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An Isotopic Assessment of Late Prehistoric Interregional Warfare in the Southcentral US

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An Isotopic Assessment of Late Prehistoric Interregional Warfare in the Southcentral US

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by

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Abstract

Skull burials are found all over the world. The cause of such ancient Native Americans deposits often lead to disagreement among scholars torn between warfare and ancestor veneration. One skull-and-mandible deposit, representing at least 352 people (A.D. 1253-1399), was uncovered at the Crenshaw site, a multiple-mound Caddo ceremonial center in southwest Arkansas. Most previous research suggested they were victims of interregional warfare from the Southern Plains or Mississippi Valley. One previous study hypothesized that this was a Caddo burial practice which expanded during the Middle Caddo period (A.D. 1200-1500) due to the adoption of maize as a staple and a dispersed settlement pattern. A dispersed population might need such a practice to be buried at their preferred ritual center due to the inability to move large numbers of bodies. This study uses multiple methods to evaluate the purpose of this burial practice including (1) lead, strontium, carbon, and nitrogen isotope analyses for geographic origins and diet, (2) geophysical analysis of settlement patterns, and (3) analyses of biological traits. The biologically available lead method, using lead isotopes from ancient animal teeth, was developed to provide a method to assess the geographic origin of the human remains. The first large-scale lead and strontium isoscape using such samples was constructed to evaluate geographic origins. Sites targeted for sampling included those with evidence of violence from the same time period (from Arkansas, Illinois, Louisiana, Mississippi, Missouri, Oklahoma, and Texas). The stable isotope signatures show that the human remains are local to sites surrounding Crenshaw and indicate or strongly suggest they are non-local to all other tested regions. The dietary evidence indicates a maize and fish diet rather than a bison diet, consistent with southwest Arkansas and not the Southern Plains. Some aspects of the diet also suggest matrilocal intermarriage and food sharing with community and ritual leaders, consistent with Caddo

cultural practices. The geophysical analysis of settlement patterning concludes that Crenshaw was among the most heavily occupied sites in the Caddo Area, if not the most, at one time. Analyses of possible ceremonial and domestic structures show that Crenshaw had a nucleated settlement pattern at least as late as the Early Caddo period (A.D. 1000-1200). It is hypothesized to have become more dispersed ca. A.D. 1200. Biological traits were compared to a nearby population in the Little River region. There were no significant differences between compared populations (locals, the skulls, or the mandibles) except the mandibles had additional tooth chipping. An analysis of mortuary patterning in the Little River region shows that there is a lack of Middle Caddo bodies at secondary mound sites nearest to Crenshaw despite the presence of mortuary structures from that time. The Caddo skull and mandible burial practice is therefore a regional burial practice associated with ancestor veneration. The ritual burial practice reflects that Crenshaw was expanding its ritual influence on previously existing surrounding sites and its ritual landscape through the dispersal of the populace around Crenshaw while the population began to adopt maize as a staple.

Acknowledgements

There are so many people to thank for their support over the years, I will undoubtably leave people out. If I do, I apologize in advance. I have added acknowledgements to each chapter, so people are often thanked there rather than here.

Ann Early provided many years of support as a dissertation advisor but was unable to serve at the end of the process. I want it to be known that she helped me, sometimes daily, with background information related to archaeology and the Caddo. She also was a springboard for many of my ideas throughout the process of formulating and executing the dissertation project. I thank George Sabo for giving me enough rope to hang myself. I did. However, I survived, and I hope that the knowledge this dissertation provides is of great use to the field. I have worked very closely with Adriana Potra, who coauthored Chapter 2, and would not have been able to complete this dissertation in the manor I did without the help and resources she provided. Jerome Rose was of great help in several ways, including helping to assemble a team to document the Little River population. Special thanks to Heidi Davis, Ashley Shidner, Nicole Smith-Guzmán, and Teresa Wilson who contributed to Chapter 6 which summarizes the results of that documentation. Ken Kvamme, besides helping train me in geophysical techniques, also helped with one of the grant proposals. Jami Lockhart also helped with geophysical techniques and particularly helped with obtaining the LiDAR data used in Chapter 5. While not a dissertation advisor, Jamie Brandon was a thesis advisor and continued to provide support and advice for this project as well. He will be dearly missed.

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Considering that there was no archaeological program for analyzing Pb or Sr isotopes from human or animal tooth enamel at the University of Arkansas (UA), I had to rely on the experience of those at other institutions. I was able to learn to do this work by traveling to the University of Illinois Urbana-Champaign and spending a week with Philip Slater, Matthew Fort, Thomas Emerson, and Kristin Hedman, Illinois State Archaeological Survey, who were kind enough to show me how to process the teeth. George Kamenov and John Krigbaum, University of Florida, supplied much useful advice about Pb isotopes and about issues with measuring isotopes on mass spectrometers. At the UA, issues with instrumentation and elemental analysis often were resolved by working with Erik Pollock and Barry Shaulis of the UA Stable Isotope Laboratory. Selina Suarez provided support through the use of the lab and microscope as well as useful advice about how to process teeth.

Dedication

It would be hard to dedicate this dissertation to anyone other than my wife, Jeni Samuelsen. She has spent years putting my learning and work before other priorities, sometimes sacrificing her own. She also spent tough years proofreading my writings until I became competent enough to write coherently. My kids, Eva, Cecilia, Edgar, and Eleanor are a constant inspiration and they drive me forward. I thank all of them for their daily love and support.

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Chapter 2: Published
Samuelsen, John R. and Adriana Potra
2020 Biologically Available Pb: A Method for Ancient Human Sourcing Using Pb Isotopes from Prehistoric Animal Tooth Enamel. *Journal of Archaeological Science* 115:105079. doi:10.1016/j.jas.2020.105079

Chapter 1: Introduction

John R. Samuelsen

1.1 The Study

This study will evaluate the geographic identities of individuals represented by a skull-and-mandible cemetery (A.D. 1253-1399) at the Crenshaw site in southwest Arkansas. When deposits of severed heads and mandibles are discovered at an archaeological site, warfare may first come to mind. However, modern western ideals are not necessarily applicable to the treatment of the dead by ancient Native Americans. Skull deposits are a worldwide phenomenon, the origins of which are often contested by scholars (Barrett and Scherer 2005; Hodder 2009; Kuijt 2009; Milner 1999; Schulting 2013; Testart 2008). Some argue that prehistoric Native Americans practiced warfare resulting in skull deposits (Schambach et al. 2011; Schwitalla et al. 2014; Sears 1956; Seeman 1988, 2007). Others proposed that such skulls represent locals, perhaps kept for the purposes of ancestor worship (Brown 1971; Eerkens et al. 2016; McAnany 1998; Pluckhahn 2003; Samuelsen 2016; Webb and Snow 1945). To this point, many Native American tribes carried their family's disarticulated remains over long distances for burial at places of significance, sometimes with accompanying rituals affirming community identity (Brown 2012; Charles and Buikstra 1983; Milner 2004; Pluckhahn 2003).

A large deposit containing at least 352 skulls and mandibles at the Crenshaw site led researchers to investigate the prevalence and extent of warfare in the intersection between the Eastern Woodlands and the Southern Plains, ca. A.D. 1200 and 1500, shortly before European contact. The Crenshaw skull-and-mandible cemetery has great importance as a baseline dataset for studying ancient conflict and cooperation because of the large number of individuals it represents. Most studies examining these remains infer identities of extra-local victims of warfare from places such as the Southern Plains or Central and Lower Mississippi Valleys, suggesting the Caddo participated in large-scale interregional warfare (Akridge 2014; Brookes 1999; Burnett 2010; Milner 1995:232; Powell 1977; Schambach 2014; Schambach et al. 2011; Zabecki 2011). Samuelsen (2016) argues that these studies suffer from methodological problems or lack clear evidentiary support, pointing out that there is otherwise little evidence for prehistoric warfare in the Caddo Area. Samuelsen's (2016) strontium (Sr) isotope analysis is the only published analysis to suggest the skulls and mandibles originated from southwest Arkansas and were buried in accordance with local cultural traditions. However, the Sr isotope data has some key weaknesses if used on its own. Only five out of the 670 prehistoric human teeth sampled in the eastern US would be considered non-local at Crenshaw using Sr analysis alone (see Chapter 2). This illustrates that the previously available Sr data alone are unable to distinguish southwest Arkansas and other regions in the eastern US and calls the origin of these remains into question. The need for other datasets, such as lead (Pb) isotopic data, and the fact that every other publication comes to the opposite conclusion, illustrate that it is not currently known if these remains are locals buried in accordance with a ritual burial practice or dismembered victims of warfare from other regions. These two starkly contrasting interpretations of this single deposit, neither presenting conclusive arguments, illustrate a large gap in our understanding of the unusual interment practices and our knowledge about the prevalence and extent of late prehistoric warfare in the southcentral United States.

This study will accomplish seven objectives. (1) Develop and test a method utilizing the multivariate and linear nature of biologically available Pb isotope ratios from archaeological animal and human teeth to determine the geographic origins of skeletal elements. (2) Furnish this new approach with a comparative multi-state map of biologically available Pb/Sr isotope ratios for use by future researchers in multiple fields, including data from Arkansas, Illinois, Louisiana, Mississippi, Missouri, Oklahoma, and Texas. (3) Demonstrate this method by analyzing the geographic origins of the Crenshaw skull-and-mandible deposits and evaluate if they are foreign victims of warfare or a burial practice reflecting the ritual community surrounding Crenshaw. Use the results of the isotopic analysis to evaluate the prevalence and extent of interregional warfare at the intersection of the Southern Plains and Eastern Woodlands ca. A.D. 1200-1500 within the appropriate archaeological context. (4) Reevaluate the dietary isotopic evidence (Akridge 2014) for the possibility of bison consumption to help evaluate if a Southern Plains origin for the skulls and mandibles is supported by carbon (C) and nitrogen (N) isotope ratios. (5) Evaluate the geophysical evidence of settlement patterning at Crenshaw to test if it is consistent with the use of Crenshaw for ceremonies and the skull-and-mandible cemetery reflecting the ritual deposition of human remains from surrounding sites. (6) Reconsider the previous biological evidence (Schambach et al. 2011; Zabecki 2011) that suggested the skulls and mandibles were foreigners by reevaluating the data and literature. This includes a comparison to a separate population for biological traits in the Little River region around the Millwood Reservoir. (7) Compare all datasets with the archaeological evidence from the Little River region sites nearest to Crenshaw to help explain the burial ceremonialism in this region during the Middle Caddo period (A.D. 1200-1500).

The questions surrounding the skull-and-mandible deposit have relevance to the Caddo Nation of Oklahoma since the remains have not been identified as their ancestors or their ancestors' enemies. Therefore, the project has the practical benefit of supplementing repatriation determinations as part of the Native American Graves Protection and Repatriation Act (NAGPRA), while simultaneously satisfying scientific research interests and the Caddo Nation's desire to accurately determine cultural affiliation prior to reburial. The uncertainty around the origins of these remains goes beyond the NAGPRA process in that it causes the Caddo and researchers alike to question if these are truly their cultural antecedents. By developing and utilizing the methods described, the project will contribute the analyses necessary to more clearly identify the geographic origins of the remains.

1.1.1 Contributions to Archaeological Knowledge

This study will address important challenges in archaeology and biological anthropology by contributing to our knowledge of conflict and cooperation among and between multiple prehistoric peoples in the southcentral US and contribute to major topics identified by Kintigh et al. (2014) as key areas where archaeologists need to contribute to our knowledge of human culture and behavior. First, the nature of ancient conflict and its dialectical impact on the development of culture need to be better defined. Second, in order to accomplish this, advances in methods "are certainly necessary" to identify and quantify ancient conflict (Kintigh et al. 2014:10-11). Traditional methods include identifying fortifications and violent trauma in human remains. These types of data can reveal the prevalence of warfare within regions but evaluating the geographic extent of warfare (i.e. how far groups would travel to war) is difficult with that type of data. Sr isotopes can evaluate geographic origins, but Sr isotopes alone are sometimes unable to distinguish between people from different areas (see Chapter 2). The use of both Pb and Sr isotopic techniques on suspected victims of violence from other regions allows this study to directly evaluate if large-scale violence took place and from how far such victims of violence may have been transported. Grupe et al. (2017:41-42) argue that Pb isotopes have great potential, but the data have yet to be "deciphered" for the purposes of biological sourcing. This study demonstrates Pb isotope ratios are decipherable for biological sourcing by using the biologically available Pb method, which compares the human remains to a large sample of animal remains and utilizes their multivariate and linear nature to detect differences between possible regions of origin.

These investigations will serve the dual purpose of providing a case study to exemplify the method and answer important archaeological questions. Due to the lack of a clear answer about the origins of this skull-and-mandible cemetery, there is a gulf separating the interpretations about the prevalence and extent of late prehistoric warfare in the intersection between the Eastern Woodlands and the Southern Plains. This study will evaluate the geographic origins of the Crenshaw skull-and-mandible cemetery to test if the ancient Caddo were committing large-scale acts of violence against neighboring regions. The concurrent and increased evidence of violence in the Southern Plains and the Central and Lower Mississippi Valleys could reflect increasing tensions between regions during a time when the Caddo greatly changed several aspects of their culture. Alternatively, verification that remains in the skull-and-mandible cemetery derive from local or regional populations may suggest that A.D. 1200-1500 in the Caddo Area presents a contrast with neighboring regions as a time and place of relative peace. Whatever the outcome, this study will demonstrate how biological Pb isotopes can be analyzed, begin to reveal the purpose behind these specialized Caddo burial rituals, and greatly inform our understanding of conflict and cooperation in the southcentral US during late prehistory.

1.1.2 The Crenshaw Skull-and-Mandible Cemetery

The Crenshaw site, located along the Great Bend of the Red River, was occupied between at least A.D. 900 and A.D. 1400 (Figure 1.1). The site is centrally located in the Southern Caddo

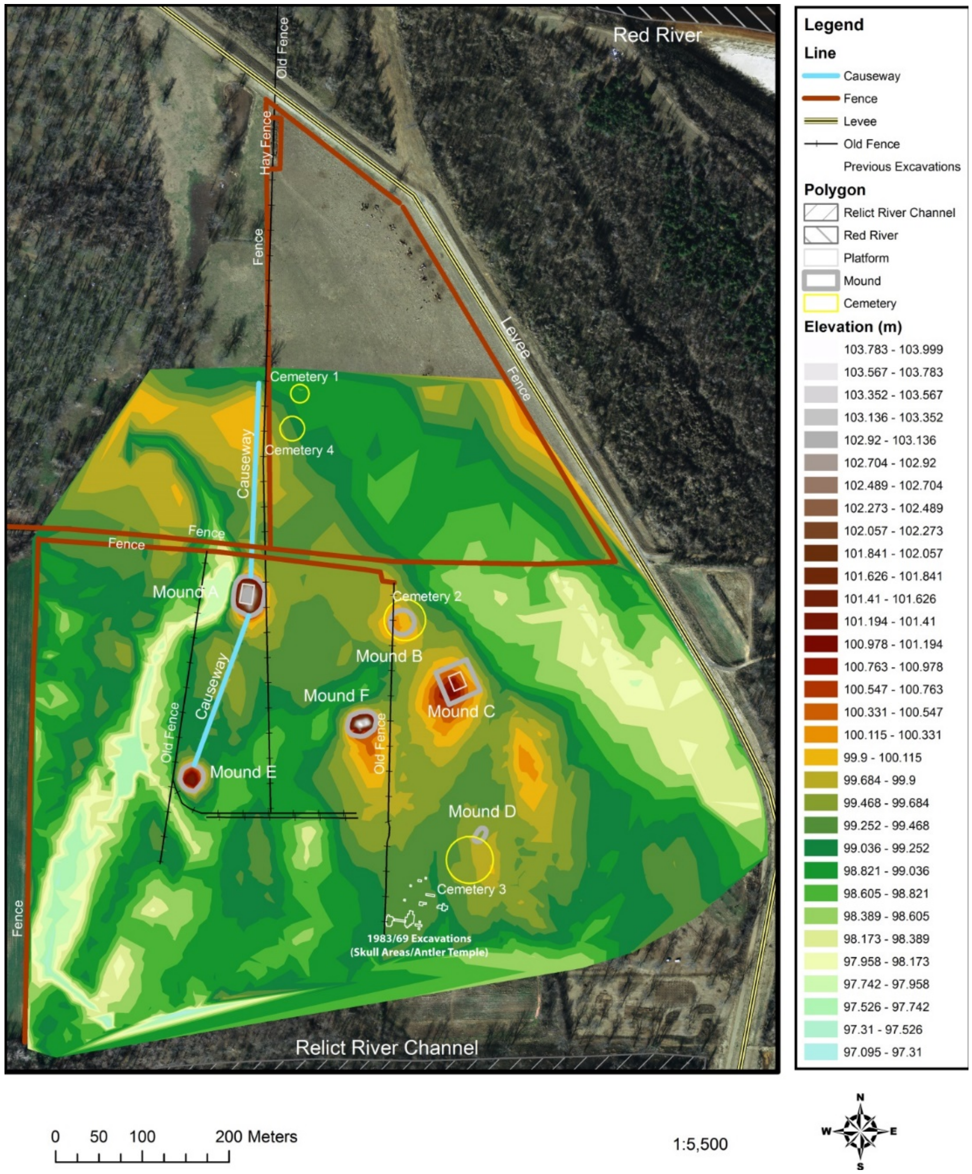

Figure 1.1 – The Crenshaw site (3MI6) and associated ancient and modern elements of the landscape. The site originally had at least six mounds (A through E). Only Mounds A and E have not been heavily excavated. Mound F was partially excavated but maintains most of its original shape. Mounds B and D were fully destroyed due to excavation in the 1930s while Mound C was totally destroyed by looters in the 1960s.

Area (Figure 1.2). The Northern Caddo Area has similarities to the Southern Caddo Area in material culture and practices, but clear differences exist. These areas combine to form a border region between the Southern Plains to the west and the Eastern Woodlands to the east but are considered to be part of the Eastern Woodlands. Crenshaw is a multiple-mound, Caddo

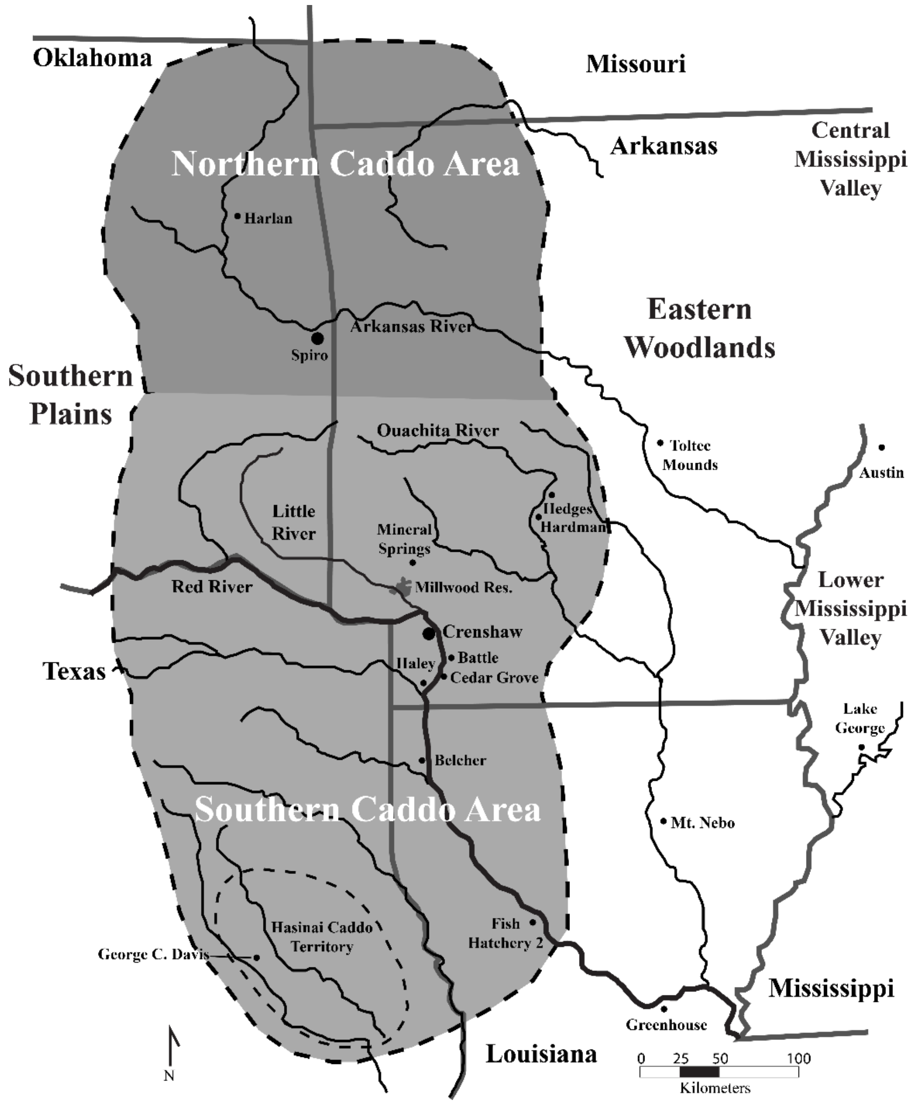

Figure 1.2 – Crenshaw and other important sites in and around the Caddo Area (from Samuelsen and Potra 2020:Figure 2).

ceremonial center that features evidence of both terminal Woodland Fourche Maline and later Caddo traditions (Samuelsen 2009). Caddo archaeologists recognize its preeminence in the region due to its placement near the Great Bend of the Red River and its clear ritual importance to the Caddo (Hoffman 1970, 1971; Schambach and Early 1982). The site was heavily used, at least as a cemetery, during Early Caddo (A.D. 1000-1200) and Middle Caddo times based on burial artifacts and radiocarbon dates on human remains, animal bone, and charcoal samples (Durham and Davis 1975; Moore 1912; Samuelsen 2014; Weinstein et al. 2003; Wood 1963).

Geophysical investigations have uncovered evidence of significant occupation areas, although the timing of occupation is unclear (Samuelsen 2010). Clarence B. Moore's (1912) documentation of the site included a map of six mounds (A through F). During the 1930s, significant cemetery areas were excavated, including the entirety of Mounds B and D. In 1961, Mound C unfortunately was the target of collectors who destroyed most of the mound, but some information was eventually published and some of the mound was salvaged by the University of Arkansas Museum (UAM) before the collectors completely destroyed it (Durham and Davis 1975; Wood 1963). Landowners and Arkansas Archeological Survey staff excavated portions of Mound F in 1968 while Mounds A and E remain mostly untested beyond the occasional pothole (Samuelsen 2009; Schambach 1982).

A large number of skulls and mandibles, at least 344 individuals (Zabecki 2011:39), were salvaged in 1983 after agricultural activity on the southern portion of the site began unearthing human remains (Figure 1.3). The excavations in the West Skull Area (WSA) and North Skull Area (NSA) were led by Frank Schambach and included many volunteers. This was not the first time clusters of skulls had been discovered at the site as the area southwest of Mound C had previously been noted by collectors for the presence of skulls. The Rayburn Cluster, a set of eight skulls, were excavated in 1968 by Schambach in this area. These remains were deposited in clusters of skulls or clusters of mandibles, with a couple of exceptions. The skull clusters generally contained from one to several people while the mandible clusters contained as many as 100 people (Zabecki 2011). While a large massacre may seem to be a possibility, direct dating of the remains showed that the practice occurred over time between A.D. 1253 and 1399, ruling out single event interpretations (Samuelsen 2014). Similarly, local warfare is very unlikely to be the cause of these deposits. If local warfare were causing such large-scale acts of violence, it would

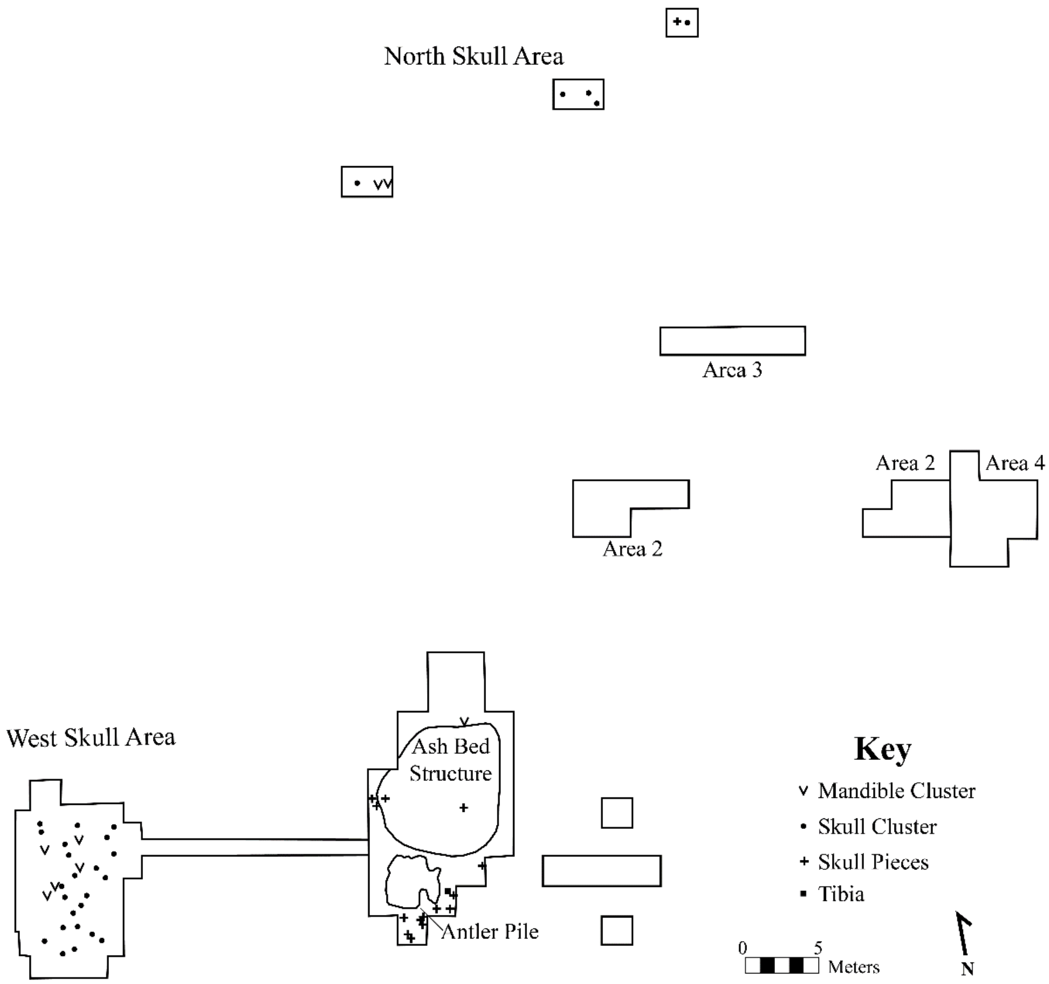

Figure 1.3 – The skull-and-mandible cemetery, ash bed structure, and antler pile. Different cluster types are marked in the North Skull Area and West Skull Area. Other pieces of human bone are marked in relation to the ash bed structure.

be expected to have great impacts on the rest of the cultural system (e.g. fortification/nucleation). This does not occur among the ancient Caddo in southwest Arkansas and neither does any strong evidence of violent trauma. The possibility that migrants translocated their ancestor's remains is also rejected. Archaeological and bioarchaeological data have consistently shown a lack of evidence for any large-scale migration in the Caddo Area (e.g. Jeter and Williams 1989:204-205; Rose et al. 1998).

There are two plausible explanations for this deposit offered by previous studies. (1) These individuals represent victims of warfare from other regions. If the victims were from distant communities, the Caddo may not have suffered reprisals, needed fortifications, or needed to change their settlement patterns (e.g. Green and Munson 1978). (2) The deposit reflects a Caddo ritual signifying Crenshaw as a place of regional ritual significance through the deposition of ancestors' remains from outlying sites.

1.2 Settlement Patterns, Burial Practices, Diet, and Warfare

Samuelsen's (2016) hypothesis that the remains in the skull-and-mandible cemetery represent locals buried at the mound center of importance in their ritual landscape relies in part on the settlement patterns around Crenshaw. For this hypothesis to be correct, the skulls and mandibles would have to be associated with members of the ritual community from surrounding sites. Therefore, the settlement pattering around the Crenshaw site during the Middle Caddo period would have to be at least partially dispersed and the Crenshaw site would have to have evidence of ritual or ceremonial activity (beyond the burial of skulls and mandibles themselves). Geophysical surveys can reveal whole landscapes (Kvamme 2003) and structural patterns that can begin to elucidate how sites were laid out and for what purposes they were used, including evidence of ceremonial and ritual activities (e. g. Hammerstedt et al. 2017; Lockhart 2007, 2010).

Settlement patterns can be defined as the way a community or society distributes itself within an environment, including elements of functional, spatial, and temporal differentiation. They have been suggested to be a correlate of the degree of warfare practiced in an area (Smith 1978). Milner (2004:121-122) suggests that warfare caused people to seek "safety in numbers" by consolidating into larger villages in the Eastern Woodlands. Fortification in larger villages allowed people to defend themselves from attacks (Milner 1999:111). In earlier times, settlement patterns may not have been greatly affected by the existence of warfare, but after A.D. 1000, warfare is reflected in fortified nucleated settlements (Dye 2009:10-13; Milner 1999:Figure 4). Indeed, after A.D. 1000, palisaded villages are common in the Eastern Woodlands, but not in the Caddo Area (Krus 2016; Milner 1999:120, 123-124; 2004:163; Perttula 2012:5).

Settlement patterns are also connected with burial practices. Outlining the local hypothesis, Samuelsen (2016) compared some potential connections in other regions, like in the American Bottom.

> Milner (2004:52-53) notes that there was a differential burial treatment between lowland riverine sites and outlying and upland sites during the Late Archaic. Specifically, the lowland riverine people were buried in full body burials while the outlying and upland people were buried in bundles. Charles and Buikstra (1983:132) argued that people who lived farther from their cemeteries may have required storage and therefore disarticulation as part of the burial practice for transporting the dead to their final resting place. Klepinger and Henning (1976:107) suggested that the smaller bones might get lost before final burial. They note that "the most important item" was the skull, followed by the long bones. Milner (2004:53) suggests a simple functional explanation for this burial practice. He states that "bundles of defleshed bones were easier to carry over long distances to burial grounds than heavy, smelly bodies." (Samuelsen 2016:131-132)

The connection between a dispersed settlement pattern and disarticulated burials provides one possible explanation for the skull-and-mandible cemetery at Crenshaw. Earlier burials at Crenshaw include large scale articulated burials in Mound C. Such burial practices would be much more difficult to accomplish if the population was dispersed across the landscape. Transporting detached skulls or mandibles would take considerably less effort. If the skull or mandible contains or represents the person who died and it was necessary to bury them at a site of ritual significance, this burial practice would efficiently maintain the ritual significance of the site and the associated community ceremonies. However, the dispersal of the population is but one explanation as Crenshaw's influence on preexisting sites may have increased during this time, resulting in more burials from more distant locations.

One thing is clear about skull deposits: the head or skull has special significance to Native Americans, just as it does for many people all over the world (Bonogofsky 2011; Brown

1971; Charles and Buikstra 1983; Pluckhahn 2003; Schulting 2013). Whatever the context or region, discoveries of skull deposits often result in significant disagreement among scholars, who are torn between competing arguments of warfare and ancestor veneration (Barrett and Scherer 2005; Eerkens et al. 2016; Hodder 2009; Kuijt 2009; McAnany 1998; Milner 1999; Pluckhahn 2003; Schulting 2013; Schwitalla et al. 2014; Sears 1956; Seeman 1988, 2007; Testart 2008; Webb and Snow 1945). For example, Sears (1956) originally suggested the skull deposits at Kolomoki in southern Georgia were war trophies. A reevaluation by Pluckhahn (2003:59-66, 201-204) challenged these interpretations. He noted that the skulls were often associated with artifacts and that multiple burial treatments (e.g. bundles and cremations) were present at different stages of mound construction, perhaps indicating differences in time or status. He (2003:194-195) concluded that the collection of cremations and skulls did not represent offerings for a single individual, but represented a corporate burial made to reinforce communal membership.

There is also significant debate over this question with Hopewell skulls and mandibles (Beehr 2011:84; Milner 1995:232; Seeman 1988, 2007; Shetrone 1926; Webb and Snow 1945; Willoughby and Hooton 1922). Web and Snow (1945:283-287) recognized the dilemma of assuming detached skulls or mandibles among Hopewell populations represented trophies as they could also represent postmortem burial treatments. Seeman (1988, 2007) used age, sex, and iconography to argue that modified human remains, including skulls and mandibles, could be indicative of warfare among the Hopewell. However, as he states (1988:567), it is difficult to know if scraping and cut marks might not instead be associated with postmortem processing of the remains of local individuals (Hemmings 1984:20-24; Web and Snow 1945:283-287). Difficulty in assessing which is the case arises from common criteria having multiple potential causes. Rightly, Seeman (2007:173) encourages formal criteria be used to distinguish between local burial practices and victims of warfare.

It is no surprise to archaeologists studying ancient warfare and peace that distinguishing between the two using archaeological data can be a struggle with current methods (Chacon and Mendoza 2007; Dye 2009; Kintigh et al. 2014; Milner 1995, 1999). Archaeologists typically use a few key datasets to assess if warfare was affecting the lives of ancient Native Americans; these include biological trauma, burned villages, fortifications, and nucleated settlement patterns. Dye (2009:7) argues that direct evidence, data that requires no inference or interpretation to result in a conclusion, can be found though skeletal trauma and burned villages. He states all other evidence for warfare is indirect. However, he (2009:11) and Milner (1995, 1999) state that some of the clearest evidence of warfare is in the use of fortifications. While Dye (2009:7) gives examples of direct evidence of warfare, he argues that there is no direct evidence of peace. Indirect evidence for peace and cooperation include community rituals, exchange networks, dispersed settlement patterns, and political organization. Chacon and Mendoza (2007:4-6) argue that warfare in ancient North America was ubiquitous and consider those who argue otherwise, such as Means and Wolf (1995), to be “radical revisionists” who view ancient warfare through an idealized lens. While it is true that ancient warfare was ubiquitous, it is also clear that there are times and places where war dominates and other times and places that are relatively peaceful. Each time and place should be independently evaluated for the prevalence and extent of ancient warfare using the available archaeological and bioarchaeological evidence.

1.2.1 Warfare in the Caddo Area

The historic record is an important source of information about warfare. The Caddo are one of only a few tribes that can be directly traced from the present into ancient times, making possible the cautious application of the direct historical approach (but see Milner [1999:107-108] and Belfer-Cohen and Goring-Morris [2009]). Although internally peaceful, the historic Caddo were under threat of violence from other tribes including the Wichita, Choctaw, Chickasaw, Osage, Tonkawan, and Apache (John 1975:166; Smith 1994). Records indicate the Hasinai Caddo of northeast Texas took heads as war trophies during historic times (Swanton 1942). A hasty interpretation of the skull-and-mandible cemetery might be trophy taking as a result of interregional warfare, but there is little archaeological evidence of warfare among the ancient Caddo. There is also little evidence of violent trauma among the ancient Caddo and the antecedent Woodland period Fourche Maline (Rose et al. 1998, 1999a, 1999b). However, a recent bioarchaeological analysis at the Akers site (34LF32) in eastern Oklahoma shows that this was not universally the case (Rowe 2017). In the rest of the Caddo Area, researchers have seen a lack of evidence for violence (Burnett 1990; Rose and Harmon 1999; Rose et al. 1998, 1999a, 1999b). Outside of the Crenshaw skulls and mandibles, the few interpretations of ancient violence in the Caddo Area mainly come from the presence of isolated skulls which often lack any justification for the interpretation they are trophy skulls (e.g. Harris 1953:63; Perino 1983:7; Story 1990:286, 339).

No evidence of fortification has been found at Crenshaw and the Caddo are not known for having fortified, nucleated villages after A.D. 1200 (Dye 2009:12; Early 2000:129-130; Perttula 2012:5; Schambach 1982). The lack of nucleated, fortified settlements in the Caddo Area suggest that their settlement patterns may have been more influenced by food procurement strategies than violence. The Caddo adopted maize as a staple during the Middle Caddo period which may have been more productive with a dispersed settlement pattern (Wilson and Perttula 2013). In sum, the available information from archaeological and bioarchaeological sources outside of Crenshaw generally show a lack of evidence for warfare. While it is clear from the historic accounts that warfare was not foreign to the Caddo (Barr 2007; John 1975:165-167; Sabo 1998; Smith 1994; Swanton 1942), A.D. 1200-1500 may have been a time when the Caddo lacked a motivation to be involved in violent conflicts with neighboring regions.

1.2.2 Warfare in the Southern Plains and the Central and Lower Mississippi Valleys

Two areas of origin for the skulls and mandibles that have been proposed are the Southern Plains and the Mississippi Valley (Akridge 2014; Burnet 2010; Brookes 1999; Schambach 2014; Schambach et al. 2011). Analyses of osteological and fortification data show that at the same time the skulls and mandibles appear at Crenshaw there is increased evidence for warfare in the Plains. While there is little evidence before A.D. 950, beginning around A.D. 1200 the Plains see a great increase in the evidence of warfare (Bovee and Owsley 1994; Brooks 1994; Lambert 2007; Owsley et al. 1994). Lambert (2007:214) characterizes warfare in the Southern Plains as consisting of small-scale raids and light intertribal warfare, relatively light compared to the Northern Plains. Brooks (1994) also notes that several areas in the Southern Plains are typified by some sort of fortification. There are many sites in Texas and Oklahoma that have some potential evidence of violence including embedded projectile points in bone, isolated skulls, and fortification (Baugh and Blaine 2017; Bovee and Owsley 1994:359; Brooks 1994; Huff and Bigs 1963; Owsley and Jantz 1989; Owsley et al. 1989; Perttula 2001; Pillaert 1963:42-43; Potter 2005; Prewitt 2012; Reinhard et al. 1990; Rose et al. 1999b:121; Ross-Stallings 2007). One site, the Nagle site (34OK4), has some evidence of interregional warfare between the Caddo and the Wichita of the Southern Plains. Despite its location in central Oklahoma, Brooks and Cox (2011) argue that Nagle was occupied by a group of Caddo people around A.D. 1200. One individual buried there had evidence of scalping and four Harrell and Wichita points in the thoracic cavity. The location of this site, well outside of the typical delineation of the Caddo Area, and the evidence of violence does provide some basis for the hypothesis that there may have been interregional warfare during this time.

The bioarchaeological record of the Lower Mississippi Valley seems to indicate that the prevalence of warfare was different in the northern and southern portions. Harmon and Rose (1989:339) note that the bioarchaeology of the Plaquemine culture in Arkansas and Louisiana remains relatively unknown due to a lack of excavations and analyses. Limited bioarchaeological data is available from Mississippi, although recent studies have begun to document what remains are available (Danforth 2012; Davis 2015; Listi 2011). There is little evidence of fortification with the exception of Lake George (22YZ557) in west Mississippi where one burned bundle burial was missing a skull (Kidder 1998:146; Ross-Stallings 2007:347; Williams and Brian 1983:49, 52). Kidder (1998:146-147) doubts that the earthworks at sites like Lake George reflect a concern about warfare, instead suggesting they have functional or ceremonial significance. Kidder also notes that the dispersed settlement patterns in the southern portion of the area could preclude the use of palisades given the lack of population nucleation. The more nucleated settlement patterns in the northern portions, like the Yazoo Basin, could suggest some concern for violence, but these sites still lack evidence for fortifications.

Evidence of violence is present in the Central Mississippi Valley and the northern portion of the Lower Mississippi Valley. In Mississippi, one burial at the Austin site (22TU549) showed evidence of being decapitated before burial (Ross-Stallings 2007:345). This site is located near a double burial at Bonds Village which contained two individuals buried without their skulls (Brookes 1999; Ross-Stallings 2007:344). Nucleation and fortification are common in the Central Mississippi Valley and include sites like Zebree (3MS20), Old Town Ridge (3CG41), Nodena (3MS3/4), and Parkin (3CS29) in northeast Arkansas; Kincaid in south Illinois; and Powers Fort (23BU10), Snodgrass (23BU21B), and Towosahgy B (23MI2) in southeast Missouri (Krus 2016; Milner 1999; Morse and Morse 1983; O'Brien 2001). One of the better examples of violence is the Norris Farms #36 cemetery in west-central Illinois where one individual had a point lodged in a bone and 11 individuals at the site were missing their skulls (Milner 1995:224; Milner et al. 1991).

Krus' (2016) recent radiocarbon analysis of palisades in the Eastern Woodlands illustrates that the skulls and mandibles at Crenshaw appeared at the same time that palisades were becoming common across the Eastern Woodlands (ca. A.D. 1200-1400). Was the Middle Caddo period in the Caddo Area a time and place of relative peace which contrasted with other regions? Could Caddo raiding parties have contributed to the need for defense in the Central and Lower Mississippi Valleys? Were such palisades only constructed to defend against neighboring communities or might they have been constructed due in part to interregional warfare?

1.3 Approach to the Problem, Methods, and Techniques

This study follows Wylie's (1992) suggestion of using multiple lines of evidence to support or refute a hypothesis. This view has been repeated often enough to suggest that there is little disagreement regarding its usefulness to identify proximal causes (Anschuetz et al. 2001; Conkey and Gero 1997; Dornan 2002; Pauketat 2001; Pollard and Bray 2007; Trigger 2006). The key to this view is to use multiple lines of evidence based on multiple theoretical backgrounds to evaluate multiple hypotheses. In this way, archaeologists can make use of data that constrains what can be said about the world (Hodder and Hutson 2003). Pollard and Bray (2007) suggest this approach to fully integrate historic and scientific elements within archaeology and Dye (2009:7) endorses this approach to the study of warfare and peace. The major focus of this study will be to test multiple hypotheses (strong inference) using Pb/Sr isotopes from human and animal teeth and include a human control group (natural experiment) from other contexts (Smith 2015). This will be combined with dietary evidence (C and N isotopes) of bison or maize/fish consumption, geophysical and isotopic evidence of settlement patterns and ceremonialism, biological evidence from human remains, and archaeological evidence of burial ceremonialism in the Red River and Little River regions.

1.3.1 Establishing the Biologically Available Pb Method

Before Pb isotopes can be confidently used to assess geographic origins, a clear method is necessary to explain how Pb isotopes from ancient human teeth can be compared, how that comparison can be done to assess if they are local or non-local, and how contamination issues particular to Pb can be determined. Chapter 2, based on Samuelsen and Potra (2020), outlines the biologically available Pb method by comparing Pb isotopes from ancient human teeth, prehistoric animal teeth, whole rocks, rock leachates, and soil leachates and determining which type of sample is most appropriate for direct comparison to human remains. It also explicitly outlines how that comparison is to be done, by analyzing 15 unique bivariate graphs for linear patterning. When humans match the linear patterning defined by the background values in all 15 bivariate graphs, they are considered local. Otherwise, the human remains should be considered non-local. Finally, Chapter 2 assesses the potential for anthropogenic Pb contamination using a variety of methods and assesses soil Pb contamination of teeth using three different methods. This defines and demonstrates a method for ancient human sourcing using Pb isotopes.

1.3.2 Assessing the Geographic Origins of the Skull-and-Mandible Cemetery

In Chapter 3, the resulting method defined in Chapter 2 is applied to the newest isotopic data obtained through a National Science Foundation Doctoral Dissertation Research

Improvement grant (grant number 1830438). Pb and Sr isotopic techniques provide archaeologists with a means to go beyond testing if warfare was present or not. The techniques and the associated methods allow archaeologists to assess how far warfare reached into neighboring regions and to what degree it affected their daily lives in a way that osteological analysis or fortification data cannot. Pb isotopes add a dimension of variability that will differentiate geographic identities of human burials at a higher resolution than is possible with Sr alone. Combining Pb and Sr is an effective method (Kamenov and Curtis 2017) as some areas with similar ratios in one element may be differentiable with the other. While the available Sr data is unable to distinguish between some regions in the eastern US, many areas have not yet been tested (e.g. Southern Plains). The new data fills this gap by sampling the Pb and Sr isotopes of multiple animal teeth from multiple sites in Arkansas, Illinois, Louisiana, Mississippi, Missouri, Oklahoma, and Texas. These data are combined with Pb and Sr isotopes from ancient human teeth from the skull-and-mandible deposits at Crenshaw and the data analyzed in Chapter 2. The resulting comparisons allow for the assessment of the geographic origins of the skull-and-mandible cemetery.

1.3.3 Evaluating Dietary Evidence of Bison or Maize/Fish Consumption

Akridge (2014) analyzed the C and N ratios of dentin from the skulls and mandibles and concluded that the variable diet represented was consistent with multiple populations from different regions. Bison consumption was suggested to be present based on these ratios. This is an important point as there is no evidence of bison consumption in southwest Arkansas, so if the skulls and mandibles represent bison consuming peoples, they would have to be from other locations (e.g. Southern Plains). However, dietary variability may be expected if the skull-and-mandible cemetery represents members of a dispersed Caddo community at the time maize was being adopted as a staple (Samuelsen 2016:132). The dietary evidence from C and N ratios is reevaluated in Chapter 4 to test if bison is the cause of these ratios or if maize and fish consumption is more likely. Importantly, different thresholds are used to include samples by using the C/N ratio contamination thresholds set by Ambrose (1990), but without the carbon percentage threshold proposed by Akridge (2014). These data are compared to C and N ratios from elsewhere in the Northern and Southern Caddo Areas to assess if the skulls and mandibles reflect the consumption of bison.

1.3.4 Geophysical Evidence of Settlement Patterns and Ceremonialism

In southwest Arkansas, the Woodland Fourche Maline tradition consisted of village settlements which changed into a more dispersed settlement pattern by Late Caddo times (A.D. 1500-1680). Precisely when, how, and why this change occurred has not been fully explored. Previous research suggested that it happened ca. A.D. 900 before the Early Caddo period (Jackson et al. 2012), but radiocarbon dates and geophysical research at the Crenshaw site (3MI6) have called this into question (Samuelsen 2009, 2010, 2014). If this change occurred alongside maize adoption in the Middle Caddo period, it would have major impacts on interpretations related to the Crenshaw skull-and-mandible cemetery. A change to a more dispersed settlement pattern ca. A.D. 1200-1250 could increase the need for this burial practice as moving large numbers of bodies to the site would not be possible. A larger-scale (~18 ha) geophysical survey was conducted over what was thought to be roughly half the site to test if additional structures existed and if they might be domestic or ceremonial in nature. Chapter 5 evaluates the geophysical evidence at Crenshaw and compares the possible structures identified to other previously excavated structures in the Caddo Area to attempt to identify domestic or ceremonial use areas at the site. They are also compared to provide a suggested time frame for these activities. This provides insight into both the level of ceremonial activity at the site and settlement pattering during the Early Caddo and Middle Caddo periods.

1.3.5 Reconsiderations of Biological Traits at the Crenshaw Site

Chapter 6 reconsiders some of the arguments made in Schambach et al. (2011) given the results of the preceding chapters. The interpretations related to biological traits previously used to suggest the skulls and mandibles represent foreigners are reevaluated. Some of these are compared to Caddo biological traits documented in the Little River region (around the Millwood Reservoir) human remains to help determine if such traits are truly inconsistent with Caddo populations. Finally, a redocumentation and reanalysis of some of the remains was performed to correct the record as to the presence or absence of some of the traits among the populations at Crenshaw.

1.3.6 Conclusion

Chapter 7 will conclude the study with a summary of the results. The results will be compared to the archaeological evidence of burial practices at Crenshaw and surrounding areas with a focus on the Millwood Reservoir area in the Little River region. Finally, an explanation for this burial practice will be outlined that is consistent with the evidence compiled from each of the preceding chapters.

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Chapter 2: Biologically Available Pb: A Method for Ancient Human Sourcing Using Pb Isotopes from Prehistoric Animal Tooth Enamel

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Abstract

This study analyzes Pb isotopes combining biological (ancient human and prehistoric animal teeth) and geological (soil leachate, whole rock, and rock leachate) samples to determine the origins of prehistoric skeletal elements. It exemplifies how the biologically available Pb method assesses the early lifetime locations of ancient human populations using prehistoric animal teeth and the multivariate/linear nature of Pb isotope data. Lead isotopes provide a valuable technique, in part due to the correlation between their six stable isotope ratios. Other studies have used Pb isotopes for similar purposes, but no clear method for determining a local range has yet been formally defined and tested. The biologically available Pb method uses many prehistoric animal tooth enamel samples to establish a baseline for local ratios in the region, then compares their ratios' linear patterning to human remains to test if they are non-local. The case study compares Pb isotopes from prehistoric animal teeth, human teeth, and whole rocks from southwest Arkansas. These results are compared to animal samples from Louisiana and Mississippi and human data from Illinois and New Mexico. Soil leachates, Pb concentrations of tooth enamel, and trace element analysis are used to assess contamination. Comparisons to *southwest Arkansas whole rock Pb isotope ratios suggest they are too variable to be used for direct comparison to ancient human remains, illustrating that prehistoric animal teeth are more appropriate for direct comparison to prehistoric human teeth. The biologically available Pb method provides a key analysis tool needed for studies of ancient human sourcing.*

Keywords: Pb; isotopes; sourcing; Sr; Caddo; warfare; contamination

2.1 Introduction

Many studies use strontium (Sr) isotope ratios to assess ancient human geographic origins by establishing a range of expected local ratios based on the content of archaeologically recovered animal tooth enamel. While this technique is effective in many places, it is clear that in some regions Sr isotope ratios are uniform across large areas. This is particularly true in the midcontinental US (Hedman et al. 2018). Having wide ranges of commonly represented ratios at the locality where human remains are found makes ancient human sourcing difficult, if not impossible, with this isotopic technique alone. Researchers have suggested that using multiple isotope ratios in combination, including Sr and lead (Pb), will lead to clearer results, allowing for better interpretations about human origins (Kamenov and Curtis 2017). Pb isotope analysis is commonly used in geologic studies (e.g. Crocetti et al. 1988; Goldhaber et al. 1995; Potra et al. 2018a, 2018b) and provides a multivariate isotopic dataset which (when combined with other elements like Sr) has the potential to be more sensitive to regional differences than Sr alone.

Pb isotope analysis has been relatively underutilized in studies of ancient human geographic origins in part due to the difficulty in getting sufficient concentrations of Pb from tooth enamel, complications associated with modern Pb pollution, and difficulty with some instrumentation (e.g. Gulson et al. 2018). Studies employing the technique for migration and sourcing studies have greatly increased in the last few years as methods and instrumentation for extraction and analysis improve (Dudás et al. 2016; Giovas et al. 2016; Grupe et al. 2018; Jones et al. 2017; Price et al. 2017; Sharpe et al. 2016; Turner et al. 2009; Valentine et al. 2008, 2015). Nonetheless, unlike the biologically available Sr method (Bentley 2006; Price et al. 2002), a method to use Pb isotopes for assessing ancient geographic origins has yet to be formally defined and demonstrated (Grupe et al. 2017). Studies often add this technique as part of a suite of elements included in multi-isotope migration and sourcing studies where little time or space is given to explicitly outlining and evaluating the effectiveness of methods used to construct Pb isotope backgrounds. This has led to the basic underpinnings of the methods generally being overlooked or assumed, in part due to its inferred similarity to the much better developed Sr isotope technique. However, some researchers have put great effort into developing the technique further (e.g. Dudás et al. 2016; Jones et al. 2017; Kamenov et al. 2018; Sharpe et al. 2016). This study aims to develop and evaluate the effectiveness of one method to establish a local background with Pb isotopes for the purpose of assessing if ancient human populations are local or non-local to a region.

First, this study outlines a clear biologically available Pb method of analysis for ancient human sourcing utilizing the multivariate and linear nature of Pb isotope data from prehistoric animal teeth. This method is demonstrated and evaluated for effectiveness through a case study of ancient human and non-migratory prehistoric animal remains from the southcentral US. Key elements of this analysis include contrasting linear differences between Pb isotope ratios from different regions and using animal samples from multiple sites as a baseline for comparison to incorporate isotopic variation within the regions being compared. Second, the Pb isotope ratios of human and animal teeth are compared to those of whole rocks, rock leachates, and soil leachates to assess the utility of prehistoric animal teeth and geologic samples, particularly whole rocks, for constructing backgrounds. Finally, the potential for evaluating contamination of tooth enamel using soil leachates, Pb concentrations of tooth enamel, and trace element analysis (Dudás et al. 2016; Kamenov et al. 2018) is discussed alongside an assessment of anthropogenic Pb contamination of the burial environment.

2.1.1 Pb/Sr Isotope Ratios and Geographic Origins

2.1.1.1 Isotopic Techniques

Sr isotope analysis is a technique commonly utilized in archaeology to determine whether people are local or non-local to a geographic area (Bentley 2006; Bentley and Knipper 2005; Bentley et al. 2004; Buzon and Simonetti 2013; Chenery et al. 2010; Eerkens et al. 2016; Hedman et al. 2009, 2018; Price et al. 1994; Price et al. 2002; Slater et al. 2014; Slovak and Paytan 2011; Thornton 2011). Pb isotope analysis is relatively underutilized but has great potential (Kamenov and Gulson 2014). Pb and Sr are trace elements found in soil, bedrock, water, plants, and animals. Plants absorb these elements from the local geology where they grow. People and animals, in turn, absorb Pb and Sr from the plants and animals they eat. Due to the mechanism of Sr absorption in the stomach, plants are the dominant source of Sr for herbivores and omnivores (Price et al. 1985). Lemons and Kennington (1983) have shown that Pb is even more severely discriminated against than Sr.

There are four naturally occurring Pb isotopes (^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb). The lightest of these, ^{204}Pb, is non-radiogenic while ^{206}Pb, ^{207}Pb, and ^{208}Pb are radiogenic and represent decay products of ^{238}U, ^{235}U, and ^{232}Th, respectively (Dickin 2005; Faure and Mensing 2004; Malainey 2011). Therefore, the radiogenic Pb isotopes are affected by the geologic age of bedrock. These isotopes increase in abundance relative to ^{204}Pb as the deposits age. Depending on the original concentrations of U, Th, and Pb in the local geology, they will have different abundances of radiogenic Pb isotopes, potentially leading to highly sensitive differences in Pb isotope ratios in different areas.

2.1.1.2 Pb Isotopes and Human Sourcing: Constructing a Local Range

Recent studies have shown that Pb isotopes are revolutionizing biological sourcing research since they result in a multi-dimensional dataset that allows for distinguishing different geographic regions (Kamenov and Curtis 2017; Kamenov and Gulson 2014). Despite the potential for environmental contaminants, Kamenov and Curtis (2017) show that Pb is extremely useful at delineating human remains from different regions, even among modern European populations, which is a strong endorsement of the technique.

Most studies combine Pb isotopes in multi-isotope evaluations of ancient human remains (e.g. Jones et al. 2017; Price et al. 2017; Turner et al 2009; Valentine et al. 2015). Some of these do not attempt to establish if the human remains are local or non-local to a region and instead focus on other questions. Those that do attempt to find non-locals each use a different method to construct an isotopic background and generally evaluate the remains by comparing to known local humans, a few animal samples, or geologic data (e.g. Jones et al. 2017; Sharpe et al. 2016; Valentine et al. 2015).

Direct measurements of soils, bedrock, and water provide an approximation of the isotopic ratios of the geologic source material. These can be highly variable. However, humans and animals amalgamate the Sr isotopes consumed as part of their diet, decreasing the range of local isotopic ratios compared to that of the source materials. Since human and animal isotopic ratios can be expected to be much more similar to each other than to rocks, it increases the value of human to animal comparisons. This has been well established for Sr and forms the basis of the biologically available Sr method (Bentley 2006; Price et al. 2002; Sillen et al. 1998; Slovak and

Paytan 2011). There is some disagreement on what samples are most appropriate for defining a local range (Grimstead et al. 2017). While some researchers concentrate on animal samples for defining Sr local ranges (Bentley 2006; Hedman et al. 2009, 2018; Price et al. 2002; Samuelsen 2016), others focus on geologic data or groundwater (e.g. Evans et al. 2010; Hodell et al. 2004).

It is unclear if the Pb isotopes behave similarly. There is a need for Pb isotope studies that combine ancient human tooth enamel, many samples of prehistoric animal tooth enamel, and geologic data from the same region to better understand how these different classes of data can be compared. Grupe et al. (2018) sampled many animal bones (not tooth enamel) and human remains but did not include a comparison to geologic data. Dudás et al. (2016:Figure 9a) showed that the geologic data in surrounding areas was much more variable than the ancient human tooth enamel, but did not include any prehistoric animals for comparison. Giovas et al. (2016) sampled geologic data and both modern and prehistoric animals. They noted great differences between geologic and animal data and suggested that the animal teeth may have been contaminated by anthropogenic Pb. However, they did not include any human remains and most problematic animals were modern samples, which would be more likely to be impacted by anthropogenic Pb. Sharpe et al. (2016), similarly to Hodell et al. (2004) with Sr, constructed a Pb baseline using mostly whole rocks with a few soil, plant, and rock leachate samples, but did not test the baseline with ancient human remains to evaluate its effectiveness. This study attempts to build on this research by combining Pb isotope data from ancient human teeth, prehistoric animal teeth, soil leachates, whole rocks, and rock leachates from a single region to determine the origins of prehistoric skeletal elements. Sampling for constructing a background focuses on prehistoric animal teeth and whole rocks, with limited comparisons to ancient human teeth, soil leachates, and rock leachates.

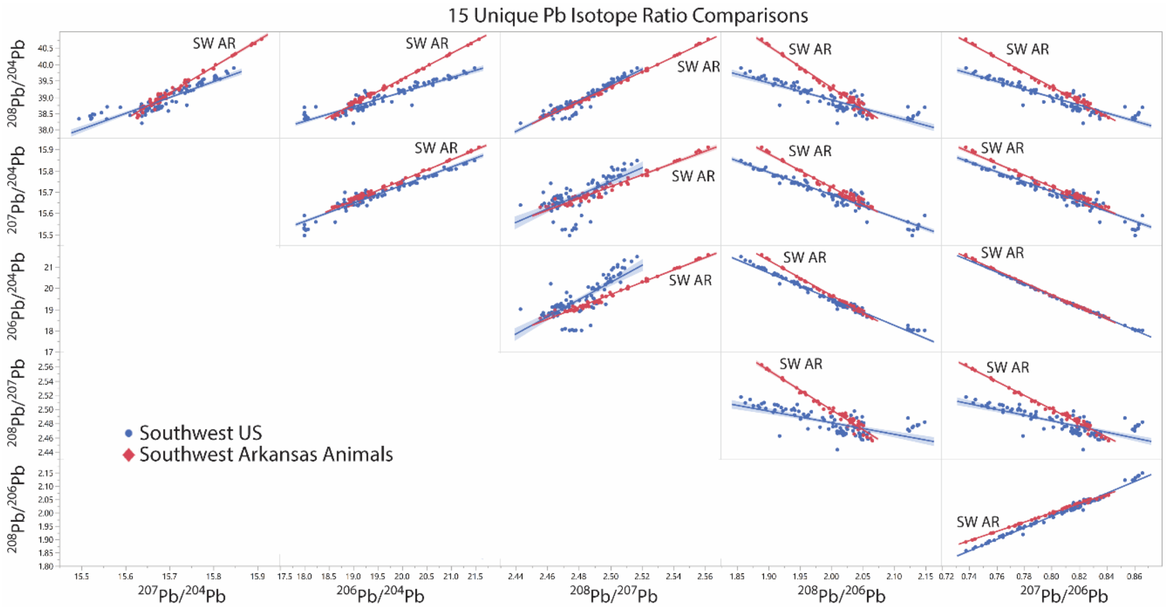

Figure 2.1 – The 15 possible unique comparisons of different Pb isotope ratios utilizing animal data from southwest Arkansas and human data from northwest New Mexico (Dudás et al. 2016; Price et al. 2017). The Pb isotope ratios of humans must match those of animals in all 15 comparisons in order to be considered local. If they overlap in 14 but are different in one bivariate diagram, they are considered non-local. The slopes of the regression lines are clearly different in many comparisons, identifying that the humans from New Mexico are non-local to southwest Arkansas.

This study examines whether the biologically available Sr method similarly applies to Pb isotope studies. This is accomplished by obtaining many prehistoric (non-migratory) animal tooth enamel samples from a region and comparing them to ancient human remains to determine if (1) the Pb signatures of animals match those of expected local human remains, (2) the resulting Pb isotope ratios of animals are capable of differentiating humans from other regions, and (3) the use of animals for establishing a local background is more effective than using only expected local human remains. Rather than defining a local range with a formula like +/- two times the standard deviation of the mean, the biologically available Pb method (as defined here) relies heavily on the differentially linear (correlative) and multivariate nature of Pb isotopes to differentiate regions. It is recommended that all six unique ratios be analyzed for linear patterning ($^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{206}Pb/^{204}Pb$, $^{208}Pb/^{206}Pb$, $^{207}Pb/^{206}Pb$, and $^{208}Pb/^{207}Pb$), which generates 15 unique bivariate comparisons (Figure 2.1). Data with linear patterns yielding different slopes may be generated by regional variability, multiple end-members, or "pseudo-isochron" dynamics (Jones et al. 2017). There is also a possibility that linear patterning could be created through in-vivo signatures getting mixed with contaminants, such as anthropogenic Pb. Regardless of the individual causes for these linear patterns defined by the Pb isotope data (assuming it is not contamination), the linear regression lines of various groups reflect the Pb signatures of the region and can therefore be used as a fingerprint to assess origins using bivariate comparisons (or multivariate comparisons, such as a principal component analysis). Thus, even if the isotopic signature of some individuals within a specific group overlap in more than one region, the slope of the regression line combined with all the isotopic values in that specific group can aid in distinguishing it from the isotopic signature of another region. It is suggested that multiple sites within a study area be sampled with multiple animal samples from each site to account for potential intra-site and inter-site variation in Pb isotopes. Once the isotopic signature of an area is defined, the human remains can be confidently compared with the background value of that area. The humans whose isotopic ratios do not match the background value should be considered non-local.

In order for human and animal teeth to be compared, differences in how they incorporate Pb need to be considered. Studies have shown that modern animals can ingest significant amounts of soil (and soil Pb), but these studies generally concentrate on modern, anthropogenic Pb contaminated environments (e.g. Johnsen and Aaneby 2019; Johnsen et al. 2019; Thornton and Abrahams 1983). In environments with heavily contaminated soils, as much as 97% of the absorbed Pb can be due to soil ingestion (Abrahams and Steigmajer 2003); however, as much as 60% can still be attributed to plant consumption in lesser contaminated environments (Thornton and Abrahams 1983). These studies also tend to investigate pasture animals that are restricted in location and feed in areas with short grass, potentially increasing root and soil ingestion. Durkalec et al. (2015) found that wild deer and bore absorbed significantly less Pb in a modern, uncontaminated environment. This is particularly important when estimating the relative contributions of plant and soil Pb as Yan et al. (2012) showed that plants may absorb less Pb relative to soil Pb as soil Pb concentrations increase. Their findings are consistent with plant Pb absorption from nutrient solutions which show that plant Pb concentrations can scale well below a 1:1 rate with increasing soil Pb concentrations (Kabata-Pendias 2011:Figure 19.4). This suggests that plant Pb could contribute significantly more Pb to animals relative to soil Pb in uncontaminated environments.

Two factors, (1) modern anthropogenic Pb contamination of soils and (2) restricted grazing areas, do not apply to prehistoric animal populations in the US. Since these factors did not affect prehistoric animals, it is likely that plants provided more Pb to their diet. Even if animals were consuming significant amounts of soil with their plants, the soil and plant isotopic ratios would have been similar (soil and dust are the major sources for plant Pb [Chenery et al. 2012]). Therefore, soil ingestion should not greatly impact the comparisons between Pb isotopes in prehistoric human and animal tooth enamel but could influence trace element concentrations. Inhalation of dust (not affected by anthropogenic Pb prehistorically) would have affected both humans and animals and therefore should not be a significant factor in comparisons.

2.1.1.3 Contamination

There is typically very little Pb in tooth enamel compared to Sr and therefore contamination of Pb in tooth enamel is of greater concern. Care has to be taken to sample only those materials which are least affected by this contamination (Dudás et al. 2016; Giovas et al.

2016; Kamenov 2008; Kamenov et al. 2018). Tooth enamel is generally used for Pb and Sr isotope analyses and has been shown to be more resistant to contamination compared to bone (at least with Sr). The isotopic signatures absorbed during tooth formation are locked into the enamel, making it particularly useful in sourcing studies (Bentley 2006; Turner et al. 2009).

There are two major considerations related to contamination that are particularly important for Pb isotope studies. First, the burial environment may be contaminated with modern, anthropogenic Pb. Tooth enamel has the potential to be contaminated by this anthropogenic Pb, but for this to be the case, the burial environment (i.e. soil) itself must be contaminated. If the burial environment can be shown to be mostly free of such anthropogenic Pb contamination, then the effect of this contamination on the teeth can be ruled out as a significant factor. Second, the teeth may be contaminated by soil whether anthropogenic Pb is a factor or not.

This study uses soil leachates (water and weak-acid leaching) and trace element analysis of soils to assess if the burial environment has been contaminated by anthropogenic Pb. This includes a trace element analysis of Pb, Cu, and Zn concentrations and comparisons to contaminated and uncontaminated locations in northern Arkansas. Soil contamination of tooth enamel is assessed using three methods. (1) Pb isotope ratios of soil leachates and teeth are compared to each other. Differences in their isotopic signature would suggest the teeth were not overwhelmed with soil Pb. (2) Pb concentration thresholds outlined by Dudás et al. (2016) are used to assess contamination of human teeth. (3) Duplicate tooth samples are assessed for contamination using trace elements based on Kamenov et al.'s (2018) study. The results of these three methods are compared to assess the effectiveness of the methods.

2.1.2 The Case Study

2.1.2.1 The Crenshaw Skull-and-Mandible Cemetery

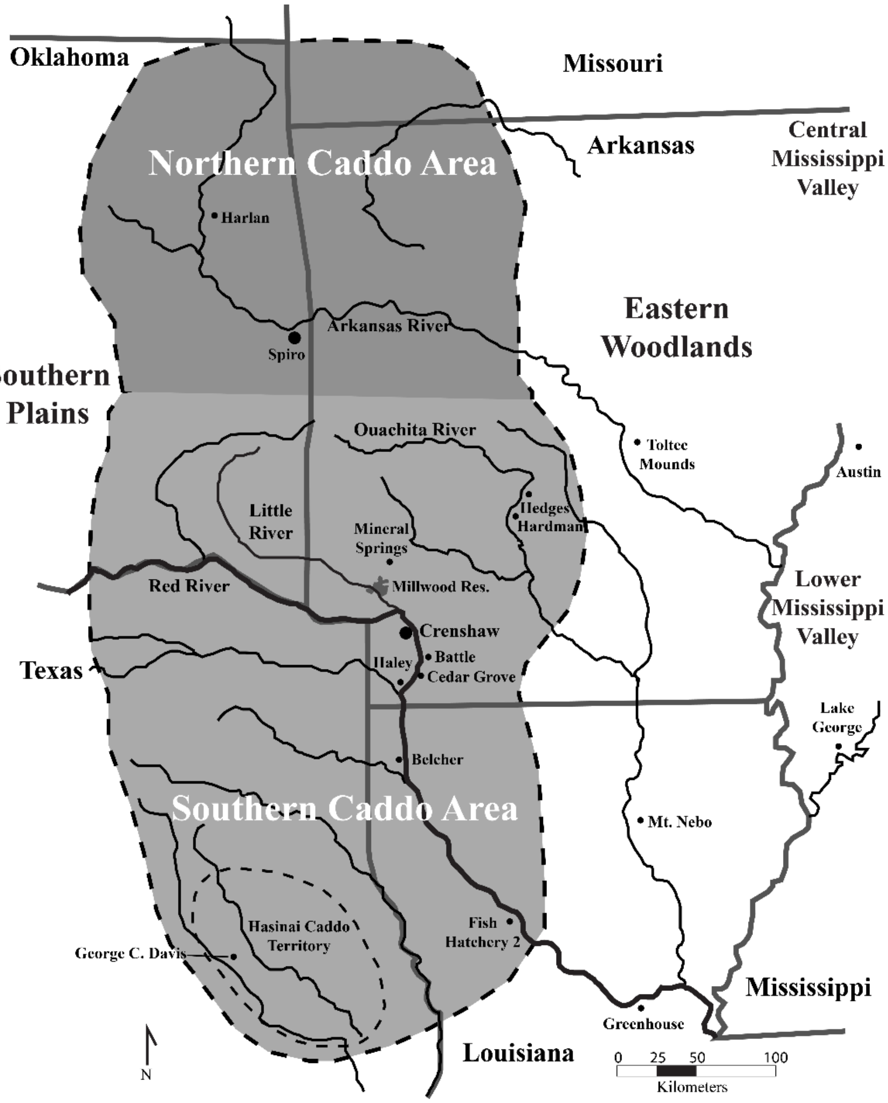

Figure 2.2 – Map of Crenshaw (southwest Arkansas) within the Caddo Area on the border between the Southern Plains and the Eastern Woodlands. The Caddo Area is considered to be part of the Eastern Woodlands. Sites sampled also include Hardman, Hedges, Austin (northwest Mississippi) and Fish Hatchery 2 (northwest Louisiana). The geology around both is made up of Quaternary alluvium. Austin is in a very large area defined by this alluvium while there are nearby Tertiary deposits around Fish Hatchery 2.

