled in with grey. Analysis of the excavation map with the original base map hidden from view provided valuable information about the distribution of the skeletal remains and potential clusters of bones. The unit C excavation map illustrates an estimation of twelve individuals based upon non-repeating, nearly complete left femora. Orientation of the bones indicates the primary interment of possibly two separate individuals (Map 4.1). The first individual contains an articulated right leg and corresponding left femur. The second individual was determined to be a subadult from the clustering of smaller bones and abbreviations on the original map indicating child remains.

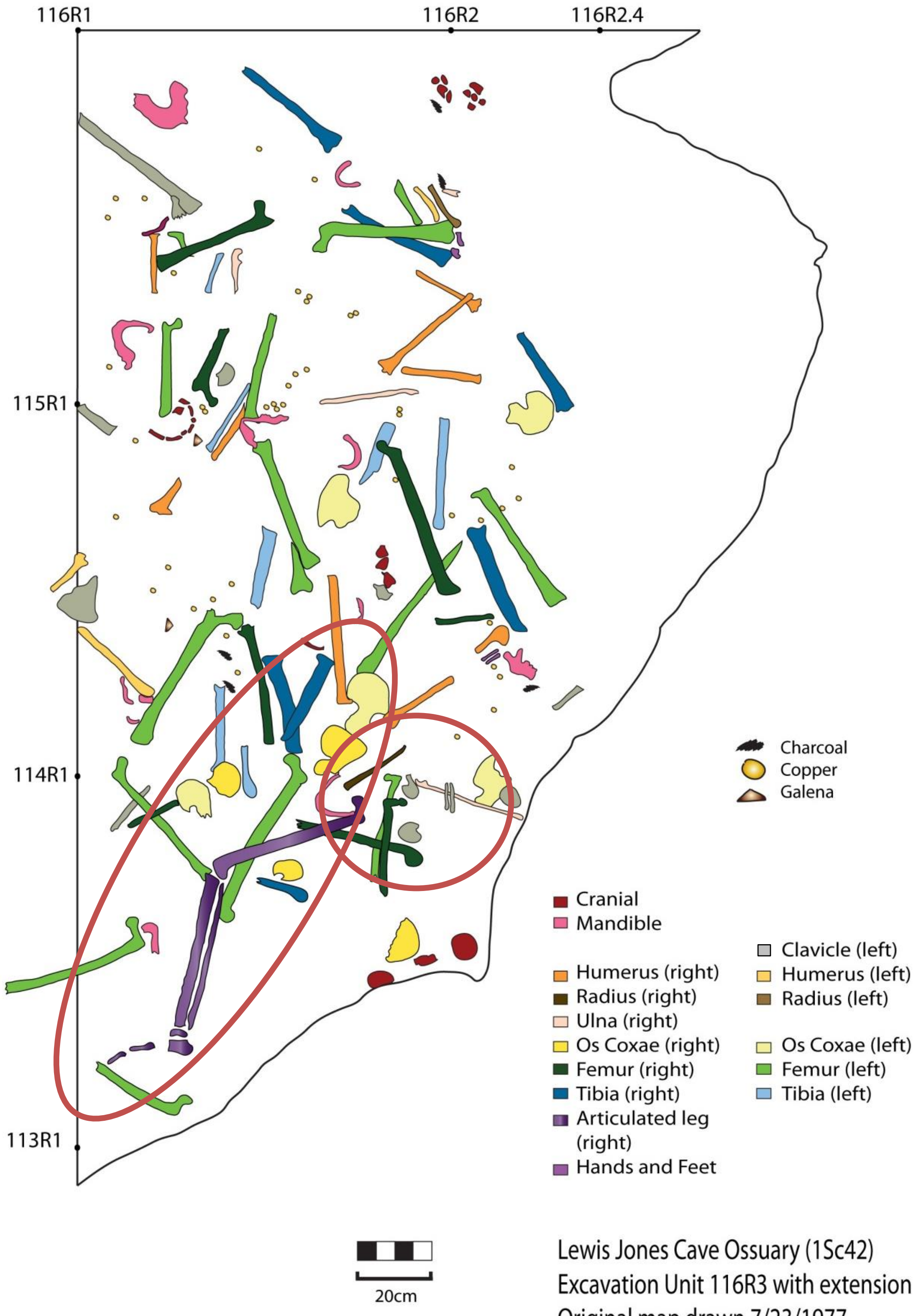


Figure 4.1 Unit C excavation map with overlaying digitized layers. Two red ovals indicate possible individuals.

Analysis of the skeletal remains included isolating all skeletal material from the original two by two unit (116R3) and the one meter extension (114R2). Sorting the isolated remains in a separate inventory indicated an estimate of 14 individuals from non-repeating left femora and os coxae. Comparison of the estimates from the digitized map and skeletal remains indicated a higher amount of bone material in the collection than what is illustrated on the map. The discrepancy between estimations and the missing illustrations of bone elements may be due to any number of reasons including preservation, the general rushed nature of a salvage excavation, time constraints during mapping, fragmentation after excavation, and breakage while in curation. The overall results from this phase would indicate there are possibly 14 individuals within this excavation unit and two confirmed individuals, a robust adult and a child, whose remains can be sorted into separate individuals. Throughout the application of this method, its appropriateness was evaluated by seven criteria.