The Crenshaw site (3MI6) is centrally located in the Southern Caddo Area (Figure 2.2). It is a multiple-mound, Caddo ceremonial center (Samuelsen 2014). Caddo archaeologists

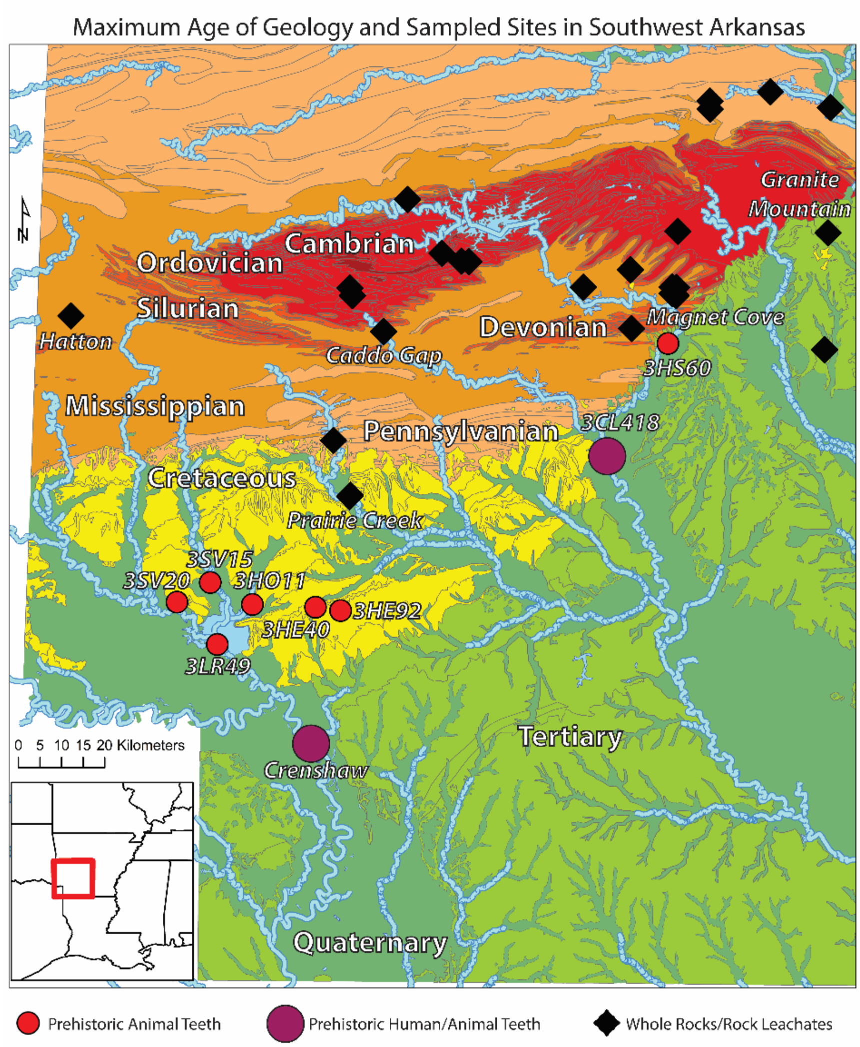

Figure 2.1 – Maximum age of geology in southwest Arkansas. Sampled locations and previously published data are identified. Animal teeth (red dots) were selected from sites in several counties in southwest Arkansas. Soil samples were selected from Crenshaw and human samples were selected from Crenshaw and Hardman (purple dots). New whole rock data (black diamonds) are from Magnet Cove and Granite Mountain while previously published whole rock and rock leachate data (black diamonds) are from Cains (2019), Duke et al. (2014), and Simbo et al. (2019).

recognize its importance in the region due its clear ritual importance to the prehistoric Caddo (Hoffman 1970, 1971; Schambach and Early 1982). Crenshaw is located on Quaternary deposits in the West Gulf Coastal Plain and is surrounded by Tertiary and Cretaceous deposits in the uplands (Figure 2.3). Further to the north, the Ouachita Mountains consist of bedrock of varying ages, from Mississippian to Pre-Cambrian. The streams and rivers that lead to Crenshaw are sourced from these mountains and therefore their weathered and redeposited sediments help make up the Quaternary landscape around Crenshaw and other sites in the Red River and Little River drainages.

Crenshaw was used as a cemetery between at least A.D. 900 and 1400 based on burial artifacts and radiocarbon dates (Durham and Davis 1975; Moore 1912; Samuelsen 2014; Weinstein et al. 2003; Wood 1963). Geophysical investigations have uncovered evidence of occupation areas, although the timing is unclear (Samuelsen 2010). Clarence B. Moore's (1912) survey of the site revealed there were at least six mounds (A through F). Mound C was destroyed by collectors in 1961, but a salvage excavation of the mound was executed by the University of Arkansas Museum which resulted in the preservation of some material and information from the mound (Durham and Davis 1975; Wood 1963). Burials were excavated from Mound F by landowners and Arkansas Archaeological Survey (ARAS) staff in 1968 (Samuelsen 2009; Schambach 1982).

In 1983, Frank Schambach and volunteers salvaged human skulls and mandibles deposited in clusters on the southern portion of the site representing 344 individuals (Zabecki 2011). These areas are referred to as the West Skull Area (WSA) and North Skull Area (NSA). Other clusters of skulls were occasionally uncovered southwest of Mound C by relic hunters. The Rayburn Skull Cluster, consisting of eight skulls, was excavated by Schambach from this area in 1968. Clusters had various numbers of individuals represented. Some consisted of a single person, others had a few skulls and a mandible included, while others consisted of as many as a hundred mandibles (Zabecki 2011). Accelerator mass spectrometry dating shows they were deposited over time between A.D. 1253 and 1399, indicating that this was not a single event, such as a large local massacre (Samuelsen 2014). They are unlikely to represent victims of local warfare. The prevalence of local warfare suggested by a deposit of such size would be expected to have major impacts in the rest of the cultural system (e.g. fortification/nucleation). This does not occur in Late Prehistoric southwest Arkansas and neither does any strong evidence of violent trauma (Samuelsen 2016). One potential exception is evident in the Ouachita region of southwest Arkansas, also culturally affiliated with the Caddo. Three burials were excavated at the Hardman site (3CL418) that consisted of articulated skeletons without skulls (Early 1993). Upside-down bowls were placed over their missing heads. Most studies on the topic suggest the skulls and mandibles at Crenshaw are victims of warfare from other regions (Akridge 2014; Brookes 1999; Burnett 2010; Powell 1977; Schambach 2014; Schambach et al. 2011; Zabecki 2011).

2.1.2.2 Limitations of Sr and the Need for Pb Isotope Studies

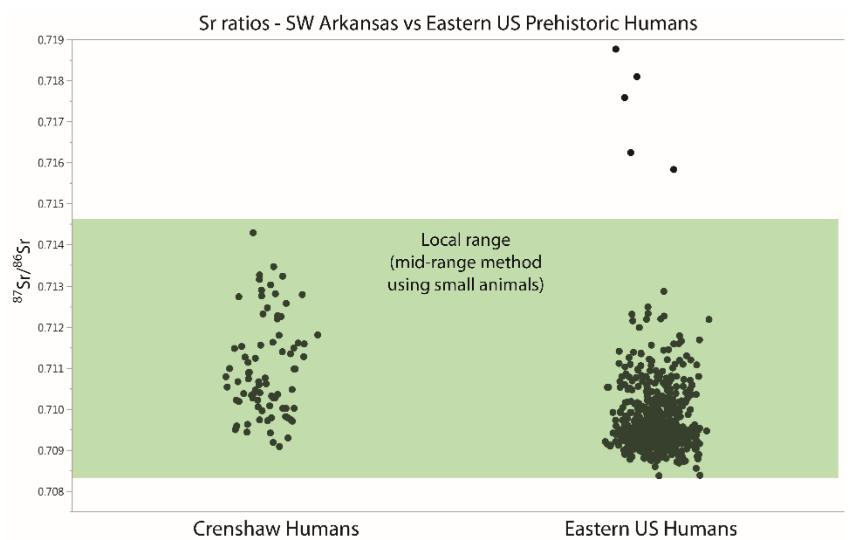

Figure 2.4 – Comparison of Sr isotopes of humans from Crenshaw and ancient humans from the Eastern US. All but five out of 670 prehistoric human teeth tested for Sr ratios in the eastern US would be considered "local" to southwest Arkansas. The data from other regions look similar to Crenshaw humans, but they are more skewed towards lower ratios (Beehr 2011; Hedman et al. 2018; Jones et al. 2017; Price et al. 2007; Samuelsen 2016; Slater et al. 2014). The five non-local teeth (representing three individuals) from the American Bottom are also non-local to the American Bottom. Available Sr ratios in the eastern US appear similar to southwest Arkansas (see also, Hedman et al. 2009).

Only one study (Samuelsen 2016) has suggested that the human skulls and mandibles found at Crenshaw were locals buried in accordance with local cultural traditions. Samuelsen (2016) reanalyzed the Sr isotope ratios of samples taken from the skulls and mandibles and concluded they were most likely local since they matched the local isotopic signature defined by the animal remains. However, key weaknesses highlight the need for additional data. The success of Sr studies relies on a small range of Sr isotope ratios at the locality where the remains were buried and different ratios in other areas (e.g. Eerkens et al. 2016). The skulls and mandibles match the local Sr range, but the ancient human Sr data from the rest of the eastern US is too similar to distinguish people from other regions based solely on Sr isotopes (Figure 2.4). Recently published Sr isotope data on animal teeth from the midcontinent confirm the similarity (Hedman et al. 2018). This greatly weakens the ability to draw conclusions based on Samuelsen's (2016) analysis since it would suggest that even if the remains came from elsewhere, they would also likely match the local Sr isotope signature.

Kamenov and Curtis (2017) note the same concern with using Sr isotopes alone, namely that they can be similar in many different regions. They state that combining them with Pb isotopes can solve this problem since different regions yield different Pb isotope ratios that can be used to differentiate between groups of people. In order to achieve this, a clear method for analyzing Pb isotopes from human remains to evaluate if they are local or non-local must be defined and demonstrated. The current study accomplishes this by comparing Pb isotope ratios from 22 distinct human teeth from Crenshaw and Hardman to 80 animal teeth from southwest Arkansas, Louisiana, and Mississippi. Published data from the Elizabeth site in west Illinois and the vicinity of Pueblo Bonito in northwest New Mexico also allowed for human to human comparisons (Dudás et al. 2016; Jones et al. 2017; Price et al. 2017). These published results are compared to illustrate the utility of the method, although are not considered a possible area of origin for the skulls and mandibles. Hedman et al. (2018), however, studied migration in the midcontinent and noted similarities in Sr isotope ratios in west Illinois (American Bottom) humans and southwest Arkansas animals, potentially indicating migration between these areas. Comparing Pb isotopes of individuals from west Illinois and Mounds C and F at Crenshaw will evaluate the possibility of migration to southwest Arkansas from west Illinois. The geologic setting in west Illinois (mostly Paleozoic) and northwest New Mexico (mixture of Cretaceous and Lower Tertiary) are quite different from southwest Arkansas. The current teeth data are also compared to current Pb isotope data from 18 whole rock and 26 soil leachate samples, and to published whole rock (n=46) and rock leachate (n=9) data from southwest Arkansas (Cains 2019; Duke et al. 2014; Simbo et al. 2019).

2.2 Materials and Methods

2.2.1 Sample Selection

Human teeth were selected from articulated and bundle burials from Mounds C (n=7) and F (n=6) at Crenshaw to serve as a local comparison (Appendix T1). The Rayburn Skull Cluster (n=5) was selected as a potential non-local group. These represent 5 skulls from an 8-skull cluster which are part of 352 excavated skulls and mandibles from the site. Second molars were used for most samples to assess their location of geographic origin during early childhood. Two samples required the use of first molars, more closely assessing their location during infancy, and one sample required the use of a third molar, assessing their location during late adolescence (Buikstra and Ubelaker 1994:47, Figure 24). Animal teeth from Mound F and near an ash bed structure on the south edge of the site (n=12) were sampled to provide a set of Pb isotope ratios from the site (Appendix T2). Other local animal samples (n=44) were selected from six sites in southwest Arkansas, north of Crenshaw: Martin Farm, Tom Jones, Bell, Millwood Site #35, Old Martin, and Graves Chapel. Human teeth (n=4) were selected from Hardman in the Ouachita region to test if the skulls could relate to headless burials from this adjacent region (would still be considered Caddo) while comparative animal teeth (n=8) were selected from both Hardman and Hedges (3HS60). In addition to published data from other regions (Jones et al. 2017; Price et al. 2017), animal teeth from the Fish Hatchery 2 site in northwest Louisiana (n=8) and the Austin site in northwest Mississippi (n=8) were selected (Figure 2.5). Both sites are situated in Quaternary alluvial deposits near major rivers. Austin was sampled because it has evidence of prehistoric violence, and headless burials recovered from the nearby Bonds site have been interpreted to be possible victims of raiding parties from Crenshaw (Brookes 1999). All animal samples were taken from prehistoric contexts and were non-migratory animal specimens. Soil

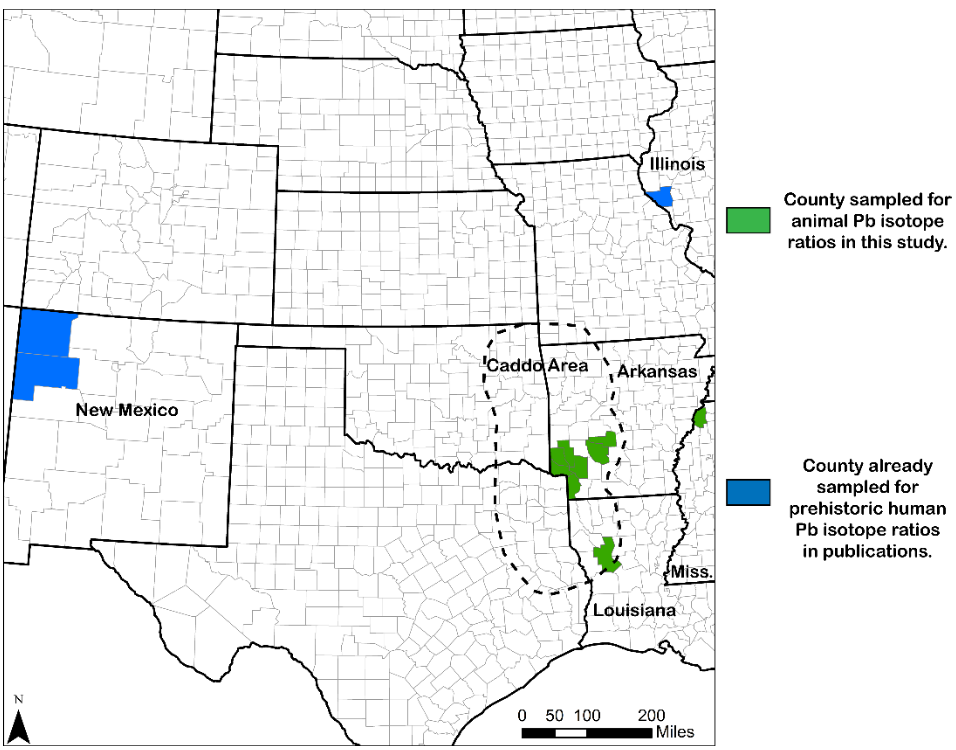

Figure 2.2 – Map showing counties sampled for Pb isotope analysis in this study and counties sampled for prehistoric human Pb isotope ratios in previous studies (Dudás et al. 2016; Jones et al. 2017; Price et al. 2017).

leachate samples (n=26) were taken from soil cores and from previous excavations at Crenshaw (Appendix T3). Igneous whole rock samples of syenites and carbonatites (n=18) were collected from two sources in central-southwest Arkansas (Appendix T4), Granite Mountain and Magnet Cove (in the immediate vicinity of Hedges). The published literature on whole rock and rock leachates from southwest Arkansas includes a variety of other locations, including Prairie Creek, which is nearest to the sites where most of the local animals were sampled (see Figure 2.3).

2.2.2 Lab Methods

2.2.2.1 Tooth Drilling and Pre-treatment

Methods for processing tooth samples generally followed El Mugammar (2014), Slater et al. (2014), and Turner et al. (2009) for strontium and lead on enamel. Each tooth was cleaned through sonication in ultra-pure water for 30 minutes and dried overnight. A microscope was used to allow for high accuracy drilling of the teeth and removal of dentin from enamel. The surface of the enamel was abraded with a drill bit to clean and remove any potential contaminants. A diamond wheel bit was used to cut approximately 50mg of enamel from each tooth. Small animal teeth often did not have 50mg of enamel present, so amounts closer to 20mg were used for these samples. Given the potential for dentin to be contaminated, it was clearly removed from all human and deer samples. While every effort was made to remove dentin from all samples, some samples of small animal teeth may have included very small portions of dentin with the enamel due to the need to maximize enamel recovery. To remove any additional contamination, the enamel was then sonicated for 60 minutes in ultra-pure water, sonicated for 30 minutes in 0.1M (all humans and animals AN57 B-AN156) or 1M (animals AN1-AN56) high-purity acetic acid, sonicated in fresh acetic acid a second time for 5 minutes, and rinsed to a neutral pH with ultra-pure water.

2.2.2.2 Soil Leaching

Soil leachates were processed following Potra et al. (2018b) and Church et al. (1994). The soil samples were placed in acid-leached polypropylene cups. Some samples had dried out and formed large chunks. About 5g of each sample was placed in an agate mortar. The soil samples were broken up with an agate pestle until they no longer formed large (>2mm) chunks. About 4g of each sample was placed in an acid-leached Teflon beaker along with 20ml of ultra-pure water, shaken, and left to settle for 24 hours. Any organic material or clear portions of water were removed from the surface with a pipette and the remaining portion was dried down on a hot plate at 80°C. The samples were then leached in 15ml of 2N HCL in a Dubnoff metabolic shaking incubator at 55°C for 2 hours. The leachate was then pipetted into acid-leached 15ml centrifuge tubes and centrifuged for 30 minutes. A 0.25ml portion of the leachate was removed for trace element analysis. A 5ml portion of the leachate was taken from each sample for isotope analysis. This was dried down and digested in 1N HBr three times. The final digestion consisted of 4ml of 1N HBr. It was then centrifuged for 10 minutes at 3900 rpm to consolidate any undigested organic material. The top 3ml of 1N HBr was removed for isotope analysis. Processing water soil leachates followed a similar procedure: 2g of sample was used, no water rinse and dry down was executed, 10ml of ultra-pure water was added instead of 15ml of 2N HCl, and a 7ml portion of the leachate was used for Pb isotope analysis. Methods for processing the whole rocks are as presented in Simbo et al. (2019).

2.2.2.3 Column Chemistry for Teeth and Soil Leachates

Column chemistry (ion chromatography) was executed in a class 100 clean room at the University of Arkansas Radiogenic Isotope Laboratory. The samples were digested in 1M HBr in acid-cleaned Teflon beakers. The columns, containing 0.1ml of Dowex 1X-8 Pb resin, were cleaned with 2ml of 0.5N HNO_3, followed by 2ml of ultra-pure water. The columns were then conditioned with 2ml of 6N HCl. Each enamel sample was loaded and then the columns were washed three times with 1ml of 1N HBr. The Pb fraction from the sample was then eluted into a Teflon beaker using 1-2ml of 20% HNO_3 and subsequently dried down on a hot plate inside a class 10 laminar flow hood. The loaded sample and wash from the Pb column processing were collected in a separate Teflon beaker. Column separation methods for whole rocks are as presented in Simbo et al. (2019) and followed Pin et al. (2014).

2.2.2.4 Pb Isotope Ratios and Concentration Analyses

The Pb fraction was analyzed on a Nu Plasma multi-collector inductively-coupled plasma mass spectrometer (MC-ICP-MS) using a desolvating system at the University of Arkansas' Trace Element and Radiogenic Isotope Laboratory (TRAIL). The dried down Pb samples were redissolved in 2% HNO_3 spiked with a thallium (Tl) standard created just before analysis, following the procedures outlined by Kamenov et al. (2004). The Pb isotopes were corrected to NBS 981 Pb standard values ($^{208}Pb/^{204}Pb$ = 36.7006, $^{207}Pb/^{204}Pb$ = 15.4891, $^{206}Pb/^{204}Pb$ = 16.9356) based on Todt et al. (1996) using a time-based bracketing method. A standard was run after every fourth sample. All standard and sample Pb data were normalized to $^{205}Tl/^{203}Tl = 2.38750$ (Kamenov et al. 2004). The standards (190) were run from August 2016 to November 2019 ($^{208}Pb/^{204}Pb = 36.675\pm0.006\ 2\sigma$, $^{207}Pb/^{204}Pb = 15.484\pm0.002\ 2\sigma$, $^{206}Pb/^{204}Pb = 16.931\pm0.002\ 2\sigma$). Average 2σ standard error for standards was low ($^{208}Pb/^{204}Pb$ = 0.002, $^{207}Pb/^{204}Pb$ = 0.001, $^{206}Pb/^{204}Pb$ = 0.001). Given the small amount of Pb in many teeth, aiming to a consistent concentration in solution for all samples is generally not possible. Sensitivity on ^{204}Pb for the 80ppb Pb standard and higher concentration samples was about 0.24v. Lower Pb standard concentration (35ppb) was used for some teeth samples with lower Pb concentrations.

Samples with the lowest concentrations were analyzed using the time-resolved analysis method which followed the procedure outlined by Valentine et al. (2008) and Kamenov et al. (2006). Blank Pb concentration levels were less than 1‰ of all human, soil, and whole rock samples. Blank levels exceeded 1‰ when compared to some animal samples with low concentrations (see Appendix T2). Pb concentrations were similarly measured on the MC-ICP-MS and normalized to the Pb standard concentrations, which were independently verified on a Thermo Scientific iCAP Q ICP-MS. Pb concentrations for teeth are based on the post-column Pb fraction. However, it should be noted that several procedures can affect these concentrations, including drilling technique, acid pre-treatment, and column yield if using the post-column fraction.

Trace element analysis of teeth (taken from the digested portion prior to column chemistry), following Kamenov et al. (2018), and soil leachates (Pb, Cu, and Zn) were carried out on the iCAP Q ICP-MS and corrected to multiple concentrations of elemental standard ICP-MS-68A. Duplicates of soil leachates were run from SO1 and SO20 (noted as "Dup"). SO1 and SO1 Dup were not homogenized before sampling (taken from two soil chunks from the same depth) to provide a measure of differences between samples at the same depth. SO20 and SO20 Dup were homogenized as soil dust prior to sampling to provide a measure of analytical procedure accuracy. Differences between SO20 and SO20 Dup were within 2SD of the standard error in all Pb isotopes. In terms of trace element concentrations, SO20 recorded 12%, 13%, and 15% higher Pb, Cu, and Zn values compared to SO20 Dup. Small differences in Pb isotope ratios between SO1 and SO1 Dup can be explained by the heterogeneity of the samples. Differences between SO1 and SO1 Dup in Pb, Cu, and Zn concentrations (13%, 18%, and 26%, respectively, higher in SO1) were similar to SO20 and SO20 Dup. This reflects strong consistency in analytical procedures for isotopes, but some variability in concentrations from leachates.

While variability in results can be introduced by the drilling technique and acid pre-treatment of tooth enamel, considerable intra-tooth differences in isotope ratios can also be due to teeth being formed over years and reflecting variable food sources (Buikstra and Ubelaker 1994; Lugli et al. 2017; Müller and Anczkiewicz 2015; Willmes et al. 2016). Teeth analyzed in this study (processed as tooth enamel chunks, not powder) cannot be homogenized until just before column separation. Therefore, intra-tooth differences can make duplicates (separate enamel chunks) more a measure of intra-tooth variability than a measure of analytical procedure accuracy. Since SO20 and SO20 Dup were homogenized and processed exactly the same as teeth during and after column separation, they provide a means of testing that portion of the analytical procedure. Four duplicate tooth samples were analyzed to ensure that intra-tooth differences (or potentially analytical issues) would not affect interpretations (Appendix T5).

2.3 Results and Discussion

2.3.1 Assessment of Contamination

2.3.1.1 Assessment of Anthropogenic Pb in the Burial Environment (i.e. Soil)

There are several lines of evidence that suggest the burial environment at Crenshaw has not been contaminated with anthropogenic Pb. This should not be surprising as Crenshaw is located in a remote environment, far from any major roads, mines, or industry. First, previous studies have shown that anthropogenic Pb generally remains in the topsoil and is relatively immobile in soil (Clemens 2013; Kede et al. 2014). Kamenov et al. (2009) tested soil at multiple depths and detected evidence of anthropogenic Pb contamination by illustrating different isotopic signatures and higher concentrations closer to the surface. At Crenshaw, soil samples from multiple depths within the same cores were tested at multiple locations (Appendix T3). The samples 25cm below the surface and deeper did not display evidence of consistently elevated Pb isotope ratios, as shown in Kamenov et al. (2009), suggesting anthropogenic Pb is not a significant factor.

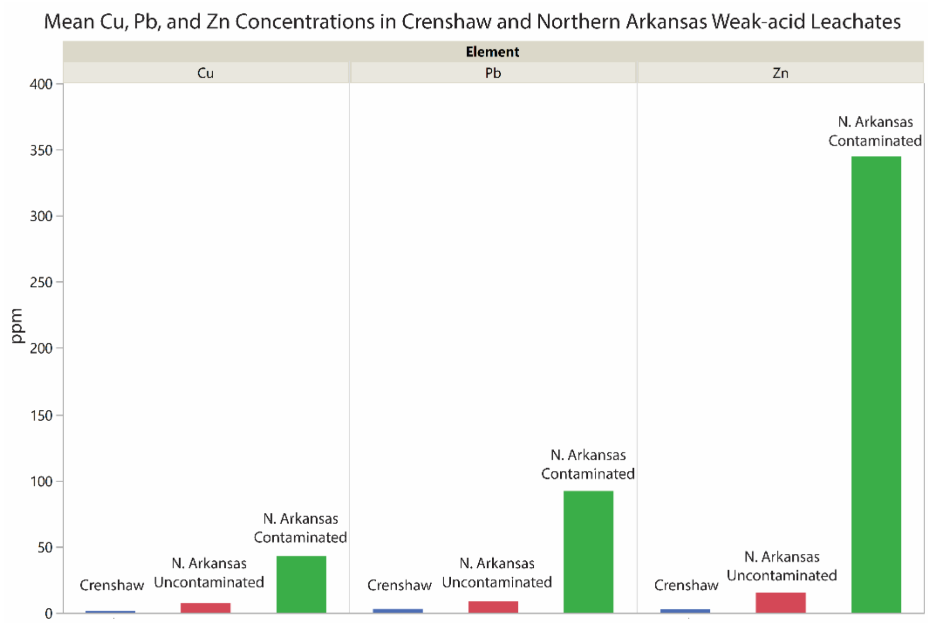

Figure 2.6 – Mean Cu, Pb, and Zn concentrations in weak-acid leachates from Crenshaw and northern Arkansas (Potra et al. 2018b). The mean from northern Arkansas uncontaminated sites included all sites upstream of mines that were interpreted to not be impacted by anthropogenic Pb contamination by Potra et al. (2018b) while the mean from northern Arkansas contaminated sites include all locations downstream from mines. The results clearly show that Crenshaw has lower concentrations than both the contaminated and uncontaminated sites in northern Arkansas, supporting the lack of significant anthropogenic Pb contamination.

Second, Pb, Cu, and Zn concentrations of soil leachates are far below what would be expected of environments contaminated with anthropogenic Pb (Figure 2.6). Soil leachates within Pb contaminated environments in northern Arkansas (Potra et al. 2018b) averaged 92.0ppm Pb, 42.7ppm Cu, and 344.9ppm Zn. By contrast, soil leachates at Crenshaw averaged 2.9ppm Pb, 1.4ppm Cu, and 2.5ppm Zn. Pb, Cu, and Zn concentrations at Crenshaw are 32, 30, and 137 times lower, respectively, than the contaminated environments of northern Arkansas. The average Pb, Cu, and Zn concentrations at Crenshaw are also lower than all uncontaminated sites in northern Arkansas. This indicates that Crenshaw is a relatively uncontaminated environment.

Third, there was a possibility that higher isotope ratios in the soil could be explained by anthropogenic Pb; however, Pb isotope signatures of water and weak-acid soil leachate samples contradict this (Appendix T3). The results of SO10 (B) and SO20 (B) show that the weak-acid leachates have slightly higher Pb isotope ratios than the water leachates. If anthropogenic Pb with elevated isotope ratios were impacting the soil, the higher ratios should have been reflected in the water leachates as these would reflect the more labile surface contaminant. Instead, the weak-acid leachates recorded higher ratios, indicating that the soil contains the higher ratio Pb and that anthropogenic Pb is not a contaminant source.

Fourth, along similar lines, whole rocks in southwest Arkansas also have both low and high Pb isotope ratios. Whole rock data (Cains 2019; Duke et al. 2014; Simbo et al. 2019) illustrate that both low and high ratios are entirely consistent with naturally occurring ratios in southwest Arkansas. Therefore, there is no need to explain high isotope ratios at Crenshaw or elsewhere in southwest Arkansas by citing foreign materials.

Fifth, it is unlikely that high ratios reflected in the human remains in Mounds C and F are due to anthropogenic Pb because of their burial depth. As mentioned earlier, anthropogenic Pb tends to be constrained close to the surface of the soil (Clemens 2013). Many of the burials tested in Mounds C and F were buried several meters below the surface (in mounds) while the Rayburn Cluster, with lower Pb isotope ratios, was buried relatively close to the surface (but below the topsoil). This is the opposite of what would be expected if high-ratio anthropogenic Pb were affecting the soil and, therefore, the teeth.

Establishing the lack of significant anthropogenic Pb contamination is extremely important as it indicates that the linear patterning in the current results is not due to a local ratio range being stretched by a contaminant. The evidence overwhelmingly indicates that anthropogenic Pb is not the cause of the linear patterning in the data and validates the linear method of analysis used in this study.

2.3.1.2 Assessment of Soil Contamination of Human Tooth Enamel

Soil contamination of human tooth enamel is assessed using three methods: (1) comparisons to Pb isotope ratios of soil leachates, (2) tooth enamel Pb concentrations, and (3) trace element analysis. First, Pb isotope data from weak-acid soil leachates and Pb concentrations from human tooth enamel were analyzed to assess contamination (Figures 2.7, 2.8). Figures 2.7b and 2.8 show that there are differences between the Pb isotope ratios of the soil and those of the human and animal teeth at Crenshaw. The linear pattern defined by the soil

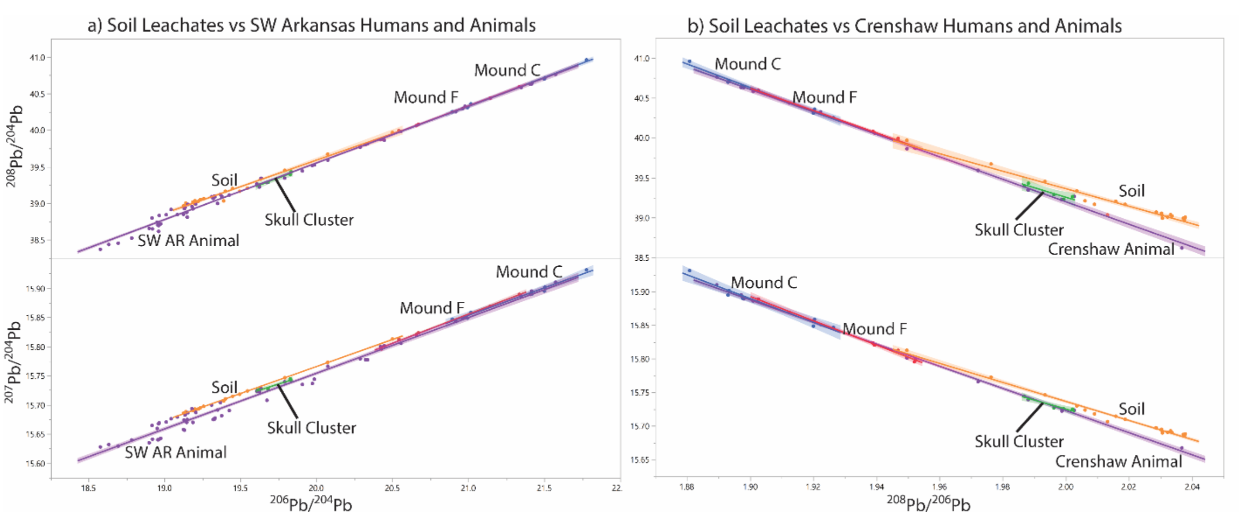

Figure 2.3 – Bivariate Pb isotope diagrams comparing weak-acid soil leachate data to human and animal data. a) Comparison of the weak-acid soil leachates to all southwest Arkansas humans/animals shows they are much more consistent with the humans/animals than other geologic data (i.e. whole rocks and rock leachates). b) Comparison of the weak-acid soil leachates to only Crenshaw humans/animals shows that they have similar Pb isotope ratios, but that there is a clear difference between the soil and the human and animal tooth enamel. The teeth with lower ratios have a different linear pattern than the soil. The soil samples do not have $^{208}Pb/^{204}Pb$ ratios higher than 40 while many teeth do have higher ratios. The tooth samples generally do not match the soil, suggesting they are not being replaced by soil contaminated Pb.

is different from that defined by the Crenshaw humans and animals (Figure 2.8). There are three exceptions to this trend, with samples HU5, HU6, and HU13 better matching the linear pattern of the soil. These samples include the highest Pb concentration in Mound C (HU6) and the second highest concentration in Mound F (HU13). This suggests that if soil contamination of the tooth enamel is present, it does not significantly affect most of the samples as they still display different Pb isotope signatures from the soil.

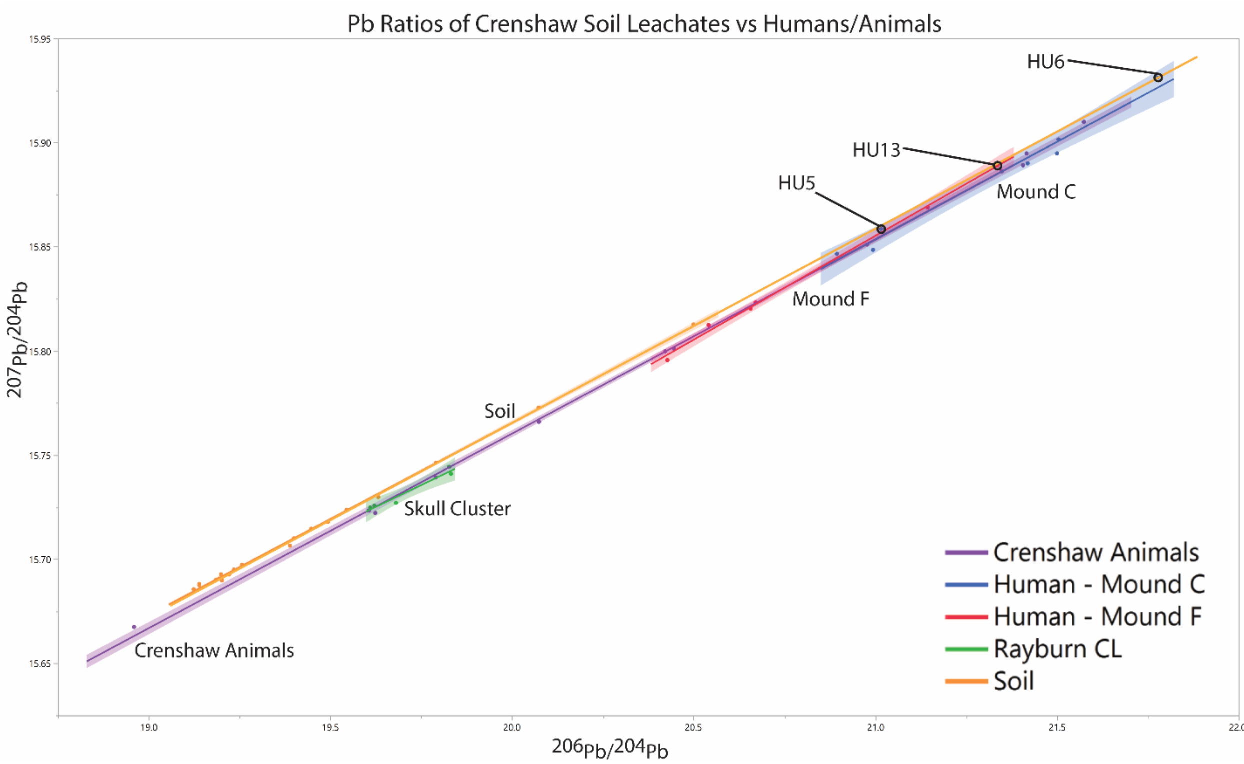

Figure 2.8 – Linear comparison of Pb isotope ratios from weak-acid soil leachates and human and animal samples at Crenshaw. Extending the fit line on soil samples to higher ratios shows that HU5, HU6, and HU13 better match the linear pattering defined by the soil than by the human and animal samples at Crenshaw. Otherwise, the soil and human/animal samples maintain different linear pattering which suggests the other human/animal samples were not greatly impacted by contamination.

Four duplicate tooth samples and two duplicate soil leachate samples confirmed the separation between these two groups of data (Figure 2.9). The four tooth duplicates were consistent with other samples from Mounds C and F. The homogenized samples (SO20 & SO20

Dup) were nearly identical and the heterogenous soil leachate samples (SO1 and SO1 Dup) were very similar. Some tooth duplicates were very similar, and some had more pronounced differences, most likely due to intra-tooth variation in Pb isotopes. Regardless, these differences did not contradict the linear patterning established by the original samples.

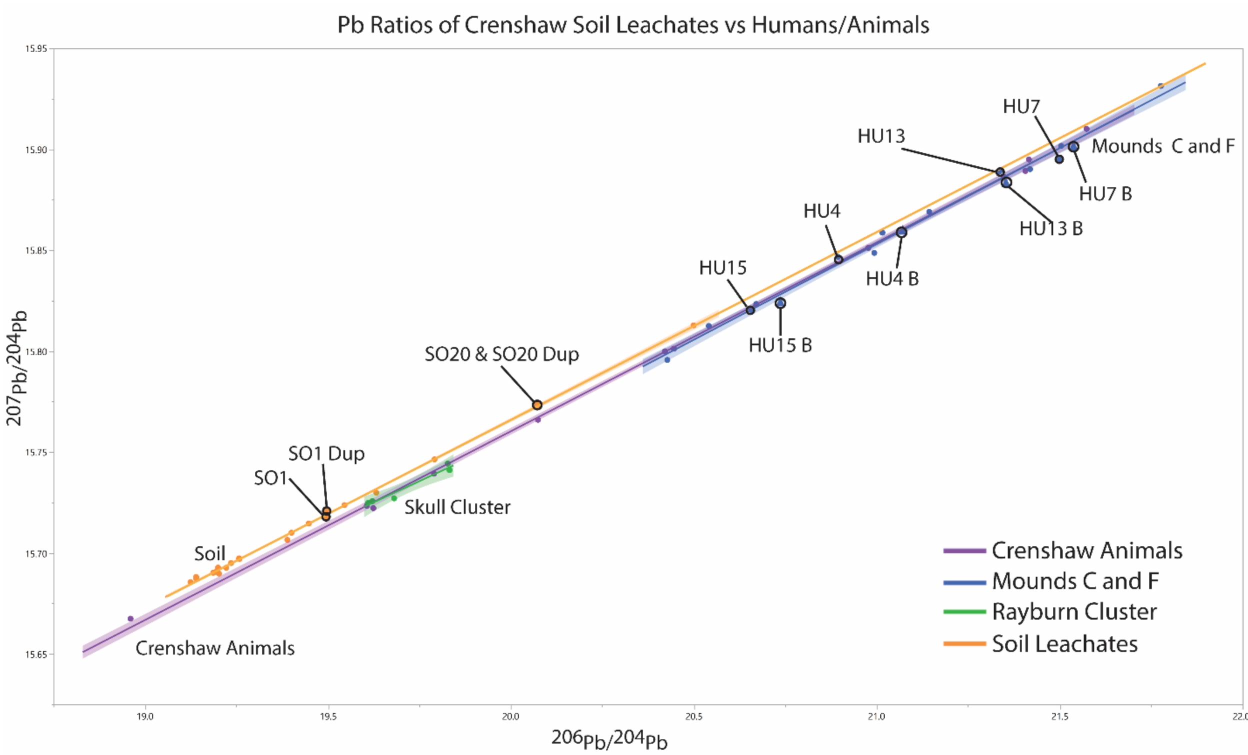

Figure 2.9 – Linear comparison of Pb isotope ratios from weak-acid soil leachates and human and animal samples at Crenshaw, including duplicate soil leachate and tooth enamel samples. The lone homogenized samples (SO20 and SO20 Dup) were nearly identical (Δ $^{208}Pb/^{204}Pb$=0.000, Δ $^{207}Pb/^{204}Pb$=0.000, Δ $^{206}Pb/^{204}Pb$=0.002). Soil leachate samples SO1 and SO1 Dup were not homogenized but were still very similar (Δ $^{208}Pb/^{204}Pb$=0.012, Δ $^{207}Pb/^{204}Pb$=0.003, Δ $^{206}Pb/^{204}Pb$=0.002). Tooth duplicates showed greater differences (Δ $^{208}Pb/^{204}Pb$=0.052, Δ $^{207}Pb/^{204}Pb$=0.007, Δ $^{206}Pb/^{204}Pb$=0.078), but these are most likely due to intra-tooth differences. Regardless, the duplicate teeth and soil leachate samples verify the Pb isotope trend lines and continue to show differences between the soil and teeth Pb isotope trends.

The second method, which assesses tooth enamel contamination using Pb concentrations, did not provide a clear understanding of contamination. Dudás et al. (2016:28) used an upper threshold of 0.7ppm and a lower one of 0.15ppm for Pb in prehistoric human tooth enamel, outside of which the likelihood of contamination would increase. The authors based the thresholds on ancient human teeth from New Mexico, so these values may only be applicable to New Mexico and not to other environments. Humans with higher Pb concentrations could also simply reflect a greater in-vivo exposure to Pb in their environment, and not post-burial contamination.

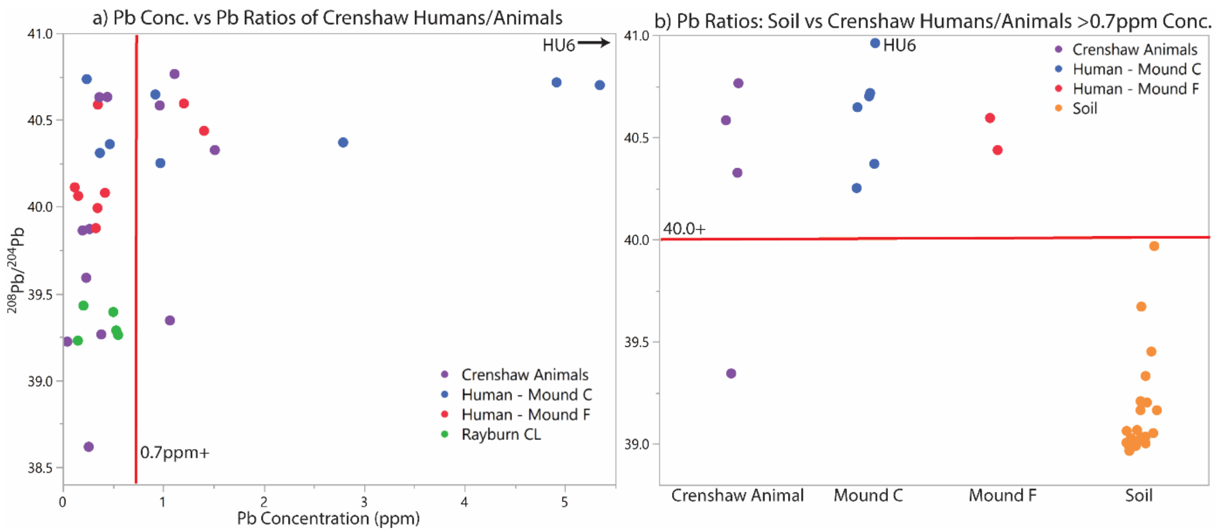

Figure 2.10 – Comparisons involving Pb concentrations on Crenshaw humans, animals, and soil. a) Bivariate plot comparing $^{208}Pb/^{204}Pb$ ratios and Pb concentrations of humans and animals. Samples with higher Pb ratios tend to have higher Pb concentrations. All but one sample above 0.7ppm had a $^{208}Pb/^{204}Pb$ ratio above 40. HU6 had the highest Pb concentration (31.5ppm) and $^{208}Pb/^{204}Pb$ ratio (40.96) and is not depicted. b) Comparison of $^{208}Pb/^{204}Pb$ ratio between weak-acid soil leachates and humans/animals with Pb concentrations above 0.7ppm. All 20 weak-acid soil leachates (duplicates excluded) have ratios below 40 and the highest two samples are statistical outliers. All but one tooth sample above 0.7ppm have ratios above 40.

No human samples at Crenshaw were below the lower threshold (0.15ppm) set by Dudás et al. (2016) with the exception of HU15 B. Human teeth from Hardman were all below this threshold, but so were most animal teeth, suggesting that the environment in this area has less bioavailable Pb. Most samples from Mound C were above the 0.7ppm upper threshold set by Dudás et al. (2016). The highest of these (HU6) was also the sample with the highest Pb isotope ratios at the site (human, animal, or soil). A third of the samples from Mound F were above 0.7ppm and none of the Rayburn Cluster samples were above 0.7ppm. In terms of Pb isotope ratios, most of the samples above the 0.7ppm threshold separated themselves from the soil leachates, suggesting this threshold is not appropriate for Crenshaw. The human and animal samples from Crenshaw that had Pb concentrations above 0.7ppm also tended to have higher $^{208}Pb/^{204}Pb$ ratios (Figure 2.10). The pattern between elevated Pb isotope ratios and Pb concentration was also somewhat represented in soil concentrations. The two soil samples (SO10 and SO20) with the highest Pb concentration also recorded the highest Pb isotope ratios, but there was no correlation. The linearity of the human, animal, and soil Pb isotope data suggest that the source for the elevated ratios has a higher concentration of Pb compared to the source for the lower ratios.

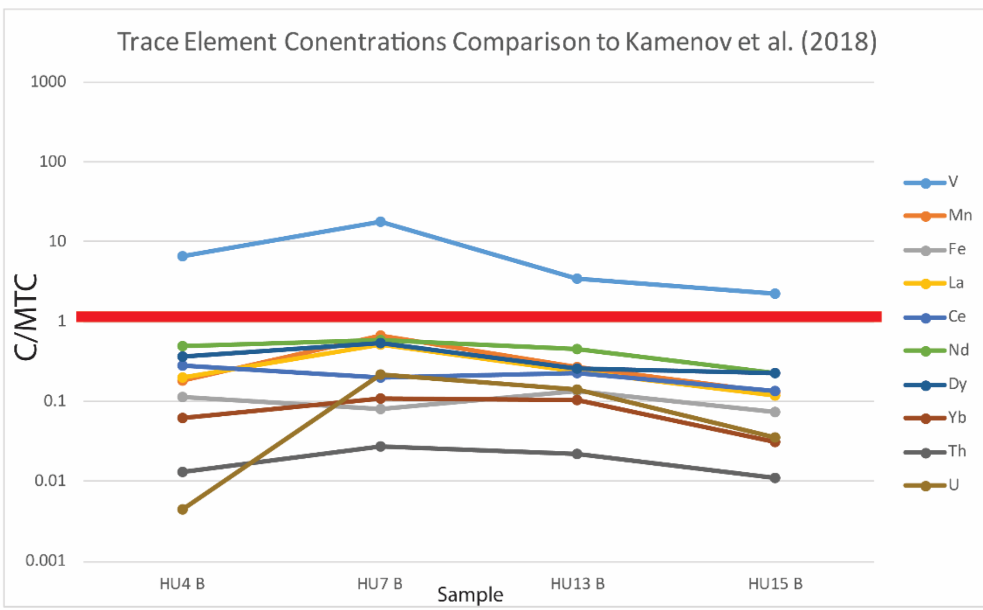

Figure 2.11 – Trace element concentrations of elements in duplicate human tooth enamel based on Kamenov et al. (2018). All element concentrations (C), with the exception of V, are below the maximum threshold concentrations (MTC). Lines below 1 C/MTC suggest the lack of diagenetic alteration. The results are consistent with Kamenov et al. (2018:Figures 1,3) showing no alteration to weak alteration and are inconsistent with Kamenov et al. (2018:Figure 4) showing strong alteration. This suggests these tooth enamel samples were not subject to significant diagenetic alteration and supports the conclusion that the high ratios and linear patterning reflect in-vivo values rather than anthropogenic or soil Pb contamination.

The third method, using trace element concentration analysis, was key to indicating a lack of contamination. Most teeth processed in this study were analyzed prior to Kamenov et al.'s (2018) study. Therefore, four duplicate tooth enamel samples were analyzed for V, Mn, Fe, La, Ce, Nd, Dy, Yb, Th, and U concentrations to determine if evidence of strong contamination could be detected among some samples with high Pb isotope ratios in Mounds C and F. The results indicated that all elements, except for V, were below the contamination threshold (Figure 2.11). If the value for V (0.3ppm) obtained on deciduous teeth by Curzon et al. (1975) is used, then HU15 B would be below all thresholds. This is consistent with Kamenov et al.'s (2018:Figures 1, 3) figures showing no alteration to weak alteration and is inconsistent with Kamenov et al.'s (2018:Figure 4) figure illustrating strong diagenetic alteration. This indicates that the high ratios in the teeth are not due to anthropogenic Pb or soil contamination and that the linear pattering is representative of in-vivo values.

The interpretation that is most in line with all these factors is that samples HU5 and HU6 have possibly been contaminated by soil. While HU13 is also close to the soil trend line, HU13 B suggests that HU13 has not been heavily contaminated, if at all. On bivariate diagrams, the remainder of the tooth samples from Crenshaw show distinct isotopic patterns compared to the soil leachates and are likely not contaminated (Figures 2.8, 2.9). Instead, the elevated Pb concentrations and elevated Pb isotope ratios in some samples are likely reflecting input from a local geologic end-member that is also contributing to the soil. As previously suggested, this indicates that anthropogenic Pb is not the source of these isotopic ratios.

When these three methods (soil leachate companions, Pb concentrations, and trace element analysis) are compared, the use of a particular Pb concentration threshold to assess contamination at Crenshaw may not be appropriate. According to the soil leachates and trace element data, the samples that are possibly contaminated range from 0.5ppm to 31.5ppm while the relatively uncontaminated samples range from 0.12ppm to 5.3ppm. A threshold of 6ppm could be used, but only one sample (HU6) is above the threshold and this sample has already been identified as potentially contaminated by the soil leachate comparison.

2.3.2 Demonstrating the Validity of the Biologically Available Pb Method

Analysis of linear patterning of human and animal Pb isotope data from Crenshaw and comparisons to other regions illustrate three significant results (Figures 2.12, 2.13). First, animal samples from Crenshaw match the expected local human population, verifying that the animal samples are capable of defining a local range that is directly comparable to human remains (Figure 2.12a). The articulated burials in Mound C and the bundle burials in Mound F match the Pb isotope data from animals in southwest Arkansas in all 15 bivariate comparisons. Second, the animals define a linear pattern that also identifies the potential non-local group (the skull cluster) as within the local range. If only the expected local human data were used, this group would have been considered non-local (Figure 2.12b).

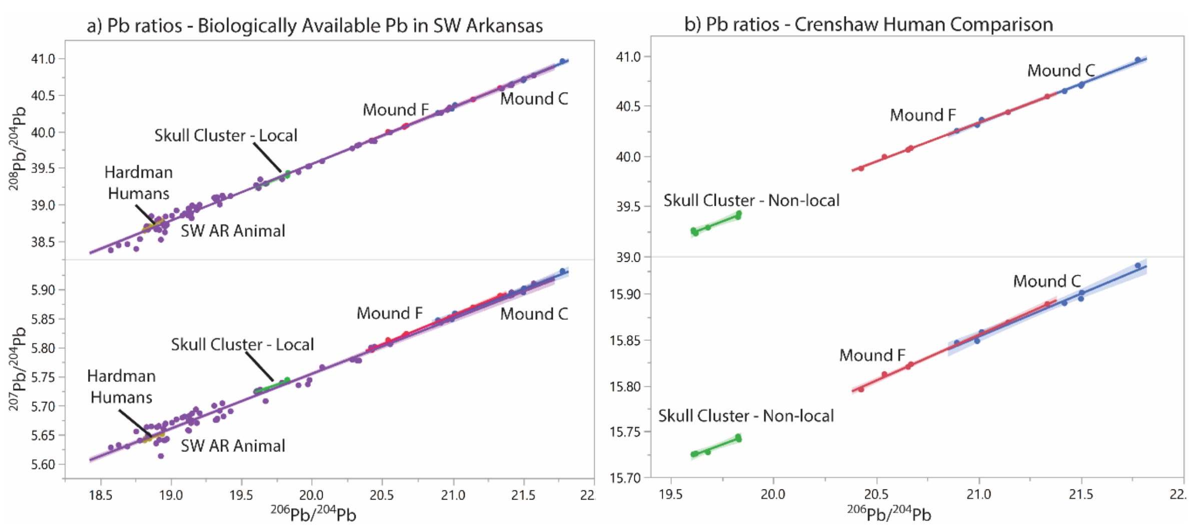

Figure 2.12 – Illustration of the importance of the biologically available Pb method. The study sampled human remains from Mound C (n=7), Mound F (n=6), and the Rayburn Cluster (n=5) from Crenshaw and burials (n=4) from Hardman. It also sampled prehistoric archaeological animals in southwest Arkansas (n=64) from nine sites (3CL418, 3HE40, 3HE92, 3HO11, 3HS60,

3LR49, 3MI6, 3SV15, and 3SV20), Louisiana (Fish Hatchery 2 [16NA70], n=8), and Mississippi (Austin [22TU549], n=8). a) Pb isotopes of human teeth from Crenshaw and Hardman and animal teeth from southwest Arkansas indicate that all the human remains are "local" to southwest Arkansas. Differences between local human groups could be explained by a number of factors (e.g. settlement patterns). Animal samples included raccoon (7), opossum (8), squirrel (8), rabbit (18), deer (33), and other small animals (6). No significant difference was seen between deer and other animals. b) Pb isotope ratios from human teeth at Crenshaw show that the articulated and disarticulated remains from Mounds C and F do not match the skull cluster, suggesting the skulls are non-local. This illustrates that not using the biologically available Pb method would lead to the wrong conclusion.

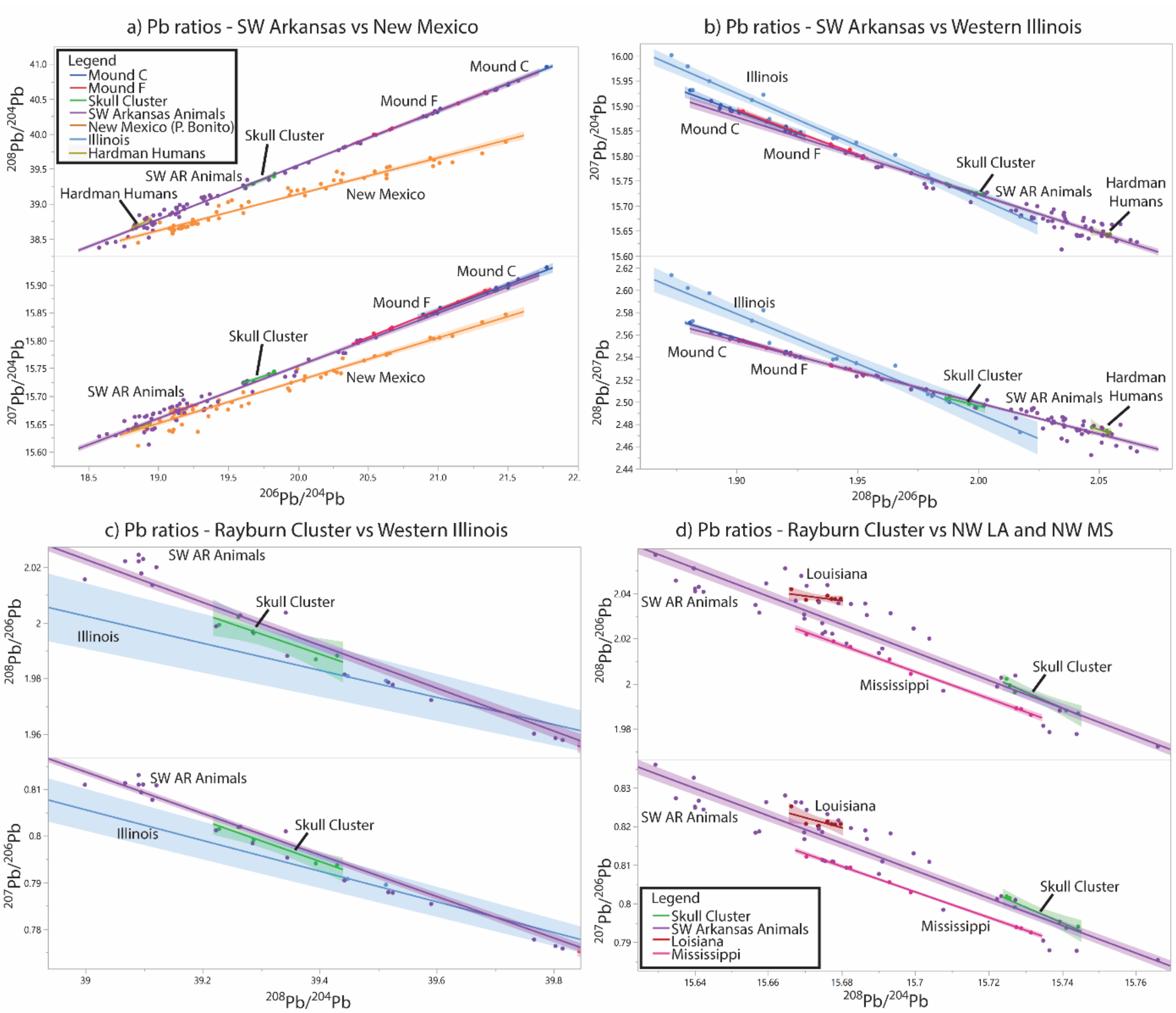

Figure 2.13 – Linear comparisons of Pb isotope ratios, each consisting of 15 different combinations of ratios (selected comparisons shown). a) Comparison of southwest Arkansas data to humans from Pueblo Bonito (Price et al. 2017). b) Comparison of southwest Arkansas data to west Illinois humans (Jones et al. 2017). c) Comparison of southwest Arkansas animals, the Rayburn Cluster, and west Illinois. d) Comparison of southwest Arkansas animals, the Rayburn Cluster, Fish Hatchery #2 (northwest Louisiana) animals, and Austin (northwest Mississippi) animals.

Third, the Pb isotope signatures of animals and humans from southwest Arkansas do not match those of human remains from New Mexico or west Illinois (Figure 2.13a,b). While there is some overlap, isotopic comparisons of each group show that the slope of the regression lines are different enough to distinguish different groups. Even in the case of the Rayburn Cluster, where individual samples are close to Illinois' range, the Rayburn Cluster distinguishes itself from west Illinois when compared as a group (Figure 2.13c). This clearly illustrates that Pb isotopes can discriminate between human remains from New Mexico and southwest Arkansas where Sr isotopes alone cannot. Similarly, the Illinois human remains would have been considered local at Crenshaw if using Sr isotope ratios alone; however, Pb isotope ratios clearly indicate that they are non-local (Figure 2.13b). The Pb isotope ratios of samples from Mounds C and F are not consistent with the linear patterning of those from west Illinois, suggesting that migration of these individuals from west Illinois is unlikely. This conclusion is, nevertheless, based only on the one locality, the Elizabeth site, that was tested.

Human and animal teeth from nearby regions were sampled to test if more proximal areas to Crenshaw could be distinguished. This included samples from the Ouachita region of southwest Arkansas and individuals from Hardman where headless bodies were buried. The Pb isotope ratios of humans and animals in this area indicate that the Rayburn Cluster did not originate from these localities in the Ouachita region, since the Pb isotope values of the Ouachita samples are too low (Figure 2.14a). The Pb isotope ratios from the Ouachita region are generally consistent with the southwest Arkansas linear patterning defined by the other sites in southwest Arkansas, despite their considerable distance and different geology. The Fish Hatchery 2 site down the Red River in northwest Louisiana and the Austin site in northwest Mississippi were also selected for sampling. Given the proximity to Crenshaw, it was not expected that Fish

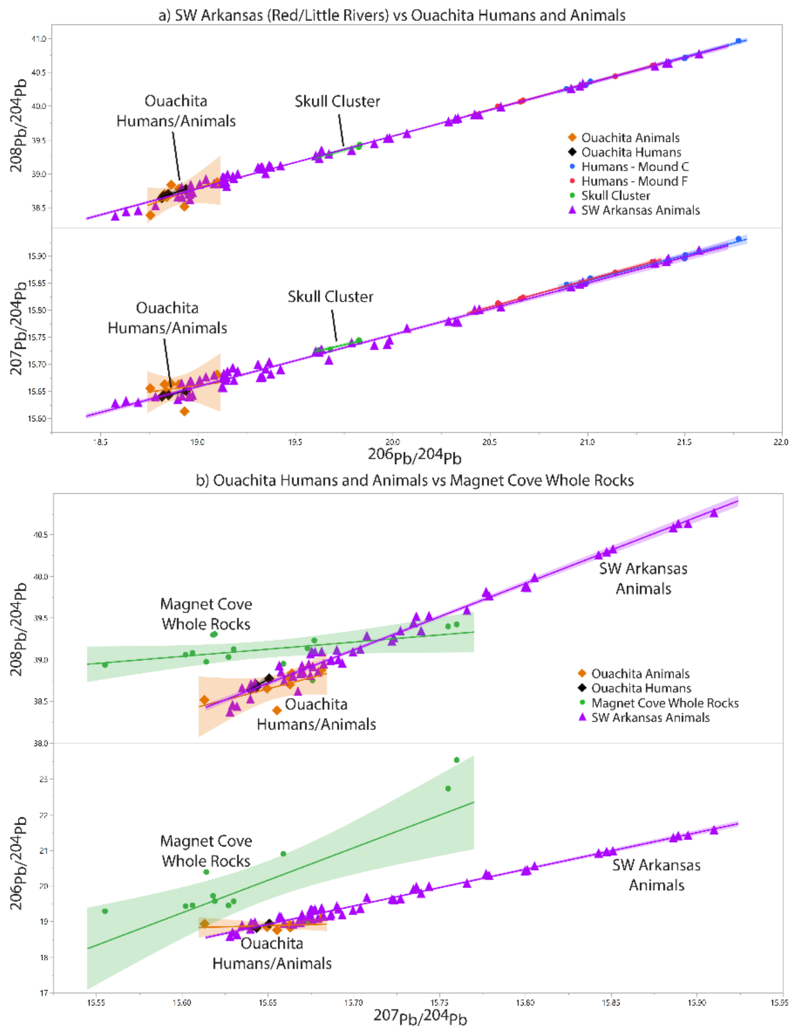

Figure 2.4 – Comparisons of Pb isotope ratios of human and animal samples from the Ouachita region sites (Hardman and Hedges) to other southwest Arkansas samples (Duke et al. 2014; Simbo et al. 2019). a) Ouachita region humans and animals are distinguishable from the skull cluster (and Mounds C and F), suggesting the skulls did not come from this area. b) Despite their close proximity, Ouachita region humans and animals are not consistent with Magnet Cove whole rocks. Magnet Cove whole rocks have extreme ratios, making the Ouachita region humans and animals better match the more distant animals from the Red/Little River sites in southwest Arkansas.

Hatchery 2 would be distinguishable. Also, it was not clear if northwest Mississippi would be different either, given the similarly young geologic setting. However, the data showed that the Pb isotope ratios for each location were restricted to a small range (Figure 2.13d). Even though they overlap with a small part of southwest Arkansas, the data clearly suggest that the Rayburn Skull Cluster, Mound C, and Mound F remains did not come from these sites in Louisiana and

Mississippi. It is important to note that the sampling is not sufficient to define a range for each of these other regions and this analysis is only capable of distinguishing these specific localities. However, the current results have established that the Pb isotope ratios from the Rayburn Skull Cluster are consistent with the Pb isotope ratios of southwest Arkansas and that they are inconsistent with the ratios from localities in the Ouachita region of southwest Arkansas, northwest Louisiana, northwest Mississippi, west Illinois, and New Mexico. This is the same cluster that has been repeatedly referred to as "trophy skulls" in the literature based on Powell's (1977) research.

This study has shown that 1) the Pb isotope ratios of animals match those in expected local human remains, 2) the Pb isotope ratios of animals are different than those of known non-local humans, and 3) the isotopic background created by animals was more effective at defining a local isotopic range than using expected local human remains. This clearly demonstrates that the method presented in the current study is valid and that, when additional clusters, localities, and regions are tested, it will provide answers to the questions surrounding the origins of the remains at Crenshaw that have otherwise been unobtainable.

2.3.3 Comparisons to Geologic Data

While the human and animal data can be directly compared, Pb isotope data from whole rocks in southwest Arkansas indicate that they are far too variable to be useful for sourcing human remains (Figure 2.15a). One concern is that the whole rock samples and the human and animal samples were collected from different locations. There are two exceptions. First, Prairie Creek (see Figures 2.3 and 2.15a) is close to the majority of sites and has extreme whole rock Pb isotope ratios compared to those of humans and animals. Second, many whole rock samples were gathered from Magnet Cove, which is in the immediate vicinity of one of the Ouachita region

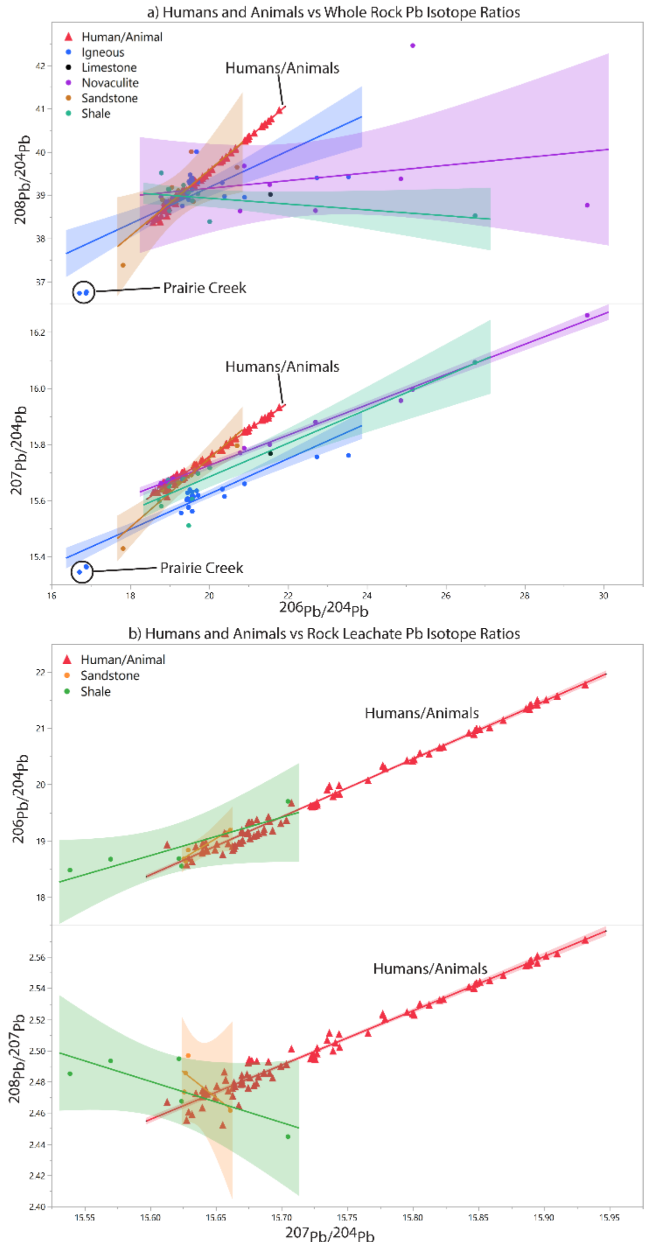

Figure 2.5 – Comparisons of southwest Arkansas humans, animals, and geologic data (Cains 2019; Duke et al. 2014; Simbo et al. 2019). a) Comparisons of humans/animals and whole rocks show that the whole rocks are far too variable to be directly compared to human remains. The whole rock sample locations closest to the animal sampling sites, Prairie Creek and Magnet Cove, have extreme isotope ratios that are inconsistent with the animals and humans. Humans/animals from other regions (e.g. New Mexico) would also be considered local to southwest Arkansas if these data were used to construct a local regional background. Higher ratios among some whole rocks indicate that the higher ratios in the human and animal data could be defined by local geology. b) Comparisons of humans/animals to rock leachates show the rock leachates are more consistent with the humans and animals than their whole rock counterparts. However, they have linear patterns that are not consistent with the humans/animals and are still more variable. Lighter leaching methods may result in more comparable data. These data suggest that these rocks could form the lower end member that defines the linear patterning in southwest Arkansas.

sites. Comparisons between the Ouachita region sites and the Magnet Cove whole rocks confirm that the whole rock Pb isotope signatures are significantly different from those of the humans and animals (Figure 2.14b). Therefore, it is suggested that whole rocks not be used for direct comparison to human remains, but they still provide some utility when the geologic regions are different enough (e.g. Kamenov and Gulson 2014). Simbo et al. (2019) showed that the Pb isotope ratios of whole rocks were more variable than those of rock leachates from the same rock samples. Despite a relatively small number of samples (n=9), rock leachates in southwest Arkansas also are much more variable than human or animal data and may not be directly comparable (Figure 2.15a); however, the limited sampling requires further research to test this. By contrast, the ratios of soil leachates from Crenshaw compare more favorably with those of southwest Arkansas animals (Figure 2.7a), but there are still differences between the soil and the human and animal remains from Crenshaw (Figures 2.7b, 2.8, 2.10). The reasoning for this pattern in geologic variability in Pb isotope ratios (whole rock > rock leachates > soil) can be inferred from the process of weathering and eventual deposition of Pb at the sites under study. The labile fraction of soils is a major source of bioavailable materials (Anderson and Hillwalker 2008; John and Leventhal 1995). Whole rocks include silicates that may not ever be biologically available due to the difficulty in their dissolution. Rock leachates are made up of the more easily mobile fraction, which is more likely to end up in river sediments and soils. Whatever is redeposited in the form of soil is mixed up and redeposited, likely reducing extreme Pb isotope ratios and creating a more amalgamated signature as is seen in the soil. This is the portion of Pb that is absorbed by plants and ingested by humans and animals. Soil and modern plants could be useful as direct comparisons to ancient humans as well but are more likely to be impacted by anthropogenic Pb. Therefore, it is suggested that the biologically available Pb method is best implemented using prehistoric animal teeth for defining the local isotopic background.

Even though the whole rocks may not be as appropriate for defining backgrounds as prehistoric animal tooth enamel, such data can provide insights into the provenance of Pb in the region. Pb isotope ratios of whole rocks from the Ouachita mountains suggest they could represent the source of the end-member with lower isotope ratios that define the linear pattering in southwest Arkansas (Figure 2.15). Some whole rock samples also indicate the presence of higher Pb isotope ratios in the region.

2.4 Conclusions

The biologically available Pb method compares the human remains to a large number of animal tooth enamel samples and utilizes their multivariate and linear nature to detect differences between possible regions of origin. This method successfully identifies non-local individuals and aids in evaluating of the origin of a skull cluster from the Crenshaw site in southwest Arkansas. It clearly demonstrates that Pb isotope ratios from prehistoric animal tooth enamel are most appropriate (particularly compared to whole rocks) for direct comparison to ancient human remains. It is unclear at this stage if the method is capable of uniquely identifying areas of origin and future studies, employing further development of the method will resolve this. The linear patterning section of this method relies on the presence of linear trends in the data, so this section may not be applicable if linear trends do does not exist within a region. Each region may have varying amounts of Pb in the environment, making a particular threshold of Pb concentration in tooth enamel difficult to apply in different regions. Based on the analysis of contamination provided here, it is suggested that trace element analysis, like the one described by Kamenov et al. (2018), be used in combination with soil samples when assessing contamination rather than relying on Pb concentrations alone. Further research in the area of contamination and decontamination of Pb isotopes in ancient teeth is needed.

Two issues prevent broad conclusions in the case study. First, the sample size of a single skull cluster is too small to make conclusions about the origin of the skull-and-mandible deposits at Crenshaw (8 of 352 individuals). Second, the number of animals from other regions is too small to provide a detailed regional map of Pb isotope ratios. All of the above-mentioned issues are being researched as part of a Doctoral Dissertation Research Improvement Grant from the National Science Foundation (grant number 1830438) and should result in further resolution of these concerns.

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Appendix

T1 – Lead Isotope Ratios of Human Teeth from Crenshaw (3MI6) and Hardman (3CL418).

Lab Number	Site	Catalog Number	Context	Tooth	Sex	Age	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	Pb ppm
HU1	Crenshaw	62-40-34	Mound C	1st L Mand Molar	Not Possible	3-4	40.715	15.902	21.504	4.915
HU2	Crenshaw	62-40-47	Mound C	3rd L Mand Molar	?	20-35	40.646	15.890	21.419	0.923
HU3	Crenshaw	62-40-48	Mound C	2nd L Mand Molar	Probable Male	35-50	40.309	15.849	20.994	0.371
HU4	Crenshaw	62-40-49	Mound C	2nd R Mand Molar	Not Possible	20-35	40.251	15.847	20.894	0.973
HU5	Crenshaw	62-40-50	Mound C	2nd R Mand Molar	Not Possible	20-35	40.360	15.859	21.016	0.470
HU6	Crenshaw	62-40-58	Mound C	2nd R Max Molar	Not Possible	5	40.960	15.931	21.777	31.482
HU7	Crenshaw	62-40-121	Mound C	1st R Mand Molar	Probable Male	50+	40.700	15.895	21.500	5.345
HU13	Crenshaw	83-376-1	Mound F	2nd L Mand Molar	Probable Female	20-35	40.594	15.889	21.336	1.207
HU14	Crenshaw	83-376-2	Mound F	2nd R Mand Molar	Not Possible	12	40.437	15.869	21.144	1.408
HU15	Crenshaw	83-376-3	Mound F	2nd L Mand Molar	Female	20-35	40.062	15.820	20.657	0.156
HU16	Crenshaw	83-376-6	Mound F	2nd R Max Molar	Not Possible	18	39.876	15.796	20.428	0.330
HU17	Crenshaw	83-376-6-2	Mound F	2nd R Max Molar	Not Possible	15	39.992	15.812	20.541	0.347
HU18	Crenshaw	83-376-7	Mound F	2nd L Max Molar	Probable Female	20-35	40.079	15.823	20.671	0.422
HU30	Crenshaw	69-66-589-1	Rayburn	2nd L Mand Molar	Probable Male	35-50	39.430	15.741	19.832	0.208
HU31	Crenshaw	69-66-589-2	Rayburn	2nd R Mand Molar	Probable Female	20-35	39.287	15.727	19.681	0.533
HU32	Crenshaw	69-66-589-3	Rayburn	2nd L Mand Molar	Probable Female	20-35	39.393	15.744	19.827	0.504
HU33	Crenshaw	69-66-589-4	Rayburn	2nd R Max Molar	Probable Male	O. adult	39.261	15.725	19.610	0.553
HU36	Crenshaw	69-66-589-7	Rayburn	2nd R Mand Molar	Possible Male	20-35	39.228	15.726	19.621	0.153
HU105	Hardman	87-710-274	Burial 2	2nd L Mand Molar	Probable Female	35-45	38.770	15.651	18.940	0.085
HU106	Hardman	87-710-326	Burial 7	2nd L Mand Molar	Probable Female	35-40	38.701	15.643	18.849	0.133
HU107	Hardman	87-710-708	Burial 12	2nd R Max Molar	Probable Male	39-44	38.674	15.643	18.824	0.090
HU108	Hardman	87-710-912	Burial 13	2nd R Max Molar	Probable Male	50+	38.638	15.640	18.816	0.082

Note: Age/sex classifications are from Burnett (1993) and Harvey et al. (2014).

T2 – Lead Isotope Ratios of Prehistoric Animal Teeth.

Lab Number	Location	Catalog Number	Site Number	Animal	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	Pb ppm
AN1	SW Arkansas	69-66-591	3MI6	Deer	40.306	15.847	20.974	1.515
AN2	SW Arkansas	69-66-587	3MI6	Rabbit	39.244	15.720	19.603	0.385
AN3	SW Arkansas	69-66-261	3MI6	Opossum	39.323	15.735	19.787	1.068
AN4	SW Arkansas	69-66-317	3MI6	Cottontail	39.569	15.762	20.071	0.235
AN5	SW Arkansas	69-66-230	3MI6	Wood Rat	38.595	15.663	18.956	0.260
AN6	SW Arkansas	69-66-389	3MI6	Swamp Rabbit	39.851	15.796	20.418	0.268
AN7	SW Arkansas	69-66-469	3MI6	Deer	39.201	15.718	19.620	0.047
AN8	SW Arkansas	69-66-389	3MI6	Deer	39.842	15.797	20.442	0.199
AN9	SW Arkansas	90-634	3MI6	Deer	40.609	15.885	21.403	0.366
AN10	SW Arkansas	90-634	3MI6	Deer	40.560	15.882	21.344	0.967
AN11	SW Arkansas	95-449	3MI6	Cottontail	40.741	15.905	21.570	1.114
AN12	SW Arkansas	90-634	3MI6	Swamp Rabbit	40.611	15.891	21.413	0.445
AN13	SW Arkansas	83-379-114	3HE92	Squirrel	40.269	15.843	20.957	1.433
AN14	SW Arkansas	82-450-20	3HE92	Pocket Gopher	38.788	15.670	19.145	3.154
AN15	SW Arkansas	83-379-264	3HE92	Rabbit	39.963	15.801	20.552	0.533
AN16	SW Arkansas	83-379-101	3HE92	Rabbit	39.505	15.740	19.982	0.203
AN17	SW Arkansas	83-379-141	3HE92	Rabbit	40.231	15.839	20.913	0.319
AN18	SW Arkansas	83-379-281	3HE92	Rabbit	39.745	15.775	20.284	0.172
AN19	SW Arkansas	84-380-158	3HE92	Pocket Gopher	38.978	15.687	19.345	1.295
AN20	SW Arkansas	2002-700-76	3HE40	Squirrel	38.638	15.631	18.895	0.321
AN21	SW Arkansas	2002-700-345	3HE40	Squirrel	38.698	15.638	18.970	0.274
AN22+	SW Arkansas	2003-685-84	3HE40	Squirrel	38.686	15.637	18.951	0.870
AN23	SW Arkansas	2002-700-34-5	3HE40	Squirrel	38.675	15.636	18.956	0.226
AN24	SW Arkansas	2002-700-34-5	3HE40	Squirrel	38.631	15.638	18.917	0.134
AN25	SW Arkansas	61-114-4686	3HO11	Raccoon	39.075	15.671	19.323	0.299
AN26	SW Arkansas	61-114-4686	3HO11	Opossum	39.065	15.672	19.327	0.443
AN27	SW Arkansas	61-114-607	3HO11	Small Rodent	38.902	15.651	19.126	0.270
AN28	SW Arkansas	61-114-685	3HO11	Rabbit	38.507	15.637	18.780	0.154
AN29	SW Arkansas	61-114-473	3HO11	Opossum	39.091	15.686	19.421	0.948
AN30+	SW Arkansas	61-114-676	3HO11	Deer	38.831	15.655	19.121	0.044
AN31	SW Arkansas	61-114-694	3HO11	Deer	39.076	15.678	19.372	0.077
AN32	SW Arkansas	61-114-638	3HO11	Deer	38.904	15.666	19.182	0.098
AN33	SW Arkansas	61-114-468a	3HO11	Deer	39.048	15.671	19.317	0.269
AN34	SW Arkansas	61-114-554	3HO11	Deer	38.856	15.666	19.141	0.096
AN35+	SW Arkansas	64-51-1	3SV20	Deer	39.422	15.731	19.903	0.040
AN36	SW Arkansas	64-51-1	3SV20	Rabbit	39.795	15.774	20.333	0.660
AN37	SW Arkansas	64-51-1	3SV20	Opossum	39.266	15.704	19.670	0.515
AN38	SW Arkansas	64-51-1	3SV20	Small Rodent	39.784	15.774	20.320	1.367
AN39	SW Arkansas	64-51-1	3SV20	Raccoon	39.497	15.733	19.969	0.214
AN40	SW Arkansas	63-39-278	3LR49	Rabbit	38.922	15.678	19.130	0.152

T2 (Cont.)

Lab Number	Location	Catalog Number	Site Number	Animal	^{208}Pb/ ^{204}Pb	^{207}Pb/ ^{204}Pb	^{206}Pb/ ^{204}Pb	Pb ppm
AN41	SW Arkansas	63-39-33	3LR49	Raccoon	39.069	15.696	19.306	0.343
AN42	SW Arkansas	63-39-57	3LR49	Raccoon	38.893	15.672	19.038	0.124
AN43	SW Arkansas	63-39-51	3LR49	Opossum	38.776	15.660	18.913	0.134
AN44	SW Arkansas	63-39-40	3LR49	Rabbit	38.414	15.627	18.628	0.154
AN45+	SW Arkansas	63-39-45	3LR49	Deer	39.097	15.699	19.363	0.048
AN46	SW Arkansas	63-39-43	3LR49	Deer	38.961	15.682	19.149	0.096
AN47+	SW Arkansas	63-39-63	3LR49	Deer	38.933	15.689	19.175	0.040
AN48	SW Arkansas	63-39-49	3LR49	Deer	38.823	15.675	19.079	0.057
AN49	SW Arkansas	64-50-3196	3SV15	Deer	39.319	15.723	19.631	0.099
AN50	SW Arkansas	64-50-252	3SV15	Deer	38.719	15.655	18.947	0.090
AN51+	SW Arkansas	64-50-203	3SV15	Deer	38.971	15.682	19.201	0.047
AN52+	SW Arkansas	64-50-341	3SV15	Deer	38.811	15.665	18.960	0.073
AN53+	SW Arkansas	64-50-325	3SV15	Deer	38.349	15.623	18.572	0.054
AN54	SW Arkansas	64-50-231	3SV15	Opossum	38.922	15.670	19.123	0.179
AN55+	SW Arkansas	64-50-319a	3SV15	Rabbit	38.824	15.667	19.006	0.090
AN56	SW Arkansas	64-50-437	3SV15	Rabbit	38.434	15.625	18.690	0.412
AN57 B	NW Mississippi	F-944	22TU549	Raccoon	39.170	15.693	19.480	0.259
AN58	NW Mississippi	F-2300	22TU549	Opossum	39.047	15.679	19.372	0.382
AN59	NW Mississippi	F-2300	22TU549	Raccoon	39.384	15.724	19.806	0.190
AN60	NW Mississippi	F-2300	22TU549	Raccoon	38.988	15.667	19.290	0.336
AN61+	NW Mississippi	F-799	22TU549	Deer	39.168	15.695	19.548	0.015
AN62+	NW Mississippi	F-2300	22TU549	Deer	39.010	15.674	19.331	0.055
AN63	NW Mississippi	F-2300	22TU549	Deer	39.405	15.728	19.846	0.055
AN64	NW Mississippi	F-1611	22TU549	Deer	39.393	15.725	19.815	0.153
AN65	NW Louisiana	16NA70-41	16NA70	Deer	38.903	15.669	19.108	0.262
AN66	NW Louisiana	16NA70-63	16NA70	Deer	38.895	15.672	19.082	0.675
AN67	NW Louisiana	16NA70-77	16NA70	Deer	38.908	15.676	19.102	2.133
AN68	NW Louisiana	16NA70-Nat_F	16NA70	Deer	38.876	15.667	19.090	0.375
AN69+	NW Louisiana	16NA70-27	16NA70	Rabbit	38.741	15.662	18.980	0.062
AN70	NW Louisiana	16NA70-115	16NA70	Rabbit	38.902	15.673	19.099	1.315
AN71	NW Louisiana	16NA70-104	16NA70	Beaver	38.910	15.674	19.104	6.080
AN72	NW Louisiana	16NA70-404	16NA70	Rabbit	38.895	15.671	19.107	0.516
AN149	Ouachita	87-710-954	3CL418	Deer	38.778	15.663	18.904	0.043
AN150+	Ouachita	87-710-647	3CL418	Deer	38.653	15.649	18.840	0.057
AN151+	Ouachita	87-710-95	3CL418	Deer	38.516	15.613	18.932	0.044
AN152	Ouachita	87-710-417	3CL418	Squirrel	38.873	15.681	19.099	0.334
AN153	Ouachita	87-710-86	3CL419	Squirrel	38.389	15.655	18.757	1.020
AN154*	Ouachita	74-746-14	3HS60	Deer	38.676	15.556	18.935	0.040
AN155	Ouachita	74-746-27	3HS60	Deer	38.837	15.664	18.863	0.060
AN156	Ouachita	74-746-28	3HS60	Opossum	38.701	15.663	18.830	0.467

Note: * Sample AN154 had high standard error and was generally excluded from analysis. + Blanks over 1‰ of these.

T3 – Pb Isotope Ratios and Pb, Cu, and Zn Concentrations of Soil Weak-acid Leachates (2N HCl) and Water Leachates (Ultra-pure Water) from Crenshaw.

Lab Number	Type	Context	Catalog Number	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	Pb ppm	Cu ppm	Zn ppm
SO1	Weak-acid Leach.	Rayburn Cluster - soil outside cranium	69-66-589-6	39.165	15.718	19.494	1.539	0.386	1.791
SO1 Dup	Weak-acid Leach.	Rayburn Cluster - soil outside cranium	69-66-589-6	39.177	15.721	19.496	1.358	0.326	1.426
SO2	Weak-acid Leach.	Rayburn Cluster - soil inside cranium	69-66-589-6	39.332	15.730	19.632	1.482	0.557	1.614
SO3	Weak-acid Leach.	Rayburn Cluster - soil outside cranium	69-66-589-7	39.033	15.707	19.389	2.114	0.441	1.938
SO4	Weak-acid Leach.	Rayburn Cluster - soil inside cranium	69-66-589-7	39.208	15.724	19.545	1.683	0.453	1.695
SO5	Weak-acid Leach.	WSA Cluster 1 - soil	83-377-2-1	38.990	15.690	19.202	1.794	1.042	2.972
SO6	Weak-acid Leach.	WSA Cluster 1 - soil	83-377-2-2	39.052	15.695	19.235	2.010	0.975	1.707
SO7	Weak-acid Leach.	WSA Cluster 25 - soil	83-377-61-3	39.028	15.693	19.221	1.254	0.504	1.020
SO8	Weak-acid Leach.	NSA Cluster 8 - soil	83-377-41-4	39.164	15.710	19.400	2.569	1.222	2.697
SO9	Weak-acid Leach.	NSA Cluster 2 - soil	83-377-25-1	39.451	15.746	19.791	1.755	0.704	1.850
SO10	Weak-acid Leach.	Mound C - Center Block, Stratum A, soil	62-40-21a	39.967	15.813	20.500	5.841	2.076	4.892
SO10 B	Water Leach.	Mound C - Center Block, Stratum A, soil	62-40-21a	39.885	15.804	20.369	0.012	0.130	0.169
SO11	Weak-acid Leach.	Crenshaw Core 6 - 25cmbs, soil		39.017	15.690	19.186	3.607	1.896	2.526
SO12	Weak-acid Leach.	Crenshaw Core 6 - 50cmbs, soil		39.067	15.697	19.258	2.791	1.724	2.018
SO12 B	Water Leach.	Crenshaw Core 6 - 50cmbs, soil		39.067	15.691	19.241	0.012	0.069	0.120
SO13	Weak-acid Leach.	Crenshaw Core 6 - 125cmbs, soil		39.006	15.691	19.194	1.177	0.493	1.046
SO14	Weak-acid Leach.	Crenshaw Core 7 - 25cmbs, soil		39.063	15.697	19.257	2.941	1.519	2.540
SO15	Weak-acid Leach.	Crenshaw Core 7 - 50cmbs, soil		39.035	15.693	19.199	4.126	2.225	2.802
SO15 B	Water Leach.	Crenshaw Core 7 - 50cmbs, soil		39.052	15.684	19.201	0.004	0.073	0.384
SO16	Weak-acid Leach.	Crenshaw Core 17 - 25cmbs, soil		38.966	15.686	19.124	3.838	2.152	3.063
SO17	Weak-acid Leach.	Crenshaw Core 17 - 50cmbs, soil		39.003	15.688	19.139	2.918	2.171	2.700
SO18	Weak-acid Leach.	Crenshaw Core 17 - 125cmbs, soil		38.990	15.688	19.139	3.494	2.585	2.888
SO19	Weak-acid Leach.	Crenshaw Core 8 - 25cmbs, soil		39.202	15.715	19.447	4.527	2.042	3.814
SO20	Weak-acid Leach.	Crenshaw Core 8 - 50cmbs, soil		39.671	15.773	20.073	5.793	2.992	4.829
SO20 Dup	Weak-acid Leach.	Crenshaw Core 8 - 50cmbs, soil		39.671	15.773	20.071	5.176	2.656	4.196
SO20 B	Water Leach.	Crenshaw Core 8 - 50cmbs, soil		39.560	15.754	19.925	0.009	0.037	0.279

Note: SO1 and SO1 Dup were not homogenized as soil prior to sampling. SO20 and SO20 Dup were homogenized as soil prior to sampling.

T4 – Lead Isotope Ratios of Whole Rocks from Granite Mountain and Magnet Cove.

Lab Number	Type	Location	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$
GM1	Whole Rock	Granite Mountain	40.002	15.634	19.681
GM2	Whole Rock	Granite Mountain	39.468	15.603	19.519
GM4	Whole Rock	Granite Mountain	39.384	15.601	19.564
GM5	Whole Rock	Granite Mountain	39.314	15.603	19.487
GM6	Whole Rock	Granite Mountain	39.361	15.606	19.538
GM7	Whole Rock	Granite Mountain	39.398	15.609	19.567
GM8	Whole Rock	Granite Mountain	39.381	15.609	19.555
GM9	Whole Rock	Granite Mountain	39.404	15.608	19.570
GM10	Whole Rock	Granite Mountain	39.381	15.606	19.571
GM11	Whole Rock	Granite Mountain	39.374	15.602	19.547
GM12	Whole Rock	Granite Mountain	39.325	15.600	19.520
MC2	Whole Rock	Magnet Cove	39.081	15.606	19.453
MC3*	Whole Rock	Magnet Cove	39.148	15.646	20.261
MC4	Whole Rock	Magnet Cove	39.297	15.618	19.721
MC6	Whole Rock	Magnet Cove	39.057	15.602	19.428
MC7	Whole Rock	Magnet Cove	39.306	15.619	19.572
MC8	Whole Rock	Magnet Cove	39.125	15.630	19.565
MC9	Whole Rock	Magnet Cove	39.031	15.627	19.450

Note: * Sample MC3 had high standard error and was generally excluded from analysis.

T5 – Pb Isotopes and Trace Element Concentrations (ppm) of Duplicate Human Tooth Samples from Crenshaw (3MI6).

Lab Num	Accession Number	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	Pb	V	Mn	Fe	La	Ce	Nd	Dy	Yb	Th	U
HU4 B	62-40-49	40.369	15.860	21.072	0.240	0.722	2.855	16.581	0.020	0.034	0.028	0.003	0.001	0.001	0.000
HU7 B	62-40-121	40.734	15.902	21.538	2.792	1.962	10.442	11.310	0.052	0.024	0.034	0.005	0.002	0.001	0.011
HU13 B	83-376-1	40.587	15.883	21.353	0.351	0.384	4.084	19.585	0.024	0.027	0.026	0.002	0.002	0.001	0.007
HU15 B	83-376-3	40.111	15.824	20.737	0.121	0.243	2.000	10.510	0.012	0.016	0.013	0.002	0.001	0.001	0.002

Chapter 3: Isotopic Assessment of the Geographic Origins of the Skull-and-Mandible Cemetery

John R. Samuelsen

Abstract

Previous research has been inconclusive about the geographic origins of a skull-and-mandible cemetery at the Crenshaw site in southwest Arkansas, ca. A.D. 1200-1500. Samuelsen and Potra (2020) outlined and tested a method to evaluate ancient human origins using Pb isotopes but lacked enough human samples to evaluate the origins of the remains and only compared to animal teeth from one site in two other regions. This study resolves these issues by constructing the first large scale Pb and Sr isoscape using prehistoric animal tooth enamel. A total of 180 animal teeth were processed from 28 prehistoric sites in Arkansas, Illinois, Louisiana, Mississippi, Missouri, Oklahoma, and Texas. The Pb and Sr isoscape is compared to the skulls and mandibles to assess their geographic origins. Trace element analysis, based on Kamenov et al. (2018), evaluated soil Pb contamination of human teeth. Trace element analysis was largely successful at assessing contamination, but some elements and universal thresholds may not be useful for prehistoric populations in different areas. Correlation analysis of the data suggests that this population had greater in-vivo exposure to rare earth elements and vanadium than modern populations. The drilling method used here, which totally removes the surface of enamel, successfully removed soil Pb contamination. The Pb isoscape was able to distinguish many other regions. When Pb isotopes were combined with Sr isotopes, they were able to establish that the skulls and mandibles are local to southwest Arkansas and indicate or strongly suggest they are non-local to all other tested regions.

Keywords: Pb; isotopes; isoscape; Sr; Caddo; warfare; contamination

3.1 Introduction

3.1.1 Ancient Human Geographic Origins and Isotopes

Assessing geographic origins of ancient human remains with isotopes requires comparisons to some type of background value. Obtaining an isotopic value from human remains does not reveal their geographic origin without first establishing the isotopic values that define the geographic areas of investigation. The resultant data from large area studies that construct these background values in multiple geographic areas are often described as "isoscapes" (e.g. Bowen 2010; Bataille et al. 2018; Hedman et al. 2018). The documentation of the isotopic values in isoscapes is useful for individual studies, but their creation also enables future research by predefining the isotopic values that should be expected. This helps predict whether future studies would be successful at distinguishing human remains from different regions. If a previously defined isoscape fails to separate different regions, then conducting future isotopic studies in these areas would not produce useful results. However, if an isoscape is able to show differences between the areas of interest, then they enable future research by illustrating they can be successful at answering research questions related to geographic origins. Without such isoscapes, obtaining funding for research can be a challenge as funding agencies may be skeptical that proposed research will be able to achieve its stated goals.

While many previous studies have constructed strontium (Sr) isoscapes (e.g. Bataille et al. 2018; Hedman et al. 2018), no study has yet created a large-scale lead (Pb) isoscape from prehistoric animal tooth enamel. In Mesoamerica, Sharpe et al. (2016) constructed a Pb isoscape using mostly whole rocks and a few other types of samples. However, Samuelsen and Potra (2020) showed that Pb isotopes from whole rocks are not the most appropriate samples for direct comparison to ancient human remains. Instead, they developed the biologically available Pb method, which uses the multivariate and linear nature of Pb isotopes from prehistoric animal tooth enamel to assess the geographic origins of ancient humans. The linear patterning of Pb isotopes from human tooth enamel are compared to animal tooth enamel in 15 unique bivariate graphs using all six Pb isotope ratios ($^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{206}Pb/^{204}Pb$, $^{208}Pb/^{206}Pb$, $^{207}Pb/^{206}Pb$, and $^{208}Pb/^{207}Pb$) to evaluate their geographic origin. Humans that do not match the animals in all 15 bivariate graphs are considered non-local.

While the method outlined by Samuelsen and Potra (2020) was successful at differentiating southwest Arkansas humans and animals from human remains in distant locations like New Mexico and west Illinois, only one site in northwest Louisiana and one site in northwest Missouri were sampled for animal teeth for comparison to southwest Arkansas. The limited sampling of animals from other regions left some doubt that the method could differentiate southwest Arkansas human remains from surrounding regions.

The goal of this research was to evaluate the geographic origins of a skull-and-mandible cemetery at the Crenshaw site (3MI6), a multiple mound Caddo ceremonial center in southwest Arkansas (Figure 3.1). The cemetery dates to A.D. 1253-1399 (Samuelsen 2014). Most previous research had suggested the 352 human skulls and mandibles represented victims of warfare from other regions (Akridge 2014; Brookes 1999; Burnett 2010; Milner 1995:232; Powell 1977; Schambach 2014; Schambach et al. 2011; Zabecki 2011). Proposed other regions of origin include the Southern Plains and the Mississippi Valley in the Eastern Woodlands (Brookes 1999; Burnett 2010; Schambach et al. 2011). However, Samuelsen (2016) argued, using Sr isotopes, that the ritual burial practice more likely reflected a regional cemetery associated with a dispersed settlement pattern. Samuelsen and Potra (2020) showed that the Sr isotopes alone could not provide a clear answer to this question and argued that Pb isotopes would provide a

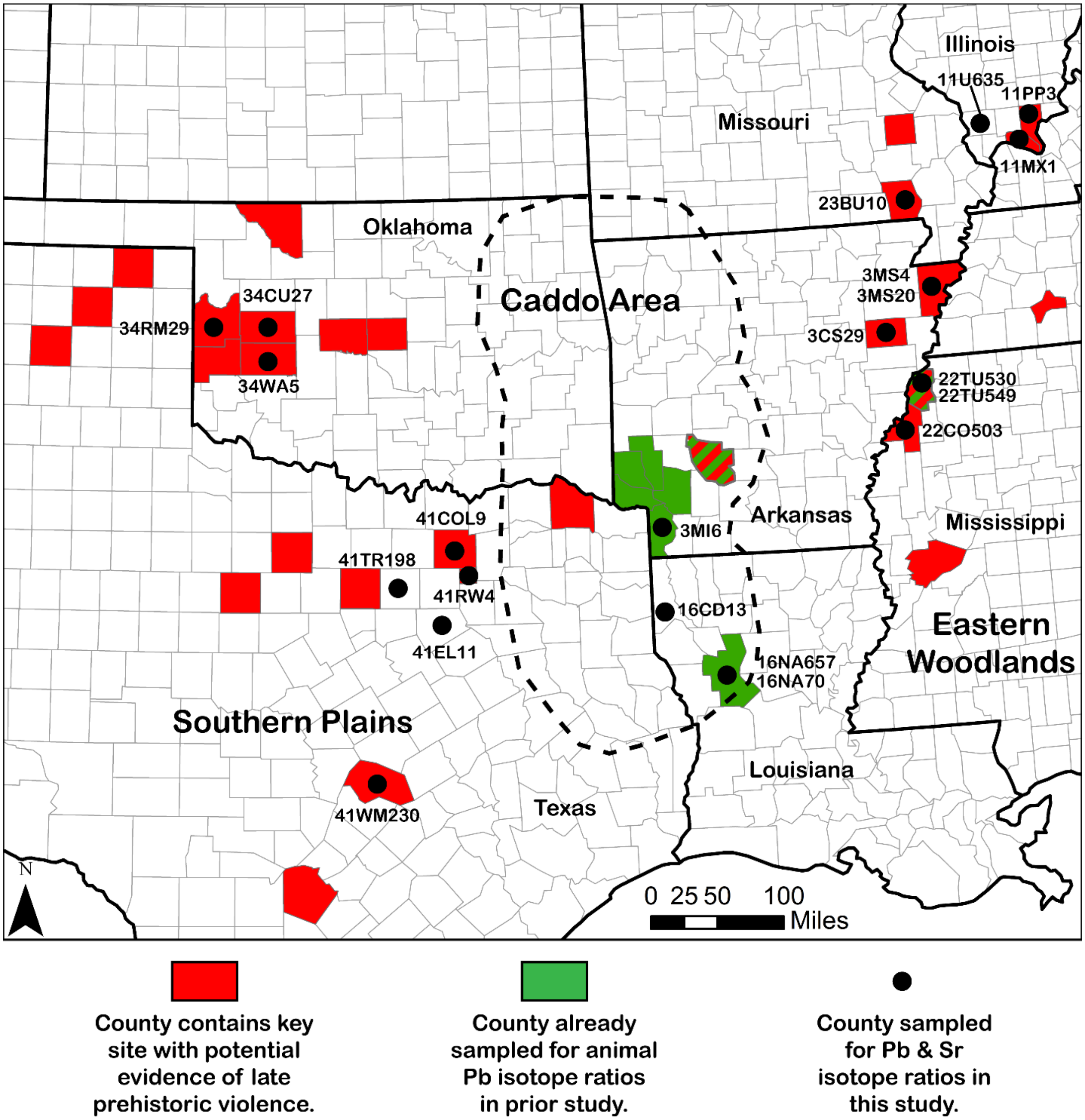

Figure 3.1 – The Crenshaw site (3MI6) located in the Caddo Area on the edge of the Eastern Woodlands and the Southern Plains. Counties with key sites having evidence of violence from the same time period as the skulls and mandibles are highlighted in red (Bovee and Owsley 1994:359; Brookes 1999; Brooks 1994; Brooks and Cox 2011; Early 1993; Harmon and Rose 1989; Harris 1953; Huff and Bigs 1963; Krus 2016; Owsley and Jantz 1989; Owsley et al. 1989, 1994; Pillaert 1963:42-43; Potter 2005; Prewitt 2012; Reinhard et al. 1990; Rose et al. 1999:121; Ross-Stallings 2007; Story 1990). Counties previously sampled for Pb isotopes by Samuelsen and Potra (2020) are highlighted in green. Counties and sites sampled for Pb and Sr isotopes in this study are identified with a black dot. Samples for Sr isotopes came from the both the newly sampled sites and those previously sampled for Pb isotopes (green) by Samuelsen and Potra (2020).

means to evaluate the geographic origins once a Pb isoscape was constructed from surrounding regions and more skulls and mandibles were analyzed.

This study attempts to accomplish this by constructing the first large scale Pb isoscape using prehistoric animal teeth for the purposes of evaluating ancient human geographic origins. This isoscape, when combined with data from the skulls and mandibles, will evaluate their geographic origins with the goal of determining if they reflect war trophies from other regions or if they reflect a local burial practice. While this study focuses on Pb isotopes due to their less developed state in the literature, a Sr isoscape is simultaneously created from the same teeth and will similarly help evaluate the geographic origins of the skulls and mandibles. Samuelsen and Potra (2020) showed that the Sr isotopes were too variable in southwest Arkansas to provide a clear answer to the questions surrounding the remains, but this was only based on the published Sr isotope data. Areas of interest, such as the Southern Plains, have not previously been tested for Sr isotopes from prehistoric animal teeth. Therefore, Sr isotope data from these areas may still help differentiate the skulls and mandibles from other regions, particularly when combined with Pb isotopes.

A National Science Foundation Doctoral Dissertation Research Improvement grant (grant number 1830438) was obtained to sample more teeth from the skull-and-mandible deposits at Crenshaw and to construct Pb and Sr isoscapes of surrounding regions using prehistoric animal tooth enamel. In addition to the 80 already processed samples (Samuelsen and Potra 2020), 100 additional prehistoric animal teeth from six surrounding states (Illinois, Louisiana, Mississippi, Missouri, Oklahoma, and Texas) and northeast Arkansas were obtained, analyzing a total of 180 animal teeth from 28 sites. Animal teeth were selected from areas with reports of violence from the same time period as the skull-and-mandible cemetery (see Figure 3.1). Since each area has different geology, and therefore potentially different isotopes, each area is evaluated separately in relation to the skulls and mandibles. This represents the largest Pb isotope dataset of its kind, providing future researchers with a replicable method and model.

3.1.2 Assessment of Soil Contamination

Pb concentrations in human tooth enamel are typically much lower than Sr concentrations and Pb concentrations in soil can often be relatively high. This makes post-burial contamination of human tooth enamel a major issue for Pb isotope studies as it increases the likelihood of anthropogenic or soil Pb contamination of the teeth (Kamenov et al. 2018; Samuelsen and Potra 2020). Therefore, contamination of human teeth should be assessed when evaluating Pb isotopes to test for the possibility of post-burial contamination. Multiple tests were done on contaminated and uncontaminated tooth enamel related to Sr isotopes. These tests showed no significant differences in Sr isotopes; therefore, the contamination analysis focuses on the potential effect on Pb isotopes.

This study follows the trace element analysis method outlined by Kamenov et al. (2018) for ancient human tooth enamel. The method is very robust because it uses multiple elements and establishes expected maximum concentrations based on modern uncontaminated teeth. This is one of the first studies to attempt to use this method, so the method is evaluated for effectiveness. Potential problems or improvements are considered. There are three potential issues with Kamenov et al.'s (2018) approach.

(1) The study did not evaluate any correlations between Pb concentrations and the elemental concentrations. For these elements to be confidently used to detect Pb contamination, they must be shown to have a correlation between higher concentrations of these elements and higher concentrations of Pb. Otherwise, it is not clear that contamination of one element has any

relation to Pb contamination. One goal of this study is to analyze this trace element data and compare it with Pb concentration data and Pb isotope data to try to detect statistically significant evidence of Pb contamination. The skull-and-mandible cemetery is particularly well suited for this type of study because of the large number of samples buried within a very small area, minimizing soil differences between contexts.

(2) Thresholds are based on modern human tooth enamel, so potential differences between modern and ancient peoples' exposure to some elements may not be incorporated in the defined thresholds. While it is recognized that modern humans have greater exposure to some elements like Pb, ancient people may have greater exposure to other elements. This would be very difficult to test because any greater concentration of these elements in ancient remains could instead be interpreted to be due to contamination. This study will use the correlations between Pb concentrations and other elements to detect which samples have evidence of soil contamination. The results will then be compared with the thresholds defined by Kamenov et al. (2018) to determine if they should be applied to these ancient remains. For the purposes of this study, R^2 is used to assess correlations as all comparisons are between two variables, although it should be noted that R^2 is the square of the coefficient of correlation rather than the coefficient itself.

(3) The concentrations of some elements in human tooth enamel are likely to be different in other regions based on the natural concentrations of these elements in the soil. While Kamenov et al. (2018) mostly use ancient human remains from Florida for comparison, this may not be representative of other regions. For example, Smith et al. (2019) showed that Florida soil has particularly low concentrations for most of these elements compared to the rest of the US. Therefore, the thresholds they defined may work for those remains, but may be problematic in areas with higher concentrations of these elements in the soil. This may be a greater issue for

ancient teeth because ancient indigenous populations are more likely to be exposed to these elements in the soil than most modern populations (e.g. Simon 1998). This study will test if there is any evidence of this issue in southwest Arkansas.

Contamination of prehistoric animal tooth enamel is also potentially an issue, but it is unclear if the trace element methods created for human tooth enamel are applicable to animal tooth enamel since animals may have biological or dietary differences (e.g. soil ingestion) that result in different elemental concentrations in their tooth enamel (Abrahams and Steigmajer 2003; Johnsen and Aaneby 2019; Johnsen et al. 2019; Samuelsen and Potra 2020; Thornton and Abrahams 1983). While developing such a method for animal tooth enamel is viewed as critical for future research, it is considered beyond the scope of the present study. Either anthropogenic Pb or soil Pb contamination of the human teeth would negatively impact the methods and conclusions in this study. However, if the animal teeth are contaminated by soil Pb, but not anthropogenic Pb, then their Pb isotope values would still be an appropriate comparison to the human remains. If it is not impacted by anthropogenic Pb, the labile portion of soil is considered a viable source of biologically available Pb ratios (Samuelsen and Potra 2020). However, uncontaminated prehistoric animal teeth are the preferred comparison.

3.2 Materials and Methods

3.2.1 Sample Selection

Human teeth were selected from a cross section of skull and mandible clusters from both the West Skull Area (WSA) and the North Skull Area (NSA) on the southern edge of the site (Figure 3.2). This included samples from WSA Clusters 1, 2, 5, 6, 17 and 25 and NSA Clusters 1, 2, and 8. Some skull clusters were sampled because they contained individuals that Burnett (2010) identified as having evidence of violent trauma, but it is important to note that when

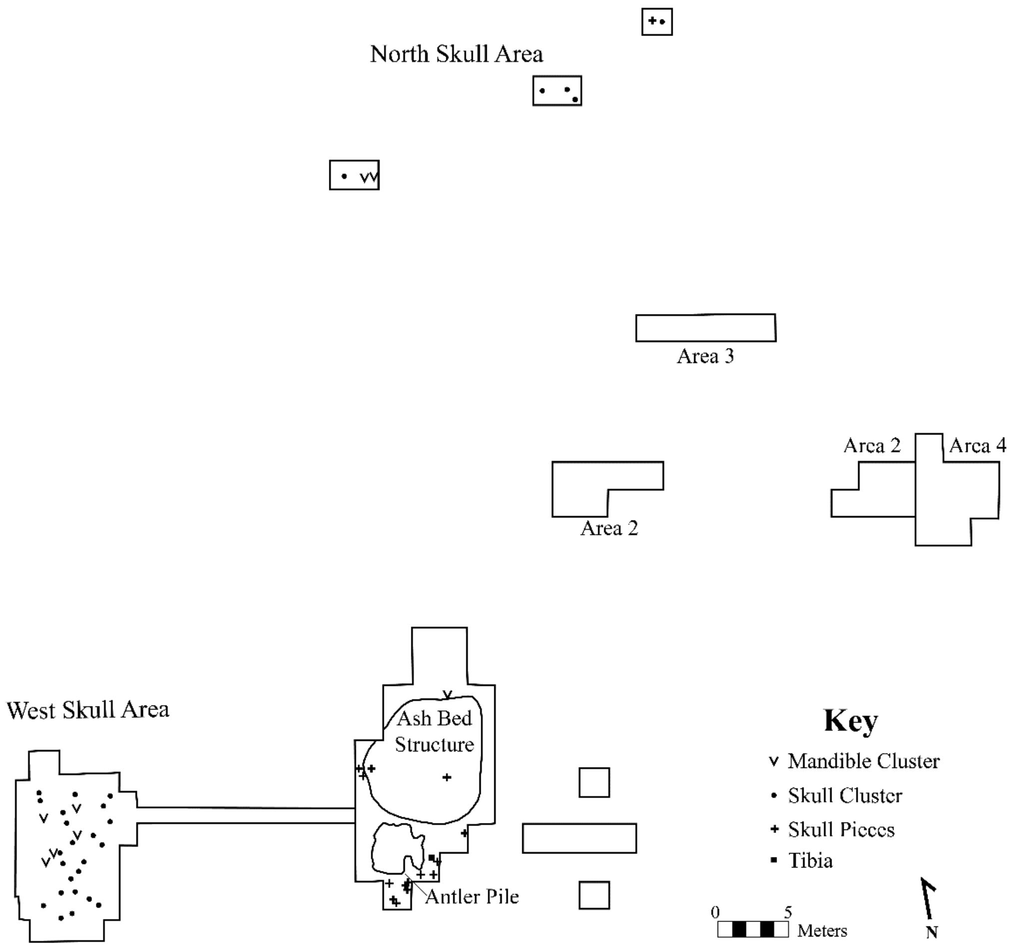

Figure 3.2 – The skull-and-mandible cemetery was excavated in two areas, the West Skull Area (WSA) and the North Skull Area (NSA). Skull clusters and mandible clusters are identified.

Zabecki (2011) reanalyzed the remains, she was unable to verify evidence of violent trauma. These skull clusters were WSA Clusters 6, 17, and 25 and NSA Cluster 1, although WSA Cluster 17 also included an isolated mandible. Some skull clusters were also sampled because they had evidence of cranial modeling (see Chapter 6). These skull clusters were WSA Clusters 5 and 6 and NSA Clusters 1 and 2, although NSA Cluster 2 also contained an isolated mandible. WSA Cluster 2 contained 112 mandibles and was sampled to investigate if mandibles might be coming from different locations than skulls. WSA Cluster 1 and NSA Cluster 8 were also sampled to provide a test of skull clusters that had been previously tested for Sr, carbon, and nitrogen isotopes (Akridge 2014; Samuelsen 2016) and to provide a test of skulls that had no suggested evidence of violence or cranial modeling. One duplicate sample from the Rayburn Cluster previously analyzed by Samuelsen and Potra (2020) was reanalyzed for trace element concentrations and isotopes. Only Sr isotopes were taken from some human teeth from the Rayburn Cluster, WSA Cluster 15 (mandibles), and WSA Cluster 18 (skulls).

Animal teeth were selected from the Southern Plains and Mississippi Valley with potential evidence of violence previously outlined in the literature from ca. A.D. 1200-1500 (Bovee and Owsley 1994:359; Brookes 1999; Brooks 1994; Brooks and Cox 2011; Early 1993; Harmon and Rose 1989; Harris 1953; Huff and Bigs 1963; Krus 2016; Owsley and Jantz 1989; Owsley et al. 1989, 1994; Pillaert 1963:42-43; Potter 2005; Prewitt 2012; Reinhard et al. 1990; Rose et al. 1999:121; Ross-Stallings 2007; Story 1990). While efforts were made to sample specific sites with potential evidence of violence, sometimes prehistoric animal teeth were of limited availability. In those cases, samples were obtained from nearby sites to provide an idea of the regional isotopic signature. Samples from the Southern Plains were collected from sites in central and west Oklahoma and in east Texas. Samples from the Central Mississippi Valley and the upper portion of the Lower Mississippi Valley were sampled from south Illinois, southeast Missouri, northeast Arkansas, and northwest Mississippi. To provide a test if a more proximal area could be distinguished with Pb isotopes and to test the range of Crenshaw's ritual influence, sites in northwest Louisiana were also sampled. Samples previously processed for Pb isotopes by Samuelsen and Potra (2020) were selected for Sr isotope analysis, further establishing the Sr isoscape in southwest Arkansas, northwest Louisiana, and northwest Mississippi.

Animal teeth were generally selected from prehistoric contexts greater than 20 cm below the surface to limit the impact of anthropogenic Pb, which did not affect animals prehistorically and typically stays close to the surface (Clemens 2013; Kede et al. 2014). There are exceptions, particularly two samples (AN174 and AN175) at Bonds Village site (22TU530) which are surface collections. This was necessary due to the lack of collections of buried faunal material at the site. Sampling this site was a top priority for this research since headless burials at the site had been previously suggested to be victims of Caddo raids from Crenshaw (Brookes 1999). Including these samples did not contradict the linear patterning defined by the other samples in northwest Mississippi.

3.2.2 Lab Methods

3.2.2.1 Tooth Drilling and Pre-treatment

Methods for processing tooth samples generally followed Samuelsen and Potra (2020) for Pb on enamel with slight modification. Each tooth was cleaned through sonication in ultra-pure water for 30 minutes and dried overnight. A microscope was used for high accuracy drilling of the teeth and aided in the removal of dentin from enamel. The surface of the human tooth enamel was entirely removed (animal teeth surfaces were abraded following Turner et al. [2009]) with a drill bit to clean and remove any potential contaminants. Any areas of discoloration were also entirely removed. A diamond wheel bit was used to cut approximately 50 mg of enamel from each animal tooth. Any cracks in the enamel were physically broken and both sides of the enamel along the cracks were removed with a drill bit. Small animal teeth often did not have 50 mg of enamel present, so amounts closer to 20 mg were used for these samples. Human Pb samples were originally drilled only for trace element analysis but were also used for isotope analysis despite representing smaller amounts of enamel (about 20 mg). Dentin was clearly removed from all human, deer, beaver, and bear samples. Every effort was made to remove all dentin from all samples, but in order to maximize enamel recovery, some small animal teeth may include small amounts of dentin. As an additional precautionary step, the enamel was sonicated for 60 minutes in ultra-pure water, sonicated for 30 minutes in 0.1 M high-purity acetic acid, sonicated in fresh acetic acid a second time for 5 minutes, and rinsed to a neutral pH with ultra-pure water. Samples were generally processed in batches of 25 teeth with multiple blanks.

3.2.2.2 Column Chemistry for Teeth

Column chemistry (ion chromatography) was executed in a class 100 clean room at the University of Arkansas Radiogenic Isotope Laboratory. The samples were digested in 1 N HBr in acid-cleaned Teflon beakers. A portion of the sample was then removed for trace element analysis. The columns, containing 80 µl of Dowex 1X-8 Pb resin, were cleaned with 2 ml of 0.5 N HNO_3, followed by 2 ml of ultra-pure water. The columns were then conditioned with 2 ml of 6 N HCl. Each enamel sample was loaded and then the columns were washed three times with 1 ml of 1 N HBr. The Pb fraction from the sample was then eluted into a Teflon beaker using 2 ml of 20% HNO_3 and subsequently dried down on a hot plate inside a class 10 laminar flow hood for isotope analysis. The loaded sample and wash from the Pb column processing were collected in a separate Teflon beaker. The liquid in these beakers was dried down at 80°C on a hotplate and redigested in 1 ml of 3.5 N HNO_3 three times. Following the final digestion in 1 ml of 3.5 N HNO_3, the sample was used for Sr column chemistry. This included the leftover portions of samples processed for Pb isotopes by Samuelsen and Potra (2020), providing Sr samples from southwest Arkansas humans (HU1-HU36) and southwest Arkansas, Louisiana, and Mississippi animals (AN1-AN72 and AN149-AN156). The columns, containing 0.1 ml of Eichrom Sr resin, were cleaned with 2 ml of ultra-pure water. They were then conditioned with 1 ml of 3.5 N HNO_3 before being loaded with the sample digested in 1 ml of 3.5 N HNO_3. The sample was then washed with four 100 µl aliquots of 3.5 N HNO_3, followed by 1 ml of the same acid. Finally, the Sr fraction was eluted into an acid-cleaned vial using 1.8 ml of ultra-pure water. An additional 0.2 ml of 20% HNO_3 was added to make the Sr fraction solution 2% HNO_3. The sample and wash that passed through the column prior to elution was collected in a separate acid-cleaned vial. The samples were generally processed in batches of 25 samples with both blanks from the acid pretreatment step and column blanks for both Pb and Sr. Blanks from the acid pretreatment went through all the same processes as the samples (post-drilling).

3.2.2.3 Trace Element Analysis

Trace element analysis was performed following Kamenov et al. (2018) on tooth enamel by taking portions from the pre-column solutions, placing them in a vial, and adding 2% HNO_3 until they were diluted 10,000 times. Trace element analysis focused on Pb and the elements identified by Kamenov et al. (2018) as useful for assessing post-burial contamination: V, Mn, Fe, La, Ce, Nd, Dy, Yb, Th, and U. Some samples were originally diluted 2,000 times, but it became clear that the Pb concentrations were not accurate. Repeated tests showed that trace element analysis was more accurate with the Thermo Scientific iCAP quadrupole inductively-coupled plasma mass spectrometer (Q ICP-MS) when diluted 10,000 times instead of more concentrated solutions. More concentrated solutions tended to underestimate the trace element concentrations of all elements. The more accurate results were verified by testing them alongside known concentration solutions on a Nu Plasma HR multi-collector inductively-coupled plasma mass spectrometer (MC-ICP-MS). The trace element analysis was carried out on the iCAP Q ICP-MS and corrected to multiple concentrations of elemental standard ICP-MS-68A and corrected for drift using a time-based bracketing method for each element. Diluted Sr and Pb fractions were also analyzed so that their concentrations could be aimed at standard concentrations during isotope analysis, if possible.

3.2.2.4 Pb and Sr Isotope Ratio Analysis

The Pb fraction was analyzed on a Nu Plasma MC-ICP-MS using a desolvating system at the University of Arkansas' Trace Element and Radiogenic Isotope Laboratory (TRAIL), following Samuelsen and Potra (2020). The dried down Pb samples were redissolved in 2% HNO_3 spiked with a thallium (Tl) standard created just before analysis, following the procedures outlined by Kamenov et al. (2004). The Pb isotopes were corrected to NBS 981 Pb standard values ($^{208}Pb/^{204}Pb = 36.7006$, $^{207}Pb/^{204}Pb = 15.4891$, $^{206}Pb/^{204}Pb = 16.9356$) based on Todt et al. (1996) using a time-based bracketing method. A standard was run after every fourth sample. All standard and sample Pb data were normalized to $^{205}Tl/^{203}Tl = 2.38750$ (Kamenov et al. 2004). Given the small amount of Pb in many teeth, aiming to a consistent concentration in solution for all samples is generally not possible. Samples with the lowest concentrations were analyzed using the time-resolved analysis method which followed the procedure outlined by Valentine et al. (2008) and Kamenov et al. (2006). Given that for human teeth the entire surface of the tooth was removed and a lower amount of enamel was used, some samples had very low concentrations (Appendix T1, T2). The effect of lower concentrations was investigated on the Nu Plasma by repeatedly running multiple concentrations (80 ppb, 8 ppb, and 0.8 ppb) of the Pb standards as samples bracketed by 80 ppb Pb standard concentrations after every fourth sample. The Pb standards run as samples were corrected to the 80 ppb Pb standard using a time-based bracketing method.

The Sr fraction was similarly analyzed at TRAIL for all human and most animal samples AN1-AN24 and AN57-AN180. Samples AN25-AN56 were analyzed at the University of Illinois Urbana-Champaign also using a Nu Plasma HR (Appendix T3, T4). The analysis program used at both locations corrected for any detected interference from Rb, Kr, and BaAr. The Sr isotopes were corrected to SRM 987 standard value ($^{87}Sr/^{86}Sr$ = 0.71025) using a time-based linear bracketing method. All standard and sample Sr data were normalized to a ratio of $^{86}Sr/^{88}Sr$ = 0.1194. Samples were diluted in 2% HNO_3 until the matched the standard concentrations, which were run at around 15v on ^{88}Sr.

Both blanks processed through all procedures and column blanks were less than 1‰ of all samples. Some blanks had slightly higher concentrations than this, but it was determined that this was due to the specific acid cleaned vials used for trace element concentrations for those blanks. It appears that these vials were leaching into the blanks over time before the blanks were analyzed. This was verified by rerunning the same blanks directly from the Teflon vials, which resulted in the concentrations being reduced to near zero. All Pb isotopic samples were run directly from the Teflon vials and would not have been impacted. All Sr isotopic samples were run from a different type of vial and would not have been impacted. All trace element samples, and many blanks, were also placed in a different type of vial where this problem did not occur.

3.3 Results and Discussion

3.3.1 Soil Contamination

Samuelsen and Potra (2020) previously showed that anthropogenic Pb contamination at Crenshaw is not a significant factor. However, soil Pb contamination still needs to be considered for each sample. This study generally focuses on Nd for two reasons. (1) Nd had the strongest correlations with the most elements. (2) Nd had the highest concentration (C) relative to the maximum threshold concentration (MTC) or C/MTC (besides V) for almost every sample. Samples HU40, HU41, and HU43 were excluded from this analysis since the trace element portion of these samples was clearly lab contaminated. The source (pipette) and timing (during trace element dilution) of this contamination was obvious and did not affect the isotopic portion of the samples as it occurred after the trace element portions were removed. HU42 was processed at a different time and therefore was not contaminated. The trace element analysis and a comparison to Kamenov et al. (2018) ordered by Nd concentration show that about half of the human tooth enamel samples fall below all thresholds with the exception of V (Figure 3.3).

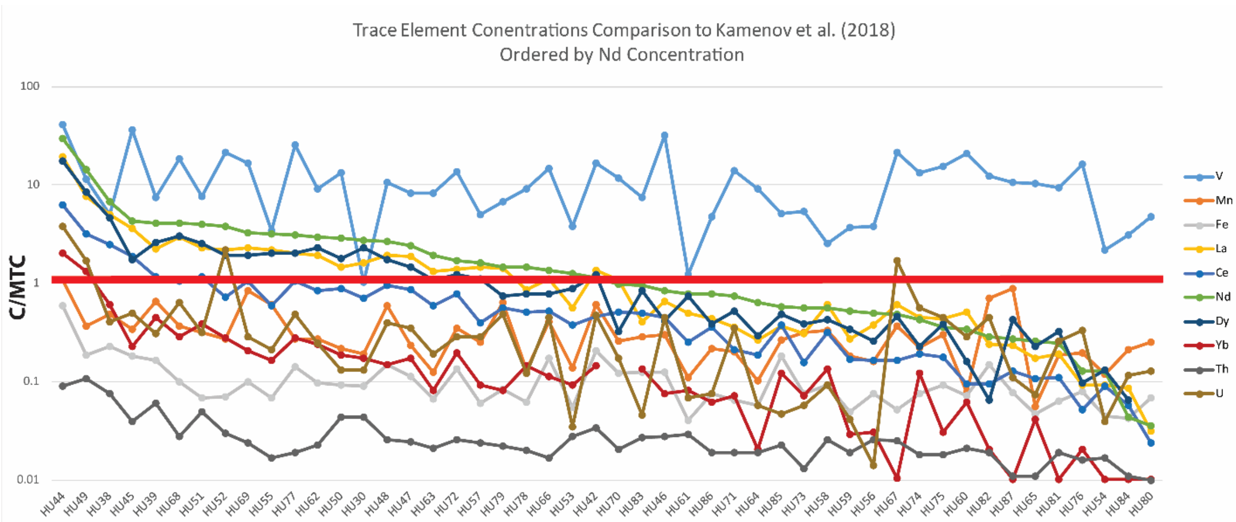

Figure 3.3 – Trace element concentrations represented by concentration (C) over maximum threshold concentration (MTC) of each element. The MTCs used in this figure are those defined by Kamenov et al. (2018).

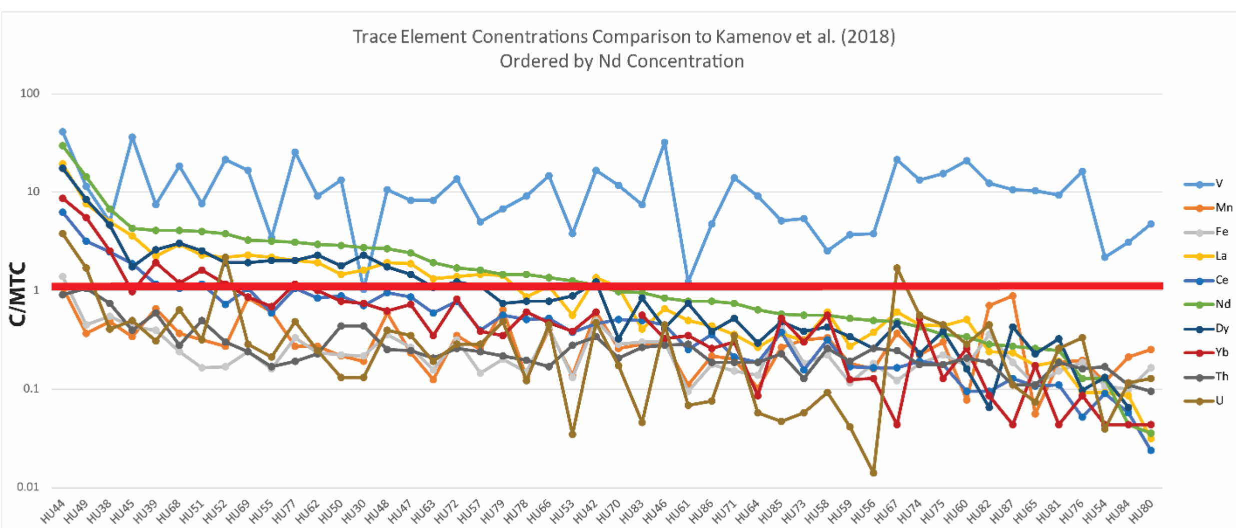

Figure 3.4 – Trace element concentrations with modified MTCs for Fe (60 ppm), Yb (0.005 ppm), and Th (0.005 ppm). In general, REEs increase at similar rates and Fe, Mn, Th, and U increase at similar rates. V seems to have no relationship with the other elements other than U.

While the thresholds originally supplied by Kamenov et al. (2018) were useful, it became apparent that certain elements correlated with each other and that when more strict MTC for Fe (60 ppm), Yb (0.005 ppm), and Th (0.005 ppm) were used, this correlation became more visually apparent (Figure 3.4). Unless otherwise stated, those are the thresholds used in all figures. Some elements clearly correlated with each other while others did not. There were three different groups of elements that more closely correlated with each other: V and U; Fe, Mn, and Th; and the rare earth elements (REE) Nd, La, Ce, Dy, and Yb.

3.3.1.1 V and U

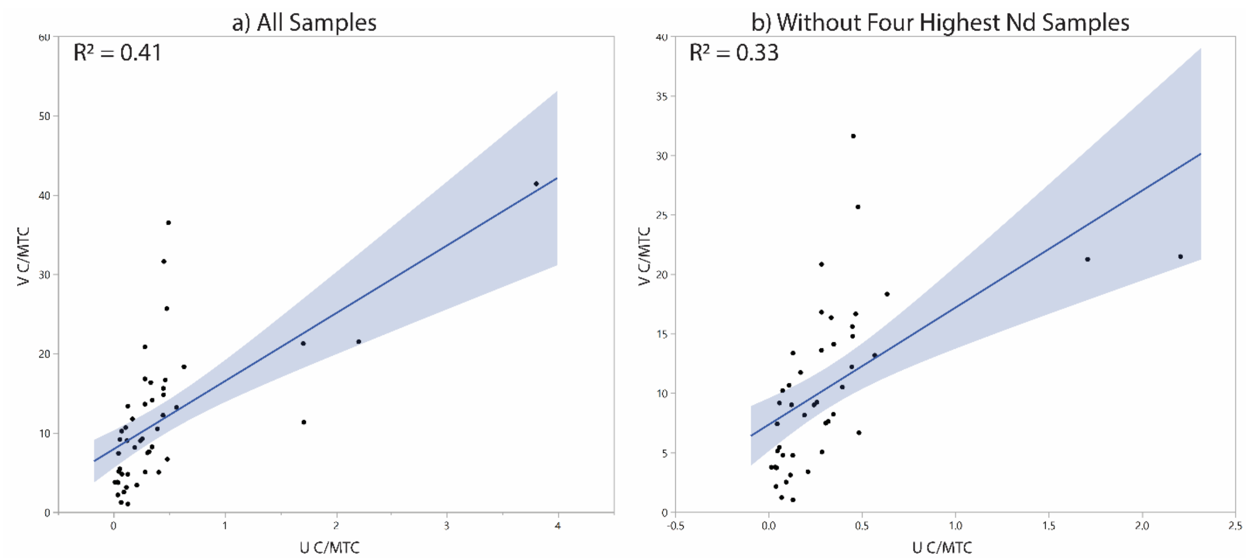

Figure 3.5 – Correlation between V and U concentrations in human tooth enamel. a) Correlation between V and U with all samples. b) Correlation between V and U with four highest concentrated Nd samples excluded. Removing apparent outliers does not significantly change the R^2 values.

The first correlation group is V and U (Figure 3.5). V correlated better with U than with any other element (R^2=0.33) and vice versa when the four highest concentrated Nd samples (HU44, HU49, HU38, and HU45) were excluded. The results indicate that a V MTC of 0.11 ppm was not useful for detecting diagenesis in tooth enamel. V does not seem to have any relation to the other elements (see Figure 3.4). In addition, V and U seem to have little to no relation to Pb concentrations (Figure 3.6). When all samples are included, a comparison of V to Pb concentrations show that there is only a very small correlation and a slightly higher correlation for U and Pb concentrations. However, when the four highest concentrated Nd samples are removed, there is no correlation with U (R^2=0.00) or V (R^2=0.00). These four samples include the two highest V concentrations samples and two of the four highest U concentration samples. These four samples are interpreted to be the most likely samples to have been contaminated by the soil. The fact that excluding them removed any correlation supports this.

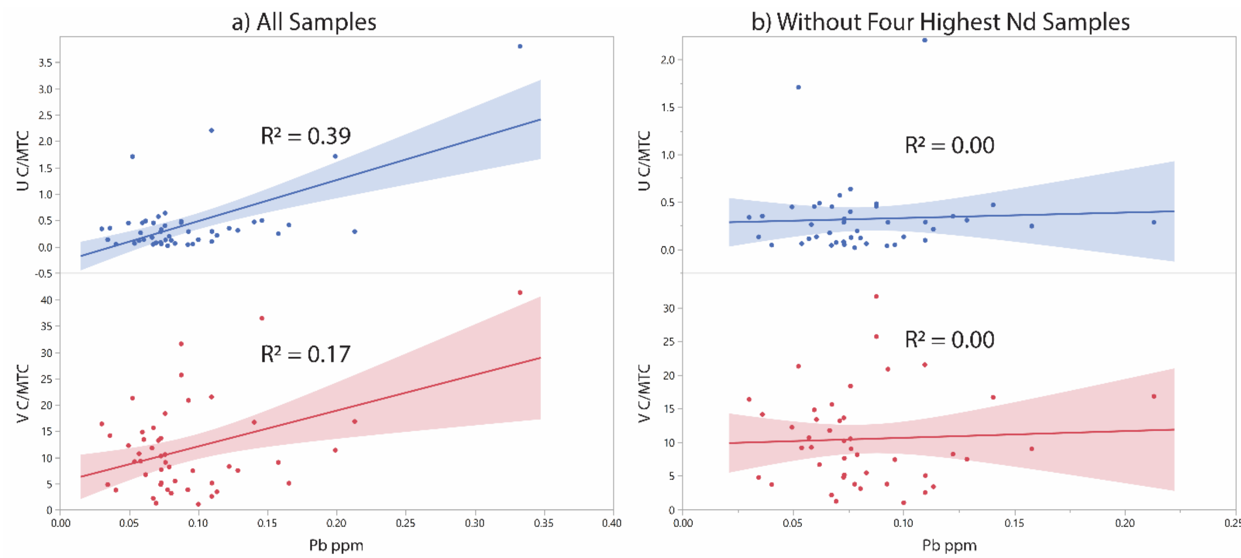

Figure 3.6 – Correlation of V and U with Pb concentrations in human tooth enamel. a) A small correlation exists for both elements with Pb when all samples are included. b) This correlation disappears when the four highest concentrated Nd samples are excluded. This suggest that V and U have high *in-vivo* variability within the tooth enamel or that the contamination of V and U have little relation to Pb contamination. The former reason is suggested to be more likely based on multiple factors.

The high concentrations of V and the lack of correlations for most elements related to V are interpreted to be for one of two potential reasons. (1) V was high *in-vivo* in this ancient population and the contamination of V is indistinguishable from the variability within the population (i.e. signal-to-noise ratio). For this to be the case, the population at Crenshaw must have had significantly more exposure to V than the modern populations examined by Kamenov et al. (2018). The lack of V correlation with other elements is highly suspected to be due to high *in-vivo* concentrations in V. If this is the case, then a V MTC could potentially be more useful in other studies if populations had significantly less exposure to V *in-vivo*, as was generally shown to be the case among ancient populations in Florida (Kamenov et al. 2018). The difference in V concentrations between ancient Florida populations and those at Crenshaw can potentially be explained by the higher content of V in southwest Arkansas soils (Smith et al. 2019). Florida soils have unusually low V concentrations compared to the rest of the US. (2) The contamination of V has no discernible relationship to the contamination of other elements and therefore cannot be used as a reliable predictor of Pb contamination. If this is the cause, then V might not be useful in any study. Regardless, this does suggest that eliminating samples from analysis based solely on a V MTC may result in many uncontaminated samples being excluded and some contaminated samples being included, even in other studies.

The relatively high variability of U compared to the other elements also suggests that U may be quite variable *in-vivo* within the population and contamination may not be as easily differentiable from that natural variability. The relationship of U to V may also suggest that *in-vivo* exposure to V correlates with *in-vivo* exposure to U. V and U high spots and low spots correlated in southwest Arkansas soil samples, which would explain correlated *in-vivo* exposure (Smith et al. 2019). However, some portion of the correlation could also be due to the biological processes that result in the deposition of these elements in tooth enamel. With the present data, it is unclear why the low correlation exists even when the four highest concentrated Nd samples are excluded.

3.3.1.2 Fe, Mn, and Th

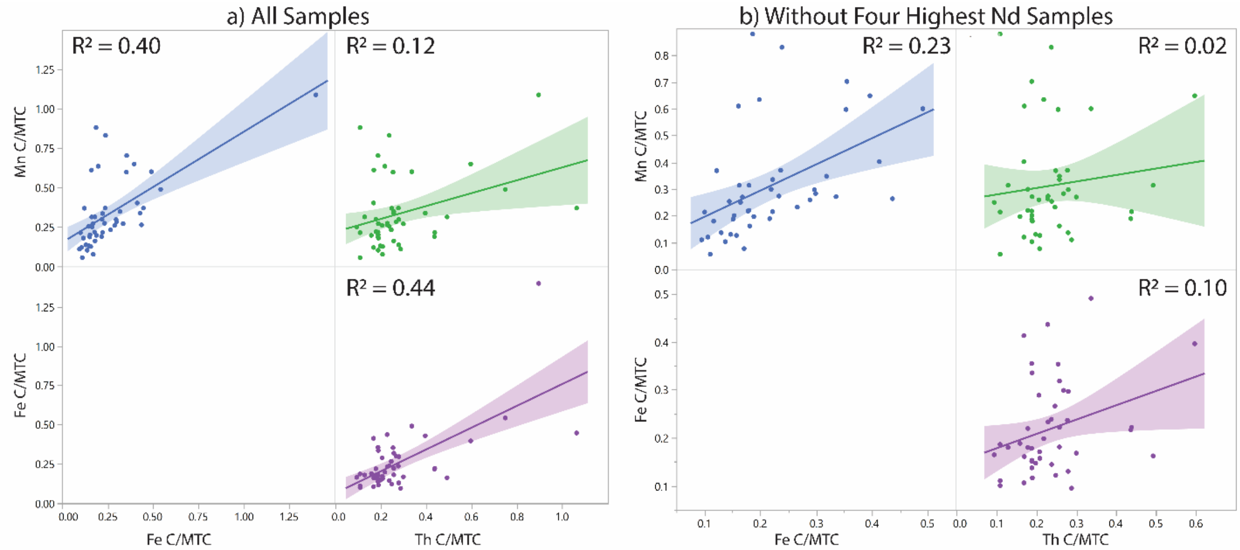

Figure 3.7 – Correlations between Fe, Mn, and Th concentrations in human tooth enamel. a) Correlations between these elements with all samples included. b) Correlations between these elements with four highest concentrated Nd samples excluded. The significant reduction in correlation between the two graphs suggests the four samples may be soil contaminated samples.

The second correlation group included Fe, Mn, and Th. Fe moderately correlated with Mn and Th, although Mn and Th did not correlate well (Figure 3.7). This is also visible when comparing them on an MTC graph where it is clear that they generally increase at similar rates (Figure 3.8). This is one reason why Th is grouped with Fe and Mn rather than with the REEs. Fe (R^2≈0.75), Mn (R^2≈0.28), and particularly Th (R^2≈0.65) correlated well with REEs but less well than REEs with other REEs and the correlations were significantly reduced when excluding the four highest concentrated Nd samples (Fe R^2≈0.10, Mn R^2≈0.10, and Th R^2≈0.40). Similar to U and V, these three elements correlated moderately well with Pb concentrations (R^2≈0.45), but once the four highest Nd samples were excluded, the correlations dropped considerably (R^2≈0.10) to the point where no evidence of contamination was suggested by this metric (Figure 3.9). A comparison with U shows that U was more variable with more extreme highs and lows relative to the other elements (Figure 3.10). Some variability of Mn was also apparent, but not like U. The lack of correlations of these elements with Pb concentrations (when the four highest Nd samples are excluded) indicates there is no significant evidence of Pb contamination related to the other samples.

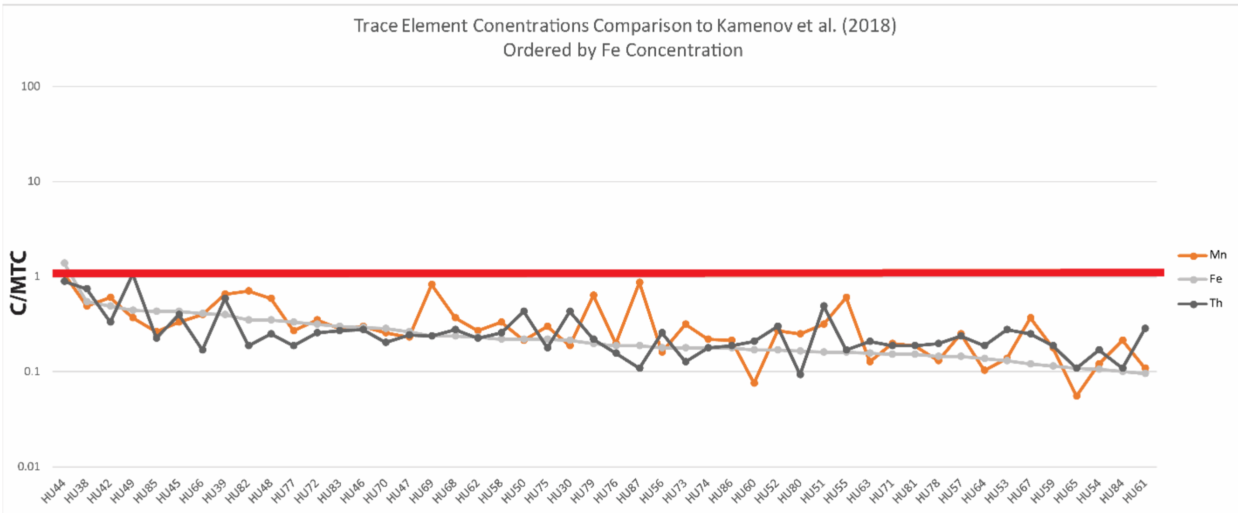

Figure 3.3 – Comparison of trace element data for Fe, Mn, and Th from human tooth enamel, ordered by Fe concentrations. While correlations are not strong, these three elements tend to increase at about the same rate. They do not increase at the same rate as the REEs.

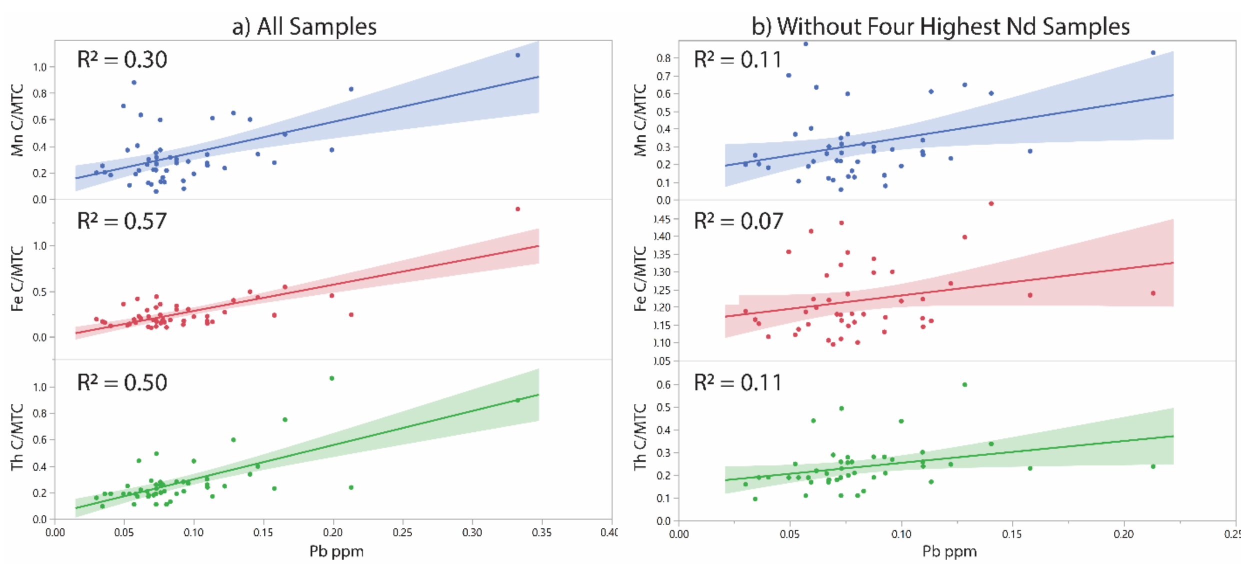

Figure 3.4 – Correlations between Fe, Mn, Th, and Pb concentrations in human tooth enamel. a) Correlations between these elements with all samples included. b) Correlations between these elements with four highest concentrated Nd samples excluded. The lower correlations with the four samples excluded suggest the lack of significant soil contamination.