1. **Time:** The total time it took to apply this method was approximately 25 hours. The time was distributed between digitizing the excavation map and actual skeletal analysis.
2. **Tools:** The only instruments required in this method were Microsoft Excel and Adobe Illustrator CS4. Microsoft Excel was used in data collection during the skeletal analysis and Adobe Illustrator CS4 was the program used to digitize the excavation map of unit C.
3. **Necessary bone components:** To determine an MNI from the skeletal remains, bone elements needed to have at least one land mark for identification and siding. When identification and siding were not possible, the bone elements were labeled as fragments.
4. **Skills:** Necessary skills in this method included the ability to identify human remains, enter data into Microsoft Excel, and use drawing tools in Adobe Illustrator. The identification of skeletal material mainly focused on the ability to differentiate bone

elements and to determine the side of the body they came from whenever possible. Data entry in Microsoft Excel only necessitated creating columns for basic bone inventory information. Additionally, a working knowledge of Adobe Illustrator was needed to digitize the excavation map of unit C. This included creating layers and redrawing different bones within each layer. Once the layers were completed, the digitized map was transferred into a PDF for resizing and placement into other documents.

5. **Subjective judgment:** An area of particular subjective judgment was determining the nature of the bone illustrations and notes on the excavation map. While some bone elements were labeled with bone and side, others were labeled with a bone abbreviation. In a few instances the illustrated bone elements were not labeled and their identification was left unknown.
6. **Problems:** An issue encountered during this phase of research was identifying different drawings on the excavation map. This was most especially true for unlabeled bone elements and areas where the cartographer redrew lines and figures.
7. **Literature clarification issues:** While this method was extrapolated from Herrmann's (2002) approach to mapping commingled human remains with GIS, there were no immediate clarification issues from the available literature. In fact, knowledge of Herrmann's (2002) techniques in applying technology to commingled human remains was helpful in working with historical excavation maps.
8. **Comments:** Comparison of the MNIs and the discrepancy between bones present demonstrates the potential concerns with salvage excavation and studies of curated collections of human remains. The digitized map not only provides context to the

commingled collection, but also visually separates different components of the excavation map that may have been missed otherwise.

The application of all four methods resulted in estimations of the number of individuals present within the collection, a start to sorting the remains into separate individuals, and an evaluation on their appropriateness in regards to a poorly preserved collection of commingled human remains. The results of the evaluation indicate each method has a set of inherent strengths and weaknesses to its approach. These characteristics assist in determining how best to approach collections of poorly preserved, commingled human remains in future osteological studies.

# CHAPTER 5

## DISCUSSION AND CONCLUSION

The focus of this study has been to analyze the methodology for commingled human remains and determine which approach is most appropriate for a curated collection of commingled human remains. To accomplish this objective, alongside the goal of gaining a better perspective of the people practicing the Copena Mortuary Complex, four separate methods were applied to the Lewis Jones Cave Ossuary Collection. In doing so, each method demonstrated certain strengths and weaknesses. These characteristics lead to suggestions for future research involving commingled skeletal remains in laboratory and field settings. In addition, the study also provided insight about the prehistoric individuals interred within the Lewis Jones Cave Ossuary who were representatives of the Copena Mortuary Complex.

In applying the basic MNI method to the Lewis Jones Cave Ossuary Collection, there were notable strengths in its use and outcome. The most notable characteristic of the basic MNI method was its simplicity in application. A researcher using this approach would only need to be able to differentiate bone elements and the side of the body the element came from to gain an estimation of the number of individuals present. According to Adams and Konigsberg (2004, 2008) and Snow and Folk (1965), the estimate can be refined further by adding mathematical applications at the researcher's discretion. Additionally, the basic MNI method is a faster approach in obtaining an estimate. Application of this method to the Lewis Jones Cave Ossuary Collection took the least amount of time with a combined 30 hours of recording data collection. The basic MNI method is a well-known and established practice in bioarchaeological and osteological studies most likely due to its simplicity. As Adams and Konigsberg (2004) have noted, there is a long history to the development of the basic MNI calculation and it is a widely used approach to commingled skeletal remains (Adams and Konigsberg 2004:138). In addition to the strengths of the basic MNI method, there are also weaknesses.