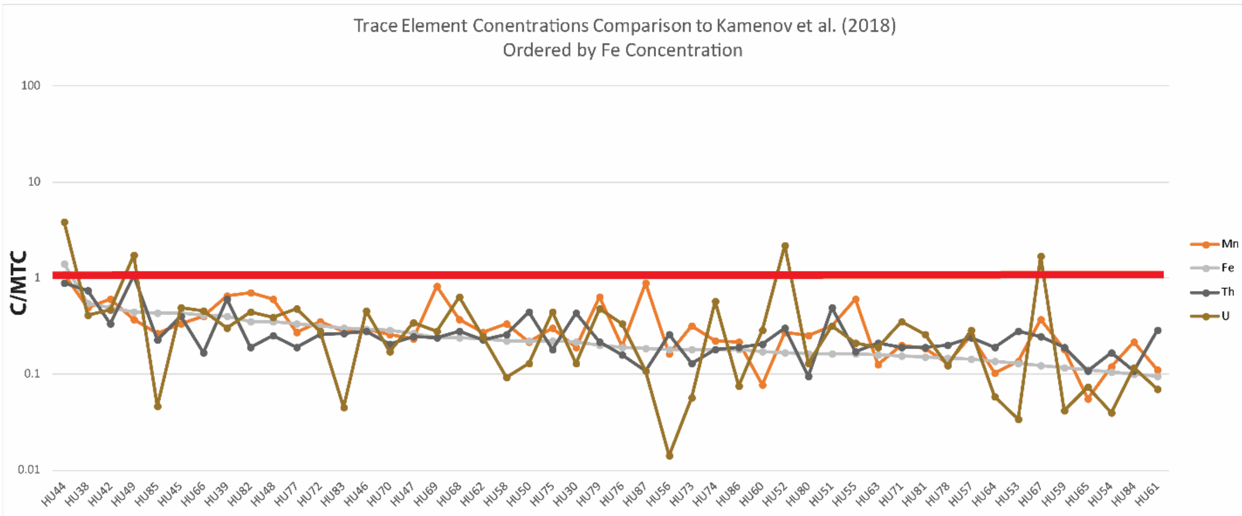

Figure 3.10 – Trace element data from human tooth enamel focusing on U's variability compared to Fe, Mn, and Th, ordered by Fe concentrations.

3.3.1.3 Rare Earth Elements: Nd, La, Ce, Dy, and Yb

The third group was Nd, La, Ce, Dy, and Yb (Figure 3.11). The correlation between these elements is extremely strong (R^2≈0.96) and can be explained by them all being REEs with similar atomic masses (Figure 3.12). This correlation is only slightly reduced when the four highest concentrated Nd samples are excluded (R^2≈0.88) except for Yb. Yb correlations are lower (R^2≈0.69-0.80). Nd and Dy have the highest correlation of all elements in each case (all samples R^2=0.99, without highest four R^2≈0.94) followed closely by Nd and La. Another similarity between these REEs is that they are expected to have very low concentrations in tooth enamel (Kamenov et al. 2018:Table 1), so any appearance of soil contamination is likely to have a major effect on the concentrations of these elements. By contrast, some of the elements in the first group, Fe and Mn, can have very high naturally occurring concentrations in tooth enamel. Therefore, contamination from the soil may be less evident as the increased concentrations may not be discernably different from the natural variation within a population. The appearance of variability in lower concentration samples in some figures is due in part to the logarithmic scale which tends to reduce this appearance of variability with higher values. Despite this variability, these elements are highly related. To further illustrate this point, when the MTCs for all other elements but Nd are adjusted, they follow Nd very closely (Figure 3.13).

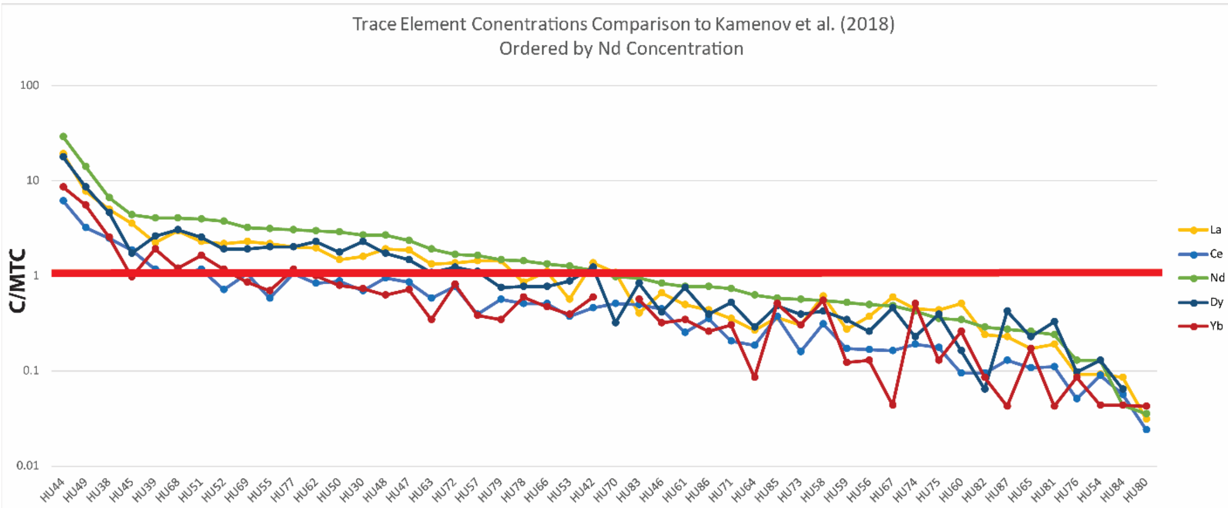

Figure 3.6 – Strong correlation and similar rates of increase can be seen in REE concentrations ordered by Nd concentrations.

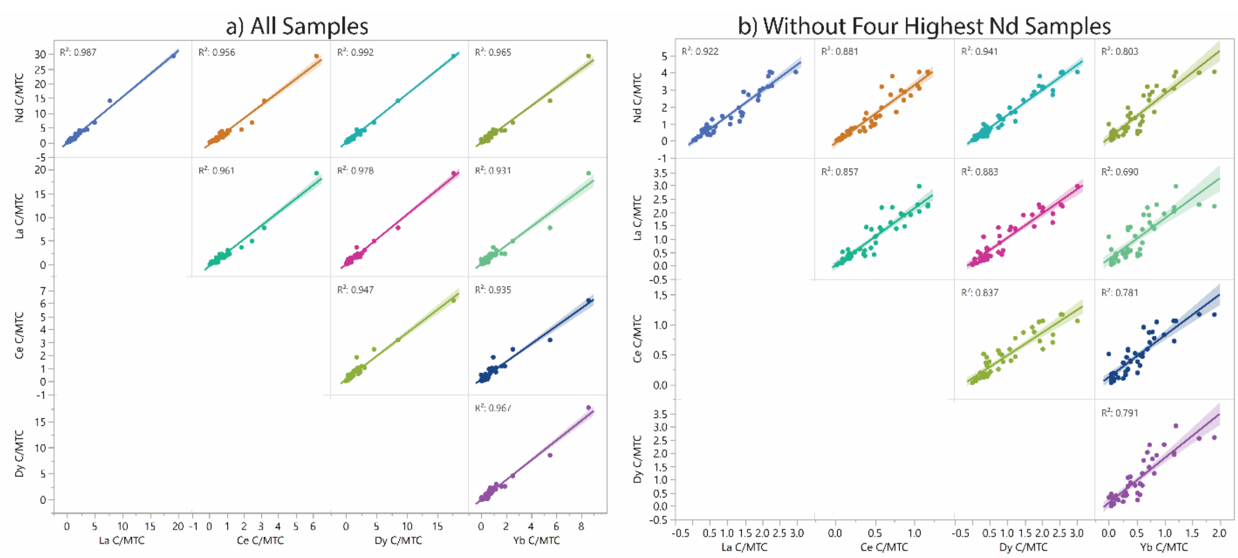

Figure 3.5 – Correlations between the REEs is reflected by very high R^2 values. a) Correlations between these elements with all samples included. b) Correlations between these elements with four highest concentrated Nd samples excluded. Correlations with the four highest concentrated Nd samples are extremely high, but weaken when those four samples are excluded, particularly for Yb.

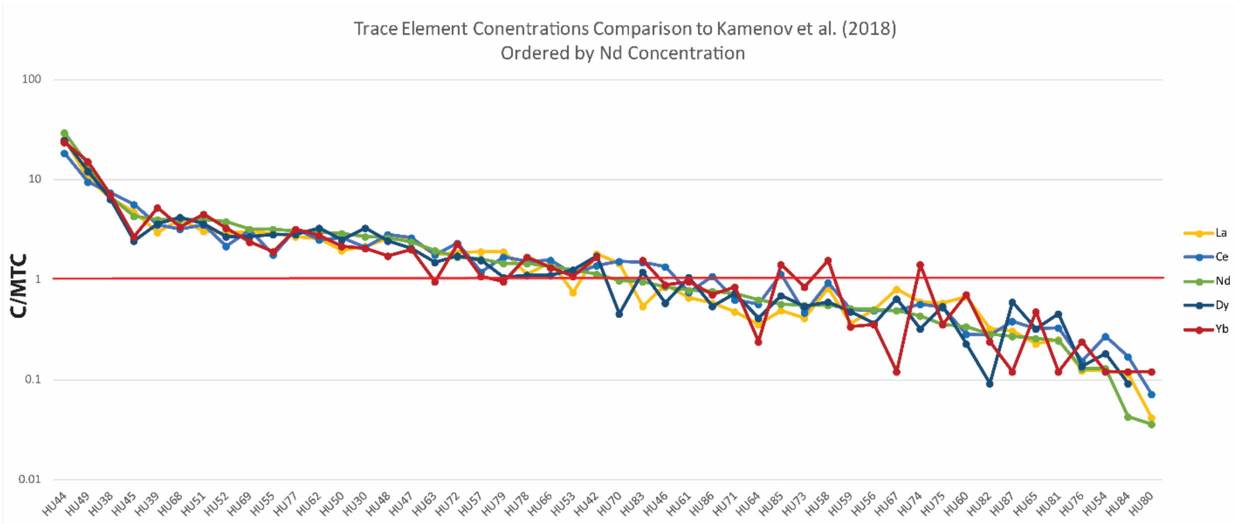

Figure 3.13 – Trace element concentrations of REEs ordered by Nd concentrations and with modified thresholds for visual effect only. When the MTCs are changed (La=0.075 ppm, Ce=0.04 ppm, Dy=0.0064 ppm, Yb=0.0018 ppm), the correlation and similar rates of increase between these elements becomes very clear. Variability appears higher with lower concentrations samples, but this is partly due to the logarithmic scale and perhaps the very low concentrations and MTCs of some elements. Pb, Fe, Mn, Th, and U have a very different rate of increase (lower) while V appears nearly random.

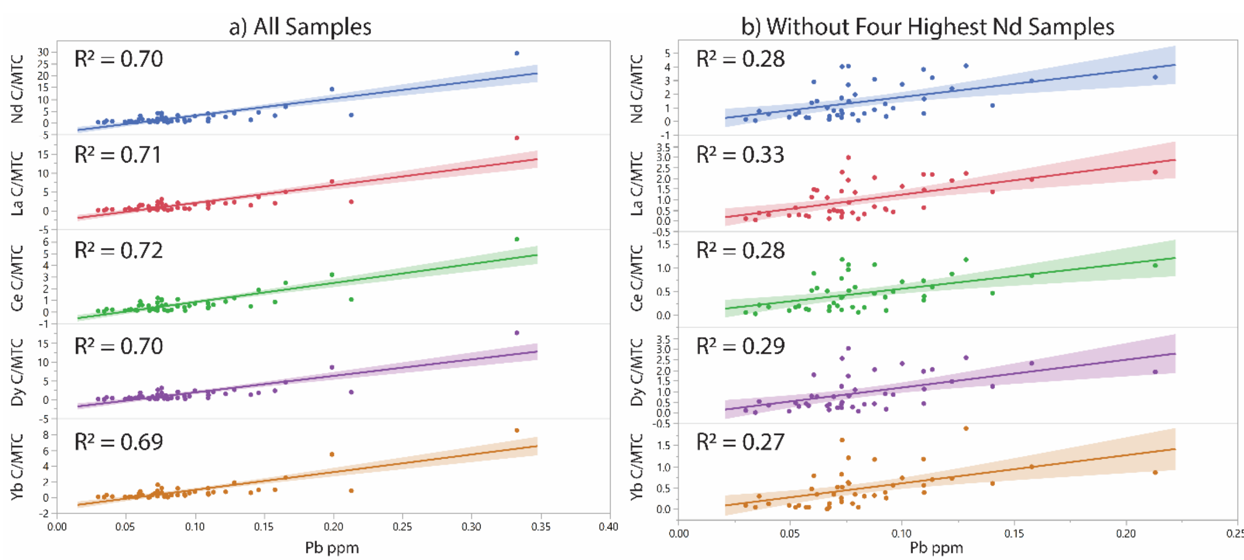

Figure 3.14 – Correlations between Nd, La, Ce, Dy, Yb, and Pb concentrations in human tooth enamel. a) Correlations between these elements with all samples included. b) Correlations between these elements with four highest concentrated Nd samples excluded. The correlation between the REEs and Pb drop considerably when the four highest Nd samples are excluded.

The only elements that have any clear correlation with Pb concentrations are REEs (Figure 3.14). They generally correlate strongly ($R^2 \approx 0.70$), but this correlation is severely reduced when the four highest concentrated Nd samples are excluded ($R^2 \approx 0.29$). Excluding additional high concentration Nd samples (even all those above the MTC) sometimes reduces this correlation in some elements, but also increases the correlation in other elements. It is therefore interpreted that the low correlation between the REEs and Pb concentrations is likely due to *in-vivo* caused correlation while the higher correlation is more suggestive of soil contaminants.

3.3.1.4 Correlation and Causation

It is important to note that the correlations shown in these groups could be caused by increasing levels of post-burial contamination, but they could also be caused by increasing *in-vivo* exposure or biological processes. The cause of these correlations should not be assumed, rather the data should be analyzed for contrasts between expected evidence of post-burial contamination with expected evidence of *in-vivo* exposure or biological processes. Correlated increases of these elements would be consistent with increasing soil contamination which would be expected to affect all these elements. However, it is also possible that increased exposure to these elements could reflect exposure to soil or other sources *in-vivo* as well. Some of these elements often correlate with each other in nature, so correlations do not necessarily equate to contamination. It is expected that clear evidence of post-burial soil contamination would be reflected in major increases to most elements across different correlation groups. This may not be the case for *in-vivo* exposure as correlation may be expected to be restricted to within correlation groups due to common natural occurrences of these elements or because of the way the body deposits these elements in tooth enamel. For example, a correlation of REEs would be expected in either case, but a correlation of REEs, Fe, Mn, Th, and U would more readily be explained by direct soil addition of these elements. It is also expected that post-burial contamination would result in stronger correlations between some of the elements and Pb concentrations given that soil contamination would result in direct addition of these elements. This contrasts with *in-vivo* exposure, where these elements go through a variety of biological processes before being deposited in tooth enamel (e.g. Gulson et al. 1998; Jenkins et al. 2001; Lemons and Kennington 1983; Metcalfe et al. 2010; Price et al. 1985; Schurr 1997, 1998). Therefore, correlations might still be expected, but may be weaker.

Evidence of post-burial contamination is clearly seen by comparing REEs and Pb concentrations when only including the four highest concentrated Nd samples (Figure 3.15). The R^2 values are as high as 1.00 for some of these and similarly high correlations are seen between Pb concentrations and Fe ($R^2 \approx 0.92$), Mn ($R^2 \approx 0.91$), and U ($R^2 \approx 0.97$). All of these, except for Yb, are statistically significant ($p<0.05$) despite representing only four samples. Correlations are not very strong with V ($R^2 \approx 0.26$) or Th ($R^2 \approx 0.27$). However, the fact that both very strong correlations with Pb concentrations and very strong correlations between the different correlation groups (REEs, Fe, Mn, and U) occur is very suggestive that this relates to post-burial contamination of Pb rather than *in-vivo* exposure. The lack of a strong correlation with V is further support for the conclusion that V was high *in-vivo* and that the high variability within the population is indistinguishable from added V through contamination. The underlying reason for the lack of a strong correlation with Th may be due to the fact that Th correlated poorly with other elements like Nd ($R^2=0.21$) in the Crenshaw soil.

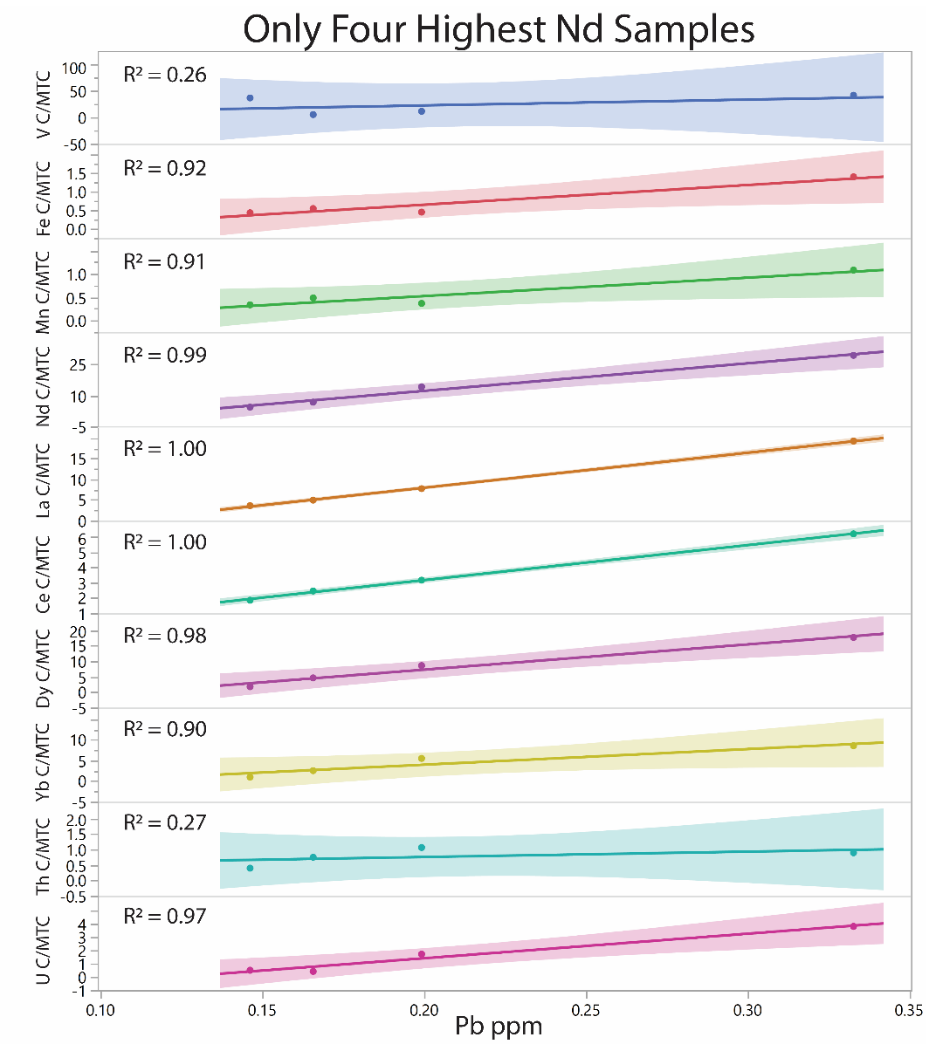

Figure 3.15 – Correlation between all trace element data and Pb concentrations in human tooth enamel only including the four highest concentrated Nd samples. The correlations are extremely strong for most elements. Lower correlated elements include V and Th. V does not correlate well with any other elements, so this is consistent with the rest of the analysis. Th may have a lower correlation because it has relatively high variability in Crenshaw's soil.

To further illustrate the significance of these correlations, other subgroups of samples can be analyzed as well. When the six samples with Nd concentrations below the highest four are similarly analyzed, the correlations are low and some have an inverse (negative slope) correlation (Figure 3.16). This is not due to subjective sample selection as this is also true if, for example, four, eight, or ten samples are used below the four highest concentrated Nd samples. In addition, there is also a lack of correlation between different correlation groups, some also being inversely correlated.

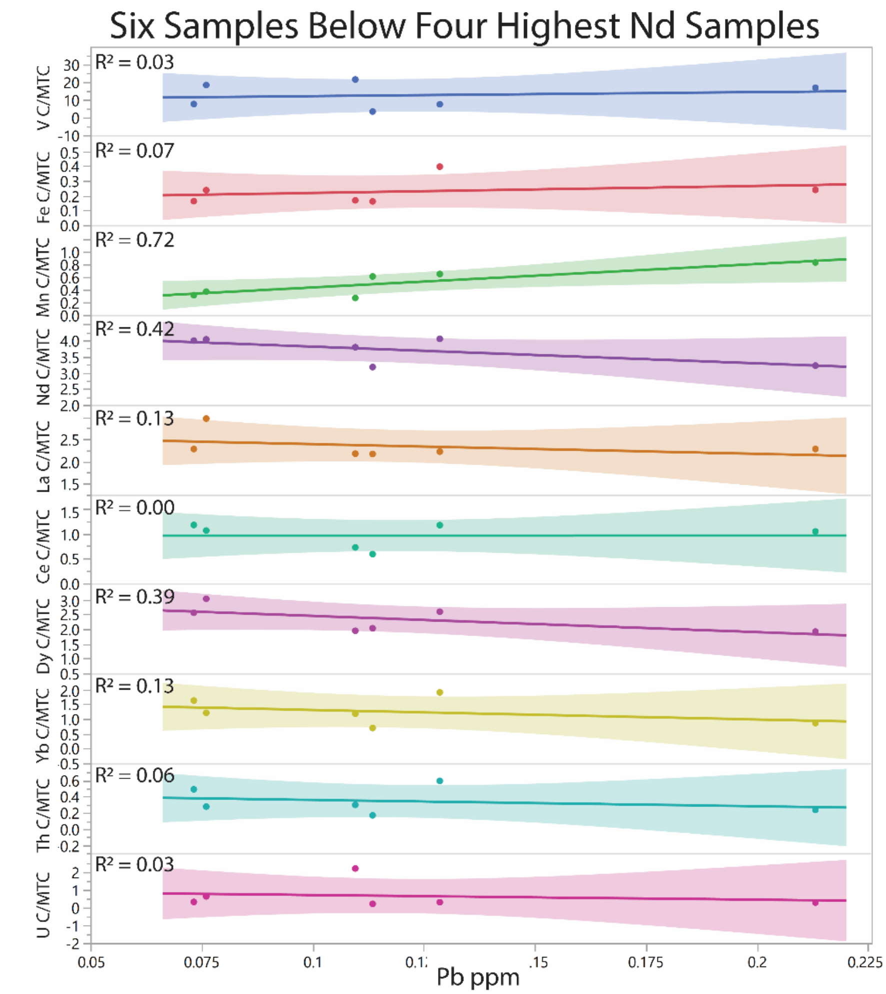

Figure 3.16 – Correlations between all elements and Pb concentrations for the six samples below 4.34 Nd C/MTC (four highest concentrated Nd samples). This shows that these samples lack significant correlations between these elements and Pb concentrations. Some of the elements are even inversely correlated (negative slopes).

Comparisons of Pb concentrations (using an MTC of 0.2 ppm for comparison only) with the REEs show that Pb has very little relationship to these elements with the exception of the samples with the highest concentrations of Nd (Figure 3.17). Many of the highest Nd concentration samples have Pb concentrations consistent with many samples below or very near the MTC. Just as with other elements, it is also expected that increased Pb concentrations might correlate with these other elements even if they were acquired *in-vivo* rather than through post-burial contamination. It is clear, though, that Pb concentrations increase at a lower rate than REEs.

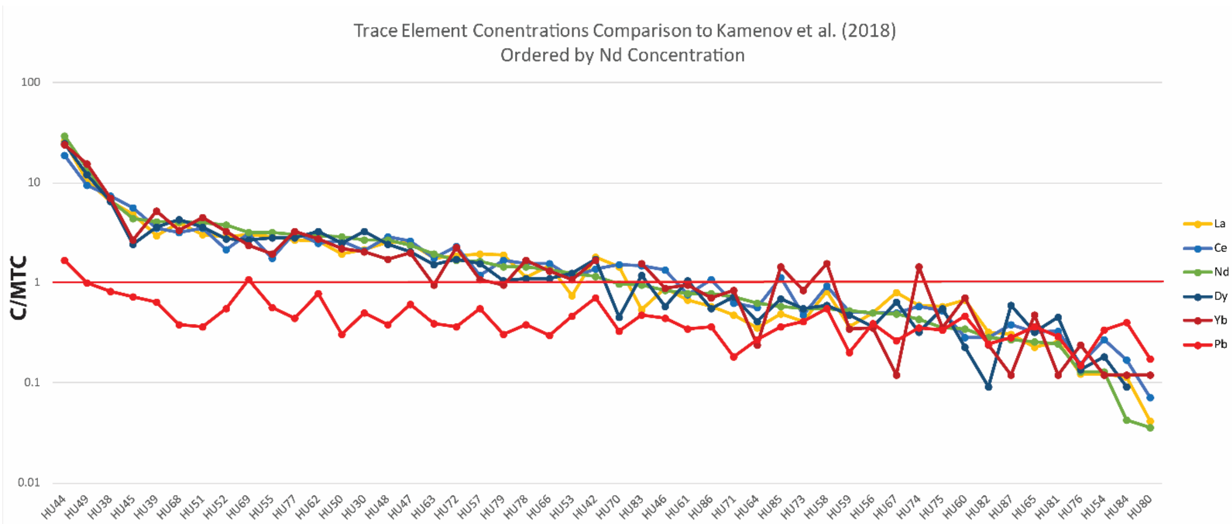

Figure 3.17 – Trace element concentrations of REEs ordered by Nd concentration and with modified thresholds for visual effect only. When the MTCs are changed (La=0.075 ppm, Ce=0.04 ppm, Dy=0.0064 ppm, Yb=0.0018 ppm, Pb=0.2 ppm), the correlation between all elements, but not Pb, becomes very clear. Pb has a more similar rate of increase to Fe, Mn, Th, and U.

When plotted on a linear scale, the gradual increases of concentrations show that soil contamination was not clearly apparent until Nd passed five times the MTC (Figure 3.18). At that point, several elements had passed the thresholds and concentrations drastically increased for the three samples with the most Nd. A linear comparison with adjusted MTCs also clearly shows where concentrations surge (Figure 3.19). Considering the miniscule amounts of some of these elements in tooth enamel and the relatively large concentrations of some of these elements in the soil, the drastically increased concentrations for these last three samples display the clearest evidence of post-burial soil contamination. Strong increases of La and Ce in the fourth sample hint that it was affected as well.

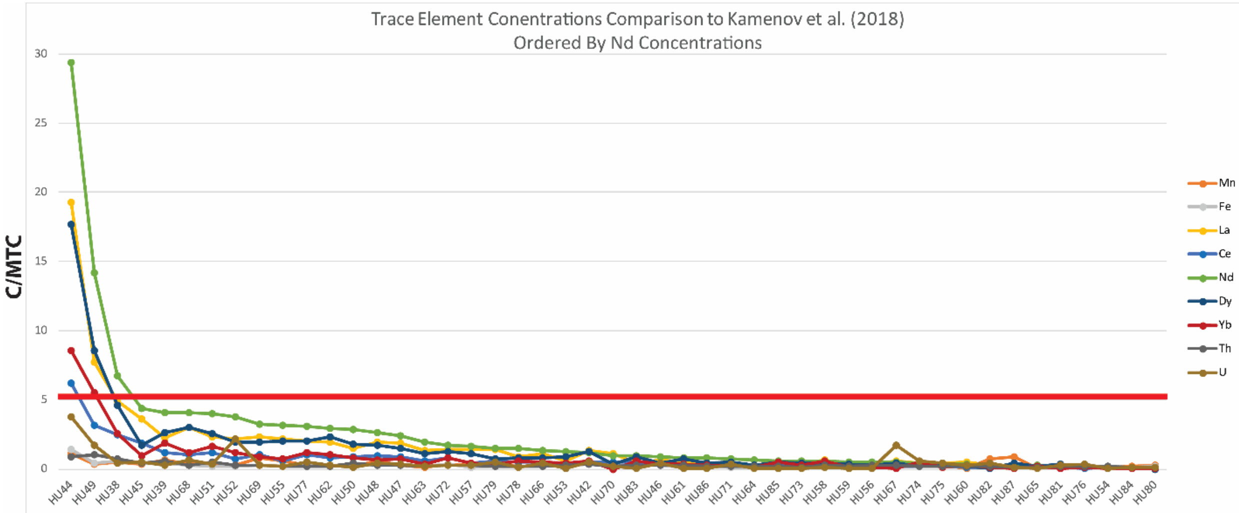

Figure 3.18 – Trace element data ordered by Nd concentrations with a linear scale. This shows the strongest evidence of soil contamination appears above five times the Nd MTC (red line). When this threshold is crossed, concentrations rapidly increase in many different elements.

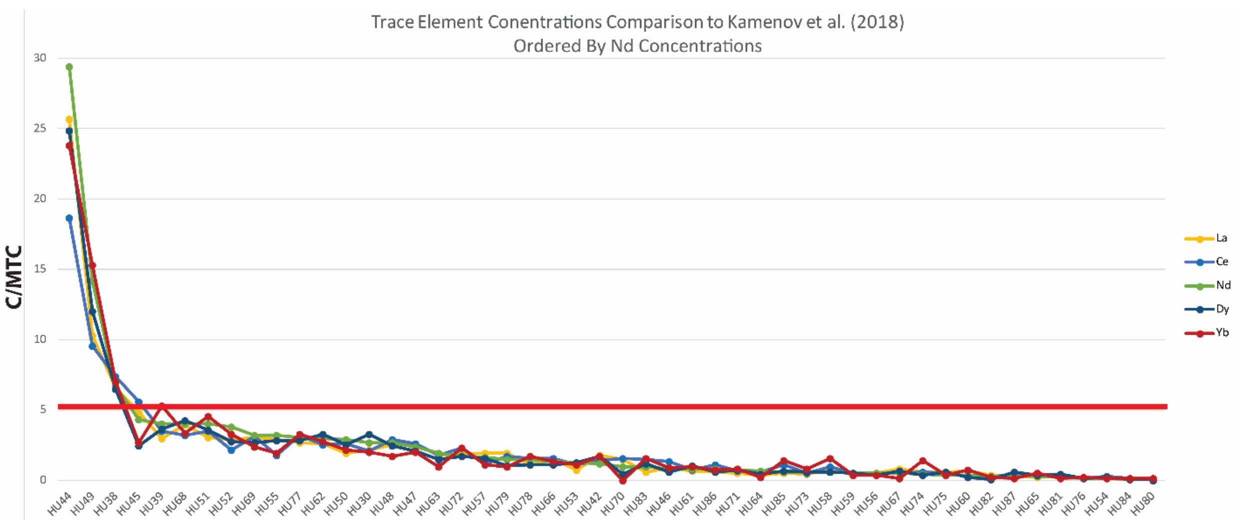

Figure 3.19 – Trace element concentrations of REEs ordered by Nd concentration, with modified thresholds, and a linear C/MTC axis. When the MTCs are changed (La=0.075 ppm, Ce=0.04 ppm, Dy=0.0064 ppm, Yb=0.0018 ppm), the correlation between these elements becomes very clear. The red line in this graph marks five times the MTCs.

Combining all this information together, the evidence suggests the four highest concentrated Nd samples are most likely contaminated. The lowest of the four contaminated samples has a C/MTC value of 4.34. By contrast, samples below this value do not show evidence of significant modification of Pb concentrations in tooth enamel. These samples show little evidence of the correlations that would be expected from post-burial contamination. As a precaution, samples above the MTC will be analyzed for differences from those below the MTC when analyzing Pb isotopes to detect any possible differences.

3.3.1.5 On Maximum Threshold Concentrations

If this analysis is correct, then the Nd MTC for this population should be about four times the value presented in Kamenov et al. (2018) and the V MTC should be more than an order of magnitude higher. This would most likely mean that this ancient population had greater *in-vivo* exposure to many elements than has been shown among modern populations. It is suspected that higher thresholds may be appropriate for different populations depending on diet and soil content of these elements where the people grew up.

This may be particularly true for ancient populations in the US if they were significantly exposed to some type of soil ingestion or leaching of these elements from pottery vessels or other sources. Indigenous populations around the world are known to be much more likely to directly ingest soil either through intentional (geophagia) or unintentional means (Anell and Lagercrantz 1958; Simon 1998). Intentional soil ingestion can be practiced in rituals, soil can used as an ingredient in food preparation, and soil can be consumed for social reasons. These behaviors can be more prevalent among pregnant mothers and young children. Indigenous populations, particularly children, can also be more exposed to accidental soil exposure through clay floors in houses and many outdoor activities (Simon 1998). Many of these factors do not apply to most modern populations. The interiors of pottery vessels in the Caddo Area are often very rough and porous and are expected to be a potential source of exposure to some of these elements. While this is a relatively under-investigated topic in ancient wares, elemental exposure through leaching has been demonstrated with some modern and much less porous ceramic wares (Ahmad et al. 2017; Dinh et al. 2018; Mohamed et al. 1995; Valadez-Vega et al. 2011; Velayudhan 2013).

As it relates to V specifically, there is some evidence that ancient and indigenous populations might have higher V concentrations and variability than most modern populations. Jenkins (1979) compiled V concentrations in human hair. The values show that samples from an indigenous group in the Amazon had V concentrations as high as 0.7 ppm, while V in human hair from Japan averaged around 0.03 ppm and the US averaged around 0.04 ppm, or about an order of magnitude lower than the indigenous population. Considerable variability (V ppm=0.004-0.625) in a modern population was also seen in human nails (Masironi et al. 1976). Jenkens (1979:133) also noted that children tended to have higher concentrations than adults, which could be important for teeth since they form during childhood (see also, Kučera et al. 1992).

As noted earlier, the difference in V concentrations between ancient Florida populations and those at Crenshaw can potentially be explained by the higher content of V in southwest Arkansas soils compared to Florida soils (Smith et al. 2019). This is also true for the REEs that Smith et al. (2019) tested (i.e. La and Ce). Therefore, there is evidence that the MTCs defined by Kamenov et al. (2018) may be appropriate for many areas, but some ancient populations may need higher MTCs for some elements. If an MTC is modified, it should be done with evidence, like the evidence of correlations presented here. In the case of V in this study, it is recommended that it not be used for assessing contamination of Pb. It is also possible that lower MTCs might be appropriate, like the lower thresholds used here for Fe, Yb, and Th. However, caution should be exercised if lowering thresholds would cause samples to be classified as contaminated when they would have otherwise been identified as uncontaminated. Modification of the MTCs without evidence could be dangerous as it could force samples to be included or excluded from analysis and greatly affect interpretations.

3.3.1.6 Contamination of Pb

These results indicate that at least half the samples from the skull-and-mandible cemetery were not significantly contaminated by anthropogenic or soil Pb. This analysis suggests that the four highest concentrated Nd samples were contaminated, and less concentrated samples were not. Since the samples with Nd concentrations over the MTC are less clear, they are included in Pb isotope analysis with different symbols so that differences could be detected between the samples above and below the MTC, if they exist. Despite the lab contamination of the trace element samples, the Nd concentrations of HU40, HU41, and HU43 were above the Nd MTC but below three times the Nd MTC and are therefore included in the above MTC group for Pb isotope analysis.

3.3.2 Isotope Analysis

3.3.2.1 Low Concentration Tests

Multiple concentration Pb standard runs showed that there were no significant problems in accuracy or precision with the 80 ppb (~0.450 v on ^{204}Pb) and 8 ppb (~0.045 v on ^{204}Pb) standards. However, the 0.8 ppb (~0.0045 v on ^{204}Pb) standard showed a dramatic decrease in accuracy and precision (Figure 3.20). This made it clear that low concentration samples would cause local individuals to appear non-local in a patterned way. The pattern consisted of a trend that directly affects linear pattering analysis because it is nearly perpendicular to the linear patterning represented by the animals in southwest Arkansas (see Figure 3.20b). This would have great effects on the human data, pushing otherwise local samples outside of the local range. In the case in Figure 3.20, it would most likely result in samples appearing below the southwest

Arkansas animals, causing them to appear non-local and as though they originated from another region. While the accuracy could potentially be corrected for, the great lack of precision would undermine the reliability of any comparisons. It became apparent that human samples under about 0.025v on ^{204}Pb had significantly decreased accuracy and precision. Given the potential for incorrect interpretations during linear patterning analysis, a strict threshold of 0.025v on ^{204}Pb was used for the humans. This was determined to be less of a factor for the animal teeth since the increased variability would not affect interpretations, so a threshold of 0.015v on ^{204}Pb was used for these samples. Few animals (n=13) fell below the thresholds because of the greater amount of enamel used compared to human samples. Animal teeth between 0.025v and 0.015v did not contradict the general patterns whereas some humans in that 0range did due to the patterned way accuracy and precision were affected.

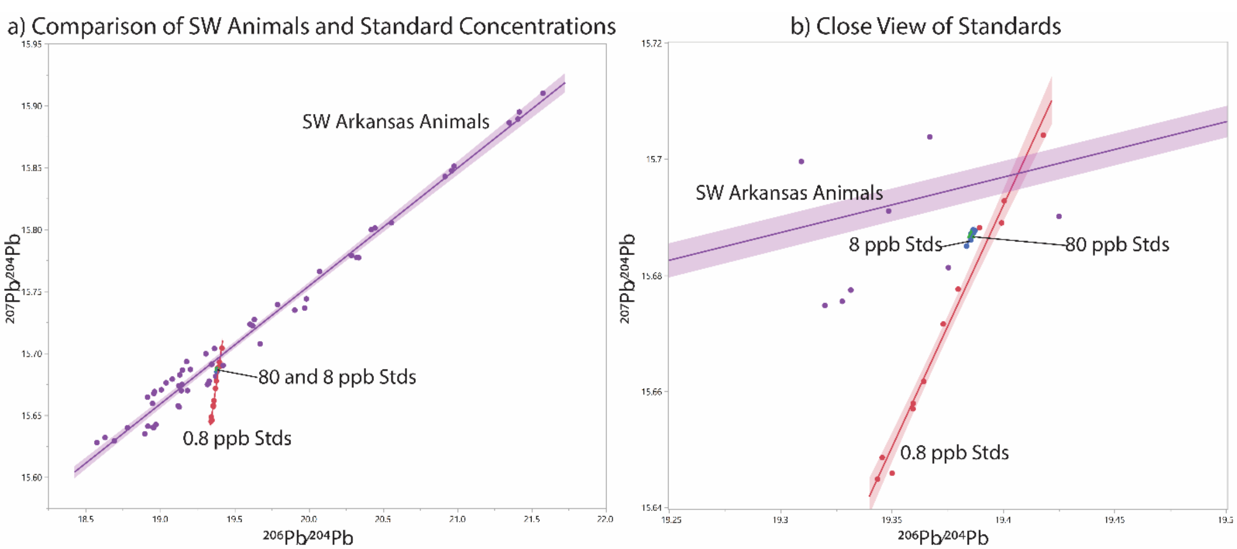

Figure 3.7 – Comparison of southwest Arkansas animal data with multiple concentration Pb standards (80 ppb, 8 ppb, and 0.8 ppb). Results show that lower (<0.045v on ^{204}Pb) could have significant effects on interpretations. However, the exact threshold is unclear with these data as the 8 ppb standard was accurate with only a small reduction in precision. Therefore, a threshold between the 8 ppb and 0.8 ppb standard was used based on the ^{204}Pb voltage and the potential to affect interpretations. Comparisons between animals and standards were made possible by adding a constant value to each standard ratio (^{208}Pb/^{204}Pb = +2.39, ^{207}Pb/^{204}Pb = +0.198, and ^{206}Pb/^{204}Pb = +2.45).

3.3.2.2 The Pb Isoscape

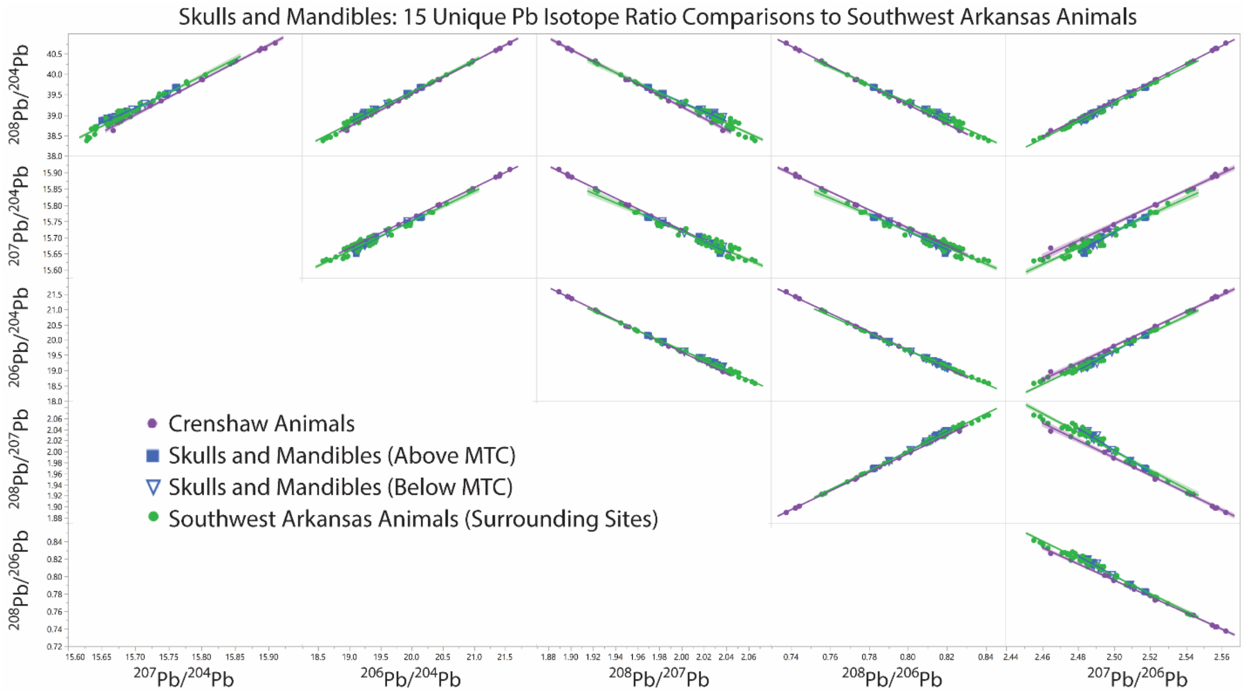

Figure 3.21 – Linear patterning analysis of all 15 Pb isotope bivariate comparisons shows the skulls and mandibles match southwest Arkansas sites in all comparisons. They generally match southwest Arkansas animals from surrounding sites better than the animals from the Crenshaw site itself.

Linear patterning analysis of Pb isotopes from the skulls and mandibles (both above and below the Nd MTC) and southwest Arkansas animals show that they are consistent with animals from surrounding sites in all 15 bivariate graphs (Figure 3.21), but generally not consistent with local Crenshaw humans and animals (Figure 3.22). The fact that the skulls and mandibles mostly match the animals from surrounding sites rather than the humans and animals at Crenshaw is consistent with a dispersed settlement pattern. This suggests the burial practice may reflect the ritual treatment of surrounding populations' remains in a regional cemetery. One sample (HU62) is slightly outside the range defined by the animals in one graph (see Figure 3.22), but this sample is at the lower end of the voltage threshold (0.0273v on ^{204}Pb) and deviates the same way

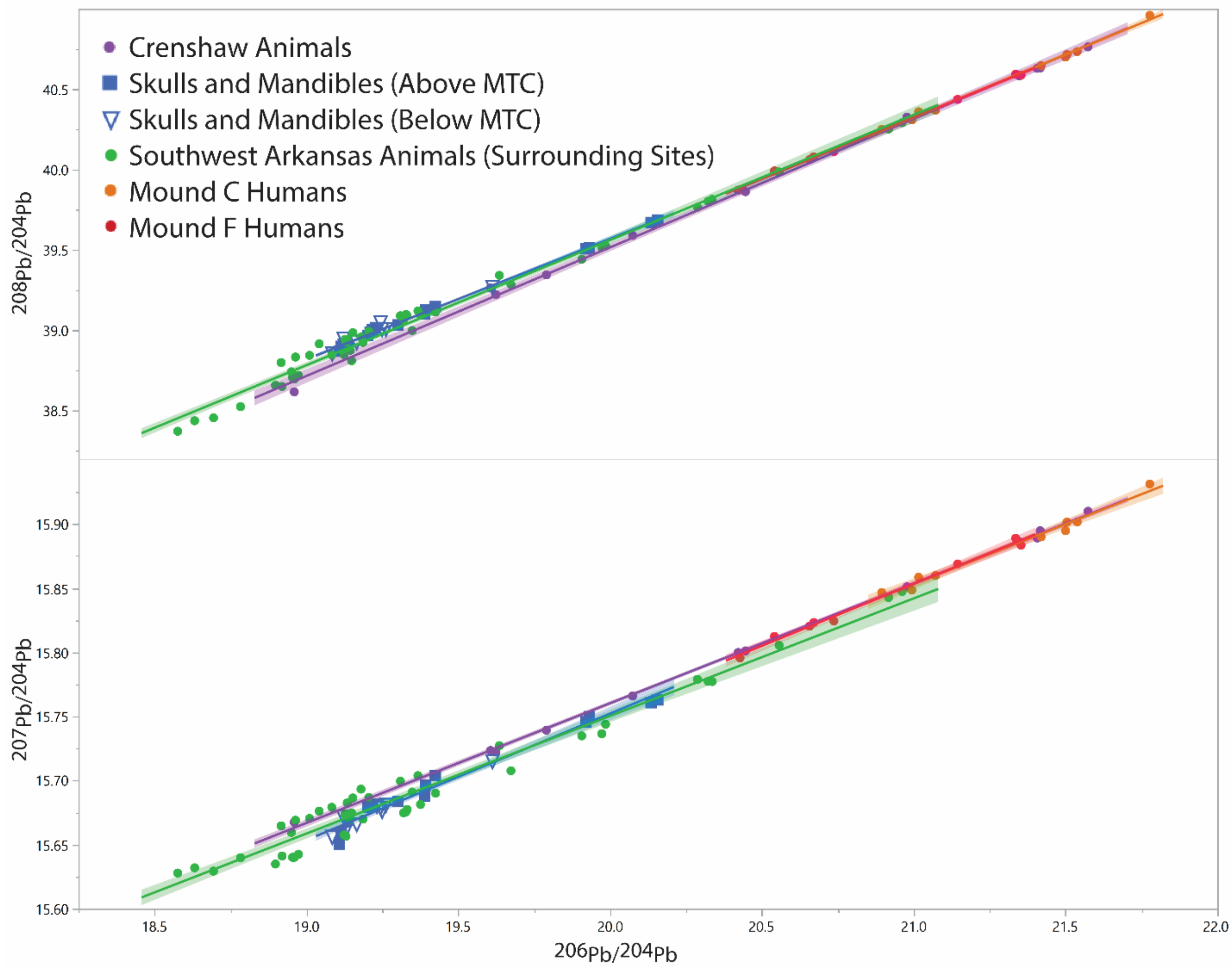

Figure 3.8 – The skulls and mandibles generally match the Pb isotopes of animals from surrounding sites rather than the local Crenshaw humans (Mounds C and F) and animals, suggesting they are coming from surrounding sites. One sample slightly extends below the animals, but this is within two times the standard error, making the difference insignificant.

the lowest concentration standards do for that ratio comparison (see Figure 3.20). The difference is within two times the standard error of the sample, making the difference insignificant.

It is worth noting that no significant difference was seen between the skulls and mandibles below the MTC and those up to 4.34 times the Nd MTC. The samples below the MTC tended to have lower ratios, but this is an artifact of the higher voltage threshold (0.025v). When a lower voltage threshold (e.g. 0.020v) is used, both samples above and below the MTC have higher ratios.

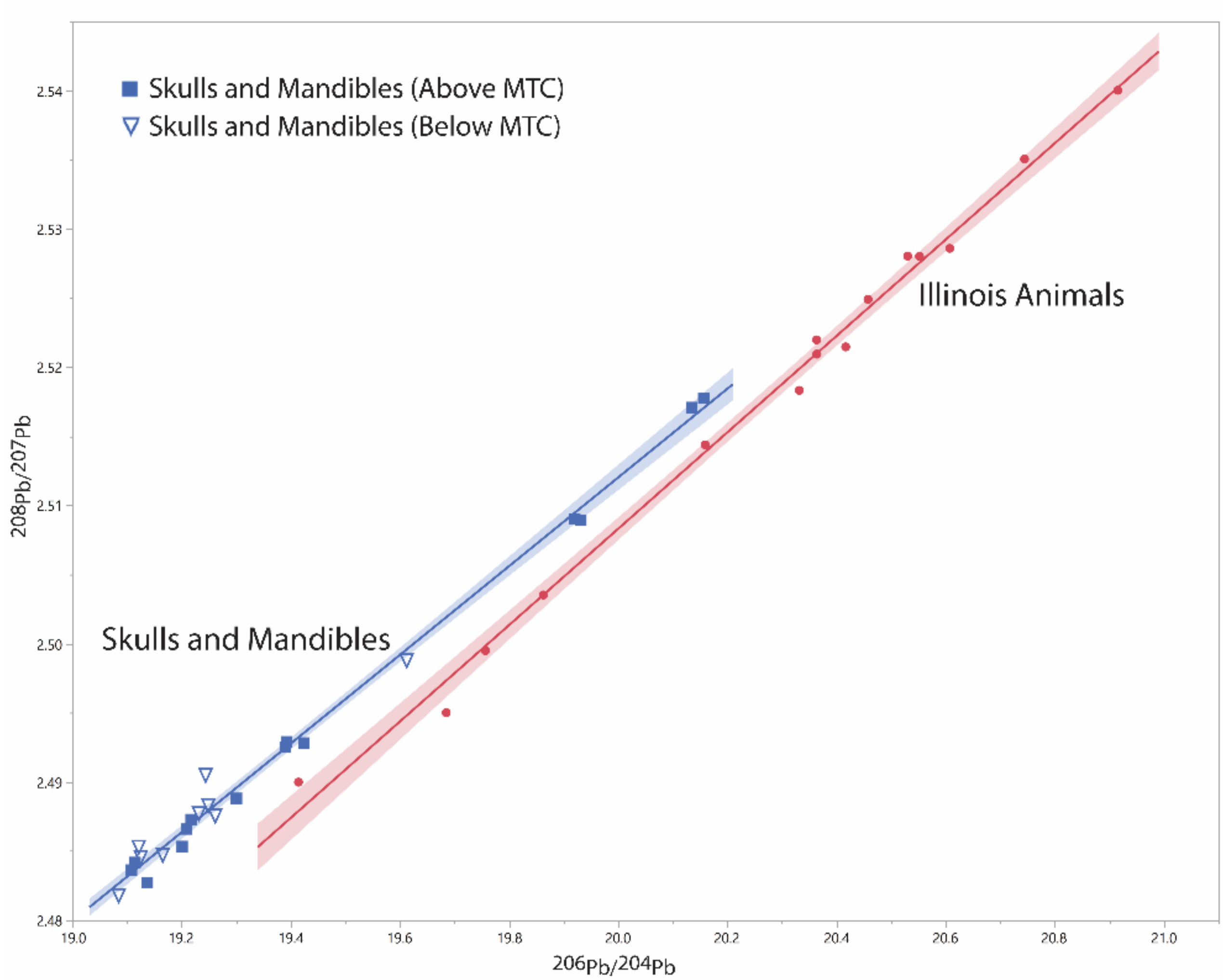

Figure 3.23 – Linear patterning analysis shows the skulls and mandibles have a different linear pattern than the Illinois animals. The Illinois animals also tend to have higher ratios. This indicates they are not from south Illinois.

Comparisons between the skulls and mandibles and south Illinois animals show that the skulls and mandibles are non-local to south Illinois (Figure 3.23). The linear patterning of animal teeth from south Illinois is clearly different from the skulls and mandibles. Sampling in southeast Missouri was limited to a single site (Powers Fort), so interpretations are limited. However, the animals from southeast Missouri are separated from the skulls and mandibles and show a much greater perpendicular range, suggesting the skulls and mandibles are non-local to this area (Figure 3.24).

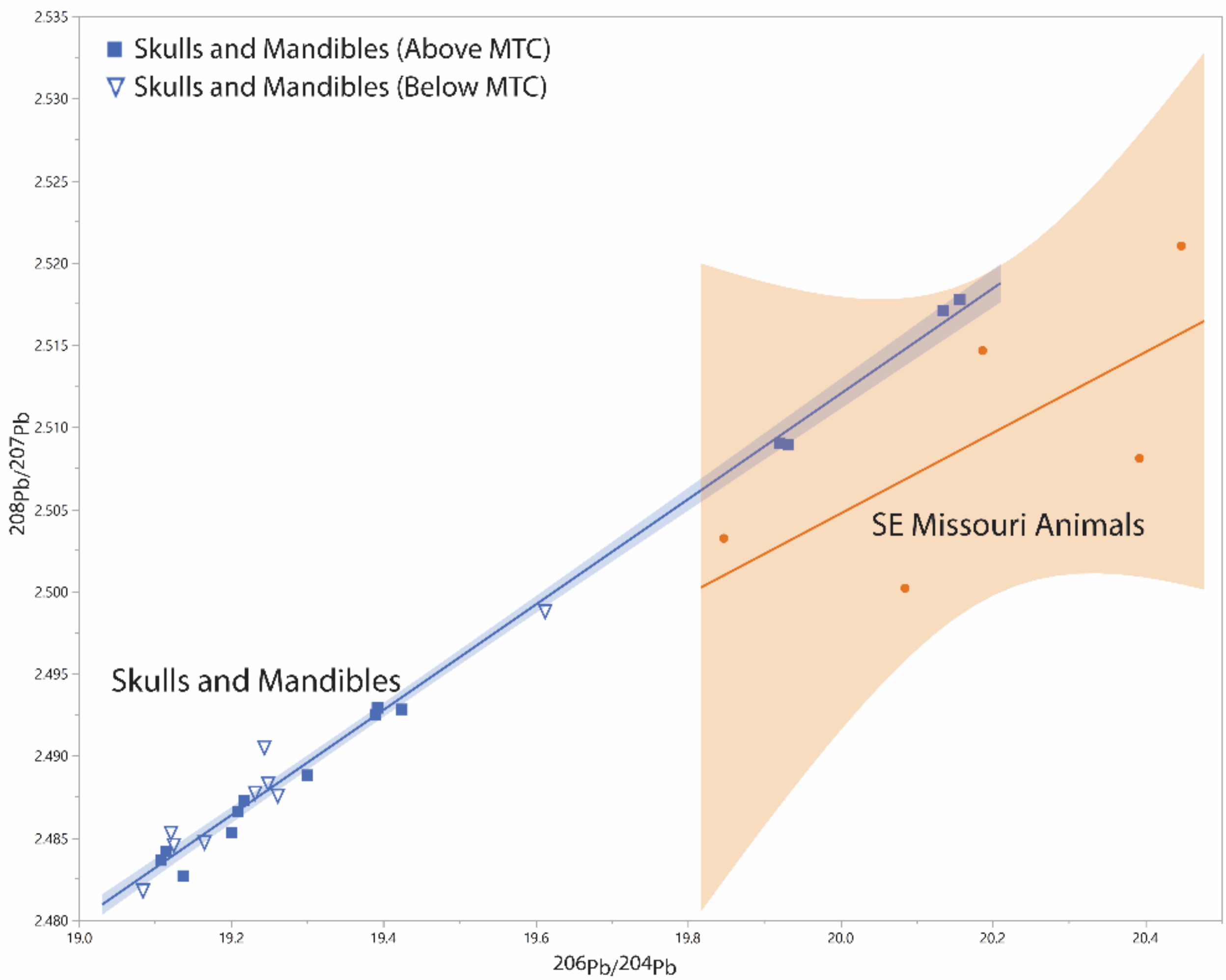

Figure 3.24 – Linear patterning analysis of the skulls and mandibles show they are different from the southeast Missouri animals from Powers Fort. This is based on a single site, so interpretations need to be tempered. However, they are very different, strongly suggesting the skulls and mandibles are not from this area.

Comparing the skulls and mandibles to Oklahoma animals very clearly show that the animals are extremely different from the skulls and mandibles (Figure 3.25). This indicates the skulls and mandibles are non-local to Oklahoma and are not coming from this portion of the Southern Plains. Northwest Louisiana animals are also distinguished from the skulls and mandibles with the exception of a few samples that are close to each other (Figure 3.26). The differences, however, are very strong and indicate the skulls and mandibles are not coming from northwest Louisiana.

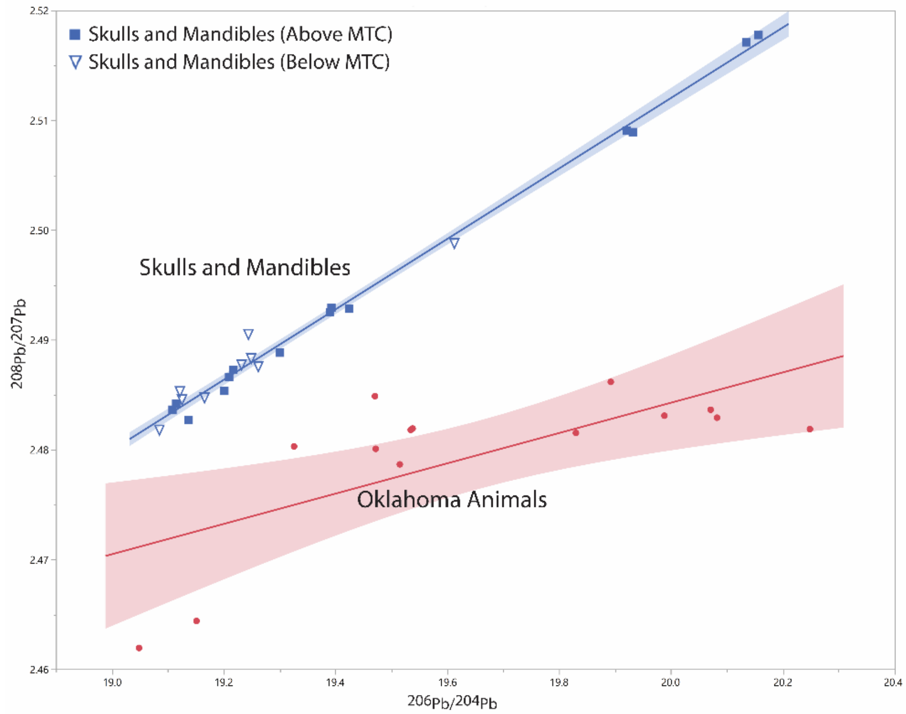

Figure 3.25 – Linear patterning analysis of the skulls and mandibles with Oklahoma animals. The animals are extremely different from the skulls and mandibles, showing they are not from this area.

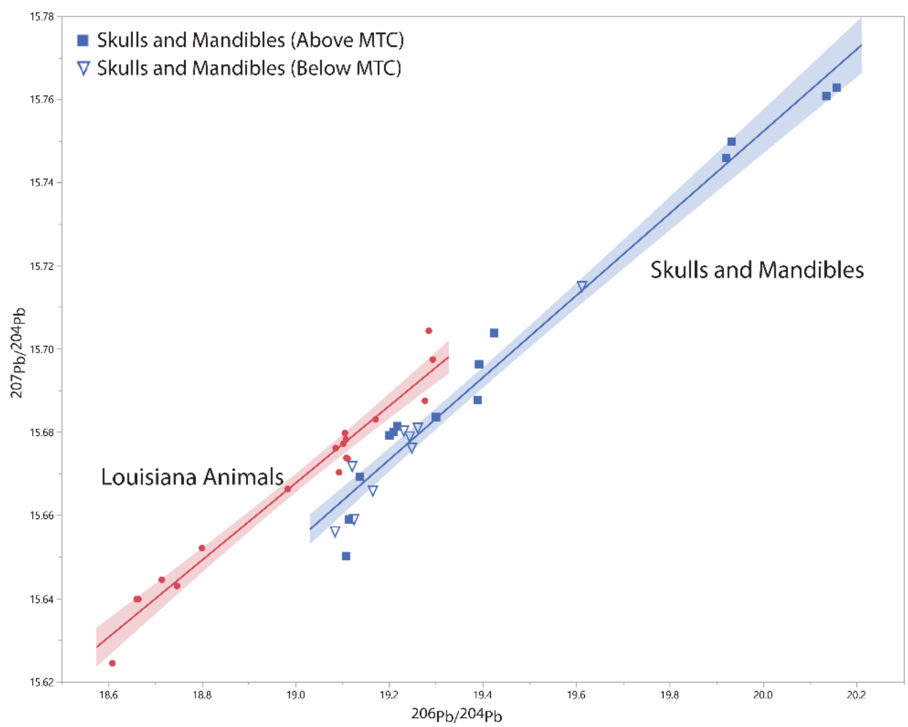

Figure 3.26 – Linear patterning analysis of the skulls and mandibles with northwest Louisiana animals. Louisiana animals maintain a different line, indicating they are not from this area.

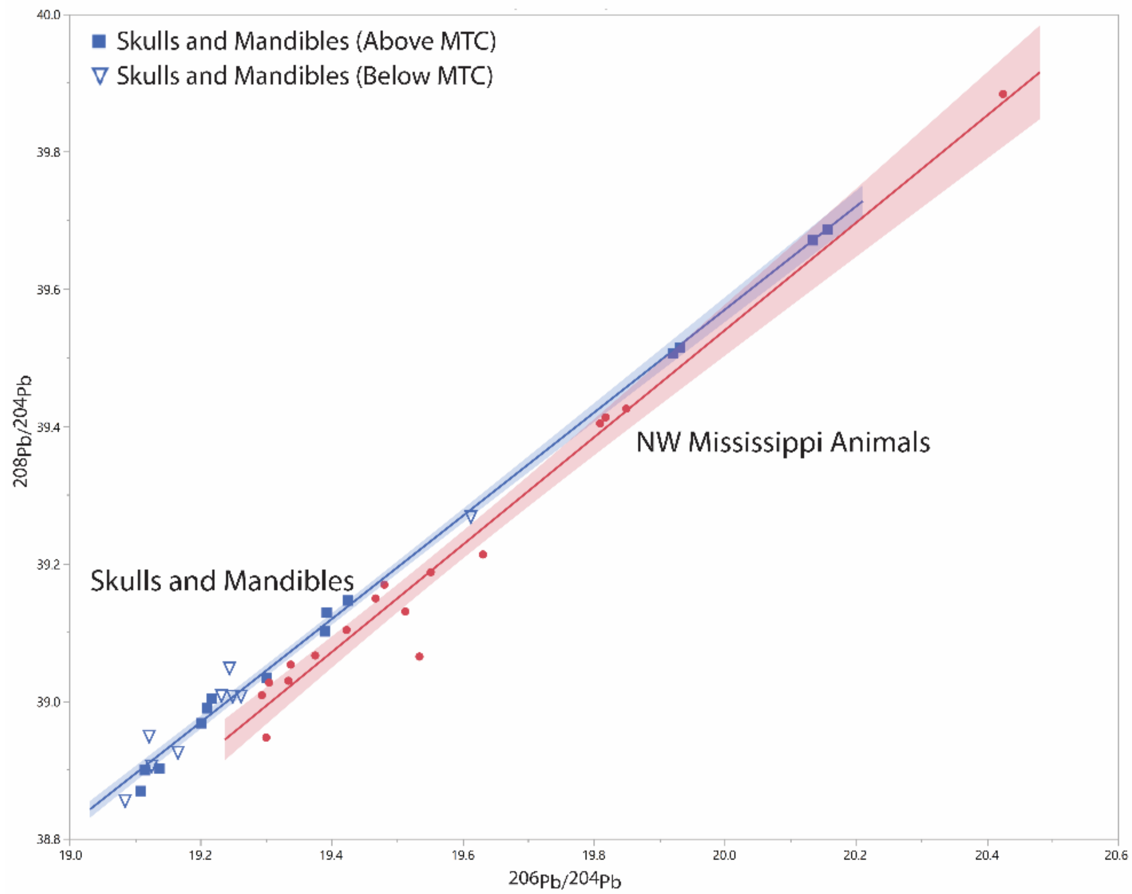

Figure 3.27 – Linear patterning analysis of the skulls and mandibles with northwest Mississippi animals show they are similar, but the linear patterning and values are generally distinguishable. This strongly suggests they are not coming from this area.

Northwest Mississippi animals have a linear pattern that is close to the skulls and mandibles but is still differentiable (Figure 3.27). One of these sites (Bonds Village) included headless burials that were previously interpreted as possibly being victims of raids from Crenshaw (Brookes 1999). The Pb isotopes strongly suggest they are not coming from this area. As might be expected given their very similar geology, northeast Arkansas is similar to northwest Mississippi but does have some overlap with the skulls and mandibles in some places (Figure 3.28). However, the linear patterning shows the lower values are not represented in the skulls and mandibles suggesting they are not coming from this area This is further supported by the narrow range of the Sr isotope data.

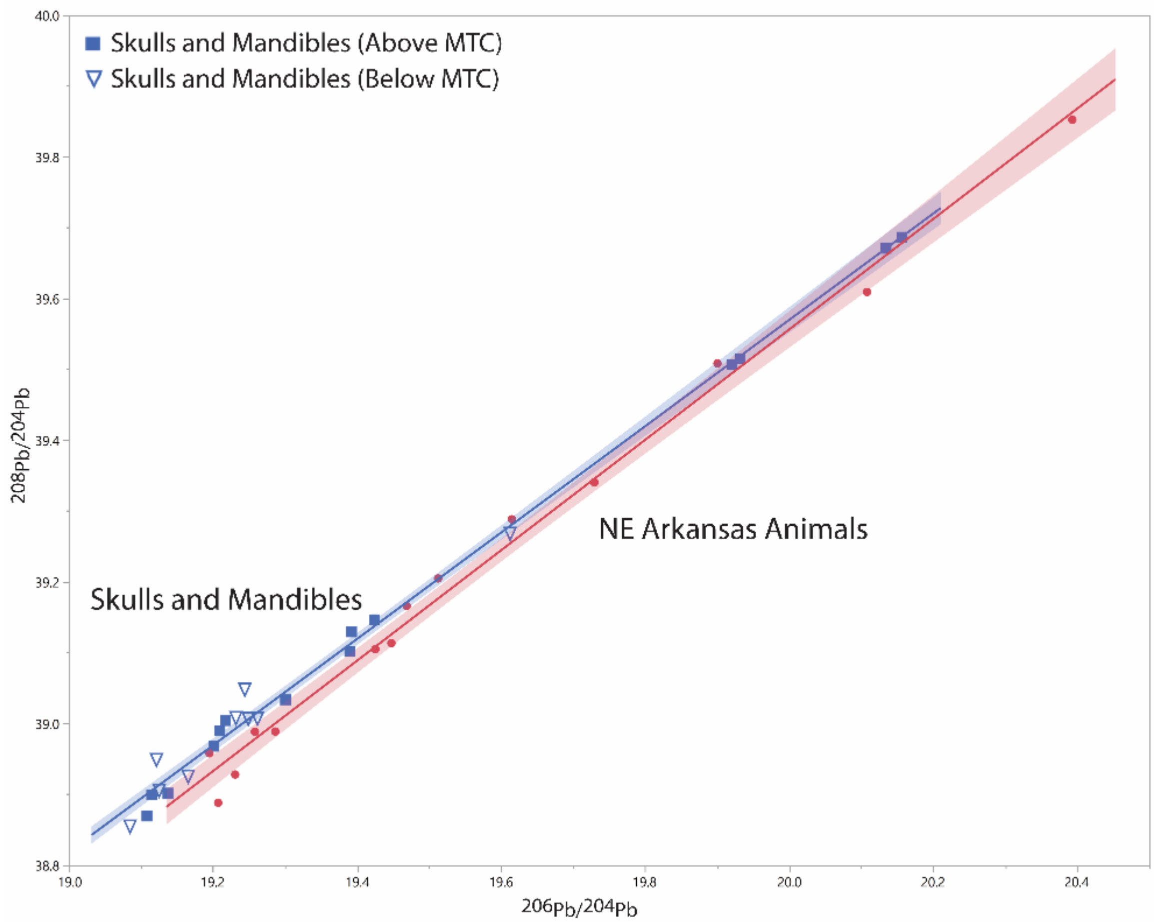

Figure 3.28 – Linear patterning analysis of the skulls and mandibles with northeast Arkansas animals. The Pb isotopes are similar and there is some overlap, but the linear patterning and lack of lower values among the skulls and mandibles suggest they are not coming from the same region. This is further supported by the Sr isotopes from northeast Arkansas having a very restricted range.

Animal teeth from Texas show a different linear pattern than the skulls and mandibles and have many Pb isotope ratios that are inconsistent with them (Figure 3.29). There is a significant area of overlap. However, it is considered very unlikely that the skulls and mandibles were coming from Texas since none of them have the lower isotope ratios represented among the Texas animals. Still, this Pb data alone cannot conclusively show that at least some of the skulls and mandibles were not coming from Texas. The addition of Sr data was very helpful in this case.

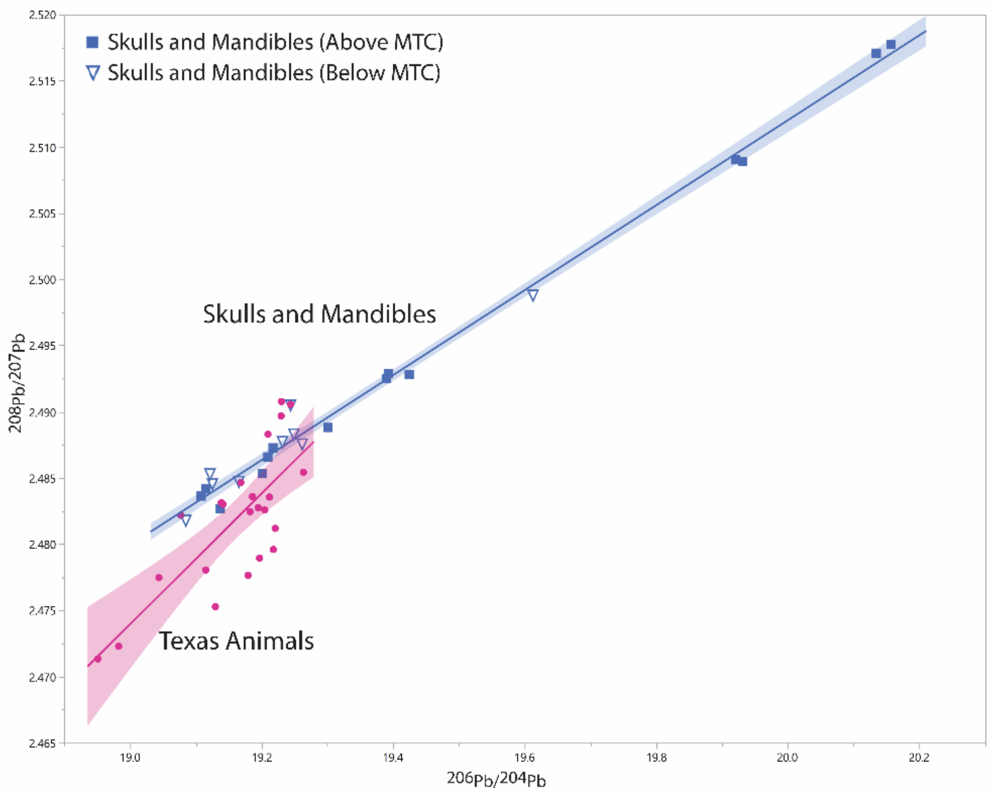

Figure 3.29 – Linear pattering analysis of the skulls and mandibles with Texas animals. There is some significant overlap in the data. It is considered very unlikely that the skulls and mandibles would be coming from Texas and none of them have the lower values represented by the Texas animals. However, the skulls and mandibles cannot be definitively identified as not being from Texas with these data alone. The combination with Sr isotope data helped with this issue.

3.3.2.3 The Sr Isoscape

The Sr isoscape developed in this study shows that the Sr isotope ratios in Mississippi, northeast Arkansas, Oklahoma, and especially Texas (with many ratios below 0.708) are generally too low for most of the skulls and mandibles, reinforcing the Pb isotope results (Figure 3.30). The Sr isotopes from Illinois, Louisiana, and Missouri by contrast are too similar to distinguish these areas. Fortunately, the Pb isotopes clearly distinguished the skulls and mandibles from these regions. The southwest Arkansas animals clearly match the skulls and mandibles but have a slightly higher range. This might be expected as humans have a broader diet that may lead to less extreme ratios. It could also be because some of the sampled sites were too far away from Crenshaw to be within its sphere of influence. Sr isotopes from Hedman et al. (2018) confirm these results where sampled areas overlap.

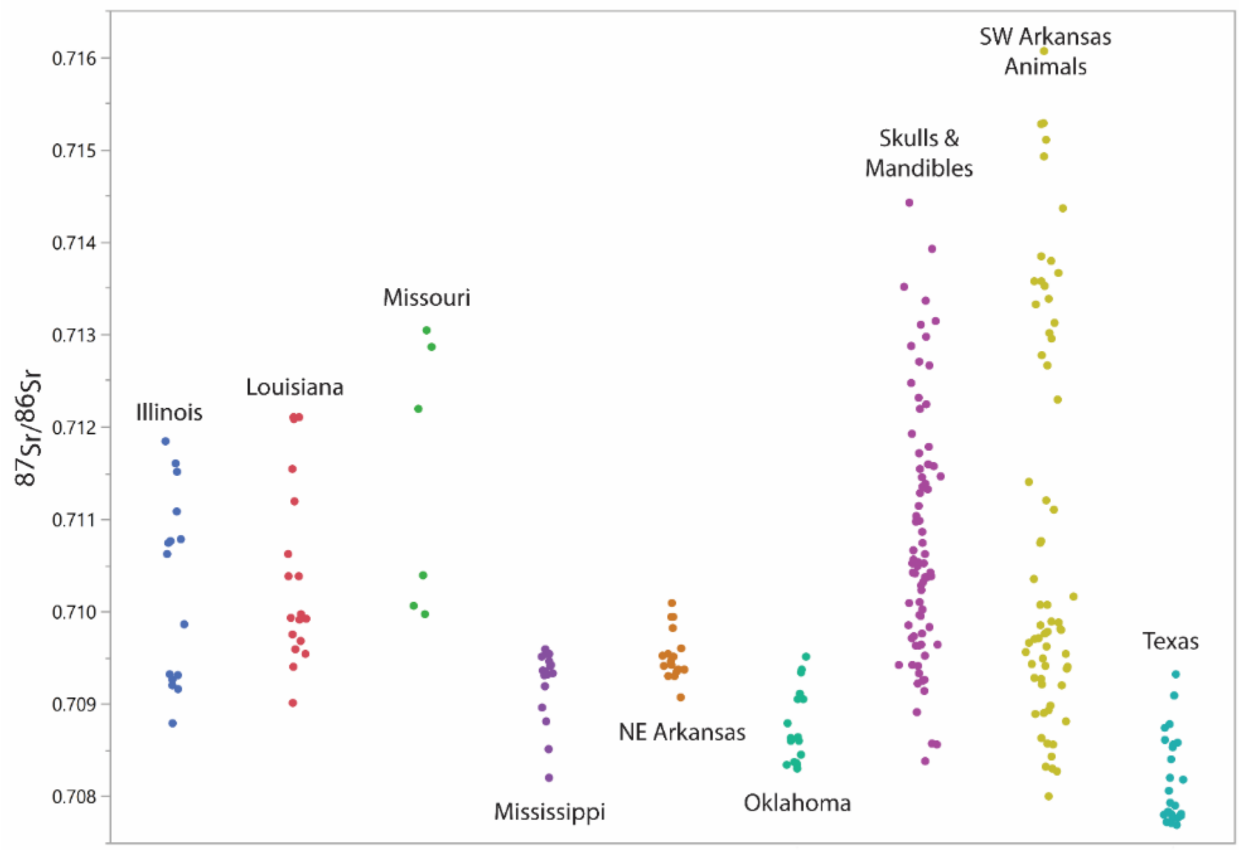

Figure 3.30 – Sr isoscape based on animal tooth enamel from south Illinois, northwest Louisiana, southeast Missouri, northwest Mississippi, northeast Arkansas, Oklahoma, east Texas, and southwest Arkansas. The skulls and mandibles best match southwest Arkansas animals, but cannot be distinguished from Illinois, Louisiana, or Missouri. The Sr isotopes from Mississippi, northeast Arkansas, Oklahoma, and Texas are generally too low for the skulls and mandibles, particularly Texas with many values below 0.708.

Further illustrating the difference between the Texas animals and the skulls and mandibles, the Sr isotope data in Texas is generally too low for the skulls and mandibles (Figure 3.31). When only the skulls and mandibles that have Pb ratios above the 0.025v threshold are included in the comparison (including all those that have overlapping Pb isotope ratios with Texas), the Sr isotopes of these skulls and mandibles are higher than every Texas animal. This strongly suggests the skulls and mandibles are not coming from Texas.

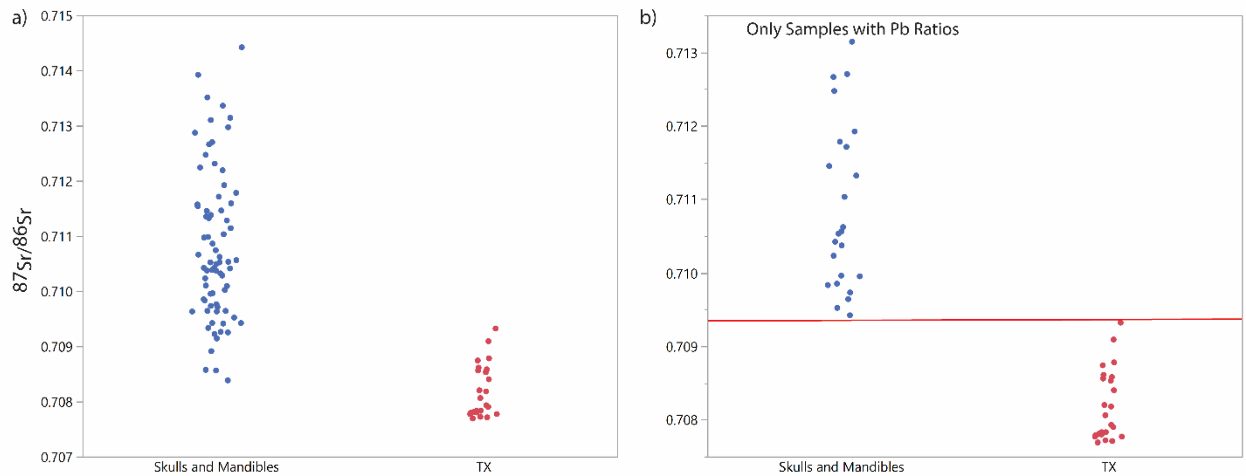

Figure 3.31 – Comparisons of Sr isotope ratios from the skulls and mandibles and Texas animals. a) Comparison of Sr isotopes of all samples. b) Comparison of Sr isotopes only including skulls and mandibles that have Pb isotopes ratios above the 0.025v on ^{204}Pb threshold. This shows that the overlaps in the Pb isotope data with Texas animals (see Figure 3.29) do not exist because they are coming from the same area. This supports identifying the skulls and mandibles as non-local to Texas.

A direct comparison of the skulls and mandibles with Texas animals using both Sr isotopes and ^{208}Pb/^{204}Pb shows that they are clearly differentiable using this method (Figure 3.32). Since this comparison does not require as high accuracy and precision as the Pb isotope linear patterning analysis, it enabled many more skulls and mandibles to be compared (those with thresholds above 0.010v). This allowed for most of the skulls and mandibles (n=41) to be compared to Texas animals, also excluding the four highest concentrated Nd samples. There is some concern with directly comparing Sr and Pb isotopes because these variables may not correlate with each other within a region. Therefore, background sampling may have to be exponentially increased to make sure that every combination of each variable is properly represented in the background. In this case, the very low range of both Pb and Sr isotopes in Texas animals made this comparison valid as both variables co-occur in a restricted range.

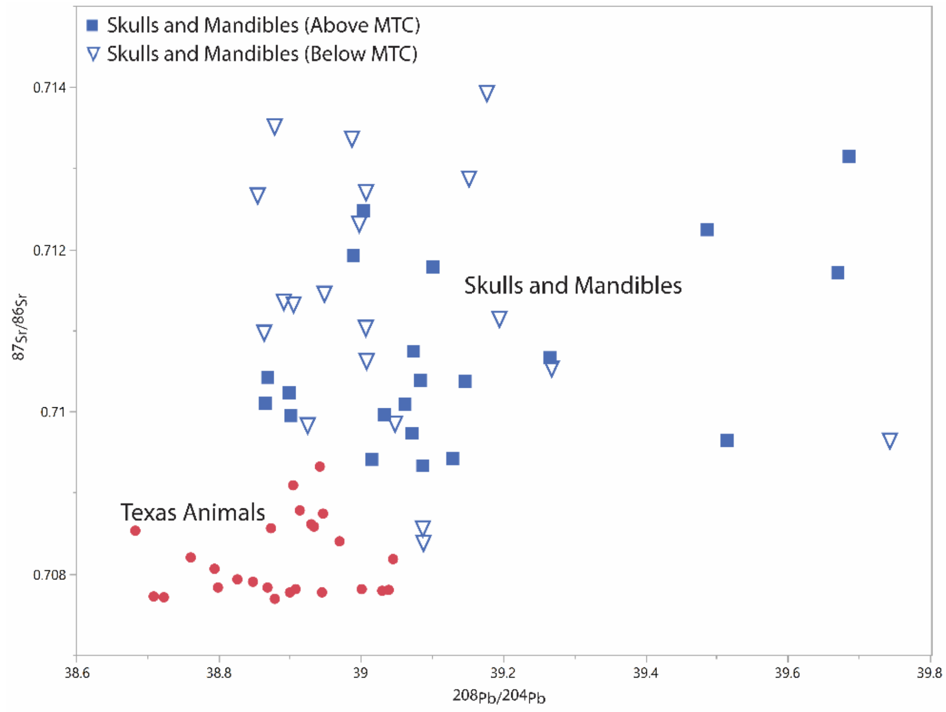

Figure 3.32 – Pb and Sr isotopes from the skulls and mandibles compared to Texas animals. This definitively shows the skulls and mandibles should be classified as non-local to Texas. Since this comparison is not linear patterning analysis, a threshold of 0.010v on ^{204}Pb was used for both humans and animals. Comparisons of Pb and Sr isotopes should be analyzed cautiously because sampling two potentially uncorrelated variables may require an exponential increase in background sampling to find all possible cases of all isotope ratios occurring together. However, since the Texas animal Pb and Sr isotope ratios were both constrained to a small range, this comparison was considered valid.

3.3.3 Contamination and Pb Isotopes

When the Pb isotope data is compared with the analysis of contamination using trace element data, several points suggest the correlation analysis was successful at identifying contamination and the lack thereof. A 0.010v on ^{204}Pb threshold was used in this analysis as it did not involve linear patterning analysis of Pb isotope ratios. A simple comparison between the skulls and mandibles above and below the Nd MTC, excluding the four highest concentrated Nd samples, shows strong consistency in Pb isotope ratios (Figure 3.33). This suggests there is little reason on the basis of Pb isotopes to suspect those samples up to 4.34 times the Nd MTC have been significantly affected by contaminant Pb.

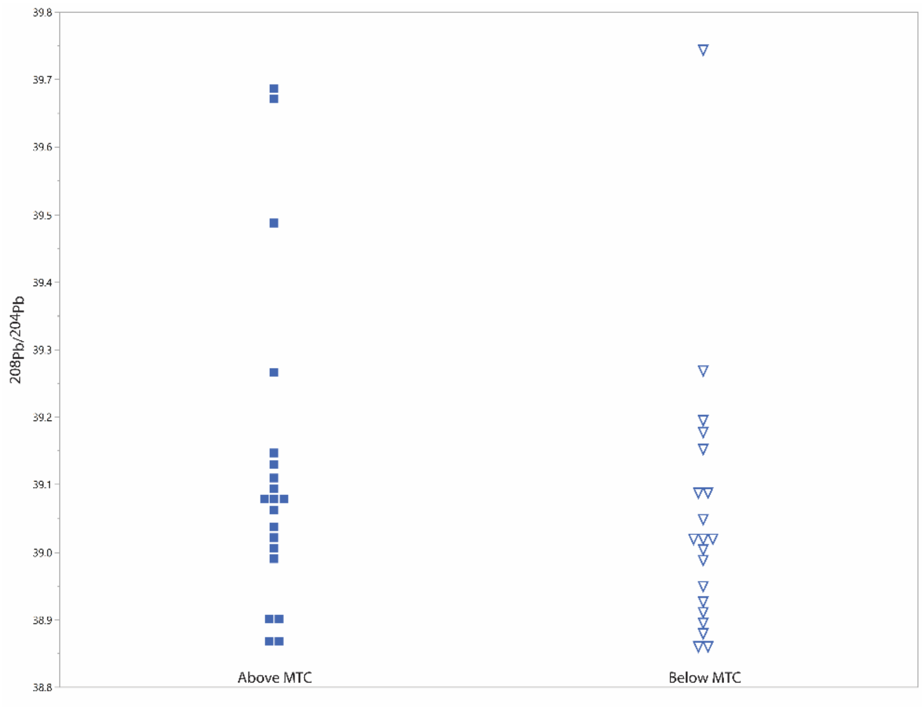

Figure 3.33 – Comparing skulls and mandibles above the Nd MTC and below the Nd MTC show that there is no detectable difference using Pb isotope ratios. This excludes the four highest concentrated Nd samples. This supports the interpretation that a higher threshold around 4.34 times the Nd MTC is more appropriate for detecting Pb contamination in this population.

A Pb isotope comparison of the soil and the skulls and mandibles from the WSA suggests that the thresholds identified in the correlation analysis of trace elements successfully identified samples most likely to be affected by contamination (Figure 3.34). Both samples above the MTC and below the MTC do not generally look like the WSA soil average. The large differences within clusters suggest that the *in-vivo* Pb isotopes are being preserved, verifying that using a higher Nd MTC (4.34 times the original MTC) seems to be identifying uncontaminated samples. Many of the samples furthest from the soil average (both above and below the soil average) include those above the Nd MTC. The results show that the samples with Nd concentrations greater than 4.34 times the Nd MTC are generally close to the WSA soil average. This suggests this threshold is appropriately identifying the samples most likely to have been contaminated. However, these samples are not very different from uncontaminated samples from the same cluster, suggesting that Pb contamination may not be significantly modifying the potentially contaminated samples' *in-vivo* values. This is also supported by HU44 B, the highest concentrated Nd sample, which has a high Pb isotope ratio compared to the soil average. It is interpreted that this sample has an even higher *in-vivo* isotope ratio. Despite it having the clearest evidence of contamination, it appears that not enough contaminant Pb was added to the sample to make it resemble the soil average. Instead it was likely moved downward to a lower ratio through the addition of lower ratio soil Pb contamination. This suggests that the other samples, with much less evidence of contamination, are unlikely to have been heavily modified from their *in-vivo* values.

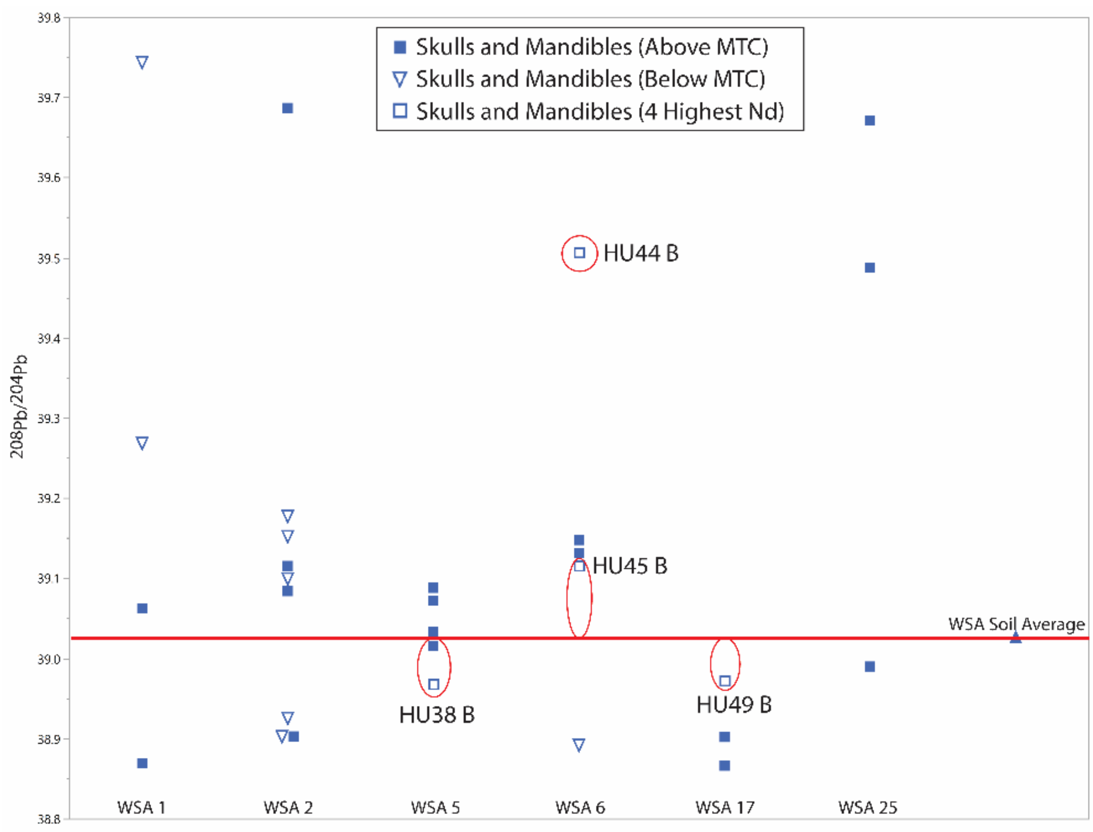

Figure 3.34 – Comparison of Pb isotopes from the WSA skull and mandible clusters to the WSA soil average. Both samples above and below the MTC do not generally look like the WSA soil average. This shows that that three of the four samples with the highest Nd concentrations are close to the WSA soil average, but other samples suggest this is about where they would be expected to fall with *in-vivo* values. A 0.010v on ^{204}Pb threshold was used in this analysis.

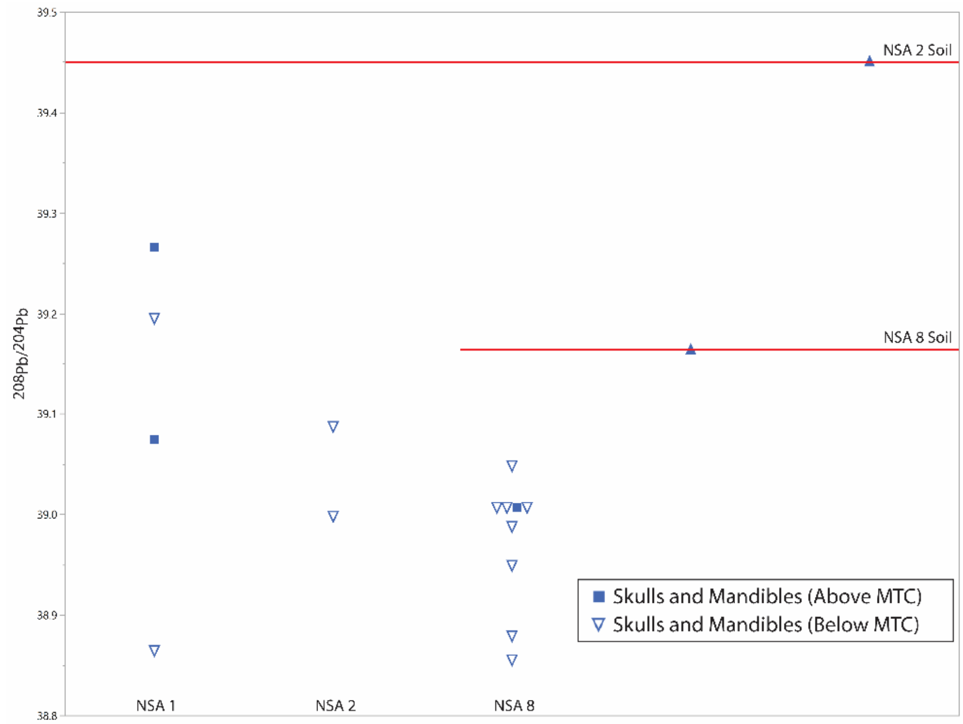

Figure 3.35 – Comparisons of Pb isotopes from the NSA skulls and mandibles show that they generally do not match the soil from their respective clusters. This is the case regardless of whether they are above or below the MTC.

The Pb isotope ratios from the NSA show a similar pattern (Figure 3.35). The skulls and mandibles from both NSA 2 and NSA 8 maintain different Pb isotope ratios from the soil for samples above and below the MTC. None of these samples were over four times the Nd MTC. NSA 1 was buried immediately next to NSA 2, allowing it to be compared to soil from NSA 2. NSA 1 also has ratios that are consistently different from this soil and includes samples from both above and below the MTC.

The similarity between the WSA skulls and mandibles and the WSA soil average could suggest general contamination of the samples (see Figure 3.34). However, this is contradicted when comparing the WSA to the NSA (Figure 3.36). The skulls and mandibles from both areas have ratios similar to the WSA soil average despite the NSA having higher ratio soil. In fact, the NSA remains match the WSA soil better than the WSA remains. What this suggests is that the WSA and NSA remains were coming from places with ratios that happen to be similar to the

WSA soil. This is supported by the comparisons to southwest Arkansas animal teeth (see Figure 3.22), as many of the surrounding sites have similar Pb isotope ratios to the WSA soil.

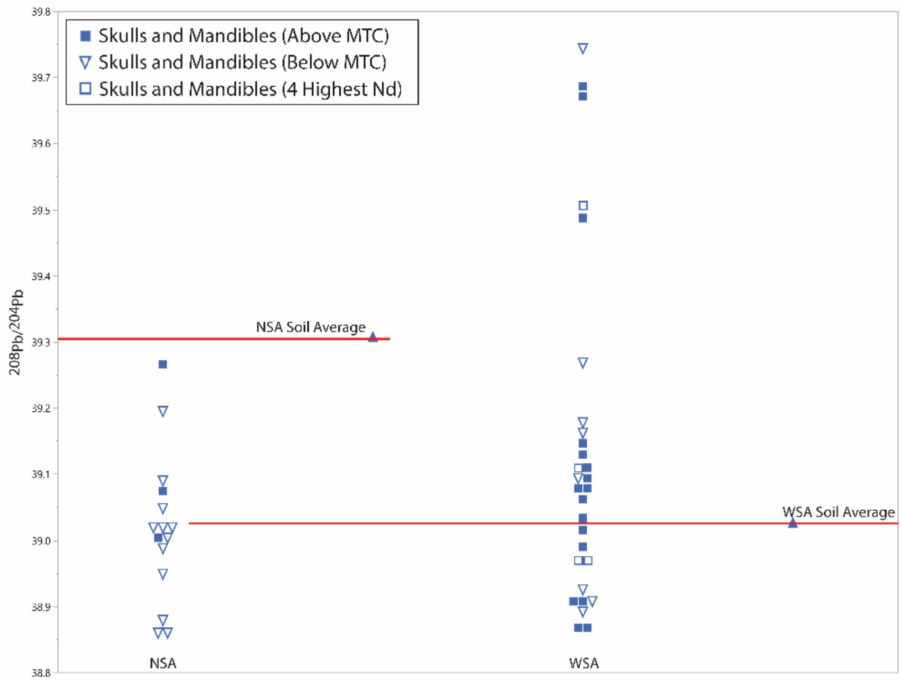

Figure 3.36 – Comparisons of Pb isotopes from the NSA and WSA skulls and mandibles to the soil averages from each location. This shows that the WSA skulls and mandibles being similar to the soil average is likely a coincidence as the NSA skulls and mandibles match the WSA soil better than the WSA skulls and mandibles or the soil from the NSA. Instead, the skulls and mandibles from both areas are likely coming from sites with similar Pb isotope ratios to the WSA soil.

A comparison of Pb isotopes between a sample (HU30) from Samuelsen and Potra (2020), a newly processed duplicate sample (HU30 B), and soil from the same cluster (Rayburn) suggests that HU30 B is less contaminated than HU30 (Figure 3.37). The linear pattern between the Rayburn soil average, HU30, and HU30 B has an $R^2 \approx 1.00$ ($p<0.05$) regardless of which of the 15 bivariate comparisons is used, which is heavily suggestive that HU30 was partially contaminated by soil Pb. This moved the Pb ratio of the contaminated HU30 towards the Rayburn soil average in a linear direction. Note that this linear direction took HU30 away from the overall Crenshaw soil linear pattern in some comparisons. This suggests that using the linear pattering method outlined by Samuelsen and Potra (2020) with soil to detect contamination can

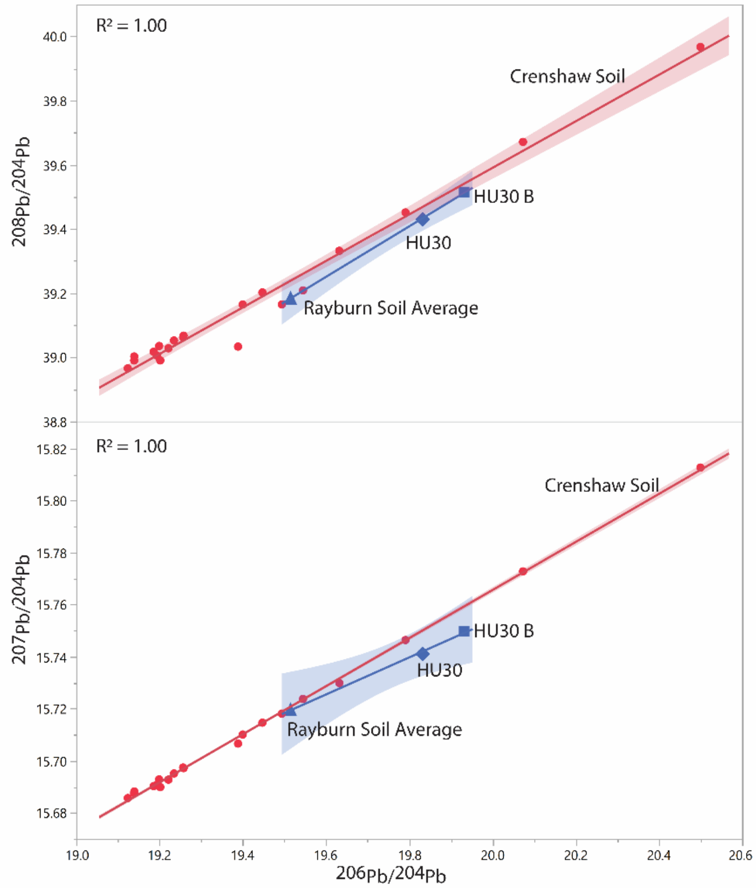

Figure 3.9 – Comparing the Pb isotopes of soil from the Rayburn Cluster, previously processed HU30, and newly processed HU30 B from the same tooth shows that HU30 B appears to be less contaminated than HU30. HU30 B was above the Nd MTC, but below four times the Nd MTC. HU30 was not sampled for trace element analysis. The extremely strong correlation $R^2 \approx 1.00$ ($p<0.05$) suggests that HU30 was modified by contaminant soil Pb from the *in-vivo* isotope values towards the soil Pb isotope ratios. It is worth noting that the Sr isotope ratios for these two samples are nearly identical ($\Delta\ ^{87}Sr/^{86}Sr = 0.00005$), suggesting little to no effect on the Sr isotope ratios.

be problematic. This echoes the example in Samuelsen and Potra (2020) where HU13 was thought to potentially be contaminated by the soil due to it matching linear patterning of the soil. However, trace element analysis of HU13 B showed that it was very likely uncontaminated. This could be due to variety of reasons, but the cause in this particular case is that the Rayburn soil itself deviates from the overall site's soil linear patterning, making the more contaminated sample move away from the site's soil linear pattern in some Pb isotope comparisons. There is also the potential that the weak-acid leaching could be too strong or two weak to properly represent the portion of the soil Pb contaminating the sample. This does not seem to be the cause in this case as the strong correlation between the teeth and soil Pb isotopes suggests that the weak-acid leachate approximated the contaminant Pb isotope ratio well.

If HU30 B is uncontaminated, as suggested by the trace element analysis, then HU30 seems to have contained about 74% uncontaminated Pb and 26% contaminated Pb based on the change in the $^{208}Pb/^{204}Pb$ ratio. This highlights a second issue with the soil linear patterning analysis used by Samuelsen and Potra (2020). The contamination of a sample will likely not be clear until the contaminant Pb totally overwhelms the sample. So, the method may be useful for evaluating very strong contamination but will likely be insufficient for identifying mildly or moderately contaminated samples. This illustrates the need to use trace element analysis in addition to soil when attempting to detect contamination. However, in the case of HU30 and HU30 B, the difference did not affect interpretations as the individual was identified as local in either case.

Although not testable due to the lack of trace element data for the original samples, this could suggest that the duplicates (marked with a "B") run by Samuelsen and Potra (2020) were slightly different from the original samples because they were also less contaminated. These duplicates also had the entire surface of the enamel removed rather than using the abrading method used for the original samples. Therefore, the differences between the duplicates and originals may be due to the removal of contamination and not due to intra-tooth differences or analytical procedure issues past the drilling stage. Again, if this is the case, it did not affect interpretations as the originals were only slightly different from the duplicates and still followed the same linear trend. While previous research has inferred that the surface is the most likely place to contain contamination (Turner et al. 2009:321), this provides documentation that the full removal of the surface successfully removes soil Pb contamination. This information also suggests that soil Pb contamination occurs on the surface of the enamel through adsorption rather than absorption. This is similar to previous studies of plants which showed that plant roots contained most of their Pb on the outer surface of the root through a similar process (Clemens 2013; Kabata-Pendias 2011). It is not clear if this would also be true for tooth samples that have been heavily contaminated by anthropogenic Pb (e.g. King et al. 2020) but was at Crenshaw, which is without evidence of significant anthropogenic Pb contamination.

3.4 Conclusions

There are important conclusions related to both the methods employed and the results of the study. The evidence that the total removal of the enamel surface successfully removed soil Pb contamination is one of the most important results for future Pb isotope research in other areas. This is because Pb contamination of tooth enamel is a major concern inhibiting wider use of the technique. The trace element analysis based on Kamenov et al. (2018) was largely successful at identifying contamination and is highly recommended for future research, although some elements and thresholds may not be useful for some ancient populations. The similar burial context aided the ability of this study to conduct correlation analysis on the trace element data. The remains analyzed in this study had the benefit of all being buried in essentially the same context, minimizing potential differences in the soil. Critically, the methods included the complete removal of the entire enamel surface. Pb concentrations could be highly variable if the surface is not entirely removed. This is both due to the surface being the most likely place to contain contamination and because it is where much of the Pb in tooth enamel is placed *in-vivo* (Budd et al. 1998). Therefore, if the removal of the surface is inconsistent, then correlations may be more difficult to observe. It could also drastically impact studies that use Pb concentrations for evaluating contamination or *in-vivo* exposure (e.g. Beherec et al. 2016; Dudás et al. 2016; Samuelsen and Potra 2020) because different concentrations of Pb may relate more to differences in how the samples were drilled than *in-vivo* or contamination differences between the samples.

The limited sampling of other regions by Samuelsen and Potra (2020) left some doubt that the biologically available Pb method would be able to distinguish the skulls and mandibles from other regions. The results of this study indicate or strongly suggest that the skull-and-mandible cemetery is made up of individuals who did not come from the Southern Plains (Texas and Oklahoma), the Mississippi Valley (Northeast Arkansas, Northwest Mississippi, Southeast Missouri, and South Illinois), or Northwest Louisiana. The biologically available Pb method and the Pb isoscape produced were successful at distinguishing the skulls and mandibles from most other regions. The Sr isotopes complemented the Pb isotopes in some cases where the Sr isotopes of the animals in other states were generally too low for the skulls and mandibles. By contrast, the skulls and mandibles have both Pb and Sr isotope ratios that are consistent with animals from sites that surround Crenshaw. It is a high bar to claim that these methods were able to uniquely identify an area of origin. However, the skulls and mandibles were determined to be local to southwest Arkansas and were interpreted to be non-local in all other tested regions.

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Stable Isotope Laboratory and TRAIL assisted the author in ensuring that the Nu Plasma ICP-MS and iCAP ICP-MS were functioning properly so that high-resolution Pb isotope, Sr isotope, and trace element data could be collected. Some Sr isotopes (AN25-AN56) were analyzed on the Nu Plasma ICP-MS at the University of Illinois Urbana-Champaign with the help of Gideon Bartov and Thomas Johnson. Celina Suarez enabled accurate tooth drilling with the use of her Leica M80 microscope. Kenneth Kvamme, Ann Early, Jami Lockhart, and Jerome Rose also supplied support at various steps. George Kamenov and John Krigbaum supplied useful advice about sample processing and analysis. Samples were obtained from Mary Suter of the University of Arkansas Museum, Mary-Beth Trubitt from ARAS Arkadelphia Research Station, Jeff Mitchem and Faye Futch from the ARAS Parkin Research Station, Juliet Morrow, Sarah Stuckey, and Brandy Dacus from the ARAS Arkansas State University Research Station, Carol Colaninno-Meeks and Carl Drexler from the ARAS Southern Arkansas University Station, Megan Cook of the Mississippi Department of Archives and History, Tamira Brennan of the Center for Archaeological Investigations at Southern Illinois University Carbondale, Pete Gregory and Jeffrey Girard of Northwestern State University, Susie Fishman-Armstrong of the Sam Noble Museum, Marybeth Tomka and Lauren Bussiere at the Texas Archeological Research Lab, and Jessica Boldt of the Museum of Anthropology at the University of Missouri. Soil cores at Crenshaw were originally collected with the help of Margaret Guccione and her students. Thanks also to Gary McAdams and the Wichita and Affiliated Tribes for supporting the analysis of animal teeth in Oklahoma.

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Appendix

T1 – Pb isotope ratios from human second molar enamel at Crenshaw (3MI6).

Lab ID	Accession	Cluster	Tooth Side	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	v ^{204}Pb
HU30 B	69-66-589-1	Rayburn	Mand L	39.5148	15.7498	19.9318	0.0279
HU38 B	83-377-6-1	WSA 5	Mand L	38.9679	15.6792	19.2012	0.0506
HU39 B	83-377-6-2	WSA 5	Mand L	39.0155	15.6837	19.2836	**0.0245**
HU40 B	83-377-6-3	WSA 5	Mand L	39.0873	15.6969	19.3832	**0.0086**
HU41 B	83-377-6-4	WSA 5	Mand L	39.0335	15.6836	19.3007	0.0616
HU42 B	83-377-6-5	WSA 5	Max R	39.0722	15.6839	19.3543	**0.0138**
HU43 B	83-377-7-1	WSA 6	Mand R	39.1293	15.6963	19.3926	0.0984
HU44 B	83-377-7-2	WSA 6	Mand L	39.5065	15.7458	19.9207	0.1484
HU45 B	83-377-7-4	WSA 6	Mand L	39.1158	15.6806	19.4207	**0.0218**
HU46 B	83-377-7-5	WSA 6	Mand	38.8920	15.6643	19.1002	**0.0106**
HU47 B	83-377-7-6	WSA 6	Mand R	39.1466	15.7038	19.4245	0.0367
HU48 B	83-377-29-1	WSA 17	Mand L	38.8658	15.6577	19.1352	**0.0130**
HU49 B	83-377-29-2	WSA 17	Mand L	38.9722	15.6690	19.2581	**0.0172**
HU50 B	83-377-29-3	WSA 17	Mand R	38.9017	15.6692	19.1374	0.0420
HU51 B	83-377-61-1	WSA 25	Mand R	38.9897	15.6800	19.2096	0.0318
HU52 B	83-377-61-2	WSA 25	Mand L	39.6708	15.7607	20.1346	0.0338
HU53 B	83-377-61-3	WSA 25	Mand R	39.4871	15.7398	19.9320	**0.0156**
HU54 B	83-377-24-1	NSA 1	Max R	39.1950	15.6983	19.4749	**0.0199**
HU55 B	83-377-24-2	NSA 1	Mand R	39.2659	15.6963	19.6394	**0.0127**
HU56 B	83-377-24-3	NSA 1	Mand R	38.7801	15.6668	18.9974	**0.0051**
HU57 B	83-377-24-4	NSA 1	Mand R	39.0742	15.6651	19.4692	**0.0133**
HU58 B	83-377-24-5	NSA 1	Mand R	38.8644	15.6514	19.0966	**0.0128**
HU59 B	83-377-25-1	NSA 2	Max	38.9980	15.6781	19.2393	**0.0139**
HU60 B	83-377-25-2	NSA 2	Mand L	38.9166	15.6993	19.2513	**0.0039**
HU61 B	83-377-25-3	NSA 2	Mand R	39.0873	15.6754	19.3924	**0.0146**
HU62 B	83-377-2-4	WSA 1	Mand L	38.8693	15.6502	19.1083	0.0273
HU63 B	83-377-2-5	WSA 1	Mand R	38.9643	15.6557	19.2705	**0.0083**
HU64 B	83-377-2-6	WSA 1	Mand R	39.7438	15.7648	20.2912	**0.0225**
HU65 B	83-377-2-7	WSA 1	Mand L	39.2685	15.7150	19.6126	0.0277
HU66 B	83-377-2-8	WSA 1	Mand R	39.0622	15.6994	19.4047	**0.0108**
HU67 B	83-377-3-3	WSA 2	Mand L	39.1774	15.6964	19.4588	**0.0210**
HU68 B	83-377-3-5	WSA 2	Mand L	39.0838	15.6971	19.3518	**0.0234**
HU69 B	83-377-3-15	WSA 2	Mand R	39.6866	15.7628	20.1568	0.0962
HU70 B	83-377-3-33	WSA 2	Mand R	39.0882	15.6764	19.4333	**0.0108**
HU71 B	83-377-3-35	WSA 2	Mand L	38.9438	15.6540	19.2542	**0.0049**

T1 (Cont.)

Lab ID	Accession	Cluster	Tooth Side	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	v ^{204}Pb
HU72 B	83-377-3-41	WSA 2	Mand L	39.0899	15.6697	19.4420	**0.0094**
HU73 B	83-377-3-61	WSA 2	Mand R	39.1523	15.6876	19.4867	**0.0118**
HU74 B	83-377-3-81	WSA 2	Mand R	38.9255	15.6659	19.1656	0.0424
HU75 B	83-377-3-89	WSA 2	Mand R	38.9057	15.6590	19.1253	0.0387
HU76 B	83-377-3-96	WSA 2	Mand L	38.6331	15.6153	18.8142	**0.0050**
HU77 B	83-377-3-101	WSA 2	Mand L	39.1016	15.6877	19.3899	0.0662
HU78 B	83-377-3-108	WSA 2	Mand L	38.8996	15.6590	19.1149	0.1860
HU79 B	83-377-41-1-1	NSA 8	Mand R	39.0040	15.6814	19.2174	0.0299
HU80 B	83-377-41-1-2	NSA 8	Max L	38.8791	15.6491	19.0831	**0.0132**
HU81 B	83-377-41-1-3	NSA 8	Max L	38.8552	15.6561	19.0849	0.0282
HU82 B	83-377-41-1-4	NSA 8	Max	38.9878	15.6815	19.2154	**0.0110**
HU83 B	83-377-41-1-5	NSA 8	Mand R	39.0072	15.6762	19.2491	0.0376
HU84 B	83-377-41-1-6	NSA 8	Mand L	39.0483	15.6789	19.2442	0.1062
HU85 B	83-377-41-1-7	NSA 8	Mand R	39.0075	15.6810	19.2618	0.0311
HU86 B	83-377-41-1-8	NSA 8	Mand L	39.0084	15.6803	19.2319	0.0324
HU87 B	83-377-41-1-9	NSA 8	Max R	38.9491	15.6718	19.1216	0.0385

T2 – Pb isotope ratios from animal tooth enamel.

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	v ^{204}Pb
AN73	Illinois	11U635	Deer	95.002 Bag 101	39.0683	15.6902	19.4143	0.0399
AN74	Illinois	11U635	Ground Hog	95.002 Bag 21	40.2480	15.8456	20.9156	0.1982
AN75	Illinois	11U635	Squirrel	95.002 Bag 24	39.8888	15.7982	20.4580	0.0959
AN76	Illinois	11U635	Squirrel	95.002 Bag 30	40.1223	15.8271	20.7448	0.0999
AN77	Illinois	11U635	Squirrel	95.002 Bag 100	39.8299	15.7964	20.4170	0.0224
AN78	Illinois	11U635	Raccoon	95.002 Bag 100	39.9483	15.8022	20.5306	0.1020
AN79	Illinois	11U635	Deer	95.002 Bag 577	39.9625	15.8079	20.5523	0.1343
AN80	Illinois	11Pp3	Beaver	14.003 Bag 162	39.3903	15.7340	19.8629	0.0283
AN81	Illinois	11Pp3	Squirrel	14.002 TU26 L2	39.2317	15.7241	19.6850	0.0966
AN82	Illinois	11Pp3	Raccoon	14.002 N224.5	39.8228	15.7904	20.3639	0.1593
AN83	Illinois	11Pp3	Oposssum	14.002 Bag 53	39.9751	15.8093	20.6077	0.0601
AN84	Illinois	11Pp3	Deer	14.002 TU26 L3	39.3094	15.7270	19.7569	0.0303
AN85	Illinois	11Pp3	Deer	14.002 TU26 L2	39.7994	15.7876	20.3642	0.2070
AN86	Illinois	11Mx1	Black Bear	1-115	39.6665	15.7759	20.1596	0.2200
AN87	Illinois	11Mx1	Deer	1-95	39.7626	15.7894	20.3321	0.1800
AN88	Texas	41RW4	Rabbit	Lot 120	38.9085	15.6482	19.1808	**0.0101**
AN89	Texas	41RW4	Squirrel	Lot 33	39.0394	15.6750	19.2440	0.0696

T2 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	v ^{204}Pb
AN90	Texas	41RW4	Beaver	Lot 118	38.9006	15.6667	19.1413	0.0422
AN91	Texas	41RW4	Beaver	Lot 117	38.9456	15.6744	19.1684	0.3990
AN92	Texas	41RW4	Beaver	Lot 115	39.0303	15.6768	19.2298	0.0551
AN93	Texas	41RW4	Raccoon	Lot 115	39.0015	15.6740	19.2097	0.1480
AN94	Texas	41RW4	Deer	Lot 119	38.8738	15.6611	19.0773	0.1277
AN95	Texas	41WM230	S. Rodent	Lot 597	38.8267	15.6708	19.1796	0.1130
AN96	Texas	41WM230	P. Gopher	XU3	38.8690	15.6755	19.2179	0.1255
AN97	Texas	41WM230	Raccoon	Lot 141-7	38.7612	15.6593	19.1298	0.0605
AN98	Texas	41WM230	S. Rodent	Lot 637	38.7946	15.6553	19.1152	0.0215
AN99	Texas	41WM230	S. Rodent	Lot 619	38.8486	15.6714	19.1969	0.2700
AN100	Texas	41TR198	P. Gopher	Lot 445	38.9144	15.6758	19.1826	0.1240
AN101	Texas	41TR198	S. Rodent	Lot 461	38.9306	15.6815	19.2049	0.1000
AN102	Texas	41TR198	P. Gopher	Lot 462	38.9343	15.6819	19.1950	0.1320
AN103	Texas	41TR198	S. Rodent	Lot 435	38.9471	15.6820	19.2121	0.3540
AN104	Texas	41TR198	Deer	Lot 408	38.9425	15.6799	19.1860	0.1580
AN105	Texas	41TR198	Deer	Lot 456	38.9052	15.6678	19.1388	0.0281
AN106	Texas	41COL9	Deer	41-18C9-2	38.7994	15.6609	19.0440	0.0289
AN107	Texas	41COL9	Beaver	41-18C9-2	38.6832	15.6527	18.9513	0.1830
AN108	Texas	41COL9	Rabbit	41-18C9-2	38.7233	15.6459	19.0673	**0.0133**
AN109	Texas	41COL9	P. Gopher	41-18C9-2	38.7091	15.6572	18.9827	0.1811
AN110	Texas	41EL11	Raccoon	Lot 120	38.8793	15.6696	19.2207	0.0625
AN111	Texas	41EL11	P. Gopher	Lot 240	38.9703	15.6795	19.2637	0.0600
AN112	Texas	41EL11	P. Gopher	Lot 240	39.0455	15.6761	19.2303	0.0744
AN113	Oklahoma	34Cu27	Rabbit	83.002	38.9917	15.6951	19.4252	**0.0050**
AN114	Oklahoma	34Cu27	S. Rodent	101.011	39.0500	15.7276	20.0824	0.1481
AN115	Oklahoma	34Cu27	Deer	101.011	39.0729	15.7162	19.8924	0.0417
AN116	Oklahoma	34Cu27	S. Rodent	101.011	38.9805	15.7084	19.8301	0.0323
AN117	Oklahoma	34Cu27	S. Rodent	101.011	39.0515	15.7348	20.2487	0.0997
AN118	Oklahoma	34Cu27	S. Rodent	101.011	39.0325	15.7194	19.9884	0.0995
AN119	Oklahoma	34Cu27	S. Rodent	101.011	39.0288	15.7145	20.0711	0.0190
AN120	Oklahoma	34Rm29	Deer	026-A/1980/20	39.0174	15.6939	19.4819	**0.0099**
AN121	Oklahoma	34Rm29	Rabbit	026-A/1980/20	38.9879	15.6902	19.4704	0.0572
AN122	Oklahoma	34Rm29	S. Rodent	026-A/1980/20	38.8837	15.6771	19.3258	0.0167
AN123	Oklahoma	34Wa5	Rabbit	26.007	39.0127	15.6959	19.5645	**0.0124**
AN124	Oklahoma	34Wa5	P. Gopher	654.006	38.9253	15.6953	19.4720	0.1232
AN125	Oklahoma	34Wa5	P. Gopher	690.004	38.9081	15.6973	19.5150	0.0883
AN126	Oklahoma	34Wa5	P. Gopher	42.005	38.5201	15.6463	19.0484	0.0290
AN127	Oklahoma	34Wa5	P. Gopher	97.008	38.9655	15.6998	19.5379	0.1010
AN128	Oklahoma	34Wa5	P. Gopher	97.008	38.9671	15.7012	19.5345	0.0415

T2 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	v ^{204}Pb
AN129	Oklahoma	34Wa5	Deer	640	38.6047	15.6650	19.1514	0.0167
AN130	Mississippi	22TU530	Raccoon	Feat. 34	38.9471	15.6861	19.3003	0.1648
AN131	Mississippi	22TU530	Grey Fox	Feat. 34	39.0271	15.6868	19.3045	0.0315
AN132	NE Arkansas	3CS29	Raccoon	1522094	39.2884	15.7128	19.6150	0.0346
AN133	NE Arkansas	3CS29	Beaver	777	38.9746	15.6510	19.3295	**0.0124**
AN134	NE Arkansas	3CS29	Raccoon	777	39.1661	15.6957	19.4690	0.0888
AN135	NE Arkansas	3CS29	Beaver	780	38.8882	15.6857	19.2072	0.1518
AN136	NE Arkansas	3CS29	Rabbit	774	39.2048	15.6953	19.5126	0.0476
AN137	NE Arkansas	3CS29	Deer	737	39.5083	15.7407	19.9005	0.1770
AN138	NE Arkansas	3CS29	Deer	777	39.3405	15.7141	19.7297	0.0318
AN139	NE Arkansas	3MS20	Skunk	75-671-6145	39.6091	15.7584	20.1082	0.0551
AN140	NE Arkansas	3MS20	Raccoon	75-671-3277	39.1136	15.6904	19.4478	0.0420
AN141	NE Arkansas	3MS20	Deer	76-1247-297	39.8523	15.7961	20.3932	0.0368
AN142	NE Arkansas	3MS20	Deer	75-671-1520	39.1133	15.6562	19.5799	**0.0043**
AN143	NE Arkansas	3MS4	Raccoon	73-432-130	39.1049	15.6907	19.4255	0.0458
AN144	NE Arkansas	3MS4	Raccoon	73-432-10	38.9580	15.6739	19.1952	0.0923
AN145	NE Arkansas	3MS4	Raccoon	73-361	38.9887	15.6802	19.2865	0.1066
AN146	NE Arkansas	3MS4	Raccoon	73-432-30	38.9885	15.6814	19.2583	0.0914
AN147	NE Arkansas	3MS4	Deer	73-430-221	38.9280	15.6757	19.2309	0.0556
AN148	NE Arkansas	3MS4	Deer	73-432-358	39.4876	15.7576	19.6495	**0.0019**
AN157	Louisiana	16CD13	Squirrel	House 5	38.4291	15.6521	18.8004	0.2671
AN158	Louisiana	16CD13	Squirrel	House 5	38.3432	15.6398	18.6645	0.1770
AN159	Louisiana	16CD13	Squirrel	House 5	38.3518	15.6445	18.7147	0.3063
AN160	Louisiana	16CD13	Deer	House 6	38.5307	15.6430	18.7471	0.0658
AN161	Louisiana	16CD13	Deer	House 6	38.4289	15.6398	18.6608	0.1319
AN162	Louisiana	16CD13	Deer	House 6	38.3723	15.6244	18.6092	0.0927
AN163	Louisiana	16NA657	Oposssum	16NA657-10	39.0758	15.6974	19.2938	0.3100
AN164	Louisiana	16NA657	Deer	16NA657-4	38.9810	15.6830	19.1716	0.0844
AN165	Louisiana	16NA657	Deer	Feat. 1	39.0282	15.6875	19.2769	0.0216
AN166	Louisiana	16NA657	Deer	Feat. 1	39.1039	15.7043	19.2852	0.2240
AN167	Missouri	23BU10	Oposssum	FS 292	39.5685	15.7764	20.3925	0.0429
AN168	Missouri	23BU10	Raccoon	FS 799	38.5653	15.4853	19.4329	**0.0010**
AN169	Missouri	23BU10	Raccoon	FS 288	39.8407	15.8035	20.4474	0.0721
AN170	Missouri	23BU10	Deer	FS 4	39.6710	15.7760	20.1867	0.1731
AN171	Missouri	23BU10	Deer	FS 218	39.3721	15.7286	19.8470	0.0205
AN172	Missouri	23BU10	Deer	FS 1	39.4851	15.7929	20.0848	0.0205
AN173	Mississippi	22TU530	Squirrel	L1.2018.8	39.0649	15.7084	19.5341	0.0580
AN174	Mississippi	22TU530	Raccoon	L1.2019.7	39.1306	15.7059	19.5124	0.1424
AN175	Mississippi	22TU530	Dog	L1.2019.6	39.1496	15.6936	19.4673	0.0580

T2 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	v ^{204}Pb
AN176	Mississippi	22CO503	Raccoon	L1.2019.5	39.6054	15.7586	20.1051	**0.0066**
AN177	Mississippi	22CO503	Beaver	L1.2019.2	39.2135	15.7233	19.6310	0.1432
AN178	Mississippi	22CO503	Deer	L1.2019.4	39.1036	15.6842	19.4228	0.0229
AN179	Mississippi	22CO503	Deer	L1.2019.3	39.8836	15.7923	20.4246	0.1363
AN180	Mississippi	22CO503	Deer	L1.2019.1	39.0532	15.6826	19.3378	0.0386

T3 – Sr isotope ratios from human second molar enamel at Crenshaw (3MI6).

Lab ID	Accession	Cluster	Tooth Side	$^{87}Sr/^{86}Sr$	2*Std. Error
HU30	69-66-589-1	Rayburn	Mand L	0.70964	0.00001
HU31	69-66-598-2	Rayburn	Mand R	0.71138	0.00001
HU32	69-66-598-3	Rayburn	Mand L	0.71049	0.00001
HU33	69-66-598-4	Rayburn	Max R	0.71297	0.00001
HU34	69-66-598-5	Rayburn	Max L	0.70925	0.00001
HU35	69-66-598-6	Rayburn	Mand L	0.70976	0.00001
HU36	69-66-598-7	Rayburn	Mand R	0.70913	0.00001
HU37	69-66-598-8	Rayburn	Mand R	0.70942	0.00001
HU38	83-377-6-1	WSA 5	Mand L	0.70952	0.00001
HU39	83-377-6-2	WSA 5	Mand L	0.70941	0.00001
HU40	83-377-6-3	WSA 5	Mand L	0.70933	0.00001
HU41	83-377-6-4	WSA 5	Mand L	0.70996	0.00001
HU42	83-377-6-5	WSA 5	Max R	0.70973	0.00001
HU43	83-377-7-1	WSA 6	Mand R	0.70942	0.00001
HU44	83-377-7-2	WSA 6	Mand L	0.71056	0.00001
HU45	83-377-7-4	WSA 6	Mand L	0.70922	0.00001
HU46	83-377-7-5	WSA 6	Mand	0.71135	0.00001
HU47	83-377-7-6	WSA 6	Mand R	0.71037	0.00001
HU48	83-377-29-1	WSA 17	Mand L	0.71010	0.00001
HU49	83-377-29-2	WSA 17	Mand L	0.70926	0.00001
HU50	83-377-29-3	WSA 17	Mand R	0.70995	0.00001
HU51	83-377-61-1	WSA 25	Mand R	0.71192	0.00001
HU52	83-377-61-2	WSA 25	Mand L	0.71171	0.00001
HU53	83-377-61-3	WSA 25	Mand R	0.71224	0.00001
HU54	83-377-24-1	NSA 1	Max R	0.71114	0.00001
HU55	83-377-24-2	NSA 1	Mand R	0.71066	0.00001
HU56	83-377-24-3	NSA 1	Mand R	0.71098	0.00001
HU57	83-377-24-4	NSA 1	Mand R	0.71074	0.00001
HU58	83-377-24-5	NSA 1	Mand R	0.71097	0.00001

T3 (Cont.)

Lab ID	Accession	Cluster	Tooth Side	$^{87}Sr/^{86}Sr$	2*Std. Error
HU59	83-377-25-1	NSA 2	Max	0.71231	0.00001
HU60	83-377-25-2	NSA 2	Mand L	0.70857	0.00001
HU61	83-377-25-3	NSA 2	Mand R	0.70856	0.00001
HU62	83-377-2-4	WSA 1	Mand L	0.71042	0.00001
HU63	83-377-2-5	WSA 1	Mand R	0.71052	0.00001
HU64	83-377-2-6	WSA 1	Mand R	0.70964	0.00001
HU65	83-377-2-7	WSA 1	Mand L	0.71053	0.00001
HU66	83-377-2-8	WSA 1	Mand R	0.71009	0.00001
HU67	83-377-3-3	WSA 2	Mand L	0.71392	0.00001
HU68	83-377-3-5	WSA 2	Mand L	0.71038	0.00001
HU69	83-377-3-15	WSA 2	Mand R	0.71314	0.00001
HU70	83-377-3-33	WSA 2	Mand R	0.70838	0.00001
HU71	83-377-3-35	WSA 2	Mand L	0.70963	0.00001
HU72	83-377-3-41	WSA 2	Mand L	0.71219	0.00001
HU73	83-377-3-61	WSA 2	Mand R	0.71287	0.00001
HU74	83-377-3-81	WSA 2	Mand R	0.70983	0.00001
HU75	83-377-3-89	WSA 2	Mand R	0.71132	0.00001
HU76	83-377-3-96	WSA 2	Mand L	0.71310	0.00001
HU77	83-377-3-101	WSA 2	Mand L	0.71178	0.00002
HU78	83-377-3-108	WSA 2	Mand L	0.71023	0.00001
HU79	83-377-41-1-1	NSA 8	Mand R	0.71247	0.00001
HU80	83-377-41-1-2	NSA 8	Max L	0.71351	0.00001
HU81	83-377-41-1-3	NSA 8	Max L	0.71266	0.00001
HU82	83-377-41-1-4	NSA 8	Max	0.71336	0.00001
HU83	83-377-41-1-5	NSA 8	Mand R	0.71103	0.00001
HU84	83-377-41-1-6	NSA 8	Mand L	0.70985	0.00001
HU85	83-377-41-1-7	NSA 8	Mand R	0.71270	0.00001
HU86	83-377-41-1-8	NSA 8	Mand L	0.71062	0.00001
HU87	83-377-41-1-9	NSA 8	Max R	0.71145	0.00001
HU88	83-377-23-1	WSA 15	Mand L	0.71146	0.00001
HU89	83-377-23-4	WSA 15	Mand L	0.71002	0.00001
HU90	83-377-23-5	WSA 15	Mand R	0.71042	0.00001
HU91	83-377-23-11	WSA 15	Mand R	0.71128	0.00001
HU92	83-377-23-18A	WSA 15	Mand R	0.70971	0.00001
HU93	83-377-23-18B	WSA 15	Mand R	0.70891	0.00001
HU94	83-377-23-31	WSA 15	Mand L	0.71442	0.00001
HU95	83-377-23-36	WSA 15	Mand R	0.71037	0.00001
HU96	83-377-32-1	WSA 18	Mand L	0.71032	0.00001

T3 (Cont.)

Lab ID	Accession	Cluster	Tooth Side	$^{87}Sr/^{86}Sr$	2*Std. Error
HU97	83-377-32-2	WSA 18	Mand L	0.71086	0.00001
HU98	83-377-32-3	WSA 18	Mand R	0.71028	0.00001
HU99	83-377-32-5	WSA 18	Max L	0.71041	0.00001
HU100	83-377-32-6	WSA 18	Mand L	0.71157	0.00001
HU101	83-377-32-7	WSA 18	Mand R	0.71159	0.00001
HU102	83-377-32-8	WSA 18	Mand L	0.71052	0.00001
HU103	83-377-32-9	WSA 18	Mand L	0.71154	0.00001
HU104	83-377-32-10	WSA 18	Mand L	0.70963	0.00001

T4 – Strontium isotope ratios from animal tooth enamel.

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{87}Sr/^{86}Sr$	2*Std. Error
AN1	SW Arkansas	3MI6	Deer	69-66-591	0.71434	0.00001
AN2	SW Arkansas	3MI6	Rabbit	69-66-587	0.70925	0.00001
AN3	SW Arkansas	3MI6	Opossum	69-66-261	0.70955	0.00001
AN4	SW Arkansas	3MI6	Cottontail	69-66-317	0.70963	0.00001
AN5	SW Arkansas	3MI6	Wood Rat	69-66-230	0.70968	0.00001
AN6	SW Arkansas	3MI6	Swamp Rabbit	69-66-389	0.70941	0.00001
AN7	SW Arkansas	3MI6	Deer	69-66-469	0.71119	0.00001
AN8	SW Arkansas	3MI6	Deer	69-66-389	0.71529	0.00002
AN9	SW Arkansas	3MI6	Deer	90-634	0.71297	0.00001
AN10	SW Arkansas	3MI6	Deer	90-634	0.71513	0.00001
AN11	SW Arkansas	3MI6	Cottontail	95-449	0.70950	0.00001
AN12	SW Arkansas	3MI6	Swamp Rabbit	90-634	0.70974	0.00001
AN13	SW Arkansas	3HE92	Squirrel	83-379-114	0.70977	0.00001
AN14	SW Arkansas	3HE92	Pocket Gopher	82-450-20	0.70978	0.00001
AN15	SW Arkansas	3HE92	Rabbit	83-379-264	0.70943	0.00001
AN16	SW Arkansas	3HE92	Rabbit	83-379-101	0.70930	0.00001
AN17	SW Arkansas	3HE92	Rabbit	83-379-141	0.70927	0.00001
AN18	SW Arkansas	3HE92	Rabbit	83-379-281	0.70919	0.00001
AN19	SW Arkansas	3HE92	Pocket Gopher	84-380-158	0.71007	0.00001
AN20	SW Arkansas	3HE40	Squirrel	2002-700-76	0.71526	0.00001
AN21	SW Arkansas	3HE40	Squirrel	2002-700-345	0.70979	0.00001
AN22	SW Arkansas	3HE40	Squirrel	2003-685-84	0.70985	0.00002
AN23	SW Arkansas	3HE40	Squirrel	2002-700-34-5	0.70980	0.00001
AN24	SW Arkansas	3HE40	Squirrel	2002-700-34-5	0.70976	0.00001
AN25	SW Arkansas	3HO11	Raccoon	61-114-4686	0.70961	0.00001
AN26	SW Arkansas	3HO11	Opossum	61-114-4686	0.70826	0.00001

T4 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{87}Sr/^{86}Sr$	2*Std. Error
AN27	SW Arkansas	3HO11	Small Rodent	61-114-607	0.70830	0.00001
AN28	SW Arkansas	3HO11	Rabbit	61-114-685	0.70832	0.00002
AN29	SW Arkansas	3HO11	Opossum	61-114-473	0.70855	0.00001
AN30	SW Arkansas	3HO11	Deer	61-114-676	0.70890	0.00001
AN31	SW Arkansas	3HO11	Deer	61-114-694	0.70880	0.00001
AN32	SW Arkansas	3HO11	Deer	61-114-638	0.71076	0.00001
AN33	SW Arkansas	3HO11	Deer	61-114-468a	0.70842	0.00001
AN34	SW Arkansas	3HO11	Deer	61-114-554	0.70889	0.00001
AN35	SW Arkansas	3SV20	Deer	64-51-1	none	
AN36	SW Arkansas	3SV20	Rabbit	64-51-1	0.70856	0.00002
AN37	SW Arkansas	3SV20	Opossum	64-51-1	0.70862	0.00002
AN38	SW Arkansas	3SV20	Small Rodent	64-51-1	0.71073	0.00001
AN39	SW Arkansas	3SV20	Raccoon	64-51-1	0.70800	0.00001
AN40	SW Arkansas	3LR49	Rabbit	63-39-278	0.71301	0.00001
AN41	SW Arkansas	3LR49	Raccoon	63-39-33	0.71365	0.00001
AN42	SW Arkansas	3LR49	Raccoon	63-39-57	0.71332	0.00001
AN43	SW Arkansas	3LR49	Opossum	63-39-51	0.71338	0.00001
AN44	SW Arkansas	3LR49	Rabbit	63-39-40	0.71357	0.00001
AN45	SW Arkansas	3LR49	Deer	63-39-45	0.71383	0.00001
AN46	SW Arkansas	3LR49	Deer	63-39-43	0.71379	0.00002
AN47	SW Arkansas	3LR49	Deer	63-39-63	0.71276	0.00001
AN48	SW Arkansas	3LR49	Deer	63-39-49	0.71109	0.00002
AN49	SW Arkansas	3SV15	Deer	64-50-3196	0.70987	0.00001
AN50	SW Arkansas	3SV15	Deer	64-50-252	0.71016	0.00001
AN51	SW Arkansas	3SV15	Deer	64-50-203	0.70898	0.00001
AN52	SW Arkansas	3SV15	Deer	64-50-341	0.71139	0.00001
AN53	SW Arkansas	3SV15	Deer	64-50-325	0.70893	0.00002
AN54	SW Arkansas	3SV15	Opossum	64-50-231	0.70956	0.00002
AN55	SW Arkansas	3SV15	Rabbit	64-50-319a	0.70940	0.00001
AN56	SW Arkansas	3SV15	Rabbit	64-50-437	0.70920	0.00001
AN57	Mississippi	22TU549	Raccoon	F-944	0.70951	0.00001
AN58	Mississippi	22TU549	Opossum	F-2300	0.70896	0.00001
AN59	Mississippi	22TU549	Raccoon	F-2300	0.70932	0.00001
AN60	Mississippi	22TU549	Raccoon	F-2300	0.70919	0.00001
AN61	Mississippi	22TU549	Deer	F-799	0.70851	0.00001
AN62	Mississippi	22TU549	Deer	F-2300	0.70820	0.00001
AN63	Mississippi	22TU549	Deer	F-2300	0.70881	0.00001
AN64	Mississippi	22TU549	Deer	F-1611	0.70933	0.00001

T4 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{87}Sr/^{86}Sr$	2*Std. Error
AN65	Louisiana	16NA70	Deer	16NA70-41	0.70975	0.00001
AN66	Louisiana	16NA70	Deer	16NA70-63	0.71038	0.00001
AN67	Louisiana	16NA70	Deer	16NA70-77	0.70997	0.00001
AN68	Louisiana	16NA70	Deer	16NA70-Nat_F	0.71208	0.00001
AN69	Louisiana	16NA70	Rabbit	16NA70-27	0.70991	0.00002
AN70	Louisiana	16NA70	Rabbit	16NA70-115	0.70940	0.00002
AN71	Louisiana	16NA70	Beaver	16NA70-104	0.70954	0.00001
AN72	Louisiana	16NA70	Rabbit	16NA70-404	0.70968	0.00001
AN73	Illinois	11U635	Deer	95.002 Bag 101	0.71108	0.00001
AN74	Illinois	11U635	Ground Hog	95.002 Bag 21	0.70932	0.00001
AN75	Illinois	11U635	Squirrel	95.002 Bag 24	0.70920	0.00001
AN76	Illinois	11U635	Squirrel	95.002 Bag 30	0.70916	0.00001
AN77	Illinois	11U635	Squirrel	95.002 Bag 100	0.70931	0.00001
AN78	Illinois	11U635	Raccoon	95.002 Bag 100	0.70926	0.00001
AN79	Illinois	11U635	Deer	95.002 Bag 577	0.70879	0.00001
AN80	Illinois	11Pp3	Beaver	14.003 Bag 162	0.70986	0.00001
AN81	Illinois	11Pp3	Squirrel	14.002 TU26 L2	0.71078	0.00001
AN82	Illinois	11Pp3	Raccoon	14.002 N224.5	0.71160	0.00001
AN83	Illinois	11Pp3	Oposssum	14.002 Bag 53	0.71074	0.00001
AN84	Illinois	11Pp3	Deer	14.002 TU26 L3	0.71076	0.00001
AN85	Illinois	11Pp3	Deer	14.002 TU26 L2	0.71062	0.00001
AN86	Illinois	11Mx1	Black Bear	1-115	0.71151	0.00001
AN87	Illinois	11Mx1	Deer	1-95	0.71184	0.00001
AN88	Texas	41RW4	Rabbit	Lot 120	0.70781	0.00001
AN89	Texas	41RW4	Squirrel	Lot 33	0.70780	0.00001
AN90	Texas	41RW4	Beaver	Lot 118	0.70777	0.00001
AN91	Texas	41RW4	Beaver	Lot 117	0.70777	0.00001
AN92	Texas	41RW4	Beaver	Lot 115	0.70779	0.00001
AN93	Texas	41RW4	Raccoon	Lot 115	0.70781	0.00001
AN94	Texas	41RW4	Deer	Lot 119	0.70856	0.00001
AN95	Texas	41WM230	Small Rodent	Lot 597	0.70793	0.00001
AN96	Texas	41WM230	Pocket Gopher	XU3	0.70783	0.00001
AN97	Texas	41WM230	Raccoon	Lot 141-7	0.70820	0.00001
AN98	Texas	41WM230	Small Rodent	Lot 637	0.70806	0.00001
AN99	Texas	41WM230	Small Rodent	Lot 619	0.70790	0.00001
AN100	Texas	41TR198	Pocket Gopher	Lot 445	0.70878	0.00001
AN101	Texas	41TR198	Small Rodent	Lot 461	0.70861	0.00001
AN102	Texas	41TR198	Pocket Gopher	Lot 462	0.70858	0.00001

T4 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{87}Sr/^{86}Sr$	2*Std. Error
AN103	Texas	41TR198	Small Rodent	Lot 435	0.70874	0.00001
AN104	Texas	41TR198	Deer	Lot 408	0.70932	0.00001
AN105	Texas	41TR198	Deer	Lot 456	0.70909	0.00001
AN106	Texas	41COL9	Deer	41-18C9-2	0.70783	0.00001
AN107	Texas	41COL9	Beaver	41-18C9-2	0.70853	0.00001
AN108	Texas	41COL9	Rabbit	41-18C9-2	0.70771	0.00001
AN109	Texas	41COL9	Pocket Gopher	41-18C9-2	0.70772	0.00001
AN110	Texas	41EL11	Raccoon	Lot 120	0.70769	0.00001
AN111	Texas	41EL11	Pocket Gopher	Lot 240	0.70840	0.00001
AN112	Texas	41EL11	Pocket Gopher	Lot 240	0.70818	0.00001
AN113	Oklahoma	34Cu27	Rabbit	83.002	0.70864	0.00001
AN114	Oklahoma	34Cu27	Small Rodent	101.011	0.70837	0.00001
AN115	Oklahoma	34Cu27	Deer	101.011	0.70834	0.00001
AN116	Oklahoma	34Cu27	Small Rodent	101.011	0.70830	0.00001
AN117	Oklahoma	34Cu27	Small Rodent	101.011	0.70860	0.00001
AN118	Oklahoma	34Cu27	Small Rodent	101.011	0.70845	0.00001
AN119	Oklahoma	34Cu27	Small Rodent	101.011	0.70863	0.00001
AN120	Oklahoma	34Rm29	Deer	026-A/1980/20	0.70836	0.00001
AN121	Oklahoma	34Rm29	Rabbit	026-A/1980/20	0.70860	0.00001
AN122	Oklahoma	34Rm29	Small Rodent	026-A/1980/20	0.70834	0.00001
AN123	Oklahoma	34Wa5	Rabbit	26.007	0.70905	0.00001
AN124	Oklahoma	34Wa5	Pocket Gopher	654.006	0.70905	0.00001
AN125	Oklahoma	34Wa5	Pocket Gopher	690.004	0.70879	0.00001
AN126	Oklahoma	34Wa5	Pocket Gopher	42.005	0.70911	0.00001
AN127	Oklahoma	34Wa5	Pocket Gopher	97.008	0.70937	0.00001
AN128	Oklahoma	34Wa5	Pocket Gopher	97.008	0.70951	0.00001
AN129	Oklahoma	34Wa5	Deer	640	0.70934	0.00001
AN130	Mississippi	22TU530	Raccoon	Feat. 34	0.70933	0.00001
AN131	Mississippi	22TU530	Grey Fox	Feat. 34	0.70935	0.00001
AN132	NE Arkansas	3CS29	Raccoon	1522094	0.70942	0.00001
AN133	NE Arkansas	3CS29	Beaver	777	0.70937	0.00002
AN134	NE Arkansas	3CS29	Raccoon	777	0.70951	0.00001
AN135	NE Arkansas	3CS29	Beaver	780	0.70954	0.00001
AN136	NE Arkansas	3CS29	Rabbit	774	0.70930	0.00001
AN137	NE Arkansas	3CS29	Deer	737	0.70937	0.00001
AN138	NE Arkansas	3CS29	Deer	777	0.70960	0.00001
AN139	NE Arkansas	3MS20	Skunk	75-671-6145	0.70994	0.00001
AN140	NE Arkansas	3MS20	Raccoon	75-671-3277	0.70952	0.00001

T4 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{87}Sr/^{86}Sr$	2*Std. Error
AN141	NE Arkansas	3MS20	Deer	76-1247-297	0.71009	0.00001
AN142	NE Arkansas	3MS20	Deer	75-671-1520	0.70982	0.00001
AN143	NE Arkansas	3MS4	Raccoon	73-432-130	0.70930	0.00001
AN144	NE Arkansas	3MS4	Raccoon	73-432-10	0.70994	0.00018
AN145	NE Arkansas	3MS4	Raccoon	73-361	0.70935	0.00002
AN146	NE Arkansas	3MS4	Raccoon	73-432-30	0.70941	0.00002
AN147	NE Arkansas	3MS4	Deer	73-430-221	0.70946	0.00002
AN148	NE Arkansas	3MS4	Deer	73-432-358	0.70907	0.00002
AN149	Ouachita - SW AR	3CL418	Deer	87-710-954	0.71357	0.00001
AN150	Ouachita - SW AR	3CL418	Deer	87-710-647	0.71266	0.00001
AN151	Ouachita - SW AR	3CL418	Deer	87-710-95	0.71007	0.00001
AN152	Ouachita - SW AR	3CL418	Squirrel	87-710-417	0.71229	0.00001
AN153	Ouachita - SW AR	3CL418	Squirrel	87-710-86	0.71352	0.00001
AN154	Ouachita - SW AR	3HS60	Deer	74-746-14	0.71312	0.00001
AN155	Ouachita - SW AR	3HS60	Deer	74-746-27	0.71606	0.00001
AN156	Ouachita - SW AR	3HS60	Oposssum	74-746-28	0.71492	0.00001
AN157	Louisiana	16CD13	Squirrel	House 5	0.70993	0.00001
AN158	Louisiana	16CD13	Squirrel	House 5	0.71154	0.00001
AN159	Louisiana	16CD13	Squirrel	House 5	0.70992	0.00001
AN160	Louisiana	16CD13	Deer	House 6	0.71062	0.00001
AN161	Louisiana	16CD13	Deer	House 6	0.71038	0.00001
AN162	Louisiana	16CD13	Deer	House 6	0.70901	0.00001
AN163	Louisiana	16NA657	Oposssum	16NA657-10	0.71210	0.00001
AN164	Louisiana	16NA657	Deer	16NA657-4	0.71210	0.00001
AN165	Louisiana	16NA657	Deer	Feat. 1	0.70959	0.00001
AN166	Louisiana	16NA657	Deer	Feat. 1	0.71119	0.00001
AN167	Missouri	23BU10	Oposssum	FS 292	0.71219	0.00001
AN168	Missouri	23BU10	Raccoon	FS 799	0.71286	0.00001
AN169	Missouri	23BU10	Raccoon	FS 288	0.71039	0.00001
AN170	Missouri	23BU10	Deer	FS 4	0.70997	0.00001
AN171	Missouri	23BU10	Deer	FS 218	0.71006	0.00001
AN172	Missouri	23BU10	Deer	FS 1	0.71304	0.00001
AN173	Mississippi	22TU530	Squirrel	L1.2018.8	0.70931	0.00001
AN174	Mississippi	22TU530	Raccoon	L1.2019.7	0.70946	0.00001
AN175	Mississippi	22TU530	Dog	L1.2019.6	0.70941	0.00001
AN176	Mississippi	22CO503	Raccoon	L1.2019.5	0.70954	0.00001
AN177	Mississippi	22CO503	Beaver	L1.2019.2	0.70959	0.00001
AN178	Mississippi	22CO503	Deer	L1.2019.4	0.70954	0.00001

T4 (Cont.)