Although these weaknesses are few, there are some aspects of the basic MNI approach that lag behind in providing information about the collection under analysis. One of the most noticeable weaknesses to the basic MNI method is the lack of providing additional data beyond quantitative analysis. The basic MNI provides just an estimate. Additional demographic information about the collection such as the age distribution and information about the less frequent bone elements like the bones that make up the vertebral column would require another phase of analysis. Additionally, using strictly the basic MNI approach will tend to provide an underestimate of the individuals present. Adams and Konigsberg (2004, 2008) suggest quantitative techniques such as the MLNI to determine the original number of individuals within the population. A potential problem with the MLNI is awareness of its existence and the necessary steps in its calculation. As with the basic MNI method, there are also certain strengths and weaknesses to the osteometric approach.

With the osteometric method, the most notable strength is the objectivity in its application. In using a technique that involves comparison by osteometrics, the researcher is removing the inherent subjectivity of osteological analysis. For instance, in the Lewis Jones Cave Ossuary Collection, femora were determined to be from the same individual or from different people based upon the similarity in dimensions. Those that were closer in both the medial to lateral and anterior to posterior subtrochanteric measurements on the femur would suggest the bilateral elements were from the same individual. This line of logic follows with

Byrd and Adams' (2003) use of a reference sample and linear regression to compare bone elements. Bone size will correlate with body proportion; therefore, the larger the individual, the larger their bones will be (Byrd and Adams 2003).

While an osteometric approach may provide an objective method in osteological analyses, there are inherent weaknesses as well. One unavoidable concern with using osteometrics as a comparison tool is the natural asymmetry of bilateral elements. A right femur and its left counterpart can be asymmetrical. With this asymmetry of bone elements, the matching of bilateral bones becomes exceedingly difficult. In the case of the Lewis Jones Cave Ossuary, an intraobserver error of ± 1 mm was included to account for measurement error and the presence of asymmetry. The problem of asymmetry when pair-matching is compounded when the entire population represented by the bone elements has a narrow range of variation in measurements. Similarity in height and robusticity will limit the applicability of using dimensional analysis as a tool to separate individuals. Another weakness with an osteometric approach is that more complete bone elements are needed. Bones that are poorly preserved, due to taphonomic processes and deterioration over time, tend not to present enough information for a complete osteometric comparison. For the Lewis Jones Cave Ossuary Collection, a majority of the remains were fragmented or incomplete. And, not being able to use femoral long bone length or the femoral head diameter, two primary measurements usually taken by osteologists, limited the capacity of osteometric sorting. If the femoral length and femoral head diameter were available, then multi-dimensional comparisons would better support the pair-matched elements. A problem that develops from the condition of the skeletal material is maintaining consistency in using standard points of measurement. The ability to correctly match bone elements is dependent upon accurately locating the same standard measurement points on each bone element. In the case of matching femora, the midshaft medial to lateral, anterior to posterior, and circumference measurements must be extrapolated when the femur is incomplete. Estimations of where the midpoint of the femur is located and measurement extrapolation casts doubt upon potential matched bilateral elements.

Applying the hierarchy of variables method has its strengths and weaknesses as well. A worthwhile aspect of applying a hierarchy of variables to a commingled collection of human remains is the availability of information on the population. In creating an inventory for the recording of multiple variables, choices can be made as to the areas of information that will be collected. In the case of the Lewis Jones Cave Ossuary inventory, variables were selected based upon the work of Church and Burgett (1996) and variables were added that were applicable to the collection. The inclusion of collection-specific variables allowed for the gathering of additional material beyond the basic data (i.e., bone element, segment, and side). With the addition of taphonomic and demographic variables, time was saved from having to conduct further osteological analyses. Variables such as age, sex, pathologies, and weathering alluded to the condition of the remains and the population that was interred in the Lewis Jones Cave. While having a source for additional taphonomic and demographic information was a strength and a beneficial aspect to the hierarchy of variables method, there were weaknesses in the application of this method.

There were two prominent weaknesses to this method application. The first weakness was the time commitment necessary for analyzing and recording each bone element. Application of the hierarchy method to the Lewis Jones Cave Ossuary Collection took around 70 hours due to creating the inventory, observing multiple variables, and recording the data. If one were to use this method on another collection of commingled skeletal remains, the time spent may fluctuate depending on the condition of the collection, number of bone elements, and number of variables used in analysis. Another weakness to the hierarchy of variables approach is the researcher's ability to maintain consistent descriptions that would later permit sorting. For instance, the Lewis Jones Cave Ossuary is an extensive collection of fragmented, poorly preserved remains. Describing the condition of the bone through variables required creating standardized descriptive categories to maintain consistency. It was only with the categorization of variables that sorting was possible of the Lewis Jones Cave Ossuary Collection. A problem that can develop from using categorical variables in this type of osteological analysis with prehistoric human remains is when there are too many similarities between bone elements. Pair-matching bone elements and sorting the individuals becomes a challenge when there is insufficient description to separate different individuals. In the case of the Lewis Jones Cave Ossuary Collection, similarities between the left and right femora required additional analysis of the femoral bone architecture of each bone element to provide potential pair-matches. As with the methods discussed thus far, there are inherent strengths and weaknesses to the mapping and analyzing of excavated commingled remains.