Lab ID	State/Area	Site Number	Animal	Accession/ Context	$^{87}Sr/^{86}Sr$	2*Std. Error
AN179	Mississippi	22CO503	Deer	L1.2019.3	0.70936	0.00001
AN180	Mississippi	22CO503	Deer	L1.2019.1	0.70942	0.00001

Chapter 4: Evaluating Dietary Evidence of Bison or Maize and Fish Consumption

John R. Samuelsen

Abstract

The Crenshaw site, located in southwest Arkansas, is too far from the Southern Plains for bison consumption to be part of a local diet. Bison consumption was proposed to be the cause of increased $\delta^{13}C$ and $\delta^{15}N$ values among detached skulls and mandibles at Crenshaw, suggesting they may be victims of warfare from the Southern Plains. However, some of the skulls have auditory exostoses, which are associated with aquatic resource acquisition. Multivariate statistical analysis shows a strong correlation between auditory exostoses presence and elevated $\delta^{15}N$ values, suggesting the elevated $\delta^{15}N$ values are most readily explainable by the consumption of freshwater fish. Additionally, $\delta^{15}N$ values decrease as $\delta^{13}C$ values increase among all groups, consistent with maize consumption. These two factors indicate that individuals with elevated $\delta^{15}N$ values have a potentially local fish/maize diet rather than a foreign bison diet. This simultaneously demonstrates the usefulness of using auditory exostoses in combination with dietary isotopes for identifying subpopulations consuming different amounts of fish. Comparisons to other samples in the Caddo Area show that they are more consistent with a variable maize diet in the Southern Caddo Area than the Plains or the Northern Caddo Area, where bison was consumed. This provides additional evidence in support of the hypothesis that these people represent locals rather than people from the Southern Plains. The results suggest the population had significant dietary diversity, consistent with the adoption of maize as a staple during the Middle Caddo period (A.D. 1200-1500).

Keywords: bison, maize, isotopes, auditory exostoses, carbon, nitrogen, Caddo

4.1 Introduction

Previously published (Akridge 2014) carbon (C) and nitrogen (N) isotopes from dentin are reanalyzed in this study for the purpose of identifying dietary differences between different burial groups at the Crenshaw site (3MI6) in southwest Arkansas (Samuelsen 2009). C and N isotopes are particularly suitable for answering questions involving the degree and timing of maize adoption among a population (Akridge 2014; Ambrose 1990; Greenlee 2002; Van der Merwe and Vogel 1978; Wilson 2012; Wilson and Perttula 2013). Such data forms much of the basis for how we understand maize adoption in the Eastern Woodlands. Unlike much the rest of the Mississippian world, it is generally accepted that the Caddo did not adopt maize as a staple until around A.D. 1300 (Perttula 2008; Rose et al. 1998; Wilson 2012; Wilson and Perttula 2013). Instead, they relied more heavily on native cultigens until A.D. 1200 to 1300 when more intensive agriculture associated with tropical cultigens became most important (Perttula 2008:98-99). Wilson and Perttula (2013) suggest this would have been a time of increased dietary variability. It is thought that maize adoption could be useful for increasing the amounts of locally available food, possibly as a response to a rise in population densities (Milner 2004:122). Adopting maize as a staple increases the agricultural demands of the population, but provides several benefits associated with efficiency and flexibility (Milner 2004:122-123; Rindos and Johannessen 1991:43; Smith 1987:49-51). The adoption of maize as a staple by the Caddo between A.D. 1200 and 1300 might have encouraged a shift to a more dispersed settlement pattern, as is seen in later times (Early 2000; Girard 2012; Perttula 2012; Schambach 1982).

There is a notable lack of information on the timing of maize adoption in southwest Arkansas. A collection of C stable isotopes from Caddo sites in the area shows that maize was only a minor part of the diet during the Early Caddo period (Rose et al. 1998:Table 6-2). During the Late Caddo period, it was clearly a staple based on stable C isotopes from Cedar Grove (Wolfman 1984:258, Table 17-1). The lack of both C and N samples from the Middle Caddo period (A.D. 1200-1500) is a problem for resolving this issue. However, two C isotope samples ($\delta^{13}C$ = -14.29 and -12.83) from the Ferguson site and four (mean $\delta^{13}C$=-11.27) from Hardman suggest moderate to heavy maize consumption among at least some of the population by the end of the Middle Caddo period (Burnett 1993; Rose et al. 1998).

Previously analyzed samples from Crenshaw on 80 people, most from the Middle Caddo period (Samuelsen 2014), could help fill this gap (Akridge 2011, 2014). However, Akridge (2014) analyzed C and N isotopes from Crenshaw and suggested that the diets represented in the Middle Caddo skull and mandible clusters were too varied to be from a single population. Instead, the conclusions suggested that they were likely war trophies from other regions. One important point in the conclusions was that some of the people had elevated C and N isotope ratios (Group 4). Akridge (2014:52) concluded this was most likely the result of bison consumption, not maize and fish consumption. Due to Crenshaw's distance from the Plains and the lack of faunal evidence of bison consumption, these people could not be locals if bison made up such a large portion of their diet. This suggests a Southern Plains origin for these people, as Burnett (2010) had previously concluded. While a fish and maize diet was considered, doubt was cast on such a diet being the cause. However, this analysis did not include an important biological variable, the auditory exostosis. Auditory exostoses, or "surfer's ear," are boney growths in the ear and are associated with repeated and prolonged cold-water activities, particularly fishing (Crowe et al. 2010; Frayer 1988; Jenkins 2013; Kennedy 1986; Okumura et al. 2007; Smith-Guzmán and Cooke 2019; Villotte and Knüsel 2016). This study will reanalyze the C and N stable isotope data of the skull clusters while considering the impact of auditory exostoses to determine if the people with elevated C and N isotope ratios were eating a foreign bison diet or eating fish and maize. Since mandibles cannot be assessed for auditory exostoses, they are not included this analysis. However, all C and N samples from Crenshaw are compared to reassess the evidence for non-locals.

4.1.1 Carbon and Nitrogen Isotopes

C and N isotopes are particularly suitable for answering questions involving the degree of maize adoption. They can detect differences in diet between different people and populations. There are two stable C isotopes which occur in nature (^{12}C and ^{13}C). Some plants discriminate strongly against ^{13}C in favor of ^{12}C, causing them to have lower ratios of ^{13}C to ^{12}C, represented by a $\delta^{13}C$ value. These plants follow a C_3 photosynthetic pathway. Others discriminate less strongly against ^{13}C and have higher ^{13}C to ^{12}C ratios. These plants follow a C_4 photosynthetic pathway. Animals and humans absorb these isotopes into the body through their food. Bone and teeth can be sampled to determine the ratio of these isotopes. Maize consumption is detectable in samples because maize is a C_4 plant while most other terrestrial plants commonly consumed in the Eastern Woodlands are C_3 plants (Akridge 2014; Ambrose et al. 2003). However, it is important to note that this is not the case in other areas where other C_4 plants are more commonplace, where marine diets may be expected, and in the Plains where bison often consume C_4 grasses. This is why bison or maize consumption could lead to similar $\delta^{13}C$ values (Malainey 2011; Price and Burton 2011; Wilson and Perttula 2013).

N isotopes provide dietary information that is complimentary to C isotopes. Two stable N isotopes occur in nature (^{14}N and ^{15}N). Similar to C isotope ratios, N ratios of ^{15}N to ^{14}N are represented by a $\delta^{15}N$ value. These values are also absorbed by the body and can be sampled from bones and teeth. N isotopes are important because $\delta^{15}N$ values rise with increasing trophic levels. This means that when organisms that are higher on the food chain are consumed, they lead to higher $\delta^{15}N$ values in the bones and teeth. Since plants are on a lower trophic level, this provides a proxy for the relative amount of plants and meat being consumed. Freshwater animals tend to have higher $\delta^{15}N$ values when compared to terrestrial animals (Ambrose et al. 2003; Malainey 2011; Price and Burton 2011). When C and N isotopes are analyzed together, patterned differences between people can be detected and past diets can be estimated.

4.1.2 Bison, Maize, Fish, and Auditory Exostoses

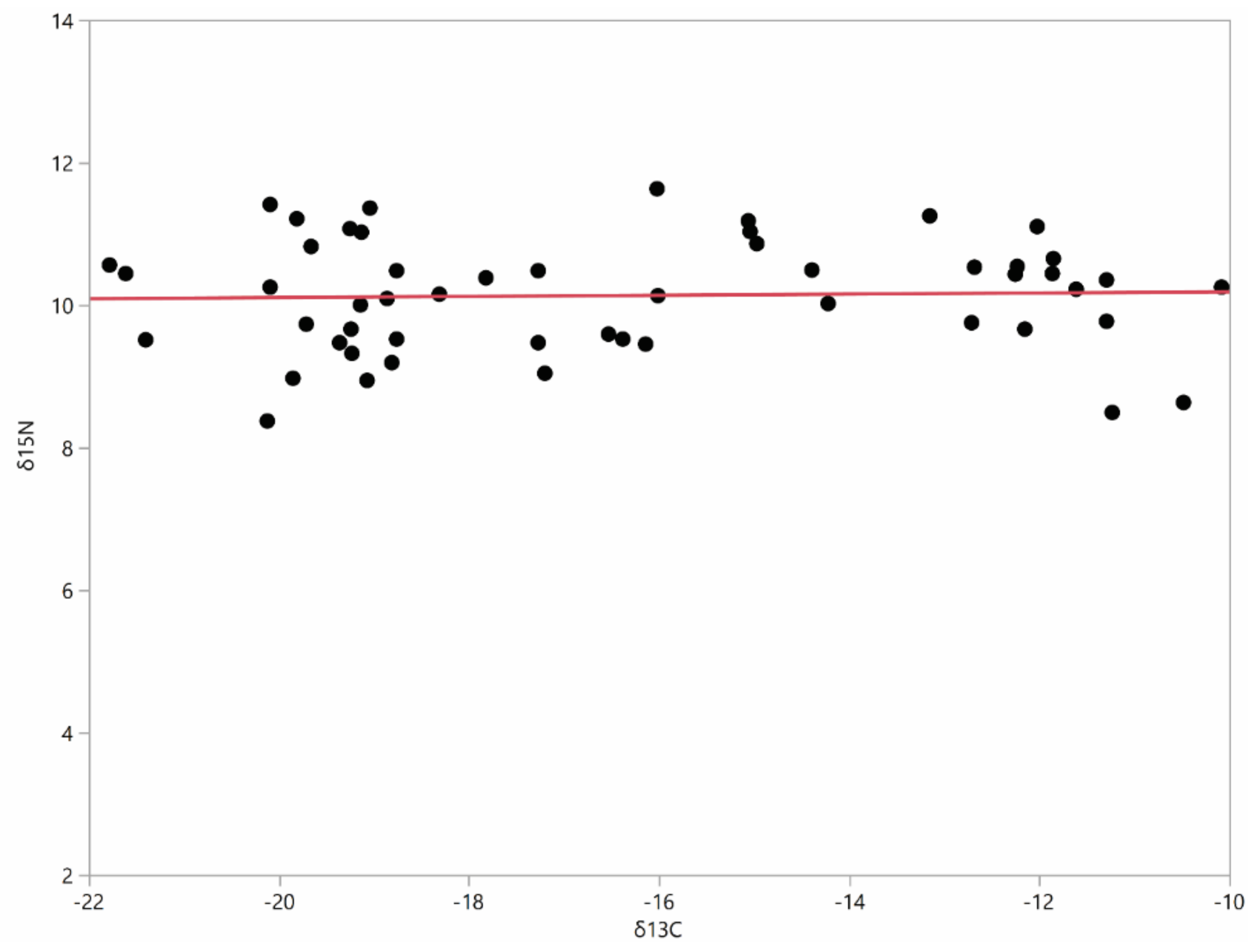

Figure 4.1 – C and N isotope ratios in the Northern Caddo Area (see Rogers 2011). The regression line has almost no slope (0.01) and no correlation (R^2=0.00).

Bison consumption, while not expected in southwest Arkansas, can be seen in the Northern Caddo Area (Figure 4.1) and on the western extents of the Southern Caddo Area

(Perttula 2008; Rogers 2011; Wilson 2012; Wilson and Perttula 2013). Wilson and Perttula (2013) note that the Northern Caddo Area has evidence of bison consumption because as $\delta^{13}C$ ratios increase, $\delta^{15}N$ ratios maintain an elevated level. This can be seen in the flat slope of the fit line. If these people were consuming maize, as in the Southern Caddo Area, the $\delta^{15}N$ ratios should drop as $\delta^{13}C$ ratios increase, reflected by a fit line with a negative slope (Figure 4.2). This is due to the falling trophic level of the overall diet as maize replaces meat.

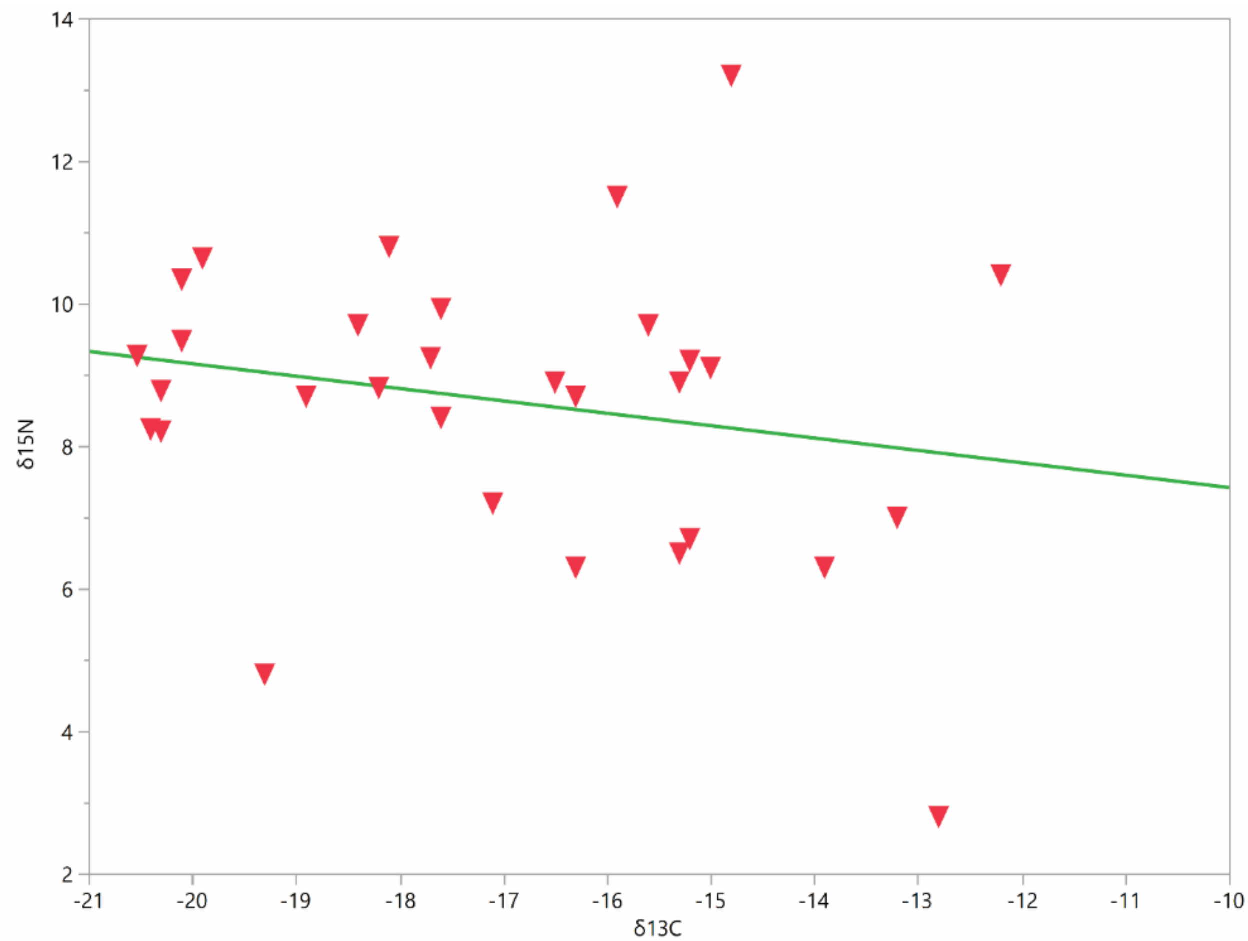

Figure 4.2 – C and N isotope ratios in the Southern Caddo Area (Wilson and Perttula 2013). The regression line has a negative slope (-0.17).

Wilson and Perttula (2013) distinguish between maize and bison diets using the correlation between $\delta^{13}C$ and $\delta^{15}N$, but also use $\delta^{13}C$ samples from both collagen and apatite. Since collagen better reflects the protein portion of the diet and apatite better reflects the whole diet, C_4 contribution from bison and maize can potentially be distinguished. However, this type of analysis cannot be done at Crenshaw since no samples were taken from apatite.

Freshwater fish tend to have elevated $\delta^{15}N$ ratios compared to terrestrial animals. So, if fish replaces terrestrial meat in a diet, it could lead to a diet with significantly higher trophic levels. If some individuals are eating large amounts of fish and maize, it could lead to elevated $\delta^{13}C$ and $\delta^{15}N$ ratios, similar to a bison diet (Figure 4.3). While Akridge (2014) suggested that the people in the skull clusters were consuming bison, it is possible that fish and maize were the cause. In order to assess which of these diets could explain these values, this study uses auditory exostoses as a means to identify people who are associated with fishing activities.

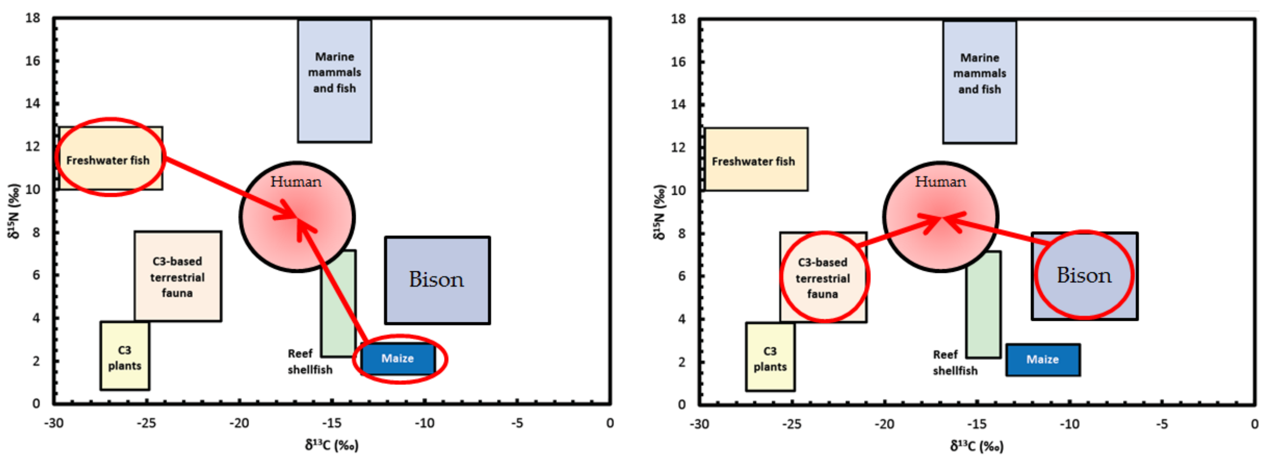

Figure 4.3 – Comparison of a moderate fish/maize diet and a moderate C_3/bison diet resulting in similar C and N isotopic results (adapted from Akridge 2011:Figure 2.2).

Auditory exostoses are associated with cold-water activities, particularly fishing. Powell (1977) first noted the presence of auditory exostoses among one skull cluster at Crenshaw, the Rayburn Cluster, and suggested it was a genetic marker that indicated they were unlike known Caddo peoples. However, while a genetic affinity for auditory exostoses have not been ruled out, they have since been repeatedly shown to be a result of human behaviors rather than genetics (Crowe et al. 2010; Frayer 1988; Jenkins 2013; Kennedy 1986; Okumura et al. 2007; Smith-

Guzmán and Cooke 2019; Villotte and Knüsel 2016). They are observable as boney growths in the exterior ear canal and are typically recorded as a non-metric cranial trait (Buikstra and Ubelaker 1994). They have been noted for being common among people of middle latitudes who participate in fishing activities where water drops below 19°C (Kennedy 1986). It is expected that the Caddo around Crenshaw may have had auditory exostoses since fishing is expected to have been a very productive way of gathering food, particularly given the larger number of oxbow lakes in the area. Importantly, the Red River in this area is below 19°C five to six months of the year and auditory exostoses have been seen on people at Crenshaw (Powell 1977; Zabecki 2011) and nearby sites like Cedar Grove (Rose 1982) and Jones Mill (Bennett 1986).

Others have attempted statistical analyses to find differences in C and N isotope ratios between those who have auditory exostoses and those who do not (Crowe et al. 2010). This can be an effective method to detect a link between fishing activities and fish consumption. Different statistical tests will be used here to determine if the skulls associated with auditory exostoses correlate with elevated $\delta^{15}N$ ratios.

4.2 Methods

The methods will utilize $\delta^{13}C$, $\delta^{15}N$, auditory exostosis presence, and burial context as variables and will be performed using JMP statistical software. First, two groups are created by separating those who are associated with an auditory exostosis from those who are not. The auditory exostosis group consists of individuals who are in a burial context where at least one individual had an auditory exostosis. The absence group consists of those individuals who were within a burial context where no one had an auditory exostosis. The remains are grouped in this way because diets within clusters are more similar than between clusters and there is reason to believe that people within clusters are more related to each other than they are to people in other clusters (Akridge 2011, 2014; Zabecki 2011). Second, Tukey's honest significant difference (HSD) test is applied to the $\delta^{15}N$ value of these two groups (see Crowe et al. 2010). This will determine if the auditory exostosis group has a higher and significantly different mean $\delta^{15}N$ value than the absence group.

Third, an ANCOVA (Vogt 1999), or Analysis of Covariance, is performed on $\delta^{13}C$ and $\delta^{15}N$ values within the groups. This is important since increasing maize consumption causes $\delta^{13}C$ values to increase and $\delta^{15}N$ values to decrease. Therefore, adjusting for the $\delta^{13}C$ value of each sample allows for the removal of the potential effect of maize on the $\delta^{15}N$ values. Doing this results in a more accurate assessment of the difference in $\delta^{15}N$ values between the groups. However, in order to do an ANCOVA, the heterogeneity of regression cannot be rejected. That is, the two groups' regression line slopes cannot be significantly different from one another. This is important to establish before an ANCOVA can be done because it indicates that $\delta^{13}C$ and $\delta^{15}N$ correlate the same way regardless of which group is being evaluated. Once the assumption of the heterogeneity of regression is upheld, an ANCOVA is done to test the statistical significance and calculate the least squares mean of the $\delta^{15}N$ values. It also provides a means to measure the correlation between $\delta^{13}C$ and $\delta^{15}N$, potentially confirming the effects of maize within the groups.

The difference in mean $\delta^{15}N$ values between fish and terrestrial mammals is also calculated. These means are compared to the different means between the auditory exostosis group and the absence group to verify that fish consumption could explain the difference. This is important to verify because a statistically significant correlation between auditory exostosis presence and elevated $\delta^{15}N$ values suggests that there is some cause affecting both variables. The only recognized cause for both auditory exostosis presence and elevated $\delta^{15}N$ values is fishing and fish consumption.

The slope of the fit line of each group are also compared, determining if $\delta^{13}C$ and $\delta^{15}N$ are inversely correlated. If the fit lines have a negative slope, it is indicative of increasing maize consumption. If they have a positive slope or even slope, then bison should be considered. Finally, the results are compared to the literature and other data sources. Lab methods for obtaining the C and N ratios were described by Akridge (2014).

4.2.1 Sample Selection

The C and N isotope samples under study are those that represent people from the skull clusters selected by Burnett (2010) and analyzed by Akridge (2014), although one sample is based on a replicate (Appendix T1). These samples were taken from collagen in the dentin portion of the second mandibular molar, which forms between the ages of four and eight years (Buikstra and Ubelaker 1994:Figure 24). The C and N isotope samples from Mound C and Mound F at Crenshaw (Appendix T2) were also originally reported by Akridge (2014). One sample is from a second or third maxillary molar and another is from an unidentified third molar. Maxillary second molars form at the same time as mandibular second molars and third molars form between the ages of 10 to 15 years (Buikstra and Ubelaker 1994:Figure 24).

Akridge (2011:22) created a new method for determining the degree to which samples from human dentin were considered invalid due to diagenesis. This new method, created citing Ambrose (1990), used problematic % C values and resulted in only 24 of the 80 individuals sampled being considered valid. Verifying that this is no small issue, if Akridge's method and threshold values are applied to Ambrose's data, it would result in 13 of the 22 "well preserved" herbivore teeth samples (59%) being identified as diagenetic. This large decrease in sample size at Crenshaw severely limited interpretations and potential statistical analyses. Therefore, this reanalysis only uses C and N isotope samples with C/N ratios inside of the range of 2.80 to 3.60

due to the potential for contamination (Akridge 2011:22; Ambrose 1990; DeNiro 1985; Larsen et al. 1992:201). The lower threshold of 2.80 errs slightly on the side of inclusion as many studies use a lower threshold of 2.90. A 2.80 threshold is more restrictive than the 2.70 threshold used by Larsen et al. (1992) and still excludes all poorly preserved teeth identified by Ambrose (1990). One additional sample is included since its rerun had a good C/N ratio. When these thresholds are used, it results in an increase of samples that are useable for analysis to 51 out of 80 (an increase of 113%). Auditory exostoses were originally identified by Zabecki (2011) and were compared with the University of Arkansas Museum's Standard Osteological Database.

Comparisons with the Northern Caddo Area use samples from Rogers (2011) and the Southern Caddo Area use samples compiled by Wilson and Perttula (2013). Those samples from the Northern Caddo Area only come from sites in eastern Oklahoma. The samples analyzed from the Southern Caddo Area only come from southwest Arkansas and east Texas. The only sites with C and N samples from Louisiana were later in time than the skulls and mandibles. This study follows Wilson and Perttula (2013:Figure 3) by comparing the regions using only those samples which are from ancient contexts. Finally, the results are compared to Mounds C and F (Appendix T2) as well as the mandible clusters (Appendix T3) to provide an evaluation that considers all C and N isotopes at Crenshaw.

4.3 Results

When the auditory exostosis group is compared to the absence group, it is apparent that some of the people in the auditory exostosis group have elevated $\delta^{15}N$ values (Figure 4.4). However, others have relatively low $\delta^{15}N$ values. Tukey's honest significant difference test shows that the auditory exostosis group has elevated $\delta^{15}N$ values ($p<0.05$). The auditory exostosis group has a mean $\delta^{15}N$ value 0.65‰ above the absence group. However, this test does not incorporate the effect of $\delta^{13}C$ on the samples. Comparing $\delta^{15}N$ values without concern for $\delta^{13}C$ values can skew the results depending on where the samples fall in each group.

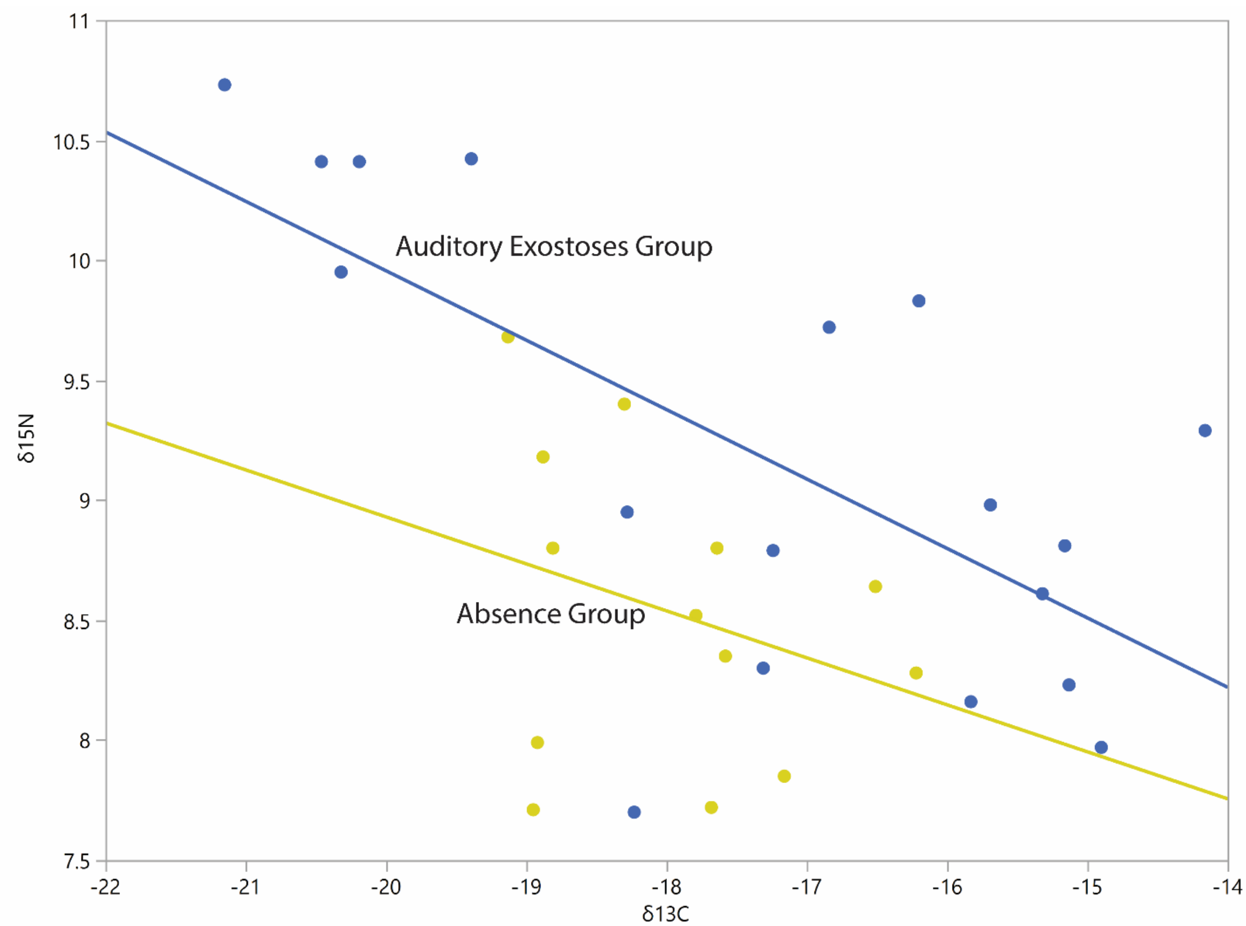

Figure 4.4 – Plot of the samples in the auditory exostosis group (blue dots) and the absence group (yellow dots). The auditory exostoses group has higher $\delta^{15}N$ values.

A test to determine if the groups have heterogeneity of regression shows that their slopes are not significantly different with a p-value of 0.675. The graph reflects this in their nearly parallel regression lines (Figure 4.4). This indicates that $\delta^{13}C$ and $\delta^{15}N$ correlate similarly in both groups and an ANCOVA can be done.

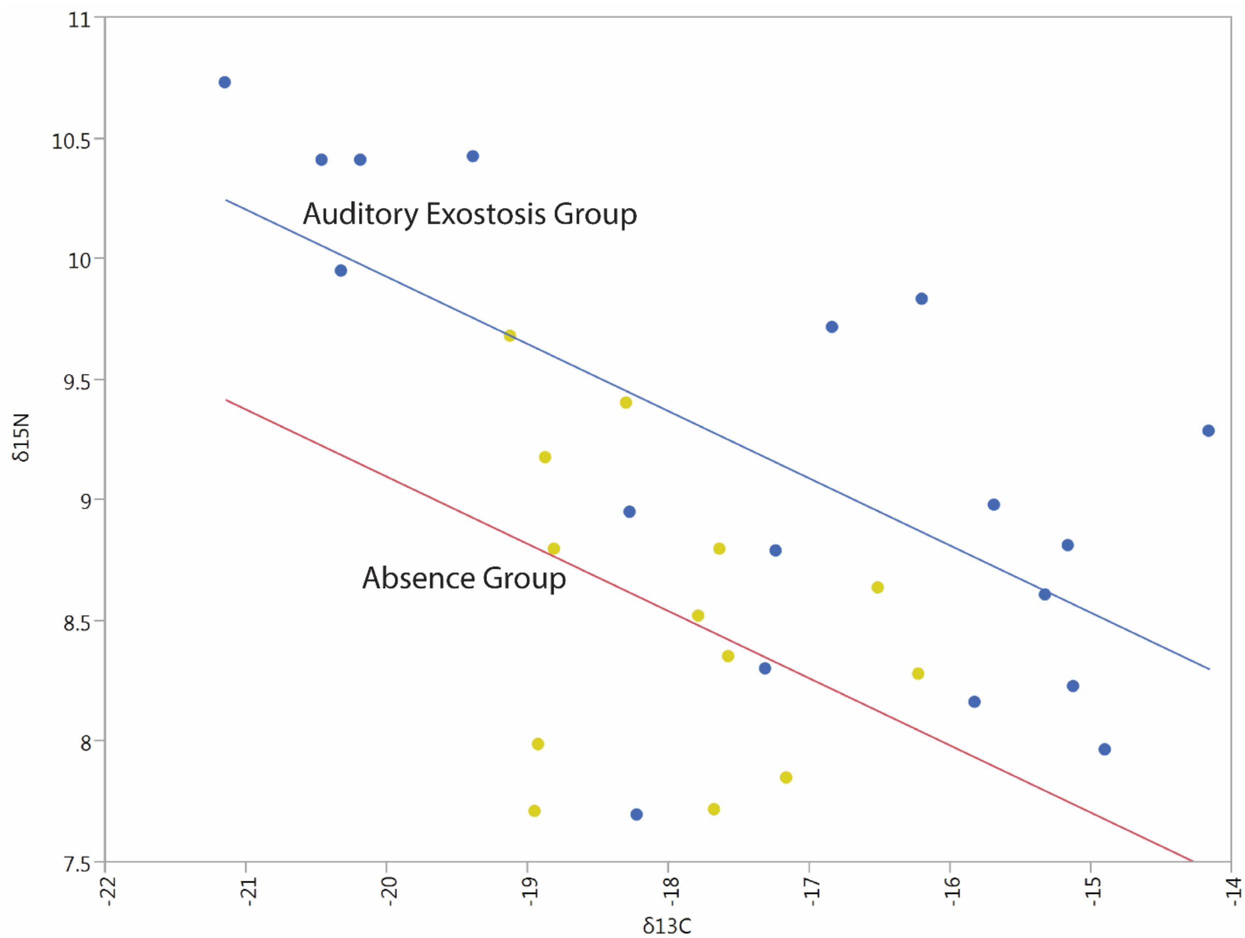

Figure 4.5 – ANCOVA of the auditory exostosis group and the absence group. The auditory exostosis group has elevated $\delta^{15}N$ values (0.83‰) compared to the absence group.

After accounting for the effect of $\delta^{13}C$, the ANCOVA results (Figure 4.5) indicate that the different $\delta^{15}N$ means between the two groups are highly statistically significant ($p<0.003$). The auditory exostosis group has elevated $\delta^{15}N$ values with a least squares mean that is 0.83‰ above the absence group. This clearly shows that those associated with auditory exostoses tend to have elevated $\delta^{15}N$ values compared to those who are not associated with auditory exostoses. Additionally, $\delta^{13}C$ and $\delta^{15}N$ correlate weakly ($R^2=0.23$), but when the auditory exostosis and absence groups are accounted for, the correlation is stronger ($R^2=0.45$).

The linear fits of both groups reflect a negative correlation of $\delta^{13}C$ and $\delta^{15}N$ (Figure 4.4). This is indicative of maize, but not bison. The equations for these lines, while not both statistically significant, show a negative slope. Interestingly, the slope for the auditory exostosis group is about 50% larger than the absence group. This means that as $\delta^{13}C$ values increase, $\delta^{15}N$ values decrease 50% faster in the auditory exostosis group. This is consistent with the idea that maize is replacing meat with a higher trophic level (i.e. fish) among those in the auditory exostosis group.

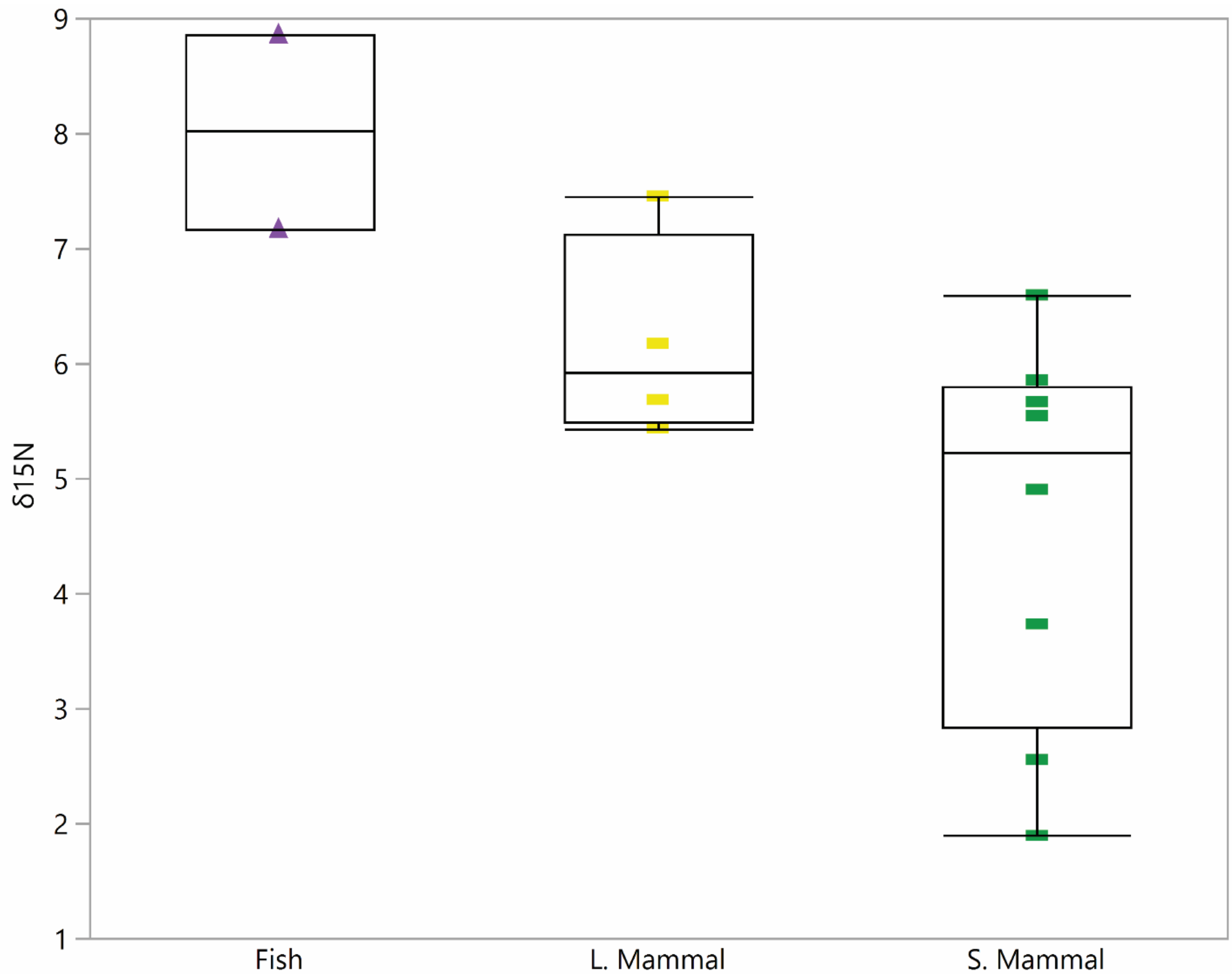

Figure 4.6 – $\delta^{15}N$ means for fish (purple), deer (yellow), and small mammals (green) verify that fish have higher $\delta^{15}N$ values at Crenshaw. Mean fish values are significantly higher than small mammals ($p<0.05$).

C and N isotopes from animals can vary greatly (Cormie and Schwarcz 1994), so testing if fish consumption would cause elevated $\delta^{15}N$ values is important. Fish and terrestrial mammals from the Crenshaw site (Appendix T4) verified that fish could cause elevated $\delta^{15}N$ values

(Figure 4.6). Although sample size was low, fish $\delta^{15}N$ values averaged about 3.5‰ higher than small mammals and 1.8‰ higher than deer. Just as important, fish and small mammals had equivalent $\delta^{13}C$ means. These two factors indicate that if freshwater fish substituted for small mammals, the diet would have elevated $\delta^{15}N$ values, but the substitution would have no effect on $\delta^{13}C$ values. Adding in the expected human increase of $\delta^{15}N$ over dietary intake (O'Connell et al. 2012), a purely freshwater fish diet in human dentin at Crenshaw may be expected to have a $\delta^{15}N$ value of 15‰. It is expected that this value would probably be higher if more samples were obtained since previous research showed higher freshwater fish $\delta^{15}N$ values (e.g. Hard and Katzenberg 2011).

In summary, the ANCOVA shows that there is a strong correlation between auditory exostosis presence and $\delta^{15}N$ values among the people in the skull clusters at Crenshaw. The only known causal factor that explains this correlation is fishing and fish consumption. This method seems to successfully identify that the auditory exostosis group is fishing and consuming more fish than the absence group. Also, the strong inverse correlation between $\delta^{13}C$ and $\delta^{15}N$ values suggest variable levels of maize are being consumed. This is inconsistent with the lack of a correlation or positive correlation that might be expected of a bison diet. In order to have confidence in these results, it is useful to compare them to other data.

4.4 Discussion

4.4.1 Comparisons between Regions

Several other lines of evidence support a maize and fish diet rather than a bison diet for some individuals represented by their skulls at Crenshaw. The comparison (Figure 4.7) of the skull clusters to values from the Northern Caddo Area in eastern Oklahoma (see Rogers 2011) show that they have significantly different slopes (p=0.006). The Northern Caddo Area has a

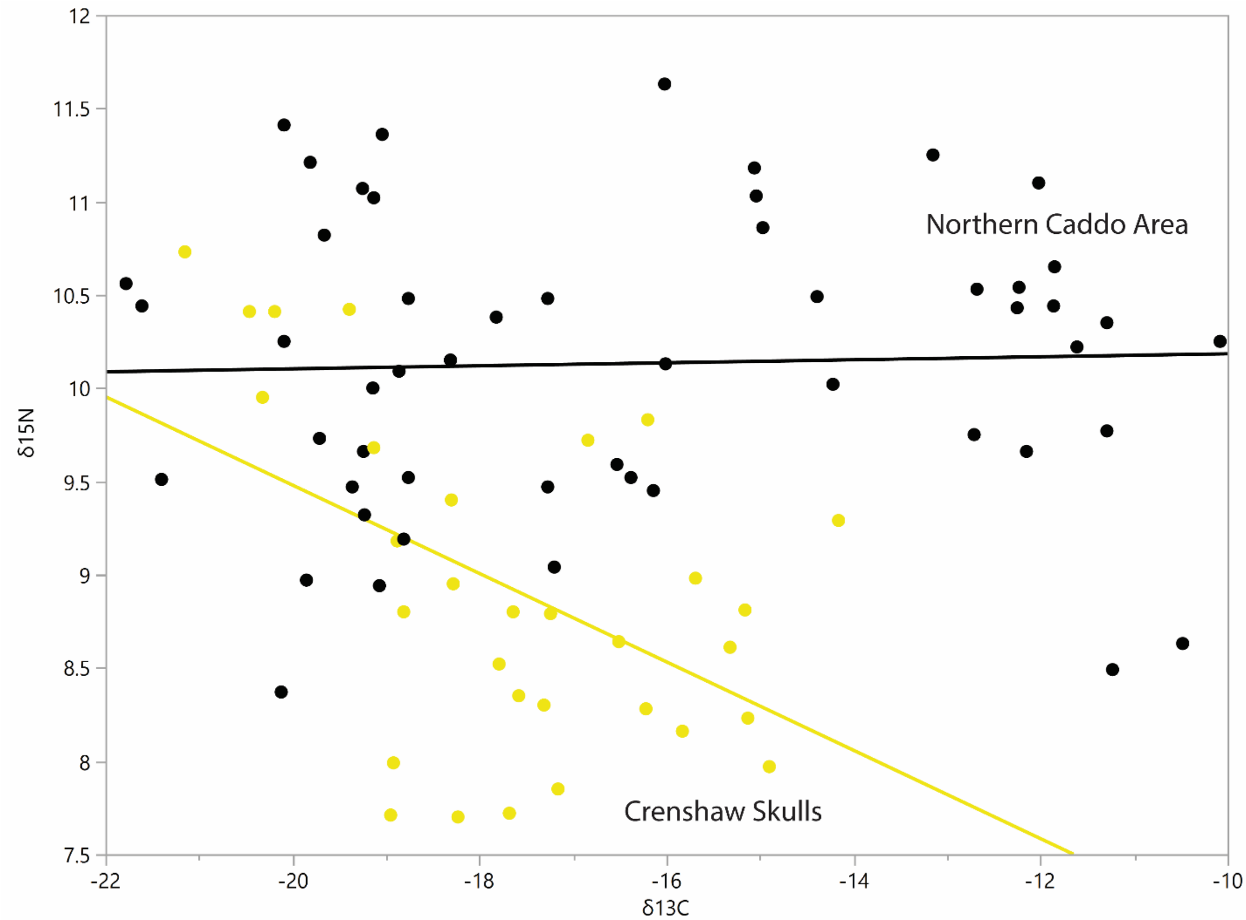

Figure 4.1 – Comparison of skull clusters (yellow) from Crenshaw with the Northern Caddo Area (black) (Rogers 2011). The regression lines clearly have significantly different slopes (p=0.006).

positive slope and there is no correlation between $\delta^{13}C$ and $\delta^{15}N$ (R^2=0.00), suggestive of a bison diet. This corresponds with Wilson and Perttula's (2013) conclusions that some of the isotopes from Northern Caddo Area are consistent with bison consumption. By contrast, the skull clusters have a strongly negative slope and $\delta^{13}C$ and $\delta^{15}N$ correlate more strongly. This clearly shows that the bison diet represented in the Northern Caddo Area is not consistent with the diets in the skull clusters. The negative slope in the skulls are more suggestive of a maize based diet because the $\delta^{15}N$ values drop as $\delta^{13}C$ increases, suggesting a decrease in trophic level (i.e. increased plant consumption).

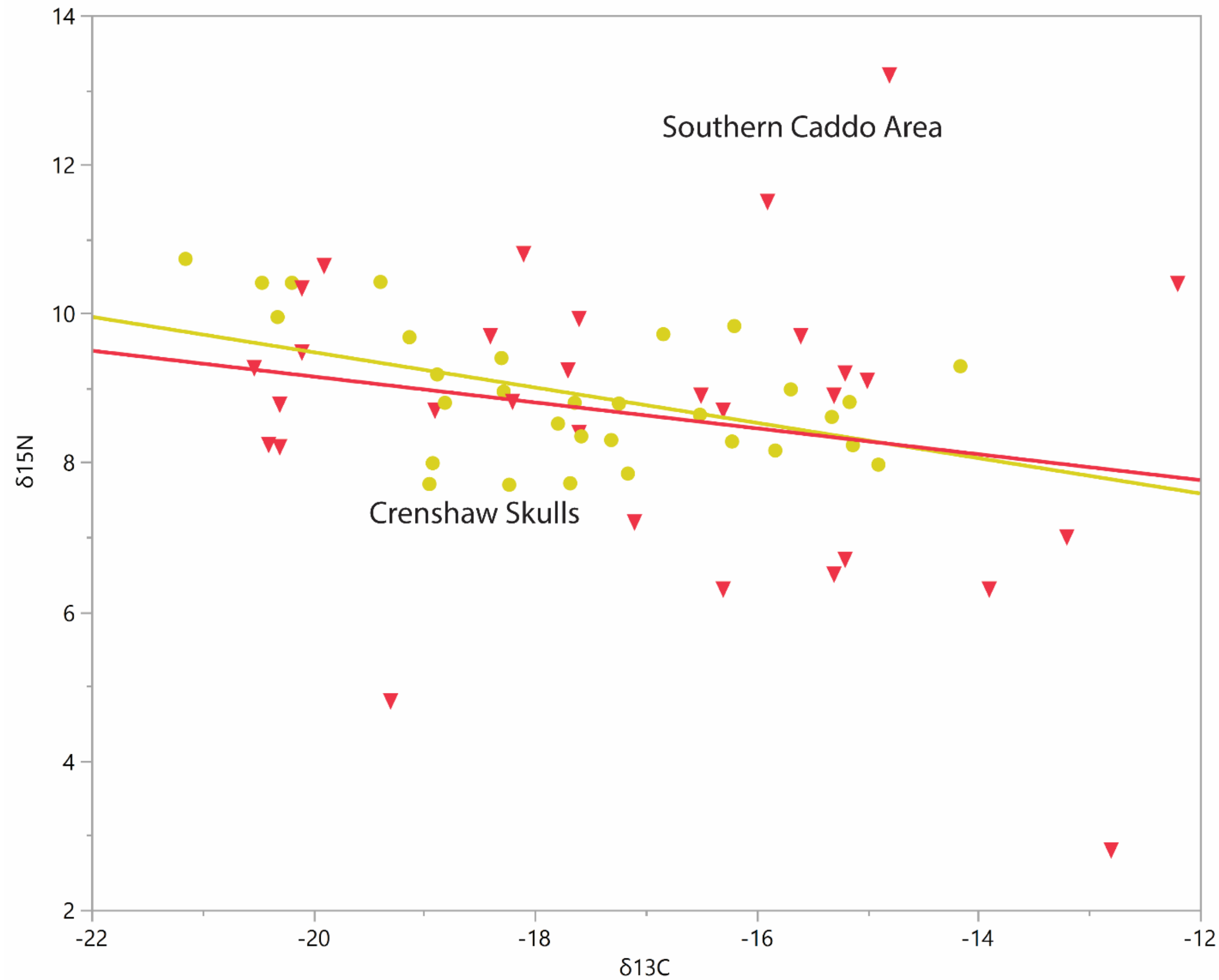

Figure 4.8 – A regression plot of the results comparing the skull clusters at Crenshaw (yellow dots/line) with the rest of the Southern Caddo Area (red triangles/line). The data from the Southern Caddo Area were compiled by Wilson and Perttula (2013). They are very similar.

The pre-A.D. 1680 values from the Southern Caddo Area are not significantly different from the skulls at Crenshaw (p=0.743). They both have negative slopes suggestive of maize. However, the people in the skull clusters have even stronger evidence of maize consumption since their $\delta^{13}C$ and $\delta^{15}N$ correlate more strongly. An ANCOVA of the skull clusters and the Southern Caddo Area (Figure 4.8) show that the least squares means for the two groups are not significantly different (p=0.678) and their slopes are suggestive of maize consumption. The $\delta^{15}N$ mean difference between the groups is only 0.16‰.

In summary, the comparisons suggest a variable maize diet for both the auditory exostosis and absence groups which is inconsistent with a heavier bison diet in the Northern Caddo Area. Comparison with the Southern Caddo Area showed the skull clusters are more consistent with the heavier maize diet and that both have highly variable $\delta^{15}N$ values.

4.4.2 Comparisons at Crenshaw

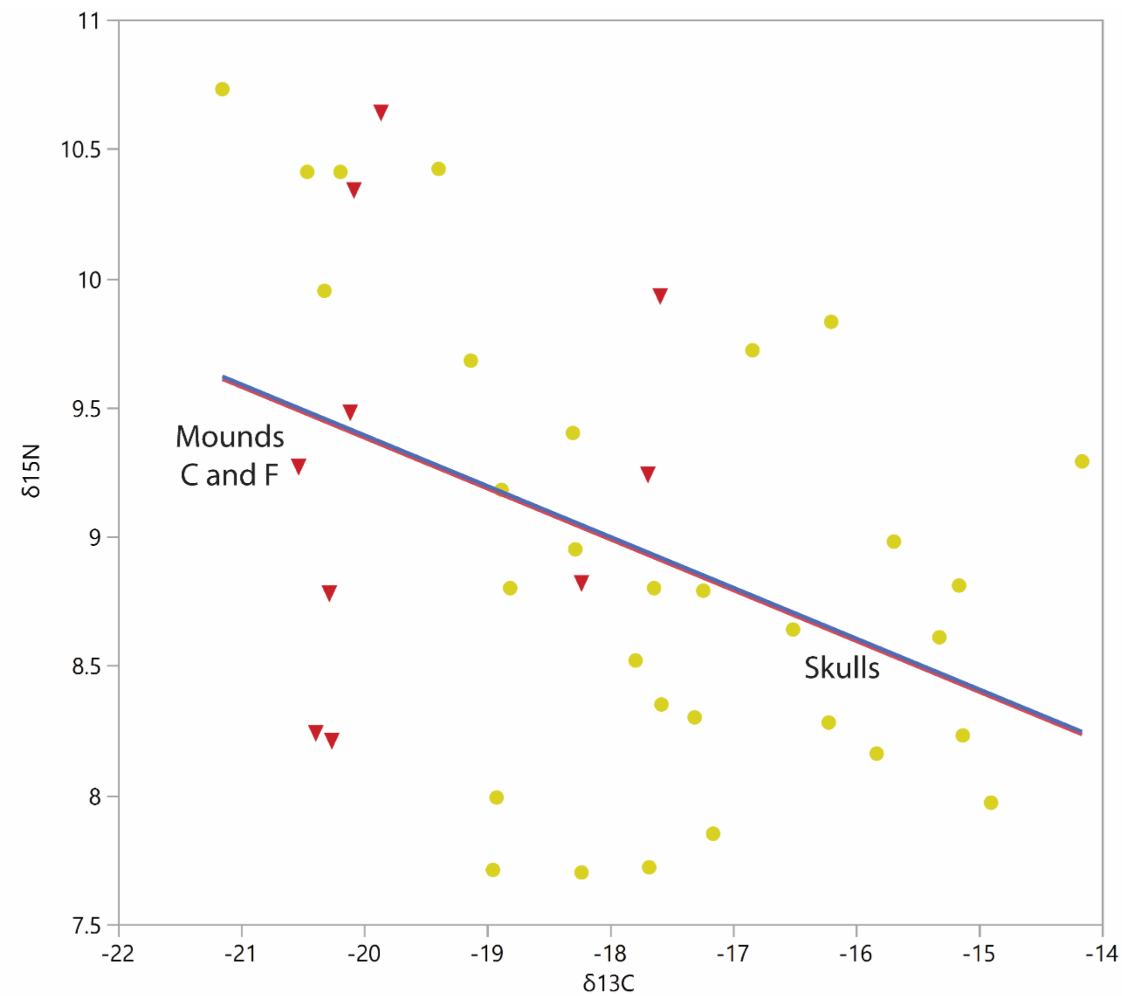

Figure 4.9 – A regression plot of the ANCOVA results comparing the skull clusters at Crenshaw (yellow dots, red line) with people from Mound C and Mound F at Crenshaw (red triangles, blue line). Note that these slopes have been adjusted to be parallel during the ANCOVA.

A comparison with people considered to be local (Schambach et al. 2011) from Mound C and Mound F at Crenshaw shows that they and the skull clusters do not have significantly different slopes (p=0.15). Therefore, an ANCOVA can be done to compare $\delta^{15}N$ by adjusting for $\delta^{13}C$ (Figure 4.9). The ANCOVA shows that the $\delta^{15}N$ means are statistically the same (p=0.975) and the slope is suggestive of maize consumption. The difference in average $\delta^{15}N$ values between the groups is only 0.01‰. The two groups are so similar that their adjusted regression lines are nearly indistinguishable. However, sample size is a limiting factor.

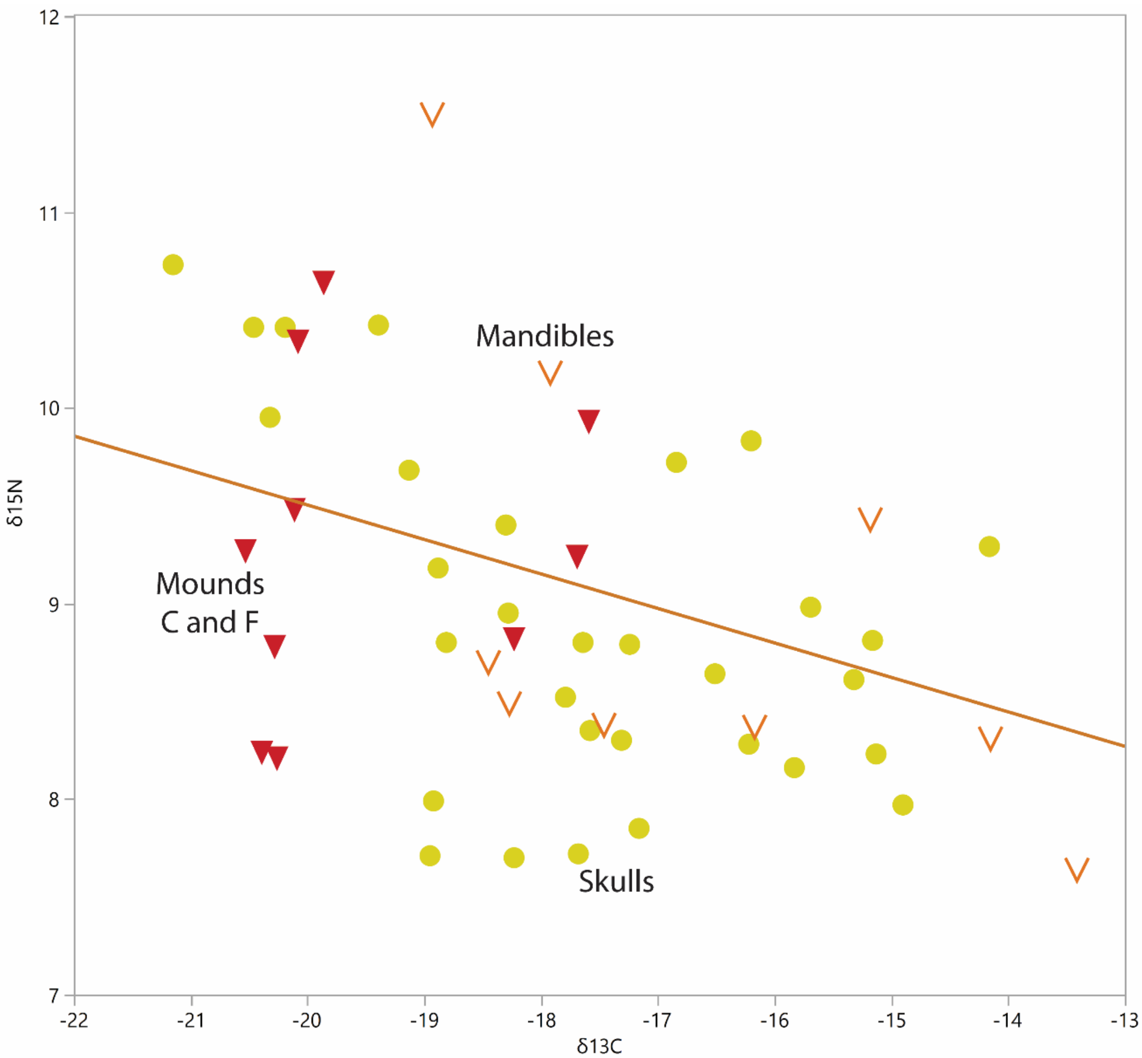

Figure 4.10 – Comparisons between Mounds C and F (locals) and the skulls and mandibles at Crenshaw. The mandibles are generally consistent with the skulls with a couple of exceptions. One mandible is not depicted (193620) and has a $\delta^{13}C$ and $\delta^{15}N$ values of -16.77 and 14.6, suggesting a different diet and a possible migrant or non-local. Values similar to this have been documented at the McLelland site (16BO236) in northwest Louisiana but represent a later time period (Tiné and Tieszen 1997).

A comparison of all samples with good C/N ratios at Crenshaw, including mandibles, shows that the mandibles generally are consistent with the skulls and Mound C (Figure 4.10). There are two exceptions. One is sample (193636) from the ash bed structure at the southern edge of the site. It has an increased $\delta^{15}N$ value by about 1‰ compared to other samples from the site. This is consistent with an individual who consumed a lot of freshwater fish and a small amount of maize which is conceivable for an individual who lived in southwest Arkansas. The other is sample 193620 from WSA Cluster 2. This sample had a moderate $\delta^{13}C$ value (-16.77) and a high $\delta^{15}N$ value (14.6). This is the only individual with some evidence of being non-local. The diet could be suggestive of a diet with marine fish as noted by Akridge (2014). However, very high amounts of freshwater fish and maize could potentially cause some similar ratios, as was seen at the later McLelland site (16BO236) in northwest Louisiana (e.g. $\delta^{13}C$=-13.0, $\delta^{15}N$=13.9) (Tiné and Tieszen 1997). The fact that other people have obtained similar ratios in the environmentally similar northwest Louisiana suggests that interpretations of this individual being non-local should be approached cautiously. Considering that this was the only sample to be substantially different from the other samples at Crenshaw, it is interpreted to most likely be a local individual with an extreme diet or possibly a recent migrant to the area, but a foreign victim of warfare cannot be ruled out with these data alone. Also, it is important to avoid focusing too much on the outliers in a dataset. The data indicate that 50 of the 51 samples are mostly consistent with each other and consistent with the expected diet of the area at the time.

A comparison of the dietary isotopes within clusters and contexts shows great similarity based on burial context (Figure 4.11). This confirms previous indications by Akridge (2011, 2014) and Zabecki (2011) that the clusters (at least the skull clusters) are more related to each other than to the whole. Differences between Mounds C and F can be explained by time and the

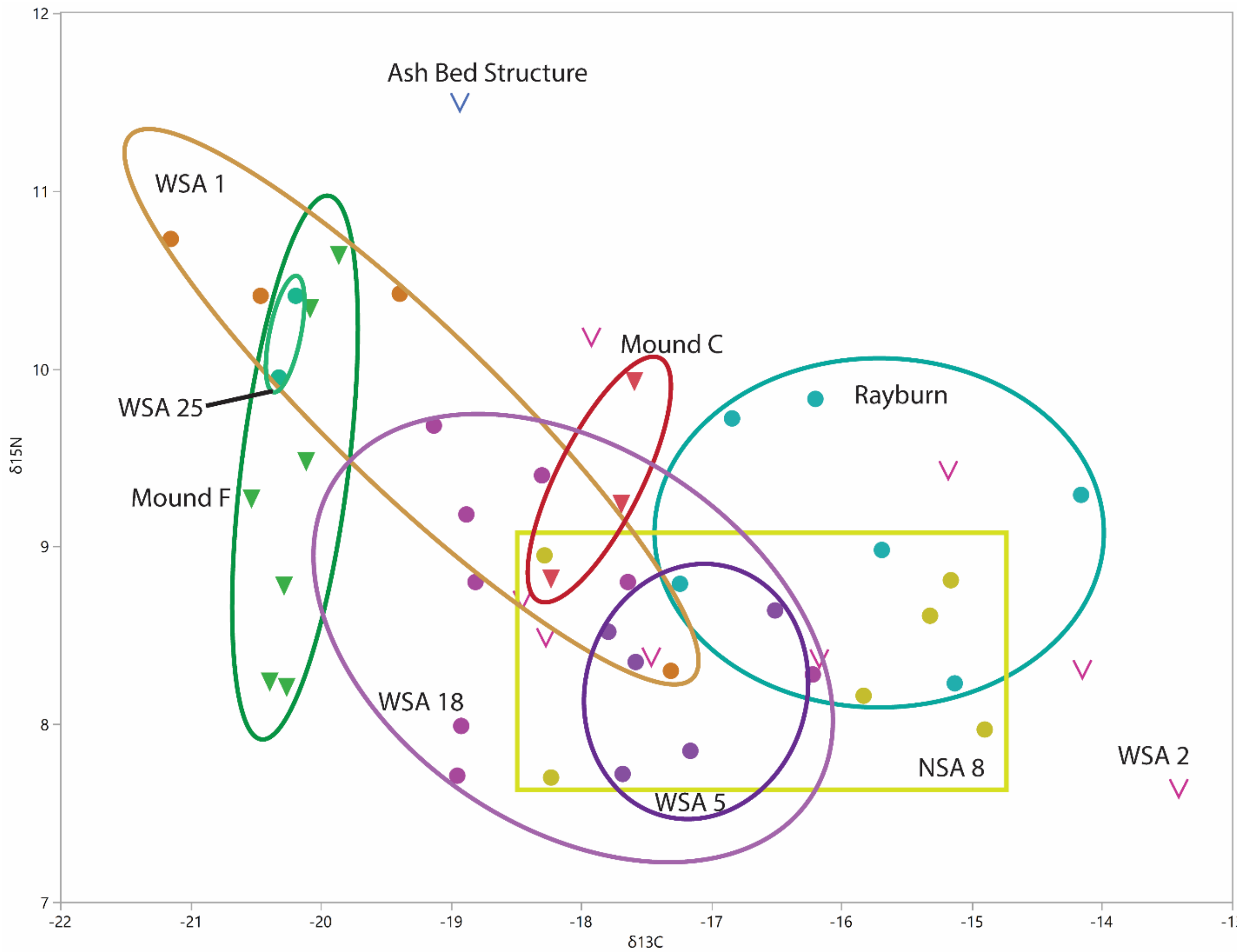

Figure 4.2 – Comparison of C and N isotope ratios by burial context. Context and clusters clearly play a large role in diet. One mandible is not depicted (193620) due to high N isotope ratios.

adoption of maize. It is interesting to note that Mound C individuals plot in the middle of the diet graph, perhaps having a diet averaged between those in the skull and mandible clusters, but having a higher trophic level representing higher meat consumption on average. This would be consistent with food practices of later Caddo ceremonies where each family brought food that was consumed by ritual and community leaders (Sabo 1998).