There are many benefits to the incorporation of plan view maps or even photographs if they are available during the analysis of commingled human remains. Visual representations of the pre-excavation bone positions can hint at how skeletal collections became commingled and can assist in estimating the number of individuals present. For instance, the vertical orientation of many of the long bones in unit C (116R3 to 114R2) may indicate the influence of water flowing through this part of the cave. As Nawrocki et al. (1997) and Micozzi (1991) have noted, water currents can not only transport bone, but shift their directionality toward a similar axis. Another notable strength in including maps during analysis is the capability to improve, save, and share historical maps through the use of digitizing software. With the excavation map of unit C, digitizing the map provided a clearer illustration of the bone distribution and the means to create an easier labeling system. Instead of labeling each bone or using a numbering system, programs such as Adobe Illustrator allow the user to fill-in drawn bones with selected colors thus allowing them to be separated visually. Furthermore, using excavation maps to supplement osteological analysis provides a visual idea of what condition the remains were in prior to the curation and long-term storage processes. Comparison between the bone elements drawn on the unit C map and those physically in the collection would indicate further fragmentation of the collection since the excavation in 1977, or conversely, incomplete mapping due to the time constraints of a salvage excavation. In line with observations of temporal differences, there are potential weaknesses to applying excavation maps to studies of commingled remains.

Inherent weaknesses to using maps in osteological analyses include the physical condition of the maps themselves, the completeness of those maps, and the skills necessary for digitizing historical maps. For excavation maps to be of use in studying curated collections of human remains, the illustrations need to be complete. In the case of the Lewis Jones Cave Ossuary, the excavation map of unit C was not complete in rendering the placement and inclusion of all of the skeletal material recovered from that area of the cave. The absence of skeletal material from the map was discovered when the skeletal analysis indicated may more bone elements than illustrated. Another weakness to this approach is that it requires knowledge of computer software that is capable of digitizing these historical maps. Digitizing the excavation map of unit C necessitated a working knowledge of Adobe Illustrator CS4. In Herrmann's (2002) digital mapping of commingled remains, he employs GIS to place the archaeological site and details of the site into geographic space. While working knowledge of GIS and Illustrator are valuable tools, they tend to be beyond what osteologists usually use while conducting research in a laboratory setting.

The results of applying four different methods to the Lewis Jones Cave Ossuary Collection and evaluating their appropriateness include a variety of characteristic strengths and weaknesses for each approach. These characteristics have led to suggestions for future research concerning commingled human remains in laboratory and field settings. In the case where a researcher conducts a study on a curated collection of commingled human remains in a laboratory setting, there are select aspects of the evaluated methods which would aid in the inventorying and sorting of the collection. One aspect that was greatly beneficial to the study of the Lewis Jones Cave Ossuary was the construction and use of an inventory using a computer program such as Microsoft Excel. Tools included in data collection programs such as Microsoft Excel allow the user to sort and organize large collections of data within very short periods of time. In addition to using a data collection program, another suggestion would be to use established variables for osteological analysis. For example, Buikstra and Ubelaker (1994) provide general standards for data collection. Using these standards, a researcher could expand the variables to include additional information pertinent to the collection under study. For example, if the focus was pathology then the inventory could split the pathology variable into congenital, transmittable, infectious, age-related diseases, and so forth. Additionally, in the case where the collection is highly fragmented, Knüsel and Outram's (2004) system of recording zones of bone elements would be helpful in sorting elements further along in the data analysis. When pair-matching is attempted, matching bilateral bone elements should be approached by first using subjective similarities then confirmed or denied by osteometric similarities. If available, excavation maps and records from the initial excavation should be consulted for any clues as to the context and relative placement of the bone elements. The overall result of these suggestions for a curation-based study within a laboratory setting would supply a means to estimate the number of individuals present and would contribute demographic information that is relevant to the context of the collection.

For situations whereby commingled human remains are analyzed in the field, it is suggested here that one naturally utilize the burial context as much as the excavation situation allows. As Herrmann (2002) has demonstrated, researchers in the field can use geo-referencing tools (i.e., total station), GIS, and photography to record the placement of bone elements. Visually and digitally recording the placement of bone elements at a site will provide context for analysis both on and off site. There are cases where it is especially important for the remains to stay in situ (i.e., Native American graves) (Herrmann 2002) and situations when there is an imminent need to remove the skeletal material as fast as possible (i.e., hostile territories during military actions). An additional suggestion when conducting analysis in the field is to utilize Wright's (2003) program discussed by Tuller et al. (2008) in which articulation points are carefully coded and recorded before the remains are excavated. Such a recording system in addition to mapping the remains would allow field analysis to be recreated in a laboratory setting. While suggesting that bioarchaeologists accurately record bone provenience seems like an obvious practice given it is extremely important, maintaining that provenience from the field to the laboratory is essential for recording and sorting skeletal elements when dealing with commingled remains.

In addition to providing suggestions for future research, the final objective of this research project is to contribute to our archaeological knowledge of the people involved in the Copena Mortuary Complex. Contributions to the Copena complex developed from the osteological analysis of the skeletal remains excavated from the Lewis Jones Cave Ossuary. Analysis of the human remains indicates there are at least 62 individuals placed in the cave. Although the bone elements are fragmented and poorly preserved due to taphonomic processes occurring within the cave environment, analysis indicates that there is a wide spectrum of demographic variation within this prehistoric population of Native Americans. Interred within the Lewis Jones Cave Ossuary are males and females ranging across all age groups. Although a majority of the skeletal collection does not have a sex designation, mainly due to the poor preservation and fragmentation of the collection, observation of more complete skulls indicate there are at least ten probable females and 16 probable males. Analysis of the os coxae (pelvic bones) would be helpful in determining the number of males and females within the collection except preservation has obliterated the presence of major morphological features used for sex determination. Additionally, there are at least three subadults that fit within an infant to young child age range. There is one subadult that could be considered an adolescent of eight to ten years of age based on dental development. Aside from the subadults, the adults range from the young, the middle aged, to the elderly. This variety in adult ages was observed through the use of the suture closure aging method and by observing age onset degenerative wear at articular joints throughout the skeleton. Both joint deterioration and the presence/absence of suture closures were the most helpful indicators of age in this weathered and animal beset collection of human skeletal material.

As with the basic demographic variables of age and sex, there are a variety of pathological and trauma-type markers found within these remains. As with any collection of prehistoric skeletal remains, the bone elements from the Lewis Jones Cave Ossuary contained indicators of periosteal reaction which is often the result of an infection that has affected the bone. Periosteal reaction, in the form of bone modification, was found in both the subadults and adults. Furthermore, this bone manifestation is found predominately on the long bones, though this may be due to the likelihood of these denser bones surviving. A particularly unusual pathological indicator found within the Lewis Jones Cave Ossuary Collection is that of treponemal infection as evidenced by the condition known as saber shin. This pathology, manifested as a bowing of the tibia, presents itself in ten adult left and right tibiae. Aside from saber shin, another unusual pathological indicator is auditory exostosis, or a small bone growth inside the external auditory meatus. In total, there are 13 incidences of auditory exostosis, ten of which are in complete skulls and three in partial temporal bones. In line with the current literature on auditory exostosis, the bone growths are only found on adult skulls (Aufderheide and Rodríguez-Martín 2011:255). In addition to pathologies, there are also indicators of trauma in the form of fractures and depression fractures. The fractures include a humerus and ulna from separate individuals that have both had time to heal. While there are several incidences of minute cranial depression fractures, one in particular is unique. The left parietal of skull #55 has a rectangular depression on the ectocranium (outside) and a callus in the exact same spot on the inside of the skull indicating the individual had months, possibly years, to heal that fracture before they eventually passed away.

Although the Lewis Jones Cave Ossuary is a less well-known Copena site, the collection does present a general sense of the people living and dying within northeastern Alabama during the middle Woodland period. The inclusion of males and females of varying ages indicate there was not a bias in who was interred within the cave ossuary. Those who were buried at the Lewis Jones Cave Ossuary show skeletal evidence of poor health in the form of periosteal reactions and treponemal infections. Although auditory exostoses are pathological manifestations, they have been argued to be caused by continual exposure to cold water (Kennedy 1986). In the context of the Copena complex and prehistoric Native Americans living in northeastern Alabama, this would indicate the people buried in the cave ossuary were utilizing the Tennessee River and its tributaries as resources. Furthermore, employment of the cave environment as a burial location and not elsewhere would lend toward the idea that there may be spiritual meaning behind the placement of deceased within a natural cave (Freidel, Schele, and Parker 1993:187). Additionally, the presence of healed trauma, whether accidental, occupational, or violently inflicted, indicates the people buried at the cave ossuary were not necessarily dying from violent deaths and then being immediately interred within the cave. Instead, skeletal evidence shows that the people who did experience some form of trauma had time to heal before their deaths. While the accumulation of demographic and health information from the skeletal remains provides insight into the lives of the people living in northeastern Alabama, it has provided a great deal of insight into the people practicing the Copena Mortuary Complex.

While the results of this research project demonstrate how certain methods for addressing commingled human remains are applicable to a curated collection of human remains, there are larger implications for the physical anthropology discipline. In applying four different methods to the Lewis Jones Cave Ossuary Collection, it was found that instead of using only one method the researcher has more success with employing an amalgamation of techniques. With this knowledge in mind, researchers in curation-based studies with collections of commingled remains may take the assessments and suggestions found in this research project and apply them to fit their situations. Furthermore, the methodological evaluations can be applied to not only studies with curated human remains but contemporary cases of commingled human remains as well. Possible situations include forensic investigations in which the recovered skeletal remains were commingled either due to violent acts to eliminate identification or because of incidences of mass fatalities. Knowledge of the different methods and techniques available for use with commingled human remains will expedite and improve any analysis in the laboratory and field settings.