4.4.3 Challenging Dietary Uniformity in a Population

Akridge's (2014) hypothesis that the Caddo diet in the Middle Caddo period should be uniform is contradicted by the literature on the subject (Wilson 2012; Wilson and Perttula 2013). Wilson and Perttula (2013) point out that as maize is adopted as a staple during the Middle

Caddo period, we should expect to see a varied diet. This is especially true among the historic Caddo who had both communal fields and family plots. In a dispersed settlement pattern, this could lead to families each having different adaptations to their local niches. What is grown in each family plot could be different from family to family. However, they might all consume food coming from communal fields. The variety expected from a dispersed settlement pattern among the historic Caddo might be even more heightened during the Middle Caddo period when they were adopting maize as a staple. As Wilson and Perttula (2013:719) state, "during a period of introduction…we might expect dietary variability to be high, as some individuals, families, and villages adopt new food items more rapidly, while others cling to old ways and traditions." Dietary variability within communities can also be seen around the American Bottom where communities had C and N isotope variability between sites comparable to the dietary isotopes at Crenshaw (Hedman 2006; Rose 2008). Therefore, the hypothesis that the Caddo should have a uniform diet during the Middle Caddo period is not supported by the literature.

More specifically, the few Middle Caddo sites with $\delta^{13}C$ and $\delta^{15}N$ samples (see Wilson and Perttula 2013:Table 3) usually have three or less samples from the time period. Three sites have between four and six samples. Of those three sites, two (Morris [34CK39] and Spiro [34LF40]) showed great diversity in the collagen $\delta^{13}C$ (-16.6 +/- 3.4 and -16.0 +/- 3.4, respectively) and Spiro showed significant diversity in the collagen $\delta^{15}N$ (9.6 +/- 1.1) (Rogers 2011). It may be questionable to use the people from Craig mound at Spiro to suggest what a community's diet was at the time, given current interpretations (Brown 2012). However, if the skulls and mandibles represent a ritual burial practice of community members from surrounding sites, then this could be comparable. Regardless, the existent data shows dietary diversity at some of the only sites with enough samples to begin to evaluate the question. The values from within these sites rival the diversity seen at Crenshaw, despite the small sample size. Comparisons to the Northern Caddo Area and Southern Caddo Area also show great diversity as a whole, particularly with N isotope ratios.

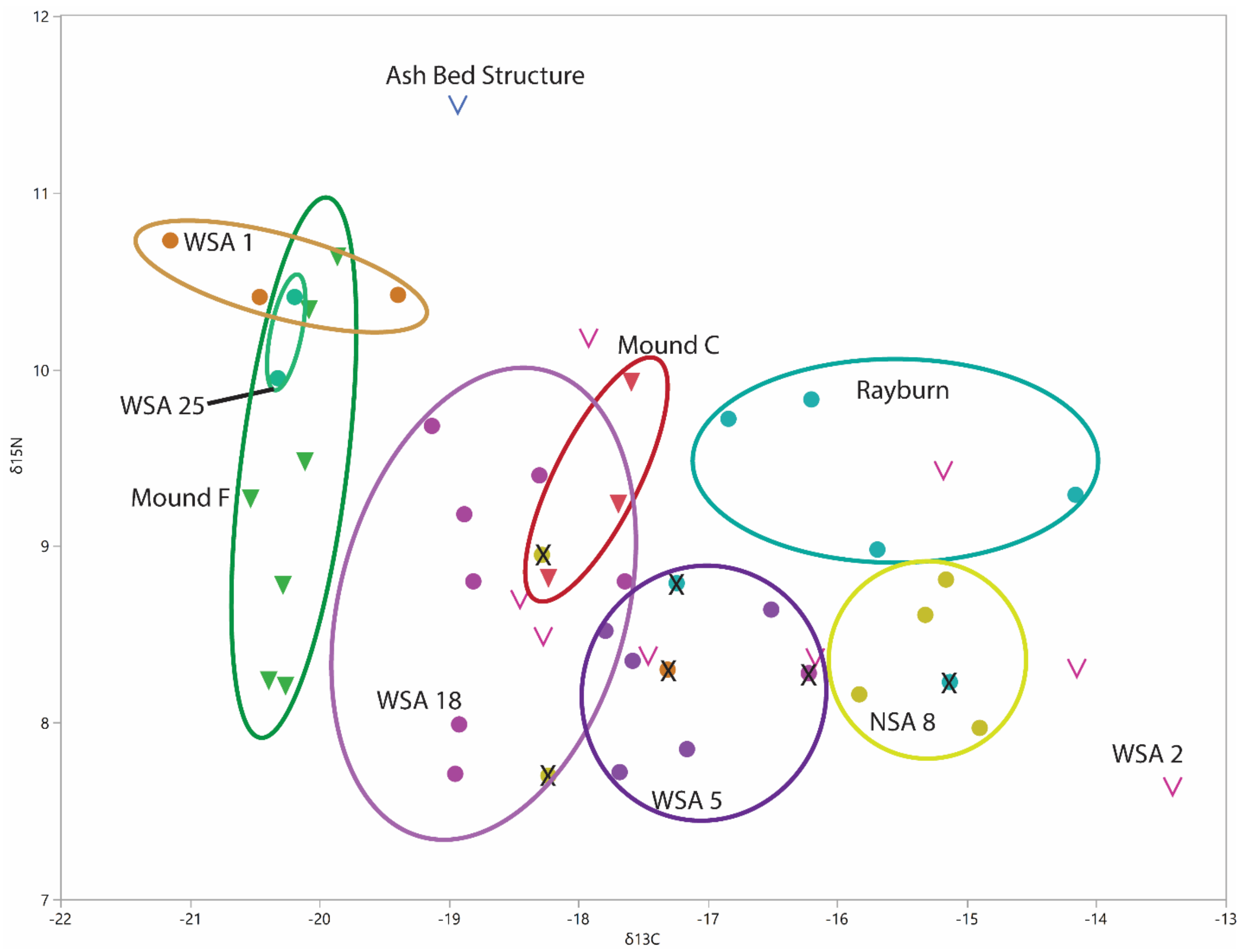

Figure 4.12 – Comparison of context and diet at Crenshaw with more tightly grouped clusters. The possibility for intermarriage between different clusters appears if more restrictive boundaries are used based on dietary isotopes. Individuals who may have grown up with one cluster (and associated diet) and moved to live with another cluster (and associated diet) are shown with an X mark. This grouping is partially subjective, but when those identified are removed, they are outside of the 99% confidence level of their respective clusters.

A comparison of the dietary isotopes based on context, but with more restrictive diet groupings, hints at the possibility of matrilocality and intermarriage between the skull clusters (Figure 4.12). It is important to note that the dietary isotopes in tooth dentin are not expected to change after childhood as dentin does not significantly remodel, so the dietary isotopes reflect their diet before they were adults. Therefore, differences in diet within clusters could reflect population mixing between families, villages, farmsteads, or other groupings. For example, one individual in WSA Cluster 1 better matches the diet of WSA Cluster 5. This could indicate that an individual that lived with the individuals in WSA Cluster 5 as a child married into WSA Cluster 1 and was eventually buried with them. Of the six potential intermarriage individuals, three were males or probable males, two were indeterminable, and one was identified as a probable female. This is generally consistent with the matrilineal Caddo tradition where the males would be most likely to relocate for marriage (Sabo 1998). Note that there isn't any evidence of intermarriage with the Mound F diet. This should be expected as the Mound F individuals were earlier in time so their diet would not be reflected in the later burial contexts.

Given the more variable diet compared to individual skull clusters, the mandibles may represent a collection of individuals who did not have strong ties to particular family groups or other community groups with the appropriate status or means for skull burial. Such a group might be expected to also have greater overall dietary variability, potentially with individuals focusing on particular resources.

4.5 Conclusion

The results indicate that the people with elevated $\delta^{15}N$ values in the skull clusters were likely consuming fish and different degrees of maize, not bison. This suggests that the people in the skull clusters at Crenshaw have a diet more consistent with people living in southwest Arkansas than areas where bison is consumed, such as the Northern Caddo Area. Other aspects of the diet were also suggestive of Caddo cultural practices, such as food sharing with ritual and community leaders and matrilocality (Sabo 1998). The dietary isotopes provide one line of evidence that the people in the skull and mandible clusters at Crenshaw may represent a local burial practice rather than people from other regions, such as the Southern Plains. Given this result, they also suggest the Caddo had a variable diet associated with the adoption of maize during the Middle Caddo period. Finally, the method outlined here of using auditory exostosis presence and absence is an appropriate test to distinguish between bison consumption and maize and fish consumption.

4.6 Acknowledgements

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Appendix

See Akridge (2014) for related data.

T1 – Samples from skull clusters with good C/N ratios (all 2nd mandibular molars).

Lab ID	Accession Number	Tooth Side	Burial Context	C/N Ratio	δ13C (‰)	δ15N (‰)	AE Presence	Group
193598	83-377-2-4	R	WSA 1	3.26	-21.15	10.73	No	Aud. Exos.
193599	83-377-2-5*	L	WSA 1	3.60	-19.39	10.42	No	Aud. Exos.
193601	83-377-2-7	R	WSA 1	3.01	-17.31	8.3	No	Aud. Exos.
193602	83-377-2-8	R	WSA 1	3.42	-20.46	10.41	No	Aud. Exos.
193603	83-377-6-1	R	WSA 5	3.08	-17.68	7.72	No	Abs.
193604	83-377-6-2	R	WSA 5	3.46	-17.58	8.35	No	Abs.
193605	83-377-6-3	R	WSA 5	3.01	-16.51	8.64	No	Abs.
193606	83-377-6-4	R	WSA 5	3.24	-17.16	7.85	No	Abs.
193607	83-377-6-5	R	WSA 5	3.39	-17.79	8.52	No	Abs.
193608	83-377-32-1	R	WSA 18	3.12	-18.3	9.4	No	Abs.
193610	83-377-32-3	L	WSA 18	2.85	-18.92	7.99	No	Abs.
193611	83-377-32-5	R	WSA 18	3.02	-16.22	8.28	No	Abs.
193612	83-377-32-6	R	WSA 18	3.07	-17.64	8.8	No	Abs.
193613	83-377-32-7	R	WSA 18	3.49	-18.81	8.8	No	Abs.
193614	83-377-32-8	R	WSA 18	3.01	-19.13	9.68	No	Abs.
193615	83-377-32-9	R	WSA 18	3.34	-18.88	9.18	No	Abs.
193616	83-377-32-10	R	WSA 18	3.32	-18.95	7.71	No	Abs.
193618	83-377-61-2	R	WSA 25	3.36	-20.19	10.41	Yes	Aud. Exos.
193619	83-377-61-3	L	WSA 25	3.46	-20.32	9.95	No	Aud. Exos.
193648	83-377-41-1-1	L	NSA 8	3.53	-18.28	8.95	No	Aud. Exos.
193650	83-377-41-3	L	NSA 8	3.26	-15.16	8.81	No	Aud. Exos.
193653	83-377-41-6	R	NSA 8	3.34	-18.23	7.7	No	Aud. Exos.
193654	83-377-41-7	L	NSA 8	2.97	-15.83	8.16	Yes	Aud. Exos.
193655	83-377-41-8	R	NSA 8	3.02	-15.32	8.61	No	Aud. Exos.
193656	83-377-41-9	R	NSA 8	2.97	-14.9	7.97	No	Aud. Exos.
193671	69-66-589-2	L	Rayburn	2.97	-16.2	9.83	No	Aud. Exos.
193672	69-66-589-3	R	Rayburn	2.99	-16.84	9.72	Yes	Aud. Exos.
193673	69-66-589-4	L	Rayburn	2.82	-17.24	8.79	No	Aud. Exos.
193674	69-66-589-5	L	Rayburn	2.89	-15.13	8.23	No	Aud. Exos.
193675	69-66-589-7	L	Rayburn	2.89	-14.16	9.29	Yes	Aud. Exos.
193676	69-66-589-8	L	Rayburn	2.88	-15.69	8.98	No	Aud. Exos.

Note: * This sample uses the rerun value since the original value had a bad C/N ratio.

T2 – Samples from Mound C and Mound F with good C/N ratios.

Lab ID	Accession Number	Tooth (Dentin)	Burial Context	C/N Ratio	δ13C (‰)	δ15N (‰)
193659	62-40-48	2nd or 3rd Max Molar	Mound C	3.09	-17.69	9.24
193660	62-40-49	2nd L. Mandi Molar	Mound C	3.12	-17.59	9.93
193663	62-40-121	1st L. Mandi Molar	Mound C	2.98	-18.23	8.82
193664	83-376-1	2nd R. Mandi Molar	Mound F	3.26	-20.26	8.21
193665	83-376-3	2nd R. Mandi Molar	Mound F	2.92	-20.39	8.24
193666	83-376-6-2	2nd R. Mandi Molar	Mound F	3.04	-20.11	9.48
193667	83-376-7	3rd Molar	Mound F	3.07	-20.28	8.78
193668	83-376-9	2nd R. Mandi Molar	Mound F	2.80	-20.53	9.27
193669	83-376-10-2	2nd R. Mandi Molar	Mound F	3.34	-19.86	10.64
193670	83-376-11	2nd L. Mandi Molar	Mound F	3.04	-20.08	10.34

T3 – Samples from mandible clusters with good C/N ratios (all 2nd mandibular molars).

Lab ID	Accession Number	Tooth Side	Burial Context	C/N Ratio	δ13C (‰)	δ15N (‰)
193620	83-377-3-1	R	WSA 2	3.24	-16.77	14.60
193623	83-377-3-10	L	WSA 2	3.45	-16.17	8.37
193624	83-377-3-12	R	WSA 2	3.49	-17.46	8.38
193626	83-377-3-14	R	WSA 2	3.38	-17.92	10.18
193627	83-377-3-20	R	WSA 2	3.44	-18.45	8.70
193631	83-377-3-32	R	WSA 2	2.97	-13.41	7.64
193632	83-377-3-36	R	WSA 2	3.20	-15.18	9.43
193633	83-377-3-37	R	WSA 2	3.13	-14.15	8.31
193636	83-377-3-62	R	WSA 2	3.45	-18.27	8.49
193636	69-66-490	L	Ash Bed Struct.	3.37	-18.93	11.50

T4 – Samples from animals with good C/N ratios.

Lab ID	Accession Number	Animal	Burial Context	C/N Ratio	δ13C (‰)	δ15N (‰)
193578	83-377-2	Opossum	WSA 1	2.82	-20.65	8.69
193579	69-66-591	Deer	Area 4	4.75	-21.96	8.05
193580	69-66-587	Rabbit	Area 4	2.96	-23.67	5.62
193581	69-66-261	Opossum	Ash Bed Struct.	3.40	-20.43	7.66
193582	69-66-268	Opossum	Ash Bed Struct.	3.18	-20.86	7.91
193583	69-66-317	Cottontail	Ash Bed Struct.	3.18	-23.13	4.90
193584	69-66-414	Cottontail	Ash Bed Struct.	3.19	-24.43	2.55
193585	69-66-230	Wood Rat	Ash Bed Struct.	2.85	-22.15	6.59
193586	69-66-554	Wood Rat	Ash Bed Struct.	3.62	-22.22	3.08
193587	69-66-364	Swamp Rabbit	Ash Bed Struct.	3.05	-24.37	5.54
193588	69-66-389	Swamp Rabbit	Ash Bed Struct.	3.34	-24.31	1.89
193589	69-66-469	Deer	Ash Bed Struct.	2.83	-21.58	6.17
193590	69-66-389	Deer	Ash Bed Struct.	3.11	-22.20	7.45
193591	69-66-262	Drum	Ash Bed Struct.	3.08	-23.57	7.17
193592	69-66-544	Gar	Ash Bed Struct.	3.11	-23.77	8.86
193593	90-634	Deer	Mound F	2.87	-21.39	5.68
193594	90-634	Deer	Mound F	2.88	-22.17	5.43
193595	95-449-63	Cottontail	Mound F	3.06	-24.04	3.73
193596	90-634	Swamp Rabbit	Mound F	3.23	-23.31	5.85
193597	90-634	Opossum	Mound F	2.88	-19.16	9.05

Chapter 5: Geophysical Evidence of Settlement Patterns and Ceremonialism

John R. Samuelsen

Abstract

Changes in settlement patterns can have a large effect on a cultural system. Settlement patterns can also change in response to dietary change, the need to adjust to threats of violence, and outbreaks of disease. In southwest Arkansas, the Woodland Fourche Maline tradition consisted of village settlements which changed into a more dispersed settlement pattern by Late Caddo times (A.D. 1500-1680). Precisely when, how, and why this change occurred has not been fully explored. Previous research suggested that it happened ca. A.D. 900 before the Early Caddo period (A.D. 1000-1200), but radiocarbon dates and geophysical research at the Crenshaw site (3MI6) have called this into question. If this change occurred alongside maize adoption in the Middle Caddo period (A.D. 1200-1500), it would have major impacts on interpretations related to the Crenshaw skull-and-mandible cemetery (A.D. 1253-1399). A change to a more dispersed settlement pattern ca. A.D. 1200-1250 could increase the need for this burial practice as moving large numbers of bodies to the site was not possible. A large-scale gradiometry survey of Crenshaw was conducted, covering ~18 ha, to detect evidence of ceremonial and domestic structures to determine to what degree the site was occupied during Caddo times. The results show that Crenshaw was one of the most, if not the most, heavily occupied sites in the Caddo Area. While absolute dating is not possible with geophysical techniques alone, a domestic presence at least during Early Caddo times is indicated by the architectural patterns and their consistency with previously excavated Caddo structures. It is hypothesized that the dispersal did not occur until ca. A.D. 1200.

Keywords: settlement patterning; geophysics; gradiometry; ceremonialism; Caddo

5.1 Introduction

Samuelsen (2016) proposed that the Crenshaw skull-and-mandible cemetery in southwest Arkansas reflected a ritual burial practice for the surrounding populace. The practice of skull and mandible burial at Crenshaw was hypothesized to represent an expanding local burial practice associated with a dispersed settlement pattern at the time the Caddo were adopting maize as a staple. This can be divided into three testable components. (1) The skulls and mandibles were part of a local burial practice. Chapter 3 provided isotopic evidence that the remains were local individuals. (2) The skulls and mandibles represent a variety of diets that might be expected at the time the Caddo were adopting maize as a staple. Chapter 4 provided isotopic evidence that the skulls and mandibles had diets from no maize consumption to heavy maize consumption, consistent with what would be expected if they were adopting maize as a staple. These chapters indicated that these two portions of the hypothesis are supported.

(3) The practice of skull and mandible burials could reflect the need for members of the ritual community to be buried at Crenshaw while having a more dispersed settlement pattern. Chapter 3 supplied isotopic evidence to support this (the skulls and mandibles better matched animals from surrounding sites) but does not address settlement pattern change through time. If the change from a more nucleated settlement pattern to a more dispersed settlement pattern occurred ca. A.D. 1200, just prior to the skull-and-mandible cemetery, it could explain why this practice was needed. Members of the ritual community who had recently dispersed and still strongly identified with the community may have needed a means to transport their remains over longer distances. Skull and mandible burials would have allowed for, potentially, the most important part of oneself (the head or mandible) to be buried (or worshiped) at Crenshaw despite

the long distance. Additionally, the expanded use of this burial practice could reflect Crenshaw's growing ritual influence on previously existing surrounding sites.

Settlement pattern change through time can be assessed using geophysical techniques. Typically, ground-truthing and absolute dating provide the best verification of this evidence. However, large-scale geophysical surveys can be used as a primary research tool to assess settlement patterns (Kvamme 2003). Samuelsen (2009, 2010) previously documented geophysical evidence of numerous possible structures at Crenshaw and interpreted that at least some of them were from the Early Caddo period (A.D. 1000-1200), but this was conducted in a limited area (~4 ha) and patterns were generally difficult to discern. In the larger study (~18 ha) presented here, evidence of ceremonial and domestic activity will be assessed at Crenshaw though analysis of architectural patterns in possible structures. This can provide an estimate for how heavily occupied the site was, provide an idea for how much of this activity was ceremonial in nature, and assess how much of the activity was related to a Caddo occupation through comparisons to previously excavated Caddo structures.

5.1.1 Settlement Patterning

The increasing use of geophysical surveys as landscape archaeology (Kvamme 2003) has greatly increased our knowledge about Caddo landscapes and settlement patterning (Creel et al. 2008; Hammerstedt et al. 2010, 2017; Lockhart 2007, 2010; Livingood et al. 2014; Maki and Fields 2010; McKinnon 2008, 2010, 2013; Osburn et al. 2008; Walker and Perttula 2008; Perttula et al. 2008; Regnier et al. 2014; Samuelsen 2009, 2010; Walker 2009; Walker and McKinnon 2012). They provide the ability, without the need for expansive and expensive excavations (Johnson 2006), to expose large areas to the survey of subsurface anomalies. Thus, in much the same way as the WPA excavations impacted our understandings of sites like George

C. Davis (Newell and Kreiger 1949; Story 1997), geophysical methods can greatly impact our understanding of sites that have not been subjected to a similar level of excavation. Since such excavations are now only rarely executed, large-scale geophysical methods provide a primary research tool for understanding whole landscapes, such as the Caddo landscape in southwest Arkansas.

The Terán-Soule model (Schambach 1982b) states that the Caddo lived in dispersed farmsteads along the river while only a few people responsible for ceremonies resided at the local centers for part of the year (see also, Samuelsen 2009). This is based on historic accounts, including the A.D. 1691 Terán map from a Caddo village along the Red River (Wedel 1978) and the Soule photographs, taken between 1868 and 1872, of a Caddo farmstead near Binger, Oklahoma (Schambach 1982c). This model has been used to describe the settlement pattern at the Crenshaw site (Jackson et al. 2012:50-52; Schambach 1982a:154). Jackson et al. (2012) state that an earlier Fourche Maline population is responsible for the village midden at the site and that ca. A.D. 900 the population dispersed into the countryside to live in farmsteads.

However, this model of Caddo settlement patterns in the Great Bend region of the Red River has been challenged. Sabo (2012) showed that there were significant problems with interpretations made from the Terán map which helped form the basis of the model. Geophysical investigations contradict the idea that Caddo mound sites were vacant or nearly vacant (Lockhart 2007, 2010; McKinnon 2008, 2010, 2013; Samuelsen 2009, 2010). Lockhart (2007, 2010) showed that ceremonial structures around Caddo mounds were part of the Caddo tradition. Samuelsen (2009, 2010) conducted a limited geophysical survey of nearly 4 ha (at most 10% of the site's area) at Crenshaw and found evidence of a village area. The interpretations state that some of these possible structures are similar to Caddo architecture and are therefore suggestive of at least a small Early or Middle Caddo (A.D. 1200-1500) presence. McKinnon (2013) showed that there were other ways to interpret the Terán map that may be more in line with archaeological site distribution during Late Caddo times (A.D. 1500-1680). This interpretation suggests the Late Caddo had farmsteads, but they were not separated by great distances. It is important to note, however, that simply showing evidence of ceremonial structures or a few residences is not enough evidence to suggest a nucleated settlement pattern or contradict a dispersed farmstead model. These are pieces of evidence that help describe how mound sites functioned, but do not supply evidence of nucleation. To support the hypothesis of a nucleated settlement pattern, enough evidence of domestic structures must be present to indicate a significant resident population.

Other mound sites in the Caddo Area have evidence of significant resident populations (Girard 2012; Newell and Krieger 1949; Perttula and Rogers 2012; Story 1997). George C. Davis was noted for having significant resident populations during the Early Caddo period because there were large scale WPA excavations which exposed large areas in which village areas could be found (Newell and Krieger 1949). Also, subsequent research at George C. Davis was intent on exposing more of the off-mound areas for research (Story 1997). These studies exposed tens of houses where clusters of houses are mostly seen in the areas next to the mounds (see also, Walker 2009). To some degree, the fact that many of these structures are placed around the mounds challenges there being a village at the site as these could reflect ceremonial structures rather than habitation areas. Story (1997, 1998) suggests that these areas represent an “inner precinct” where important ritual or social functions would have taken place. She suggests that the areas away from the mounds were used as the village areas. In sum, the use of large-scale excavations paired with later geophysical work exposed large numbers of houses and allowed for the interpretation of residential populations during the Early Caddo period.

By contrast, no large-scale excavations associated with WPA or other work was conducted at Crenshaw, at least, not any excavations interested in structures or habitation. Instead, Crenshaw has seen over a hundred years of looting and excavations centered largely on the mounds and burials (Samuelsen 2009). The first professional off-mound excavation interested in habitation areas was done by Frank Schambach in 1969. He immediately found evidence of an Early to Middle Caddo (A.D. 1161-1254) ceremonial structure and what was interpreted to be a nearby Late Fourche Maline midden area (Samuelsen 2014). However, small scale excavations such as these could not compare to the areas opened by the WPA excavations at George C. Davis. Since such excavations are not currently possible, a large-scale geophysical survey is the only way to better understand occupation and settlement patterns at Crenshaw at a scale that is comparable to what has been done at George C. Davis.

5.1.1.1 When Did Dispersal Happen?

It is unclear how far back in time the dispersed farmstead settlement pattern applies in southwest Arkansas. The Woodland period Fourche Maline lived in villages based on the significant evidence of large midden areas (Schambach 2002). It is not known at what point the Fourche Maline and/or Caddo transitioned from a more nucleated settlement pattern resembling villages to a more dispersed settlement pattern using farmsteads.

While Jackson et al. (2012) state that Crenshaw was a Fourche Maline village until A.D. 900, there are major issues with this interpretation. First, this is not consistent with the radiocarbon dates from Mound F. Mound F contained dozens of human remains in various states of articulation and disarticulation which have been interpreted to be coming from surrounding sites (Schambach 1997). It contains some of the earliest material from the site, suggested it was created towards the beginning of the occupation. However, the mass grave in Mound F dates between A.D. 895 and 1015 (Samuelsen 2014). This highlights the contradictory interpretations of the timing of the construction of Mound F and the dispersal of the population. The Fourche Maline could not have established Crenshaw as a village in A.D. 900 and have then dispersed into the landscape in A.D. 900. Girard et al. (2014) suggest that the material at Crenshaw is simply younger than previously thought and that the Early Caddo tradition did not appear until ca A.D. 1050. This would suggest that the dispersal of the population did not take place until A.D. 1050 at the earliest. While this is one possible explanation, more radiocarbon dating would be needed before this possibility could be properly evaluated at Crenshaw.

Schambach (1982a:150-158) conducted exploratory excavations at Crenshaw in 1969 and suggested that most of the midden areas are due to a Late Fourche Maline occupation. This is based on the midden being "almost entirely Fourche Maline as opposed to Early Caddo" (Jackson et al. 2012:50-51). However, there are four potential problems with this. (1) The excavations at Crenshaw were restricted to a very small area, potentially missing much of the time depth of the site. (2) Crocket Curvilinear Incised is found among Coles Creek Incised and French Fork Incised sherds in these midden areas with "less than 5%" decorated sherds (Schambach 1982:151-152). This is on the high end for a Fourche Maline midden as Schambach (2001:29) argues that Fourche Maline middens typically have about 1% decorated sherds. (3) Hoffman (1970) notes that Crocket Curvilinear Incised is a clear Caddo type in both the Great Bend and Little River regions. This is also clear from types included with Caddo burials at Crenshaw (Wood 1963). (4) Radiocarbon dating (Samuelsen 2014) placed some of these areas after A.D. 1000, suggesting that these same areas described as Fourche Maline midden are, at the very least, also Early Caddo midden areas.

Schambach (1982a) does not describe Hickory and Holly Fine Engraved as part of the midden areas. However, these fine ware types are found associated with Crocket Curvilinear Incised in burials at Crenshaw (Wood 1963). Story (1998:20) also mentions the fact that Hickory and Holly Fine Engraved are found in burials at George C. Davis, while Crocket Curvilinear Incised is found only among the Early Caddo midden areas. The midden areas explored by Schambach (1982) were not near the mounds. This emphasizes the potential differences between mortuary/ceremonial and domestic contexts as it relates to ceramic design. It suggests the spatial separation in the use of fine wares (Hickory and Holly Engraved) and utilitarian wares (Crocket Curvilinear Incised). That is, the lack of Hickory and Holly Engraved in the midden area may be related to selective use of those vessels for ceremonial purposes. They therefore might not be found near domestic occupation areas. Finally, since Coles Creek Incised and French Fork Incised are both Late Fourche Maline and Early Caddo types, they would not be useful in identifying differences between Late Forche Maline and Early Caddo midden beyond the percentage of decorated sherds. However, the percentage of decorated sherds could also be influenced by whether the midden is in ceremonial or domestic contexts.

Shovel tests from a levee rehabilitation project in the 1990s found evidence of Early and Middle Caddo midden areas in the northeastern portion of the site (Kelley and Cox 1998). A recent soil core, Crenshaw Core 17, on the northern portion of the site also contained evidence of midden 1.75 m beneath the surface. This core contained a rim sherd at this depth with a Middle Caddo design (Ann Early, personal communication). Samuelsen (2009) also highlighted that midden was found over Middle Caddo burials in the 1930s. This would indicate that this midden was deposited no earlier than Middle Caddo times. However, it is important to note this was very close to Mound B where ceremonial activity is very likely to take place. Certainly, formal analysis of these materials, controlled excavations informed by geophysical techniques, and absolute dating would provide better support for settlement pattern interpretations. Even when not considering geophysical data, the current evidence suggests that there was significant occupational activity at Crenshaw after A.D. 1000. However, it is not known much of this activity is domestic and how much is ceremonial.

5.1.2 Ceremonialism

Ceremonialism could be viewed as one way that people maintain group cohesiveness. Ceremonies likely had many purposes and were of great significance to the people who participated in them. Smith (1978:490-491) identifies several activities that would encourage group cohesion which take place at a local center. Each of these could be viewed as being ceremonial in nature. These ceremonial activities include seasonal ceremonies, burial ceremonies, rites of passage, kin or status related rituals, and corporate labor projects such as mound building, fortification, or maintenance. These aspects of ceremonialism relate directly to settlement patterns. The need to encourage group cohesiveness may be even stronger for dispersed communities. Ceremonies related to dispersed communities could include large group burial areas (Perttula 2012), like the skull-and-mandible cemetery at Crenshaw.

One potential problem with analyzing settlement patterns using geophysical evidence is the need to show whether a structure or group of structures is used for ceremonial or domestic purposes. Ceremonial structures imply the use of the site for important rituals but are not necessarily evidence that large numbers of people were living at the site. Several authors note the importance of separating domestic and ceremonial/public structures for the purposes of analysis because different activities may be represented by each (Lacquement 2007a:2-3, 2007b:50-51; Brennan 2007; McConaughy 2007:111-112; Scarry 1995:221-222). These studies often include structure size as a key component of determining whether a structure could be categorized as domestic or public. Also, some studies identify ceremonial structures based on other aspects, such as extended entranceways, ramps, and other special architectural features (Lacquement 2007a:2-3; McConaughy 2007:111-112; Perttula 2009).

In the Caddo area, certain architectural features detectible by geophysical instruments can be readily interpreted as evidence of ceremonial structures. Perttula (2009) highlighted extended entranceways as an aspect of specialized structures in order to show the diversity of structure form. Sabo (1998) suggested the importance of specialized structures to Caddo communities would result in visually apparent architectural features, including extended entranceways, central hearths, and structures of different sizes. Trubitt (2009) emphasized that structures associated with mounds were often burned and covered with earth while domestic structures are typically unburned. Story (1997, 1998) interpreted that certain large scale and specially built structures close to mounds were likely ceremonial or communal in nature. Many of these aspects of architecture can be evaluated using interpretations from geophysical analysis, especially when using gradiometry due to its ability to detect hearths and burned structural remains (Kvamme 2003, 2006).

Of the many previously identified possible structures at Crenshaw (Samuelsen 2009, 2010), only three had anomalies suggesting the presence of extended entranceways and only two of those appeared convincing. These same possible structures were some of the clearest possible structures within the surveyed areas. The many other possible structures were more difficult to interpret with less distinct patterns and weaker magnetism. Many of these may simply be anomalies reflecting pits, graves, or activity areas and may not be structures at all. The survey focused away from the mounds on the southern section of the site which represents only a small portion of the extant site area (50-60 ha). This study will resolve these issues by surveying a much larger area (~18 ha), by including areas around some of the mounds, and by focusing interpretations on anomalies that have specific qualities that relate to known Caddo architecture.

5.2 Methods

Gradiometry is an extremely useful geophysical technique (Kvamme 2006) and can be used to detect structure size, shape, the presence of extended entranceways, and the likelihood that the possible structures were burned. Comparing different geophysical patterns on the landscape could be productive to determine if certain areas were used for domestic or ceremonial/public purposes (Hammerstedt et al. 2017; Kvamme 2003; Lockhart 2010). The data from this instrument also tend to have stronger and clearer results if the structures were burned or resulted in strong modification of the surrounding soil. This suggests that well-built and burned structures would be more likely to appear in the results than would a lightly framed unburned structure. This could result in the underrepresentation of domestic structures if the data are not processed for the purpose of detecting more subtle anomalies or if multiple technologies are not used (Hammerstedt et al. 2017).

A large-scale geophysical survey of the site was conducted to give a view of the landscape (Kvamme 2003). Given the speed limitations of available technologies and the need for detecting burned features, gradiometry was collected over a large portion of the site to help determine the spatial organization and the areas likely to represent special use areas. A Bartington Grad601-2 dual gradiometer was used to quickly detect prehistoric structures,

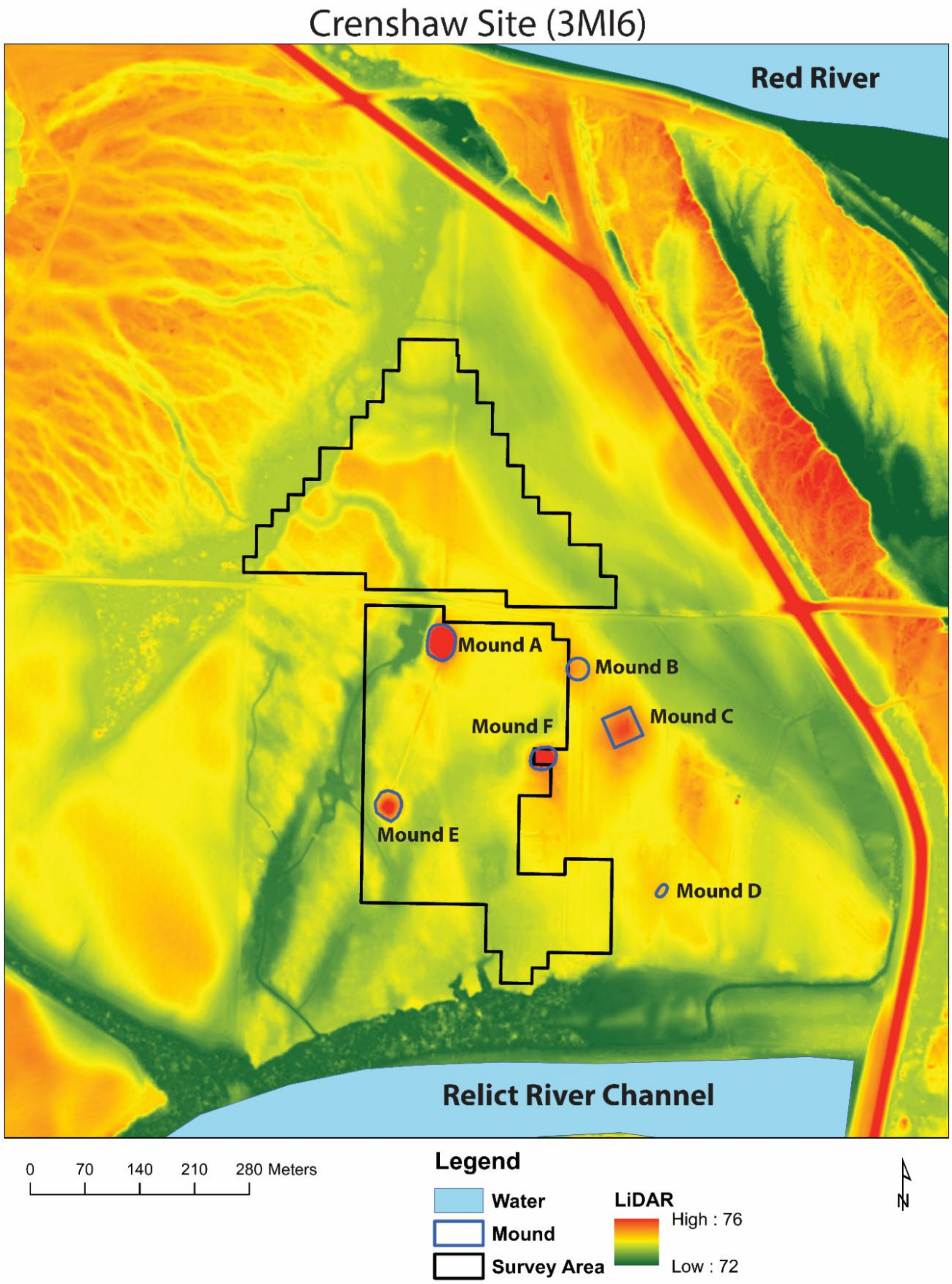

Figure 5.1 – The Crenshaw site (3MI6) with LiDAR and the area surveyed with gradiometry. The positions of Mounds B, C, and especially D were adjusted according to the LiDAR data.

features, and activity areas that have magnetic properties. Two one-week collection episodes increased the coverage from under 4 ha to over 18 ha of the site with gradiometry (Figure 5.1). This was possible by utilizing the Arkansas Archeological Survey's (ARAS) two Bartington 601-2 gradiometers, by using a third from the Center for Advanced Spatial Technologies (CAST), and by the effort of many people helping to set up the grids and collect data. Data was collected in 20x20 m grids using the zig-zag method.

Topographic data was analyzed in concert with the gradiometry by utilizing Light Detection and Ranging (LiDAR) data. LiDAR has seen increasing use as the data become more readily available. It is useful for detecting archaeological sites and topographic anomalies due to its ability to produce high resolution topographic data (Bewley et al. 2005; Devereux et al. 2005). This is particularly useful when the number of trees in an area makes high resolution topography with a total station difficult. LiDAR systems emit a pulsed laser beam which reflects off the surface of the earth and is then detected by their sensors. In many cases, the resulting data includes measurements from the roofs of structures and the tops of trees. This requires data processing to remove such data. One particularly useful aspect of LiDAR is that some beams can penetrate through canopies and reflect off the ground, allowing for a topographic measurement of the surface once the higher values associated with the canopies are removed.

The geophysical results were analyzed for evidence of possible structures and other types of features (Figure 5.2). This consisted of pattern recognition, evaluating the degree of magnetism, and evaluating the consistency of anomalies with known Caddo architecture. Areas likely to be related to ceremonial/public structures and those related to domestic spaces were assessed by comparing architectural characteristics, such as size, extended entranceways, and internal anomalies. The resultant data was processed in TerraSurveyor and exported into ArcGIS software for comparison to other datasets, such as LiDAR, aerial photography, and satellite imagery. In general, the LiDAR, aerial photography, and satellite imagery confirmed patterns previously identified by Samuelsen (2009), but most of these related to modern land use rather than evidence of ancient activities. One exception being a possible causeway north of Mound A continuing north to the levee. This could be ancient, but also coincides with the location of a historic fence line (Samuelsen 2009). A mound east of the levee with a modern house on it is visible in the LiDAR, but Larry Head, landowner of the western portion of the site, stated that this was built so that the house would be above the flood waters. Anomalies with particularly high magnetism and bipolar qualities were assessed to identify potential metal interference. Metal interference was identified by exporting multiple transparent files with different nanoTesla (nT) thresholds and overlaying them on the geophysical anomalies in ArcGIS. This allowed for anomalies of different strength, magnetism, and bipolar qualities to be readily identified (Figures 5.3, 5.4).

The geophysical data is presented at high and low scale and with clipping at ± 1 nT, ± 2 nT, ± 4 nT, and ± 5 nT. For close-up figures, ± 1 nT and ± 4 nT are figured for the North Area. Close-up figures of the Central Area are presented clipped at ± 2 nT and ± 4 nT. This was done differently because the magnetism of the Central Area tended to be stronger. Clipping to ± 1 nT tended to cause the more obvious anomalies to become unintelligible. Close-up figures are marked with very likely structures (green) and possible structures (orange). Very likely structures need almost no interpretation. Possible structures are less clear, but this would particularly be expected of domestic structures (e.g. unburned). Unmarked close-up figures, hill shade figures, and sky view factor figures are available in the Appendix (Klemen et al. 2011).

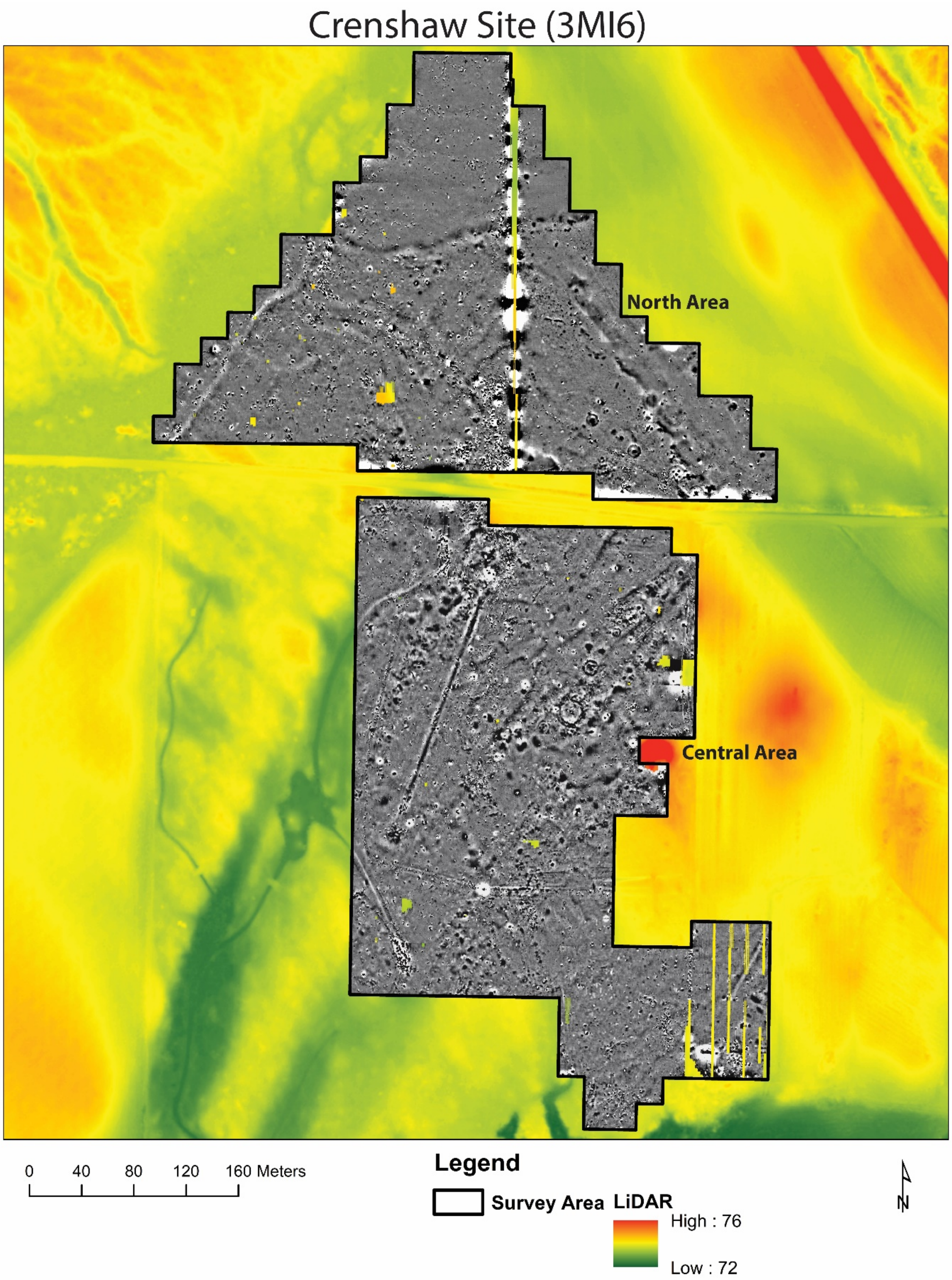

Figure 5.2 – Gradiometry data processed and clipped at ± 2 nT on LiDAR data.

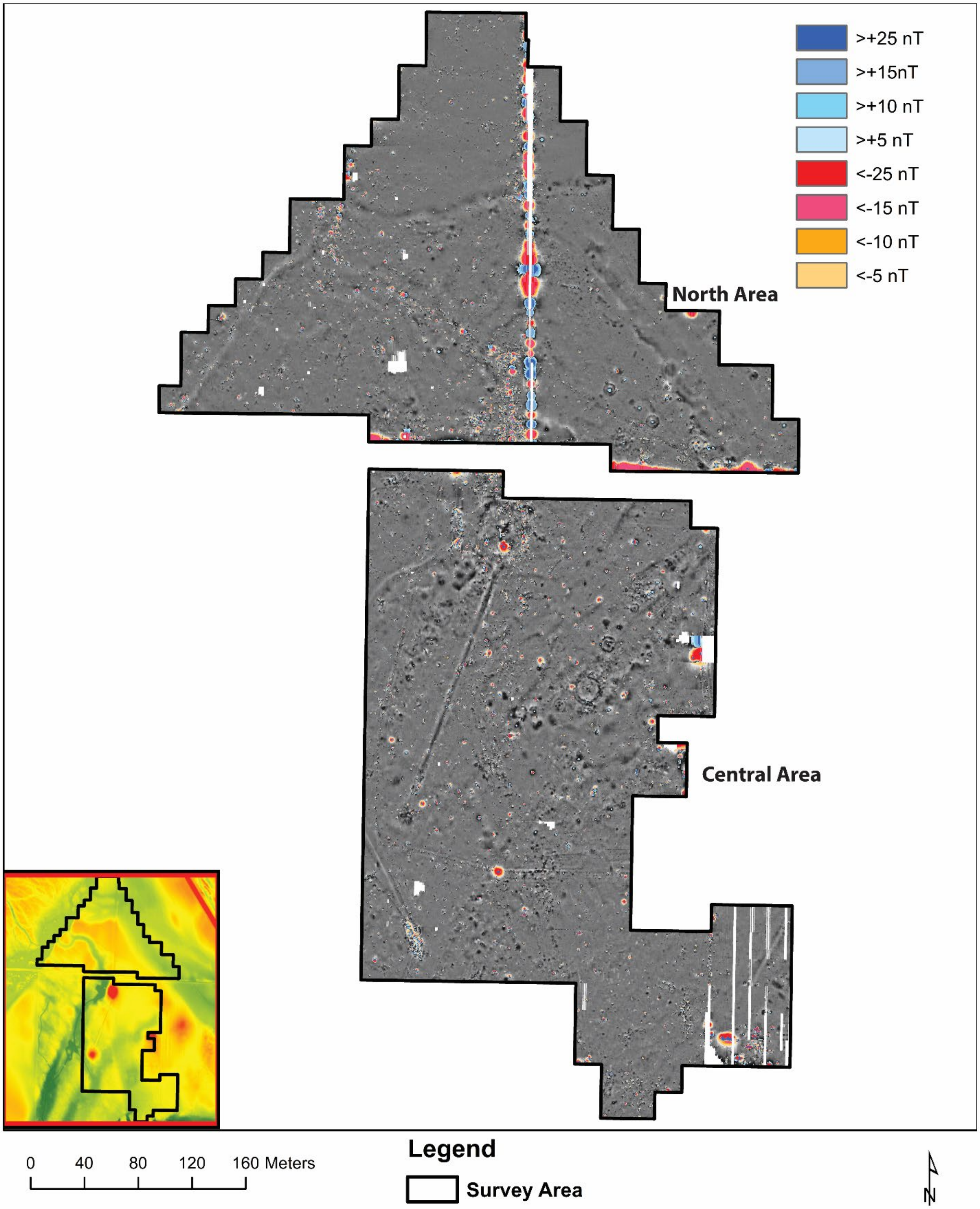

Figure 5.3 – Gradiometry data clipped at ± 5 nT with higher and lower magnetism anomalies highlighted.

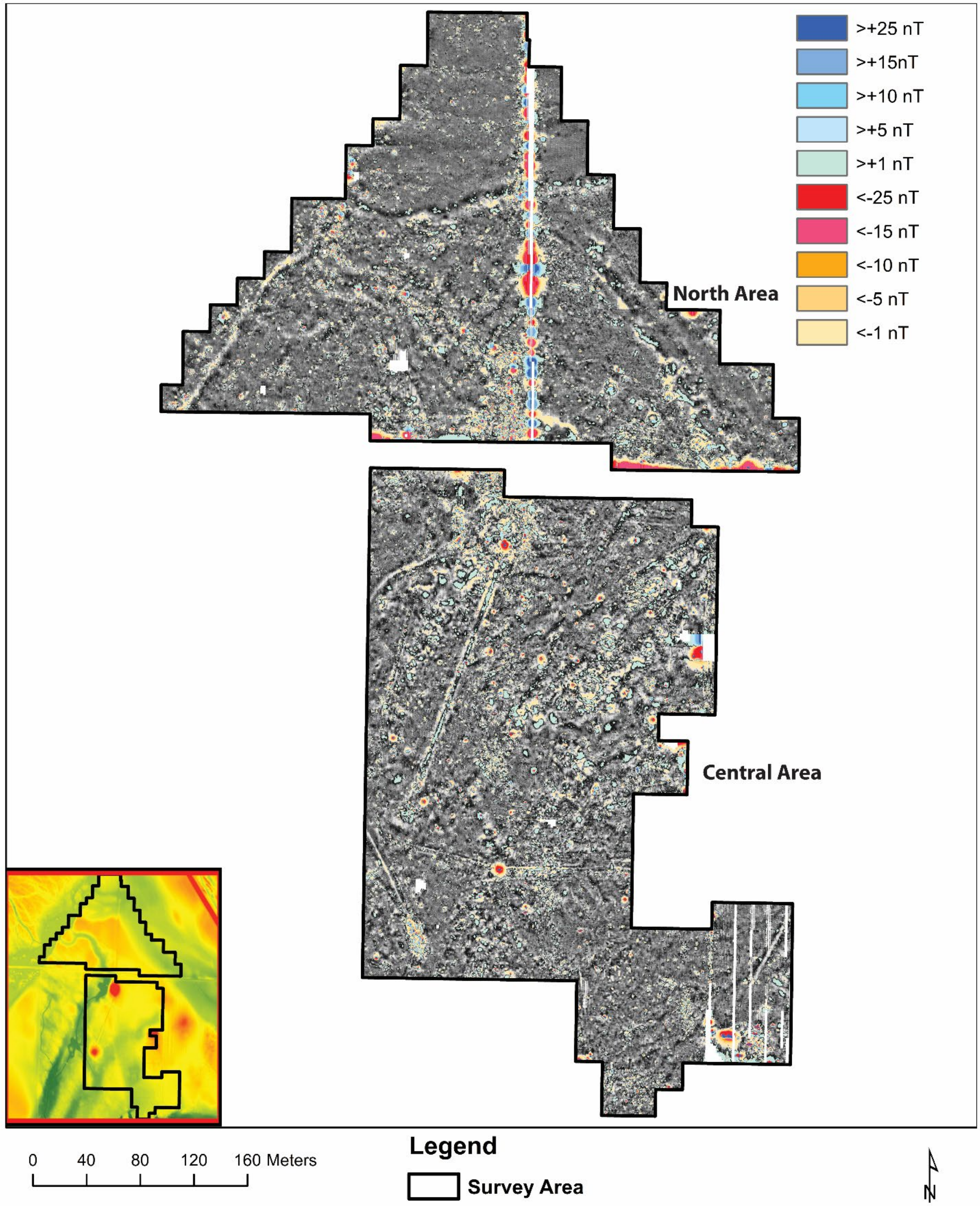

Figure 5.4 – Gradiometry data clipped at ± 1 nT with higher and lower magnetism anomalies highlighted.

5.3 Results

There are several important anomalies that are immediately clear in the results (see Figure 5.2). Mound A has a rectangular area of high magnetism surrounding it and a possible structure in the middle. Metal obscures much of the mound. This is likely due to a historic fence line that went through this area (Samuelsen 2009). Unexpectedly, Mound E also has a faint rectangular pattern of low magnetism surrounding it and has a possible structure in the middle. This and the LiDAR data suggest that Mound E was originally rectangular, like Mounds A and C, rather than its current circular shape. The causeway between Mounds A and E is very clear as evidenced by the linear area of high magnetism with low magnetism on each side. There are many long linear patterns in the data. Most of these are related to historic fence lines or roads. Besides the previous documentation of these (Samuelsen 2009), this is evidenced by the metal scatters that often accompany these lines. Areas where there are topographic reliefs tend to display winding linear patterns of high and low magnetism. These are helpful as they verify that the LiDAR data and the geophysical data are accurately georeferenced. These can also be useful for indicating areas that may have been impacted by river action in the past. Some of the low areas with linear patterns represent areas where drainage ditches were dug to help drain the site. There are also some weak linear patterns of high magnetism with an unclear cause, particularly in the areas between Mounds A, B, and E.

This analysis focuses on the newly acquired data as analysis of the southeastern portion of the data was previously done by Samuelsen (2009). The data collection focused on two areas termed the “North Area” and the “Central Area” (see Figure 5.2). Since this is a large area, figures were produced from each sub-area. The North Area showed evidence of many structures in parts (Figures 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12).

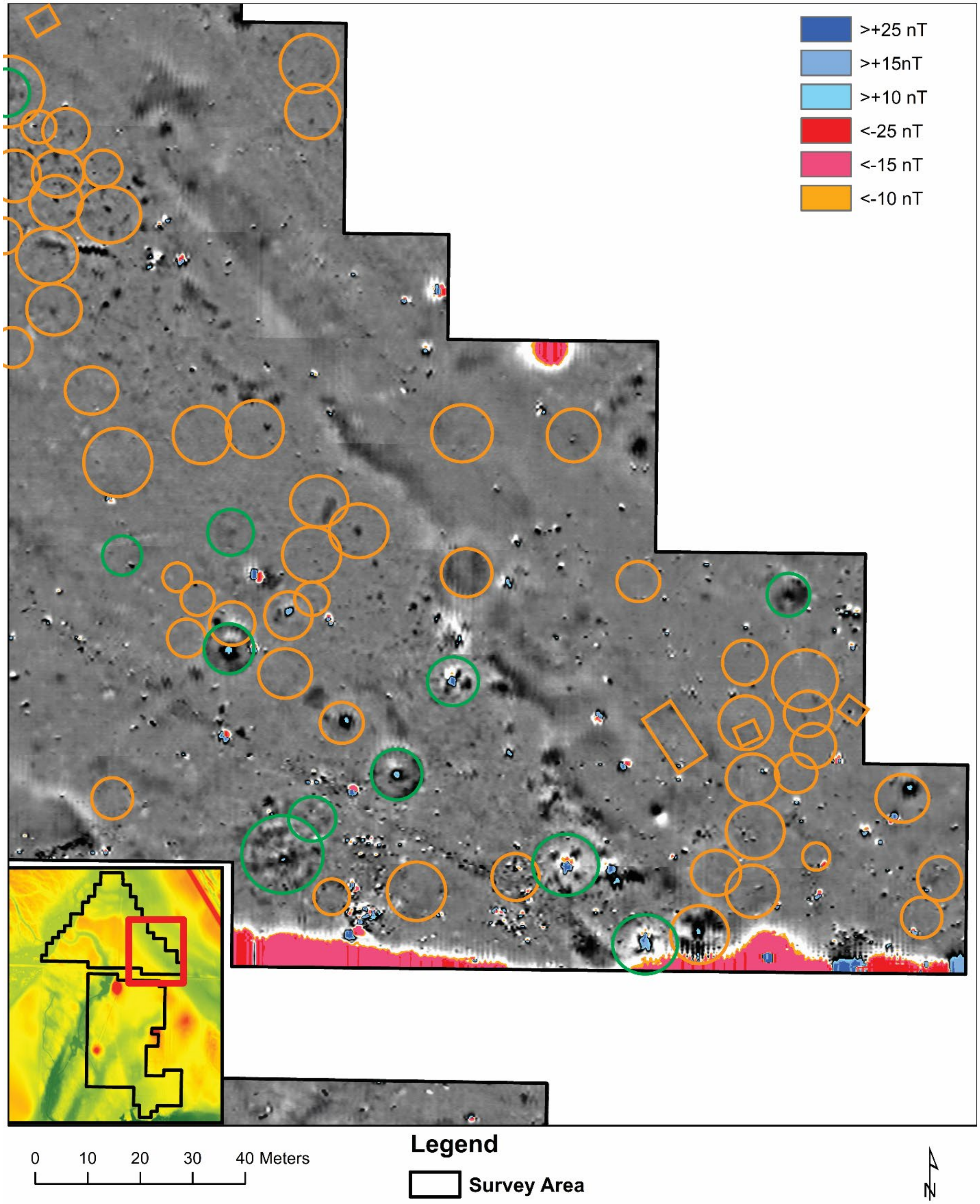

Figure 5.5 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures.

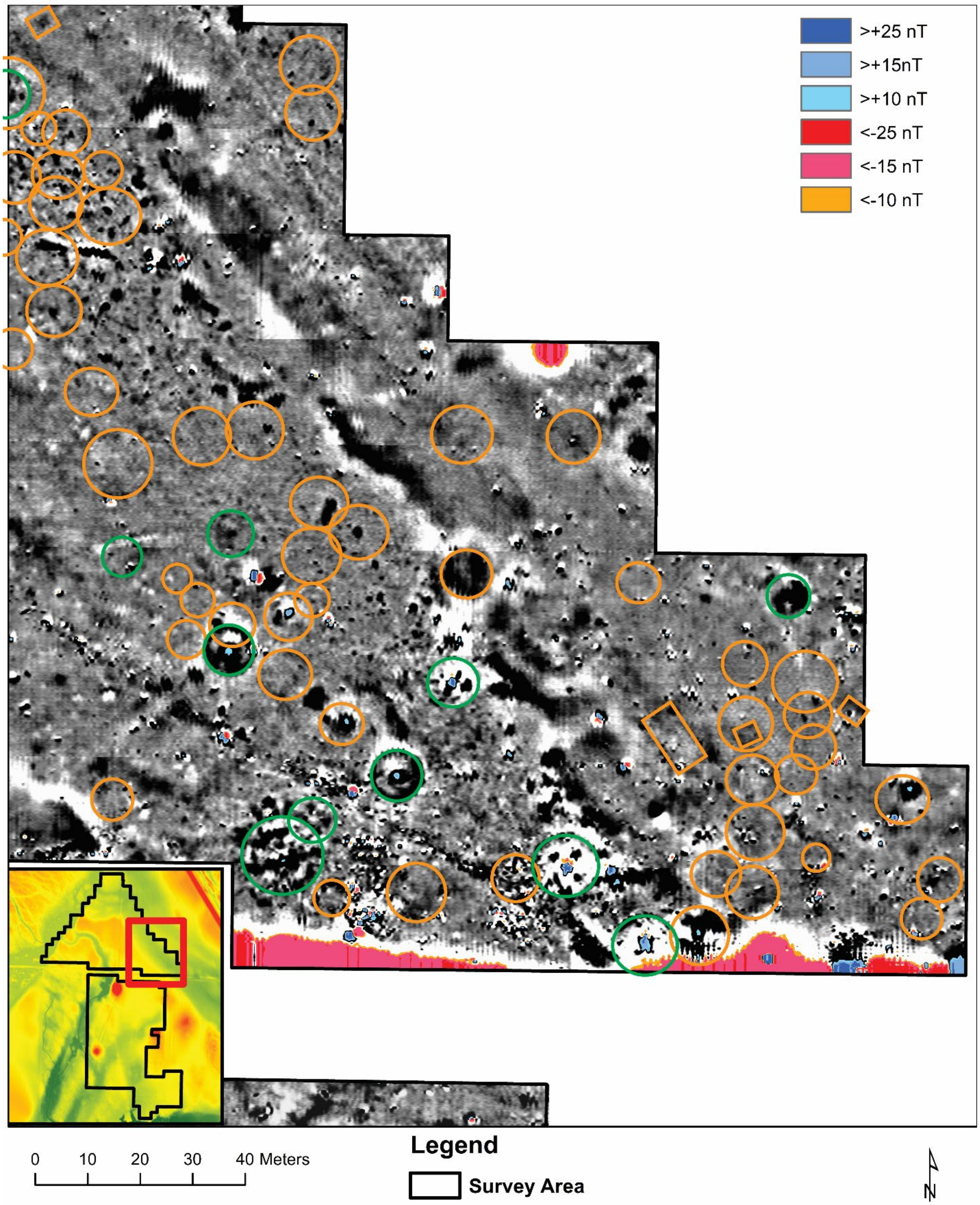

Figure 5.6 – Gradiometry clipped at ± 1 nT with likely (green) and possible (orange) structures.

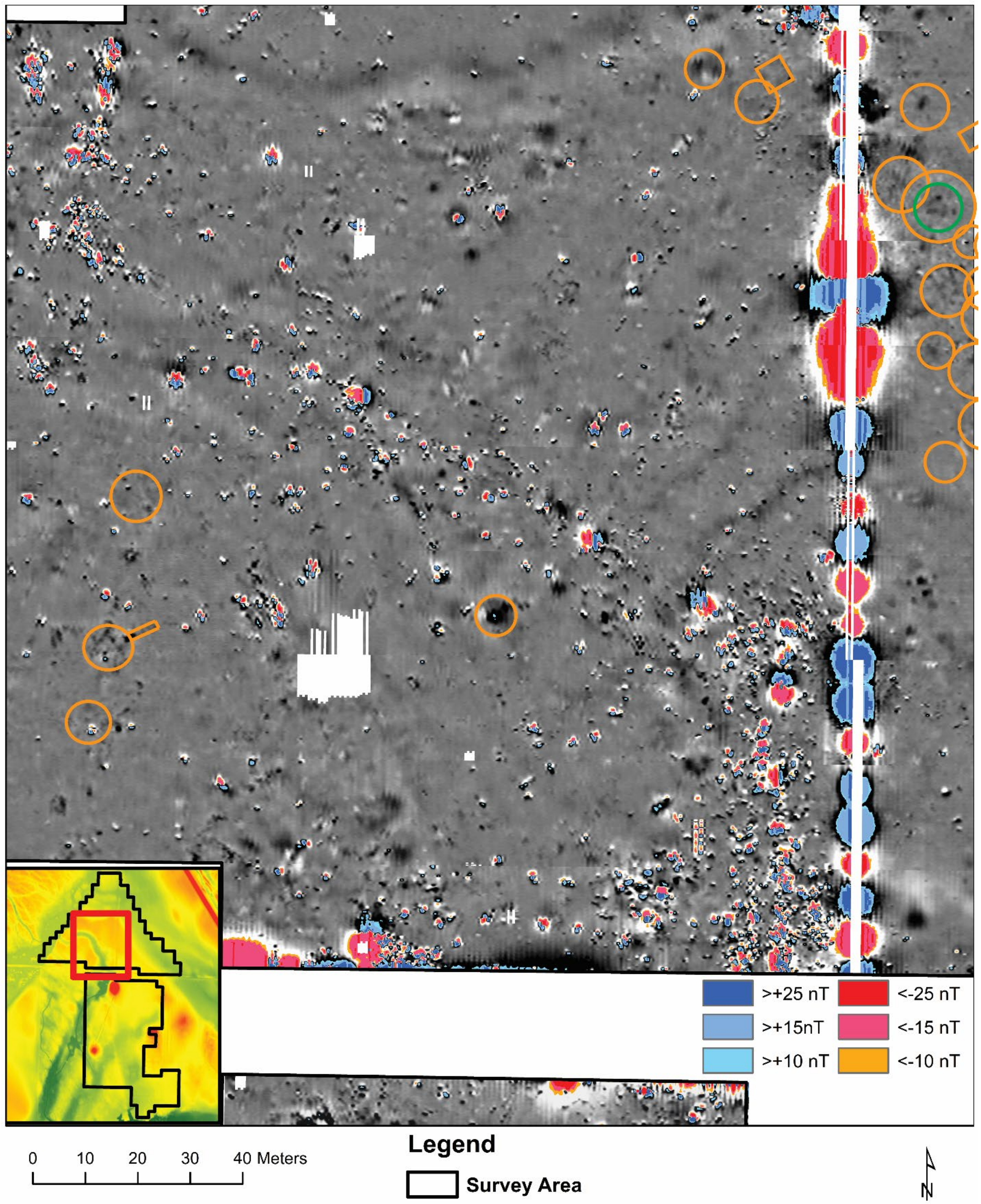

Figure 5.7 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures.

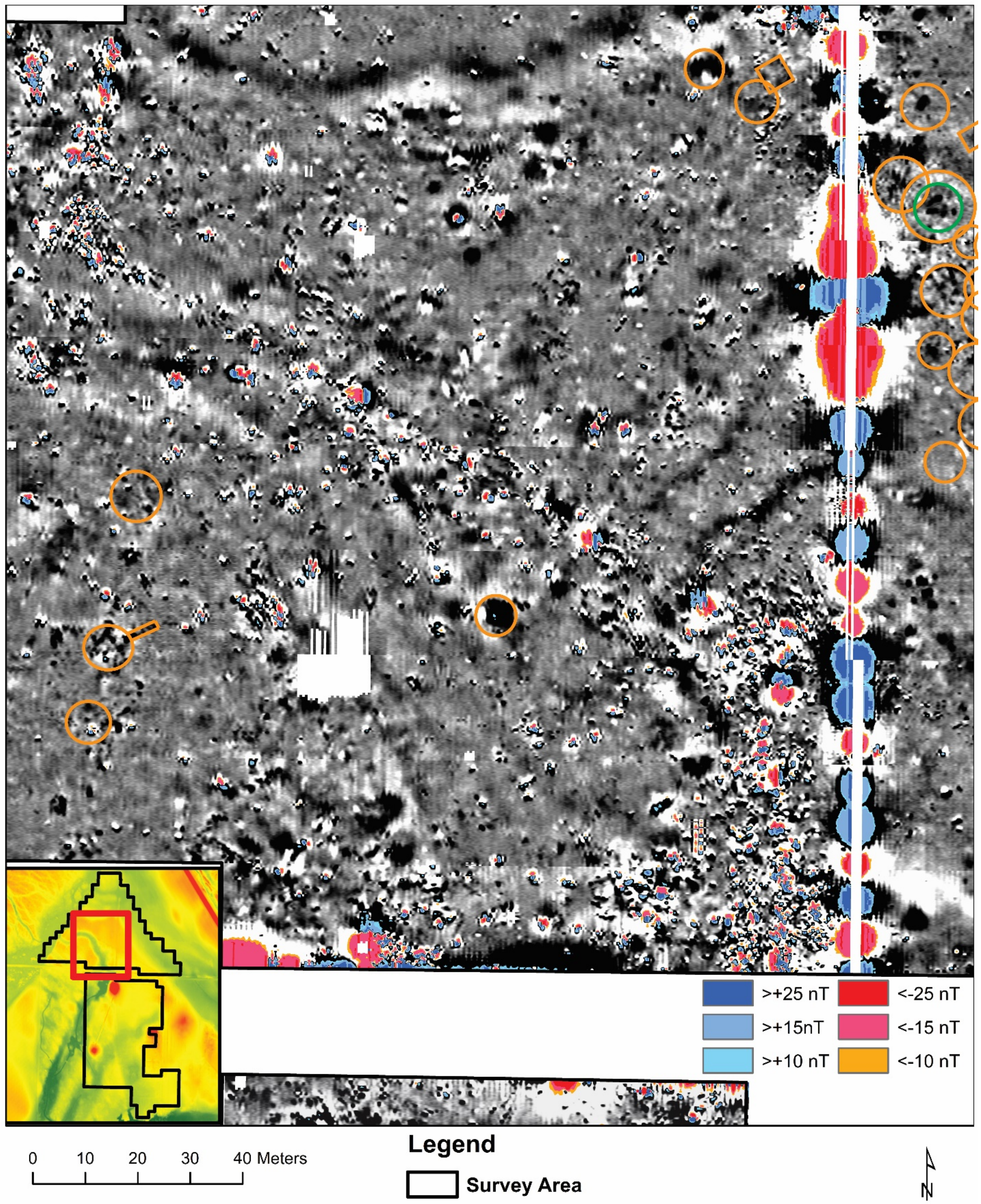

Figure 5.8 – Gradiometry clipped at ± 1 nT with likely (green) and possible (orange) structures.