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## APPENDIX A

Example of a Copena traits list
The Wheeler Basin survey[1]

Mound structure

1) Conical earth mounds
2) Mounds with inclusive burial pits
3) Scattered post molds
4) Pits lined or floor with or containing deposits for foreign clay

Burial traits

5) Extended in the flesh
6) Skeleton preservation very poor; little more than trace or outline
7) Deposit of burned human bones, inclusive (perhaps cremation)
8) Skull disarticulated, separated
9) Burial pits below mound base
10) Artifacts accompany subsoil burials
11) Pottery vessels absent from burials
12) Galena as burial furniture
13) Mica as burial furniture
14) Flexed or bundle burials in upper part of mound (some appear to be intrusive)
15) Spades or other exceptional artifacts definitely placed under head of skeleton

Stone

16) Celts, greenstone, 17'' to 7'' long, pointed pole, high polish
17) Pipes, elbow form
18) Pipes, large zoomorphic, steatite
19) Spades, schist, many large-1x6x26''
20) Flint knives, ovate, finely chipped, 5'' to 8'' long
21) Flat-bar gorget, expanded center, steatite or chlorite
22) Stone artifacts (spades, celts, pipes) intentionally broken and parts deposited together
23) Deposit of galena throughout mound

Shell

24) Disk shell beads
25) Large marine shell vessels and unworked shells

Copper

26) Reel-shaped objects
27) Celts about 5''
28) Beads, spherical, drilled
29) Beads, cylindrical, rolled sheets
30) Spool-shaped ear ornaments
31) Long copper bead found with stained teeth (may suggest single nose bead)
32) Copper reels and other copper artifacts intentionally broken and fragments deposited

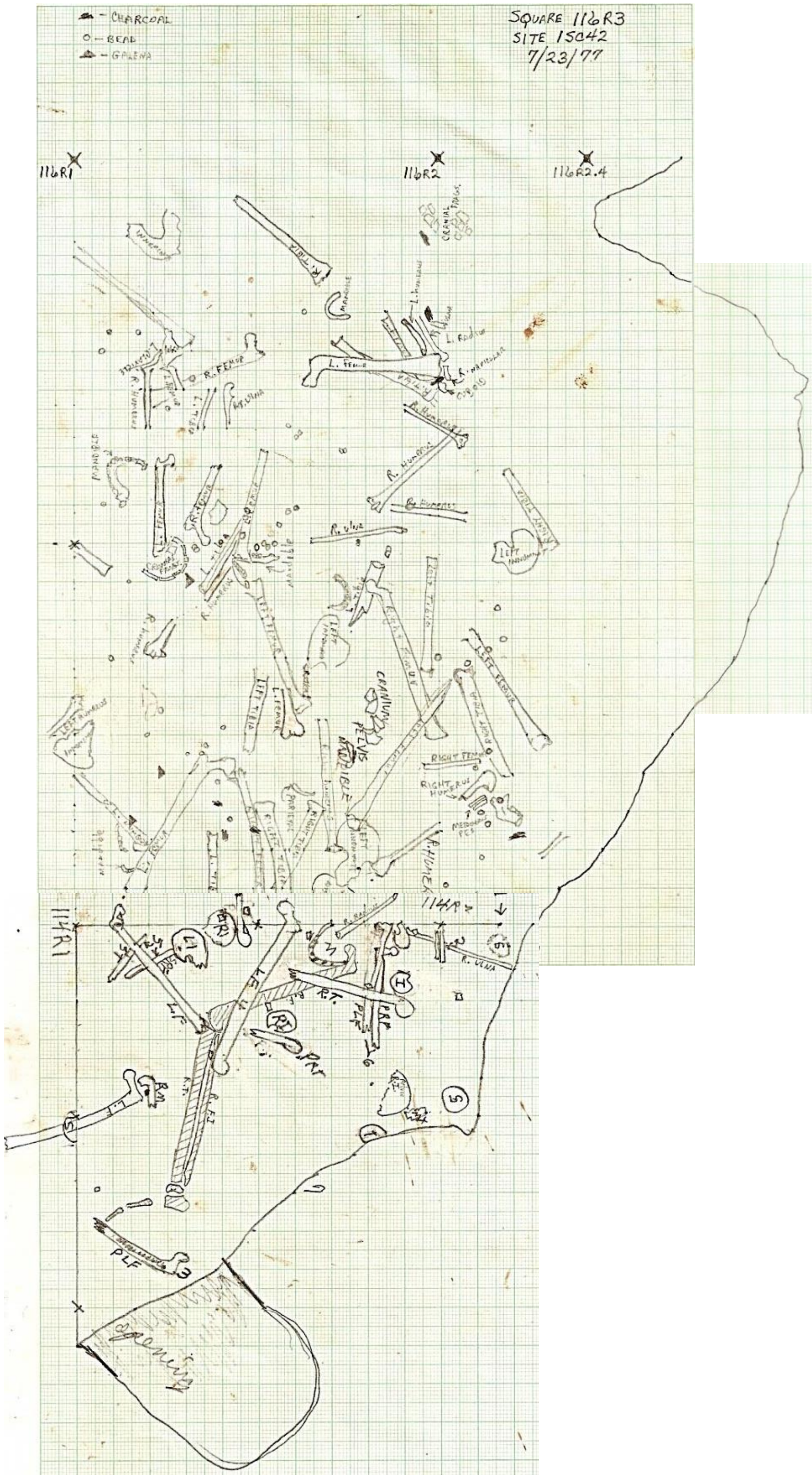
33) Bracelets, flat-bar, bent end to end

<u>Miscellaneous</u>

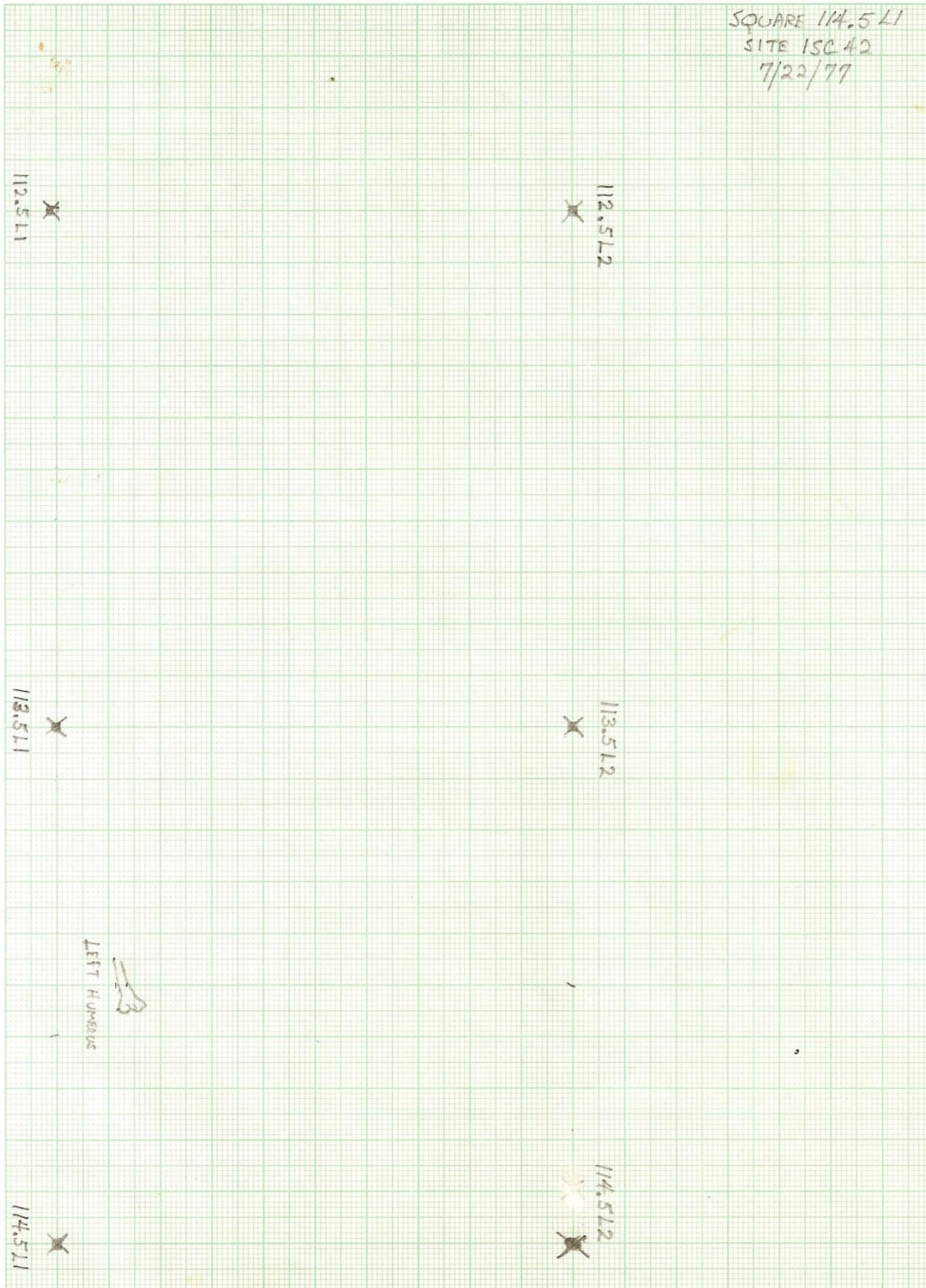
34) Mounds in vicinity of large river
35) Mounds frequently occur in groups of two or more
36) Woven textiles preserved by copper salts

[1]Trait list copied in its entirety as presented in Webb (1939) pages 189-190.

APPENDIX B

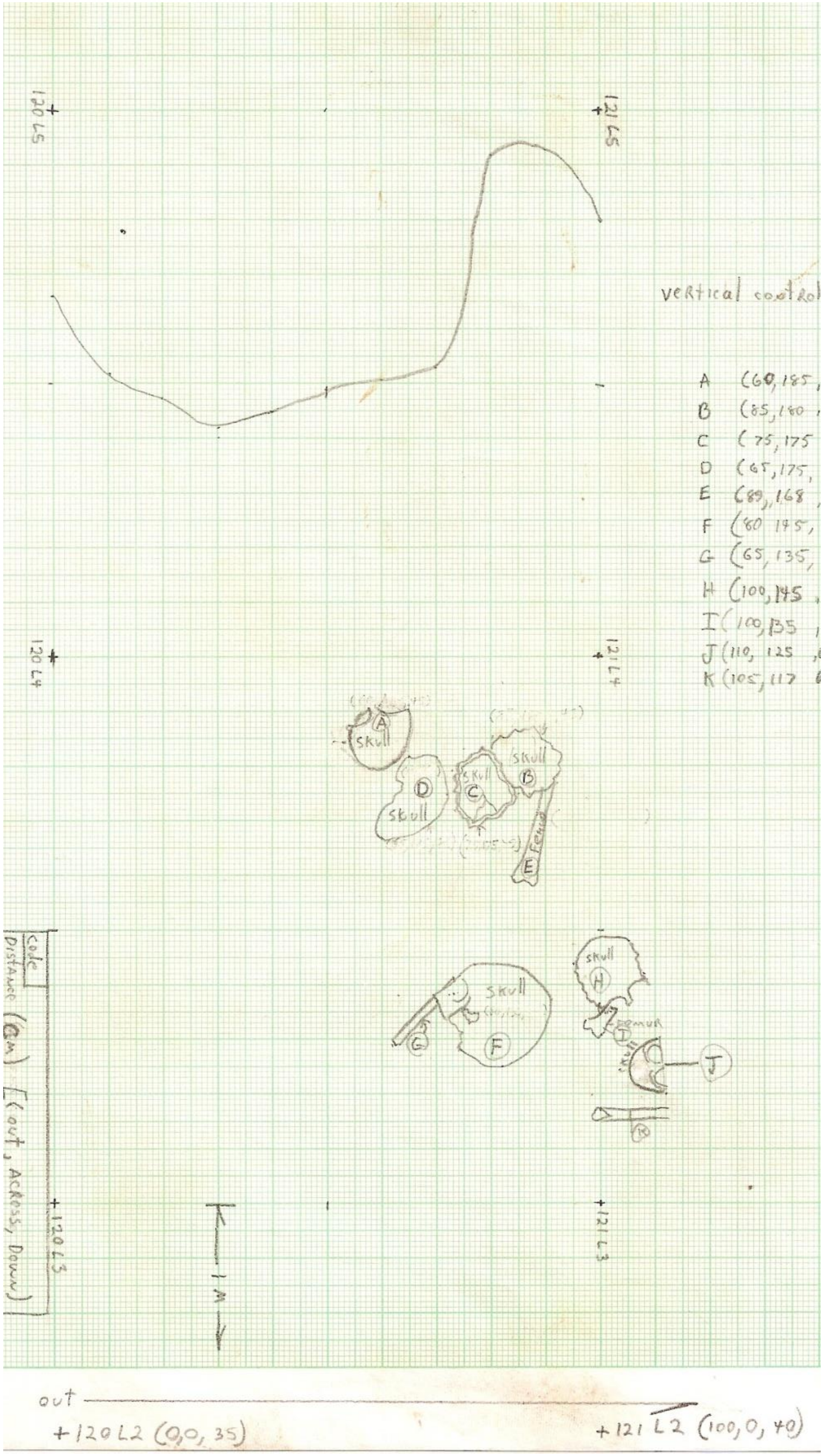



Appendix B. Compilation of excavation maps from units 116R3 and 114R2 that display the partial record of the skeletal material recovered. Illustrator unknown.




Appendix B continued. Excavation map of unit 114.5L1 demonstrating the partial recording of skeletal material. Illustrator unknown.

Appendix B continued. Excavation map of unit 121L3 demonstrating the partial recording of skeletal material. Illustrator unknown.



APPENDIX C

| | Statistical | Osteometrics | Hierarchy of variables | Mapping |
|---|---|---|---|---|
| Time from beginning to end (hours) | | | | |
| Tools (Software, measuring, etc.) | | | | |
| Necessary bone components | | | | |
| Skills (Computer, osteological, measurements, etc.) | | | | |
| Areas requiring subjective judgment | | | | |
| Problems | | | | |
| Clarification issues with the literature | | | | |
| Comments | | | | |

Appendix C. Blank evaluation form.