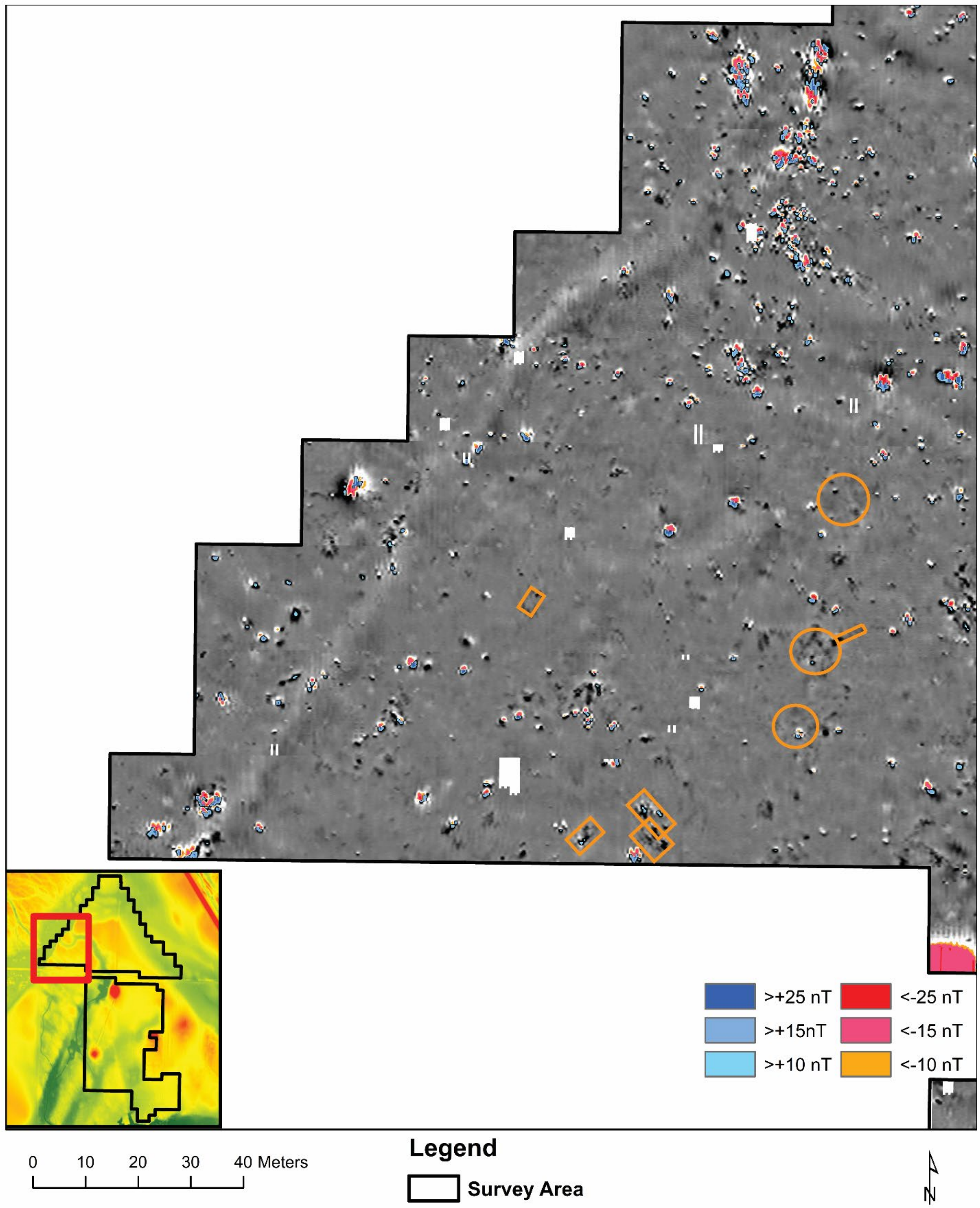

Figure 5.9 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures.

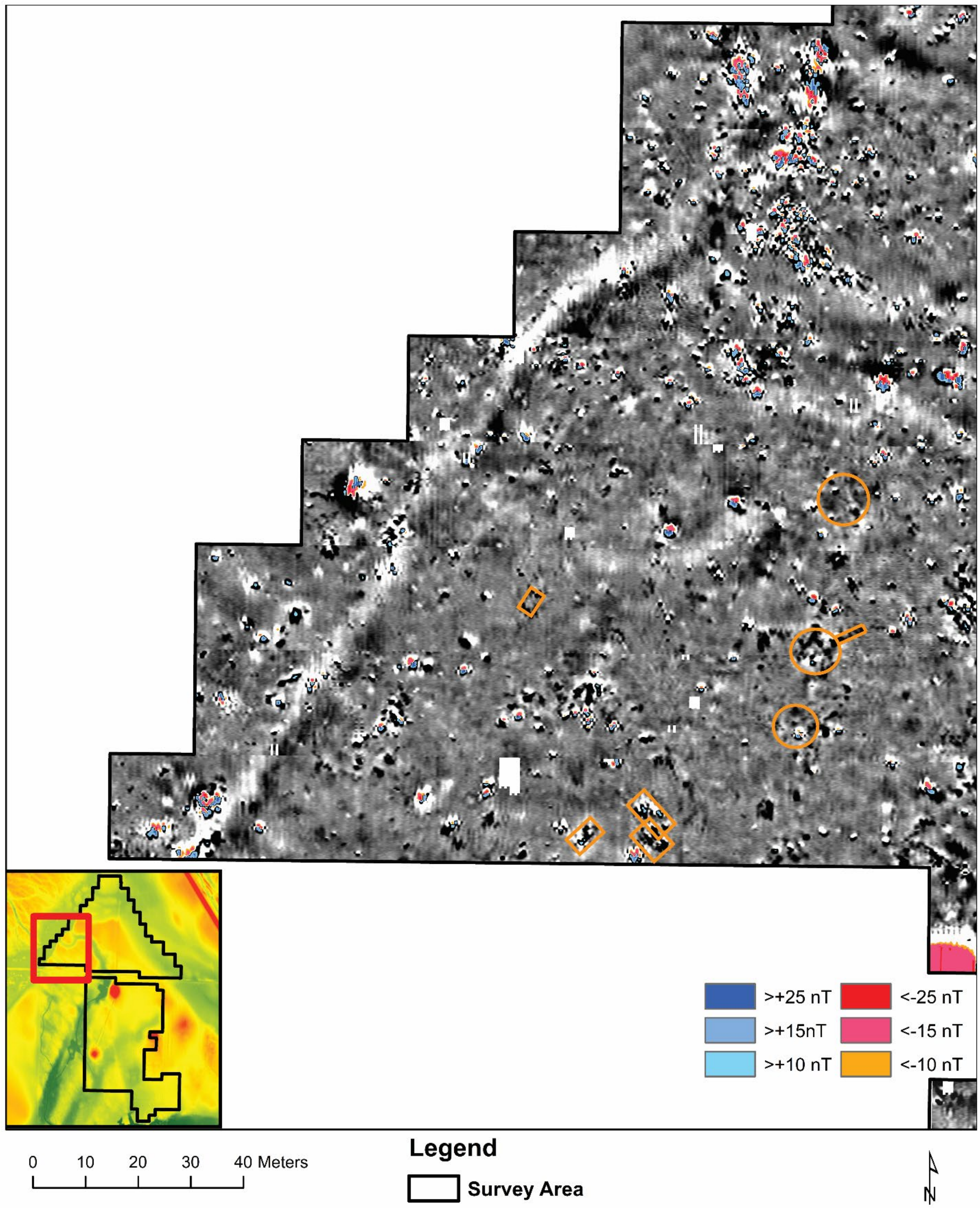

Figure 5.10 – Gradiometry clipped at ± 1 nT with likely (green) and possible (orange) structures.

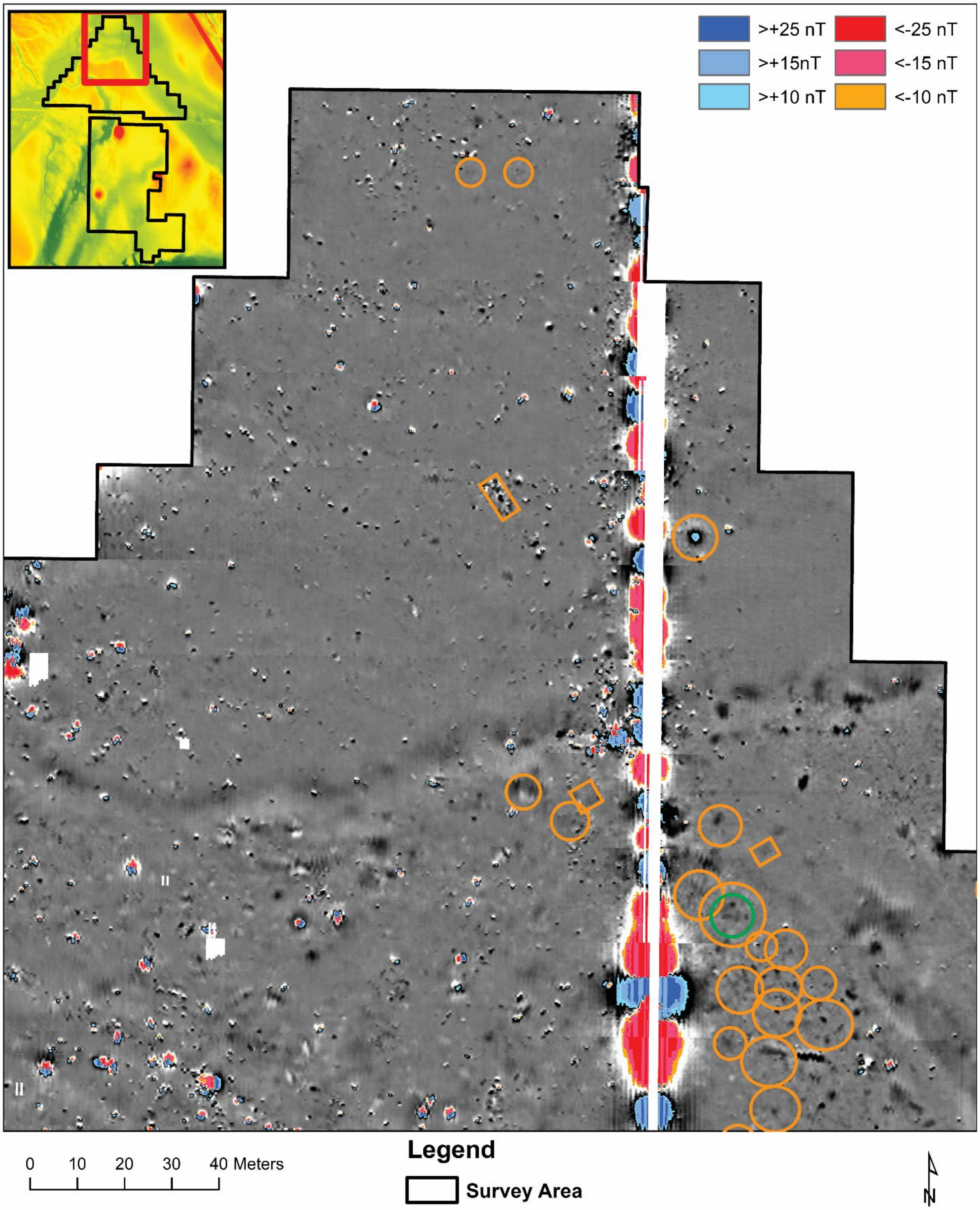

Figure 5.11 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures.

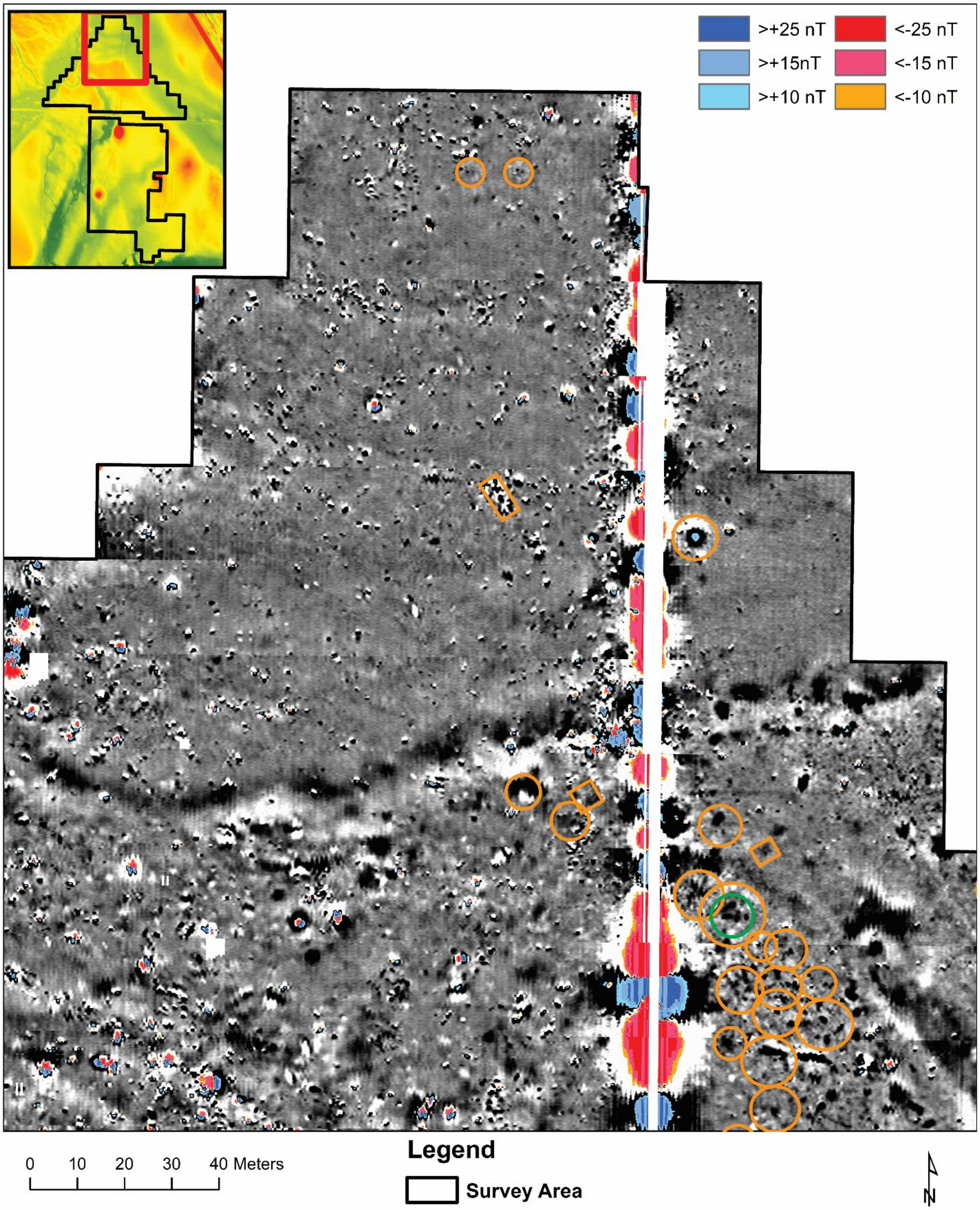

Figure 5.12 – Gradiometry clipped at ± 1 nT with likely (green) and possible (orange) structures.

The North Area of the site extends beyond the surveyed area to the east where Late Fourche Maline, Early Caddo, and Middle Caddo midden areas were uncovered as part of a levee rehabilitation project (Kelley and Coxe 1998). The North Area results show evidence of old channel scars associated with topographic lows (Figures 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12). There are also some of the most obvious house patterns in this area, including a few that have the classic “button” pattern of four posts around a central hearth seen well over 150 miles away at the George C. Davis site (Newell and Kreiger 1949; Walker 2009; Walker and McKinnon 2012). Some of these also have distinct and strong magnetic anomalies suggesting they were burnt hearths, although there is no evidence of extended entranceways. There is a northwest to southeast alignment of these structures near the topographic low.

The evidence for structures in the western and northern portion is scant (Figures 5.7, 5,8, 5.9, 5.10, 5.11, 5.12). This may have something to do with overlaid river sediments. First Old River is just to the west of this area and the modern river is to the north and east. These could deposit significant amounts of alluvium. First Old River was still active in the early 1800s when the Freeman and Custis expedition documented the area (Flores 1986). It is possible that natural levees could be burying anomalies to the point where the gradiometer is no longer able to detect them. The northernmost area is to the west of the previously mentioned Crenshaw Core 17 that found midden buried 1.75 m beneath the surface. This could mean that additional structures are hidden beneath the alluvium. However, it is likely that there is just less ancient activity in these areas as the southeast portion of this area (Figure 5.5, 5.6) shows strong evidence of structures in the topographic low areas. It is extremely likely that more structures would be revealed north and east of this area because the possible structures continue to the edge of the survey area and because Kelley and Coxe (1998) documented midden in that area.

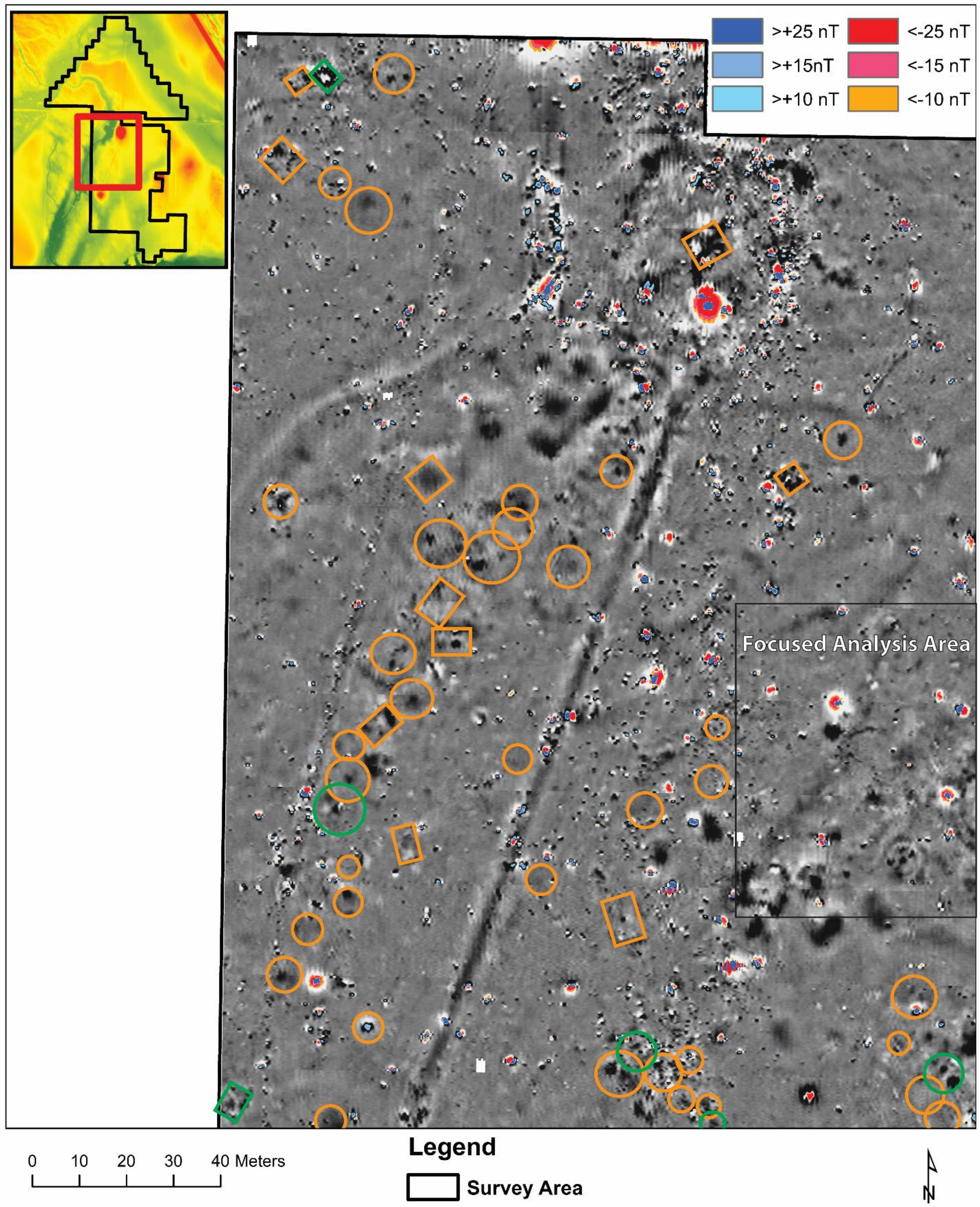

Figure 5.13 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures.

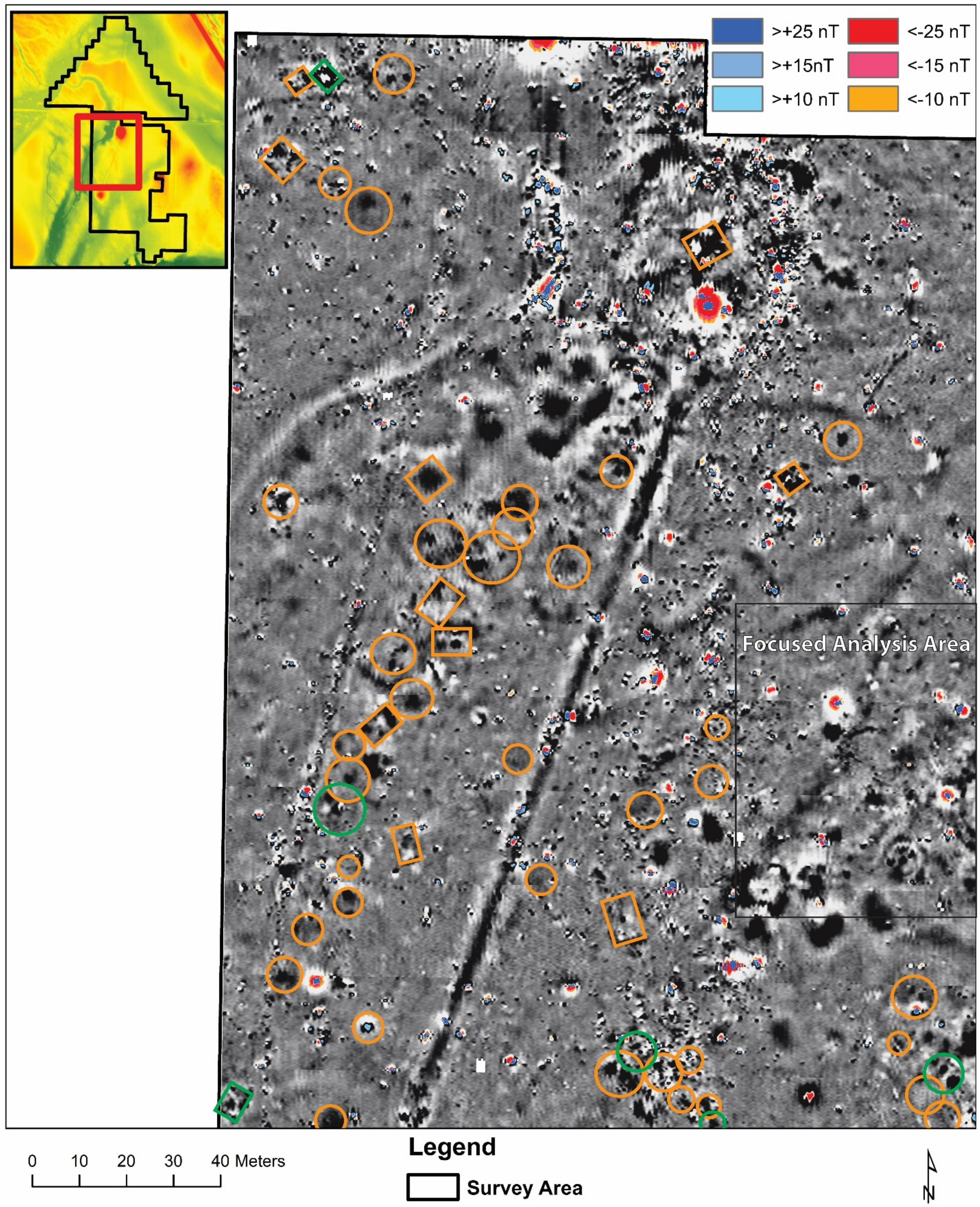

Figure 5.14 – Gradiometry clipped at ± 2 nT with likely (green) and possible (orange) structures.

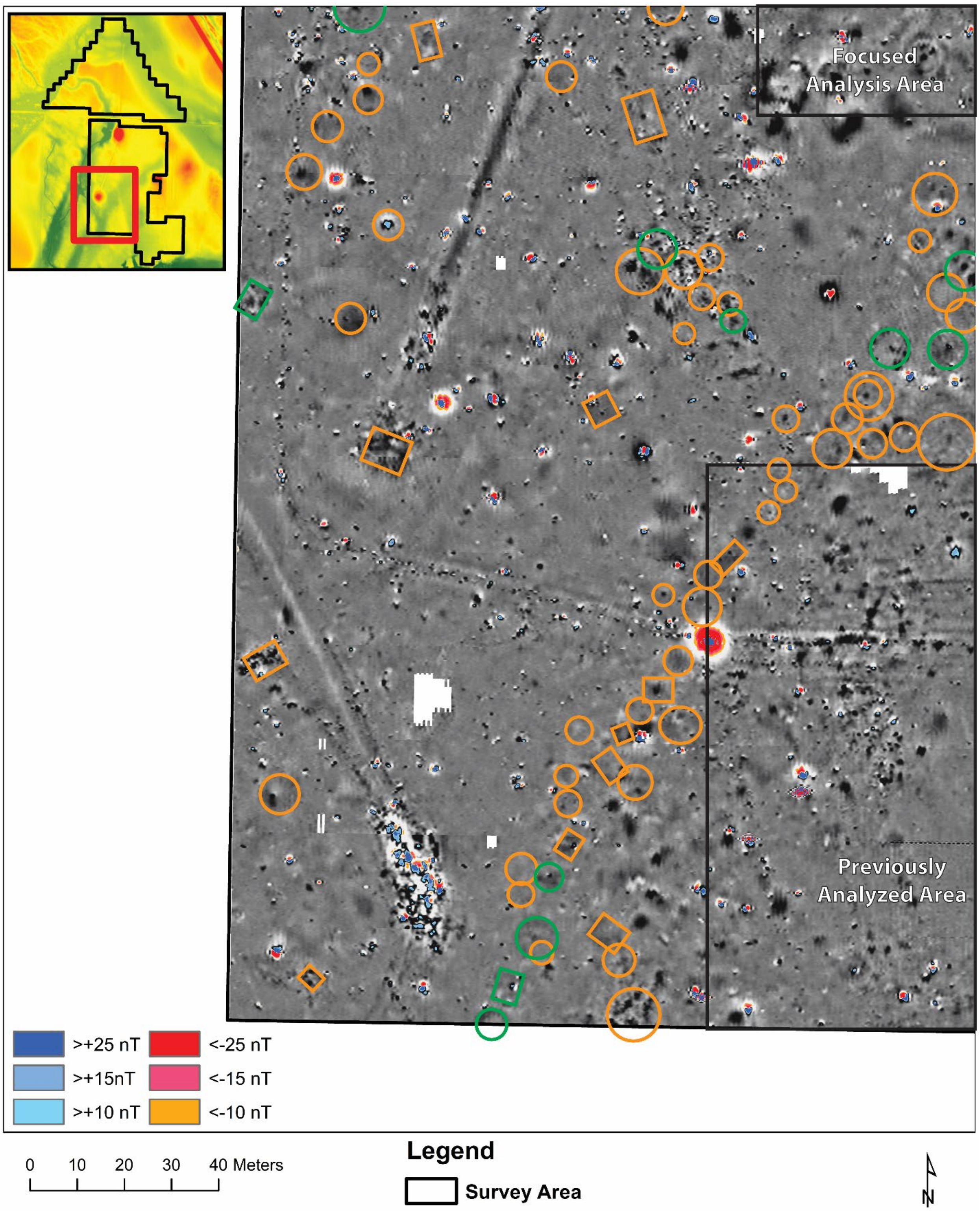

Figure 5.15 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures.

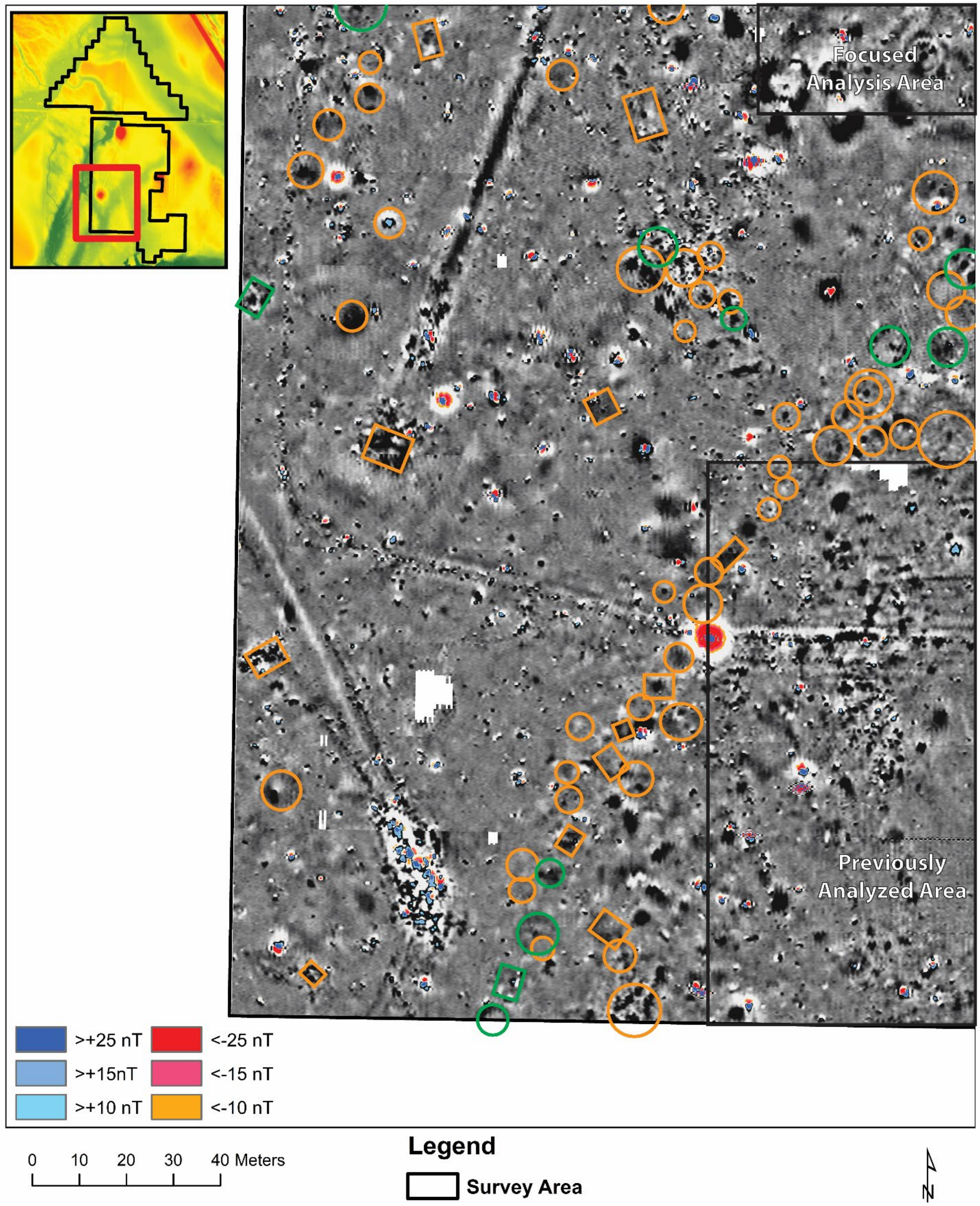

Figure 5.16 – Gradiometry clipped at ± 2 nT with likely (green) and possible (orange) structures.

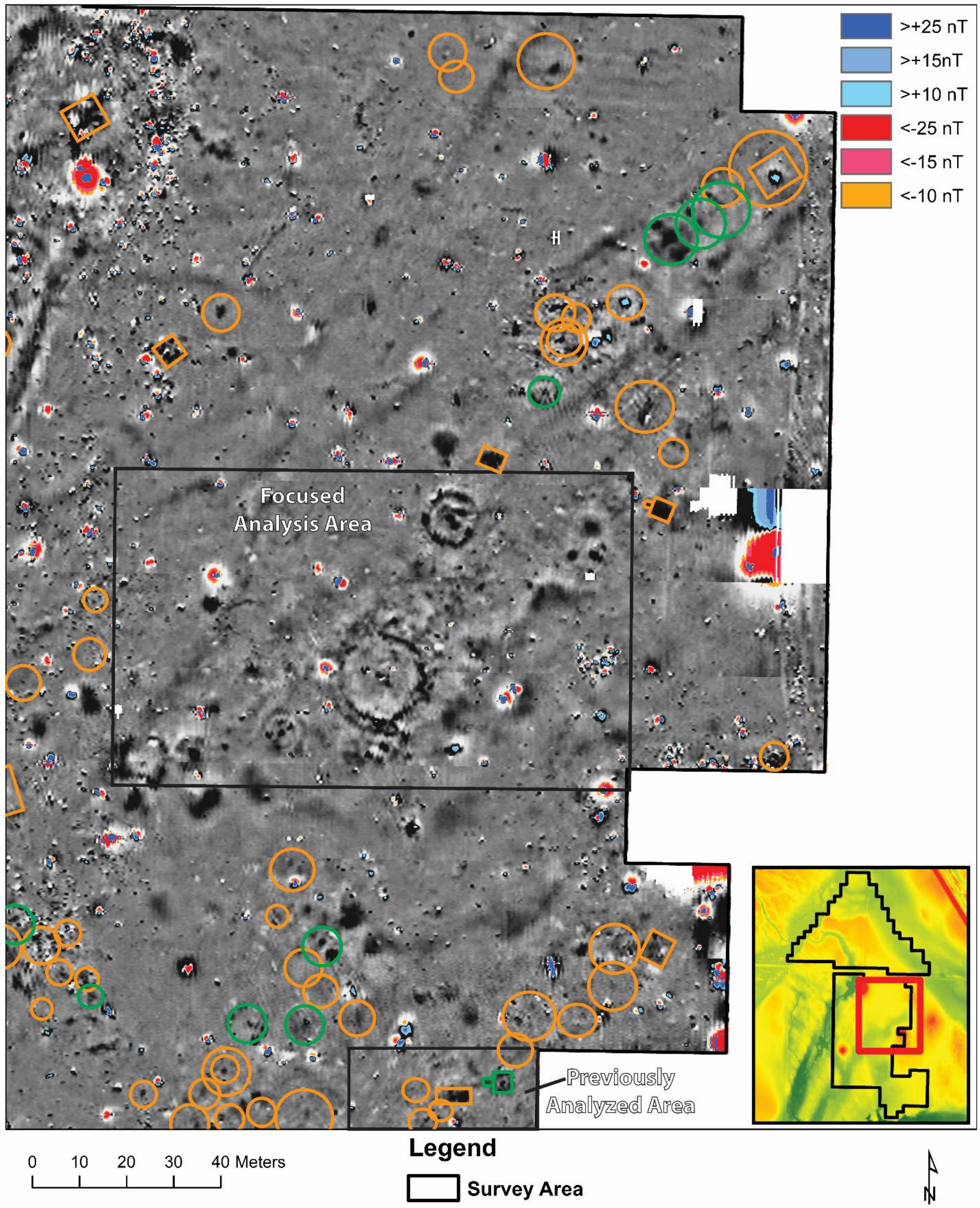

Figure 5.17 – Gradiometry clipped at ± 4 nT with likely (green) and possible (orange) structures. The Focused Analysis Area is interpreted separately.

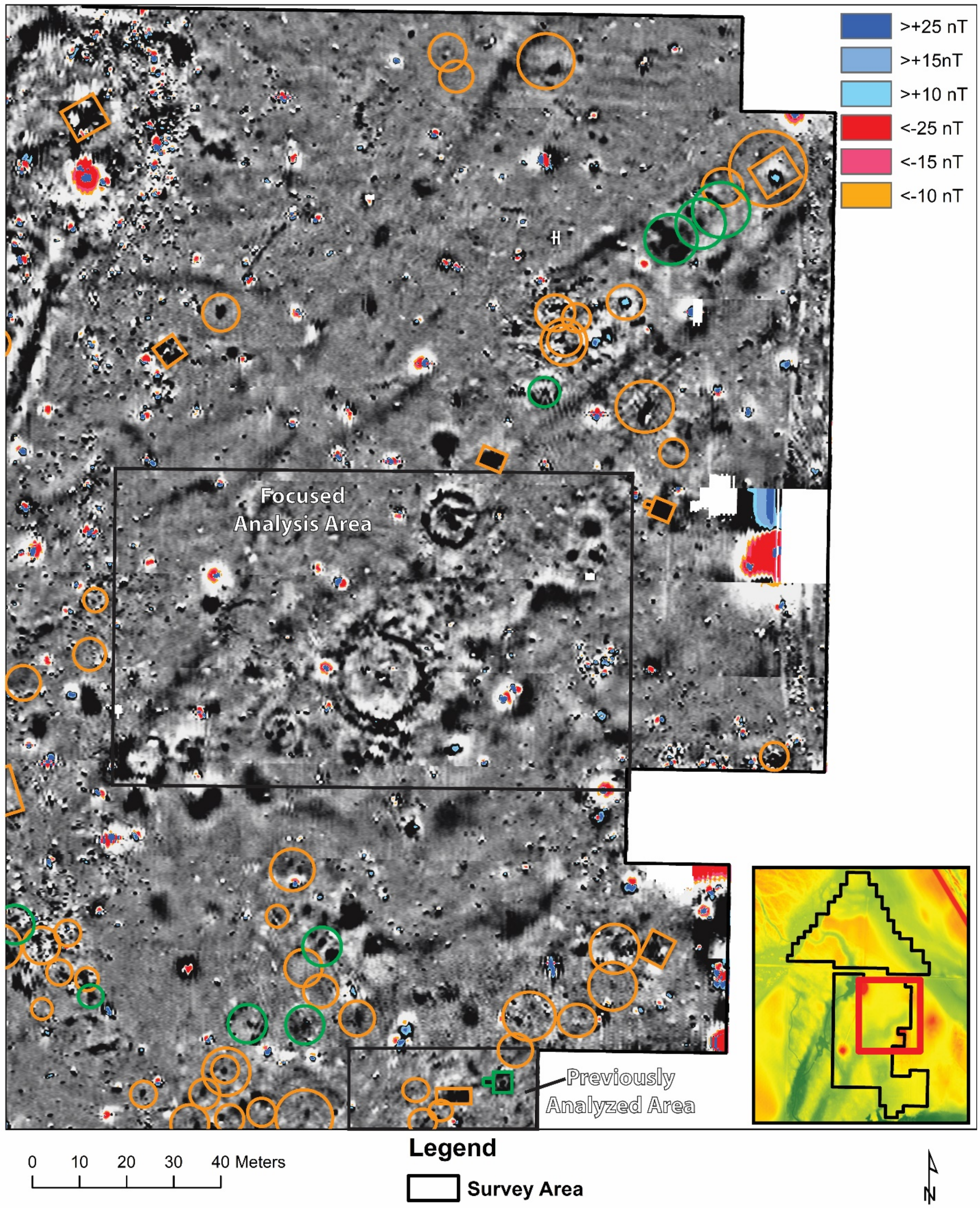

Figure 5.18 – Gradiometry clipped at ± 2 nT with likely (green) and possible (orange) structures.

The Central Area is characterized by the presence of numerous overlapping possible structures, generally arranged in linear patterns, and often arranged alongside topographically low areas or near Mounds B and F (Figures 5.13, 5.14, 5.15, 5.16, 5.17, 5.18). These possible structures are generally not in low areas but are located near and lined against them in linear patterns. Topographically high areas are often targeted for excavation, but in this case, targeting only high areas would have missed most of the activity at the site. Instead, the topographically high areas may have been plazas or spaces reserved for specific communal or ritual activities. There is also a noticeable gap of possible structures surrounding Mound A, particularly to the east, which is the flattest and highest area of the site thus far collected. Most identified structures were circular, but many were square or rectangular. Central hearths were very common, but not always present. Sometimes possible structures were identified due to circular or rectilinear patterns indicating a possible wall. Some structures were obvious with complex internal anomalies or extended entranceways while others were difficult to identify due to the lack of clear hearths, wall lines, or strong magnetism related to burning. The Focused Analysis Area in Figures 5.17 and 5.18 is interpreted separately in the discussion section.

The fact that several possible structures were identified in the northwest corner of the Central Area is very important as it shows that the area to the west of the channel scar contains intact ancient deposits. This indicates that the site clearly extends to the west of the channel scar. It therefore may also extend into the field to the west.

The likely and possible structures identified excluded many anomalies that may also be structures, such as the numerous areas of high magnetism surrounded by areas of low magnetism (e.g. southwest of Mound A in Figure 5.14). These types of anomalies are all over the site, some with strong rectangular or square patterns. Samuelsen (2009) interpreted that one of these was a structure with a large interior pit based on a previous excavation of part of one of these anomalies. However, this interpretation is tenuous without more information, so these types of anomalies were not included in the analysis of structures in this study unless there was some other factor that suggested they were a structure (e.g. evidence of a hearth or extended entranceway).

5.4 Discussion

5.4.1 Linear Patterning and Overlapping Structures

The linear patterning of structures indicate that Crenshaw was heavily occupied in at least one time period (Figures 5.19, 5.20). Linear patterning of structures heavily implies that they were constructed with other nearby structures in mind. This means that many would have stood at the same time, indicating a significant resident population. This may not be the case if they were ceremonial in nature, but most of the identified possible structures away from the mounds do not have evidence suggesting a ceremonial function. Most are therefore interpreted to be domestic structures. These possible structures also tend to have weak patterns that make it difficult to be confident that any particular anomaly is a structure. However, the linear patterning adds to the confidence in the interpretations. These possible structures also tend to occur near topographic lows. This suggests that the Caddo created a delineation of space by placing structures close to water or on subtle slopes, which left the highest areas of the site available for other activities. It is important to note the possible structure in Mound A and the presence of a rectangular possible structure in the center of Mound E. These are the first pieces of evidence relating to a structure in mound at Crenshaw.

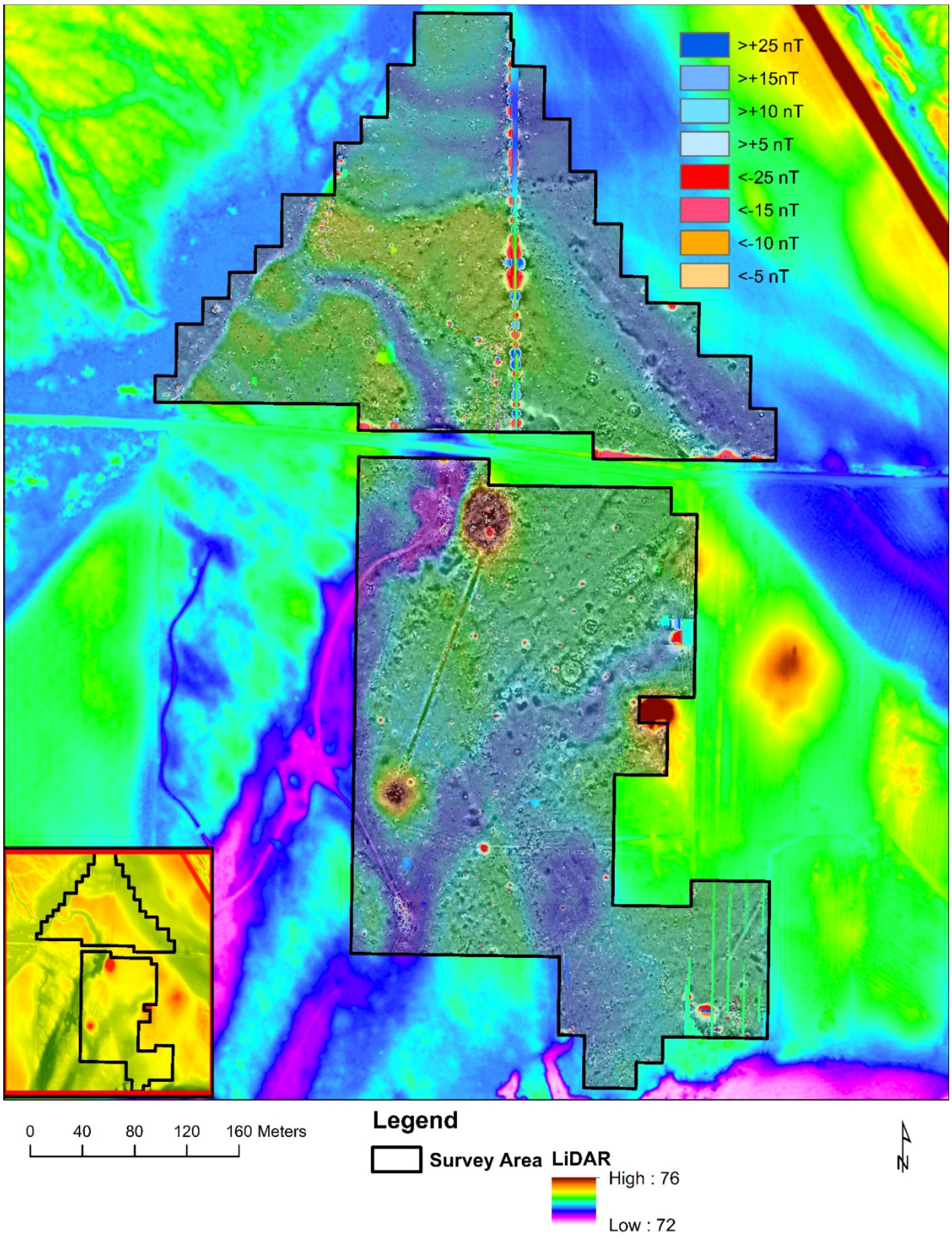

Figure 5.19 – Gradiometry overlaid on LiDAR shows strong agreement between technologies.

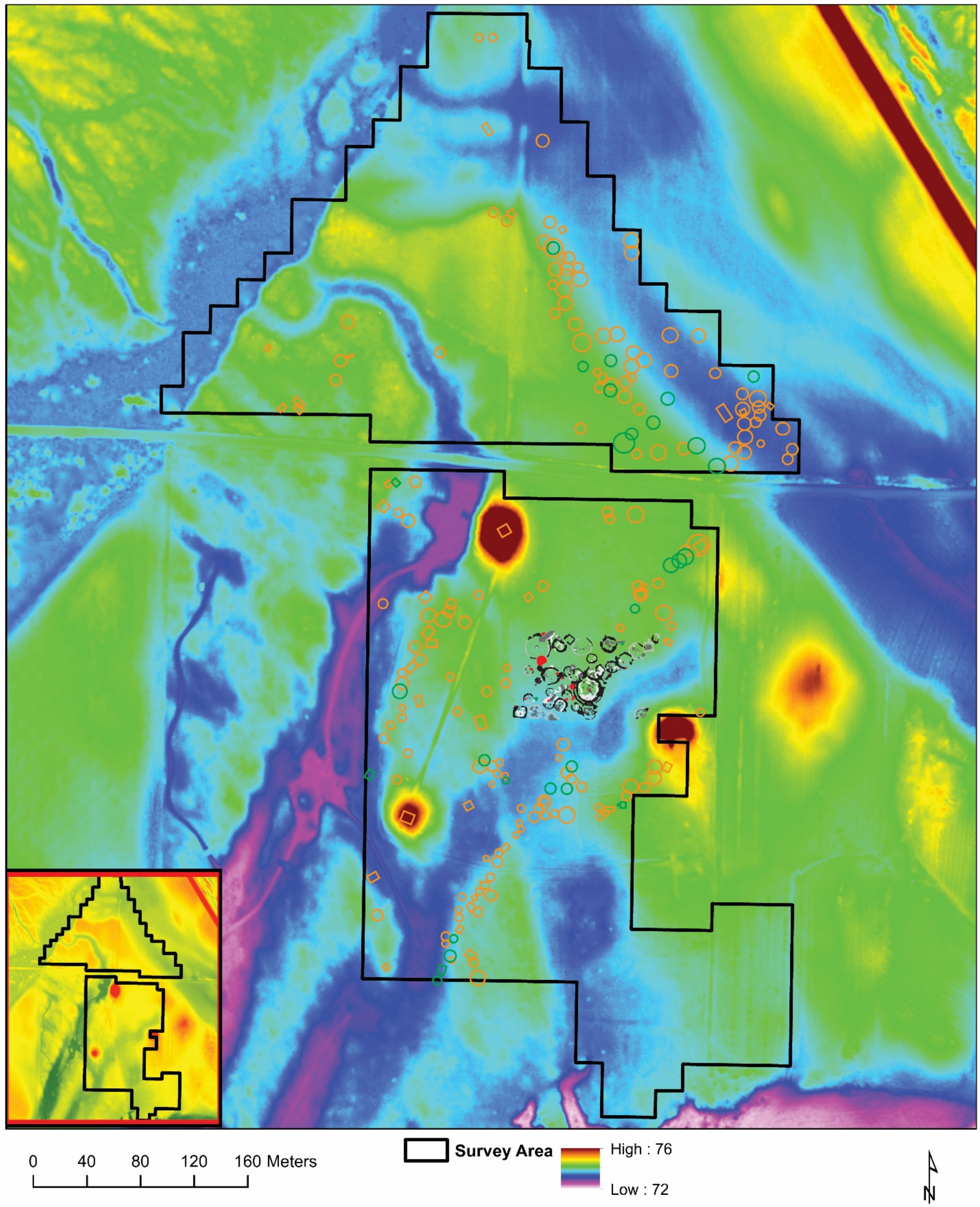

Figure 5.20 – Possible structures overlaid on LiDAR shows they typically occur near topographic lows. Note that anomalies identified as possible structures by Samuelsen (2009) in the previously analyzed area (southeast portion) are not included.

There is also evidence of significant overlapping structures in several areas. This indicates these areas were also used for a significant period of time and do not represent a short occupation period. It is not possible to provide a definite time range of occupation without excavation and absolute dating, but this does suggest that Crenshaw was heavily occupied for an extended period of time.

One particular linear pattern of structures was long and seemed to form a quarter circle on the southern portion of the site (see Figures 5.19, 5.20). This included many possible structures on the edge of the previously analyzed area. While it cannot be stated with confidence, the clear arcing of this line suggests that it may continue to the south and to the east, potentially forming a half circle of structures. There is some evidence to support this, including reports of structures being encountered by looters just east of this area and some midden excavations by Schambach (1982) on the eastern portion of the site. If this does continue in a semi-circular fashion, the skull-and-mandible cemetery would be located near the center of it. It is also possible that this is just an artifact of the topography.

5.4.2 Focused Analysis Area

Anomalies in the Focused Analysis Area were mapped so that an in-depth analysis could reveal more subtle components of the possible structures. It was clear from the results that this area northwest of Mound F was particularly important given the size and details of the anomalies. In order to help highlight the possible structures in the data, the gradiometry results were mapped alongside the possible structures (Figure 5.21). Structure walls and internal anomalies were highlighted, giving them different colors according to whether they were represented by areas of high or low magnetism. This can be used to determine what architectural features might be present based on what practices may have caused high or low magnetic anomalies. The linear arrangement of possible structures is apparent in these interpretations as they can be seen lining the blue elevation line in an east-northeast to west-southwest direction (see Figure 5.20). Note that possible structures generally do not appear below this line and begin to appear again on the other side of the possible borrow area. This supports the interpretations as it would not be expected for structures to be built in flood prone areas.

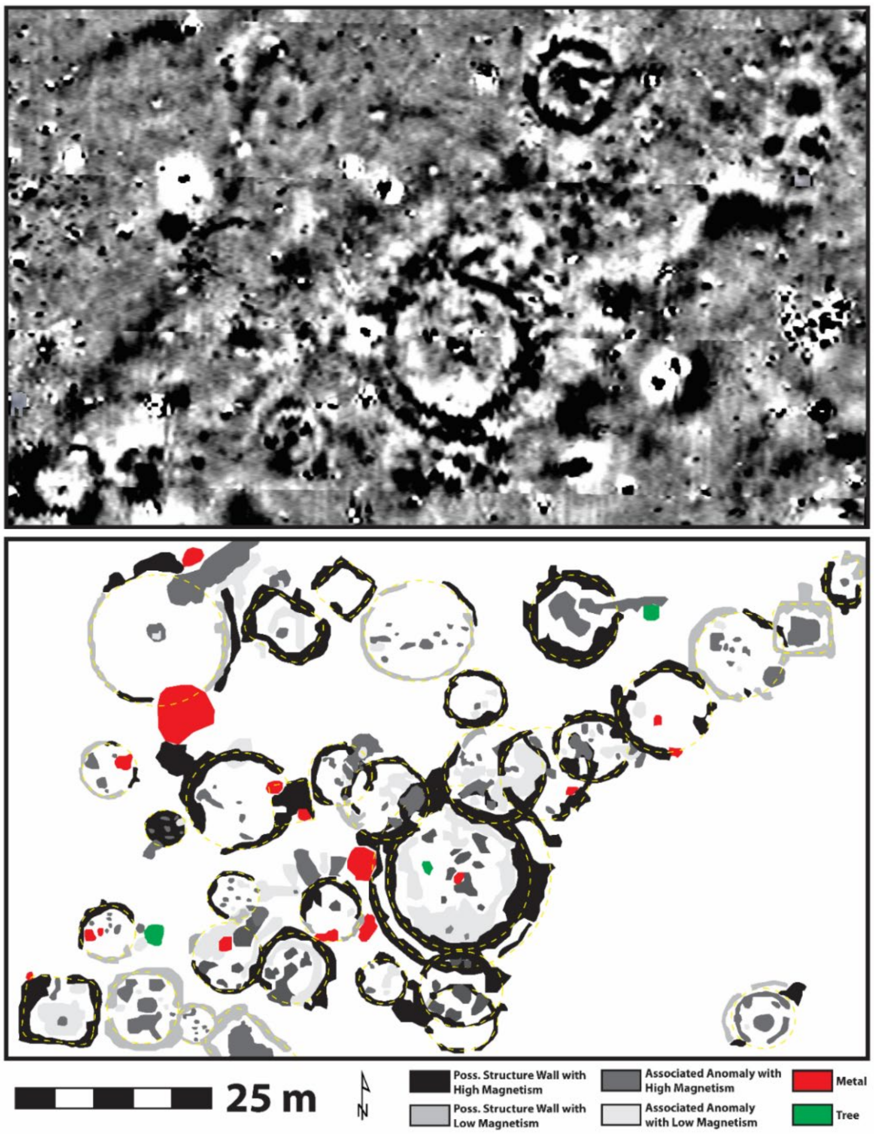

Figure 5.21 – Gradiometry clipped at ± 2 nT. Possible structures are marked below. As many as 33 possible structures were identified in this one-hectare area. Many are interpreted to have extended entranceways. Some are nearly 20m in diameter and appear to have double wall lines.

The location of 33 likely or possible structures in this area, many of which may have extended entranceways, have clear wall lines, or have been burned, suggests that this area was used heavily for ceremonial activities. The area west of Mound B with similar patterns may be a continuation of this area as the linear pattern of possible structures continues in that direction. Some of the more notable anomalies include structures about 20 m in diameter, double wall lines, and extended entranceways which seem to begin from within the structure. It is important to note that extended entranceways, according to Rogers (1982) and Perttula (2009) are thought to extend only as early as A.D. 900, suggesting a Caddo cultural affiliation for these possible structures. By contrast, only one Fourche Maline structure has been excavated in southwest

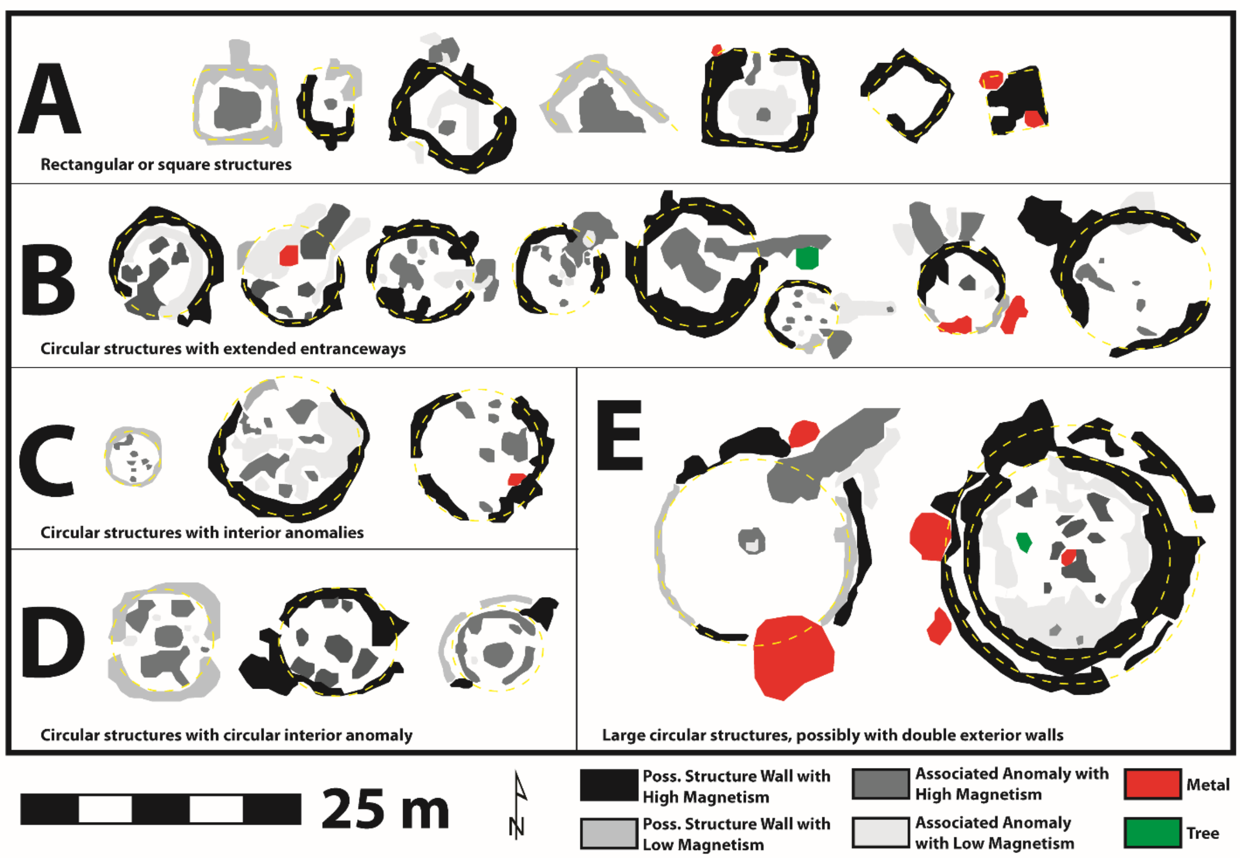

Figure 5.1 – Possible structure types identified in the Focused Analysis Area, northwest of Mound F.

Arkansas (Wood 1981), suggesting they are ether rare or too ephemeral to be readily identified using gradiometry. In order to evaluate structure purpose and time period of use, they were typed and then compared with known Caddo structures from other sites (Figure 5.22). These types are used as a tool for hypothesizing about structure function and time and may not accurately represent how the Caddo themselves would have categorized them.

Structures were separated into five types. Type A consisted of rectangular or square structures with or without extended entranceways. Noticeable across the site are rectangular or square structures with large internal areas of increased magnetism. Some have clear wall lines and internal anomalies while others resemble the large areas of increased magnetism surrounded by rectangular patterns of low magnetism. However, at least one of these appears to have an extended entranceway.

Type B consisted of circular structures with extended entranceways. Notably, many of these have areas of high magnetism that originate from within the structure and continue outside the structure, forming the appearance of an extended entranceway, perhaps lined with ash or some other burned material. Some also have areas of low magnetism on either side, which would be consistent with the presence of a wall line. Low magnetism can indicate wall lines due to the removal of topsoil to create the posts but can also be due to wall trenches. Some have internal circular anomalies, suggesting that Types B and D may overlap.

Type C consisted of circular structures without extended entranceways and no strong patterns of internal anomalies. However, some have anomalies suggesting the presence of a central hearth. There were not many of these in this area but there were many more elsewhere at Crenshaw, particularly in the eastern portion of the North Area. Structures in Type D are circular with internal anomalies that may form a circular pattern within the wall line. This pattern is seen at other Caddo sites, most notably at Belcher (Webb 1959). Type E consisted of large structures about 20 m in diameter with double wall lines and extended entranceways. It is difficult to determine if the double wall lines represent a single structure with two walls or two structures built at different times with slightly different diameters.

Although not given a type designation, there were structures in other parts of the site that fit other anomaly patterns that have previously been established. This included multiple "button" style houses (see Figure 5.5) previously documented at sites like George C. Davis (Newell and Kreiger 1949; Walker 2009; Walker and McKinnon 2012) and included several linearly aligned, triple pit structures previously identified by Samuelsen (2009:102-103) at Crenshaw west of Mound B. These are similar to Feature 33 at George C. Davis (Figure 5.23). These commonalities indicate striking similarity in architectural grammar between these two sites despite being over 150 miles apart.

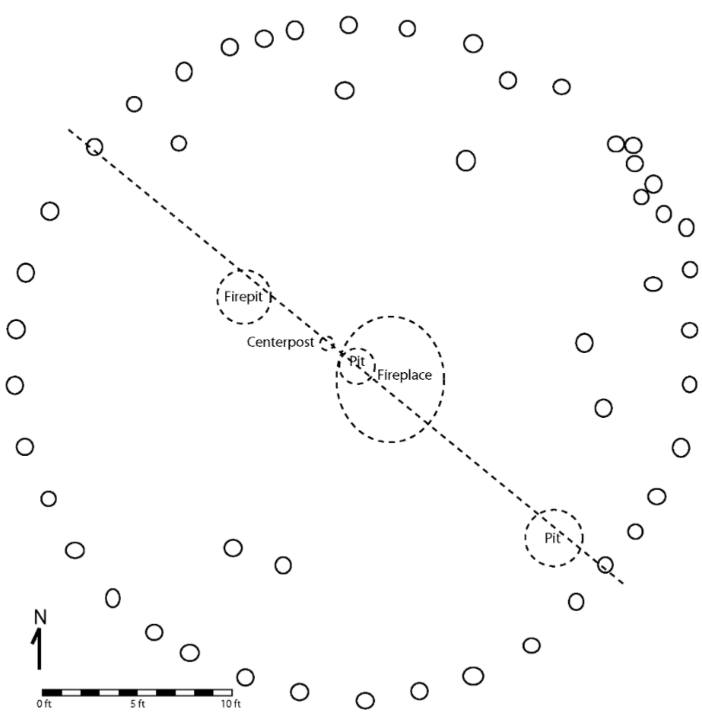

Figure 5.23 – Feature 33 from the George C. Davis site (after Newell and Krieger 1949:Figure 17).

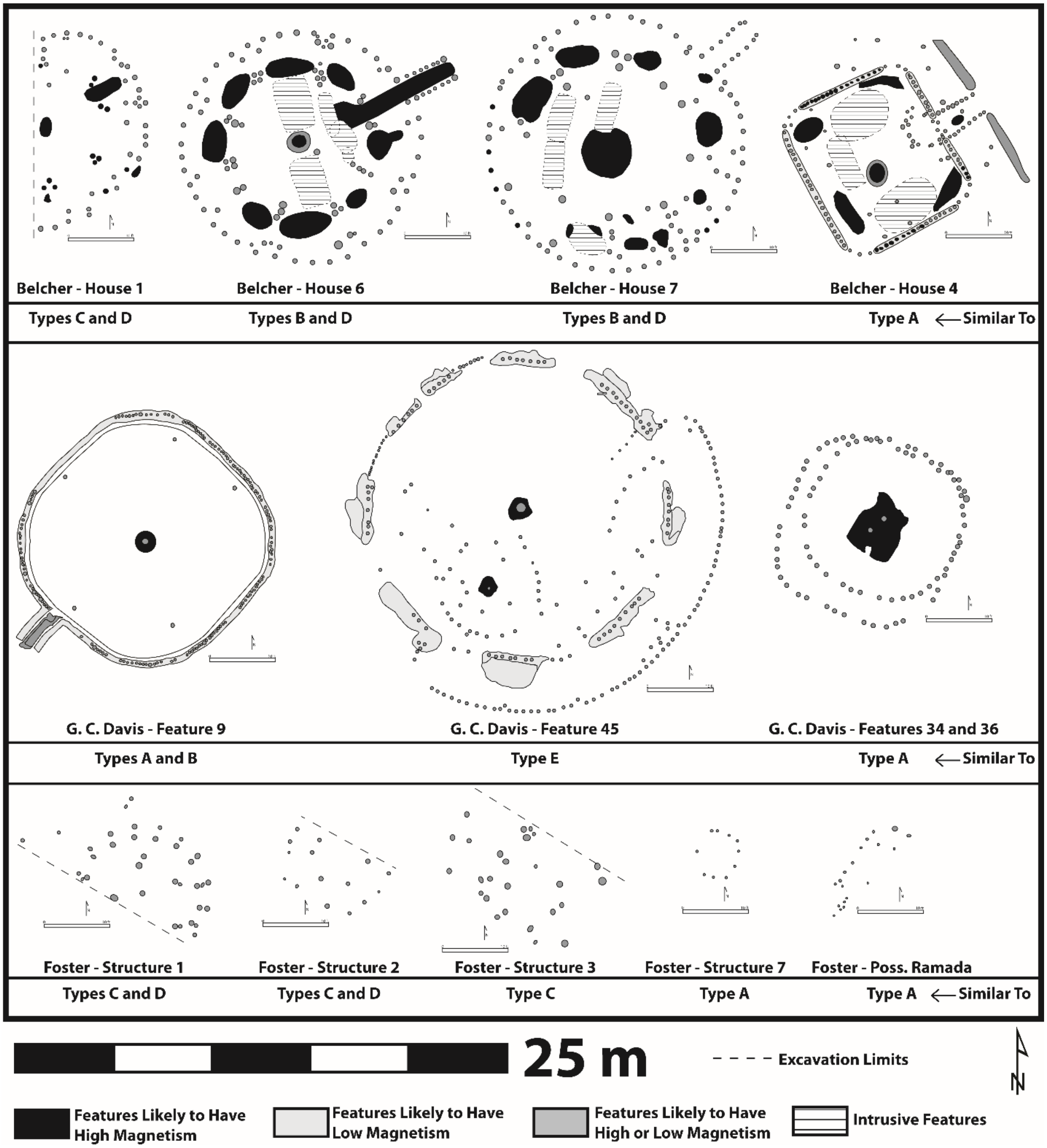

Figure 5.24 – Comparable structures from other Caddo sites, including Belcher, George C. Davis, and Foster (Buchner et. Al 2012; Newell and Kreiger 1949; Webb 1959). Interpreted architectural patterns at Crenshaw are similar to some of these structures.

The five types were compared to previously excavated Caddo structures from other sites (Figure 5.24). Comparisons include structures from Belcher (Webb 1959), George C. Davis

(Newell and Krieger 1949), and Foster (Buchner et al. 2012) in order to compare examples from different time periods, regions, and use contexts. Most importantly is that the structures from Foster are considered to be part of a farmstead while the structures from Belcher and George C. Davis were interpreted to be for ceremonial use. The structures at Foster are noticeably smaller, less internally complex, lack extended entranceways, and had little to no evidence of burning. At Belcher, there are circular internal patterns of ash pits in two houses (6 and 7), which would cause high magnetism as seen in some of the anomalies at Crenshaw. In addition, both Belcher House 6 and George C. Davis Feature 9 would likely lead to extended entranceways defined by areas of high magnetism surrounded by areas of low magnetism, again, as seen in many of the possible structures at Crenshaw. The large double walled possible structures look most like Feature 45 from George C. Davis, also interpreted to be a ceremonial structure. One of the anomalies has an internal anomaly that compares very well with the post mold filled central hearth in Feature 45.

Based on the comparison with known Caddo ceremonial structures from other sites, evidence of burning, strong and clear patterns, larger sizes, and presence of extended entranceways, this area appears to have been heavily used for ceremonial purposes. The large number of possible structures with extended entranceways is not replicated elsewhere within the surveyed area. While there are many other possible structures, they typically do not form as strong and obvious patterns as the ones in this area and rarely have anomalies suggesting the presence of extended entranceways.

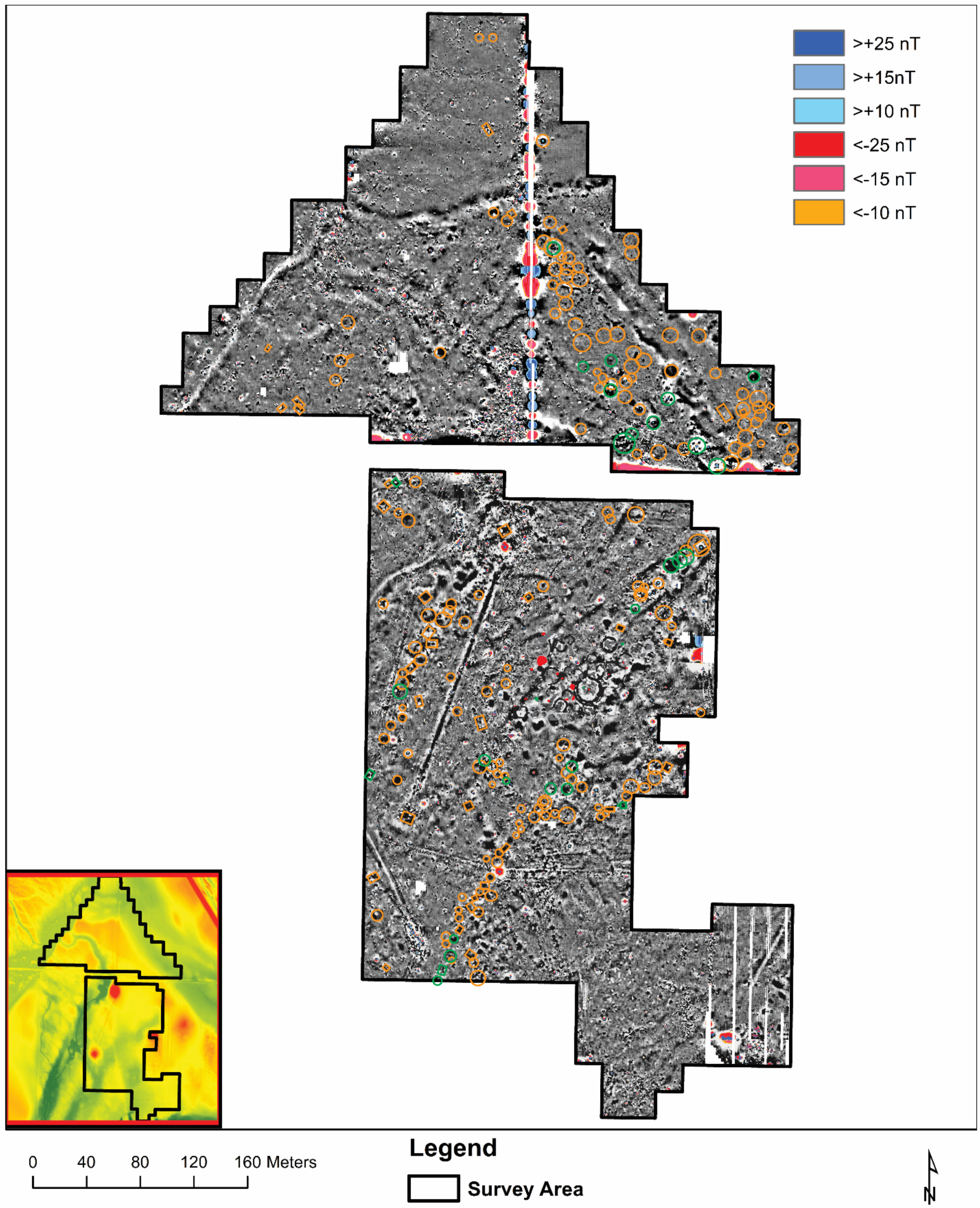

Figure 5.25 – Structures overlaid on gradiometry for both areas surveyed in this study. Linear patterns as well as overlapping structures occur, suggesting both time depth and contemporaneity.

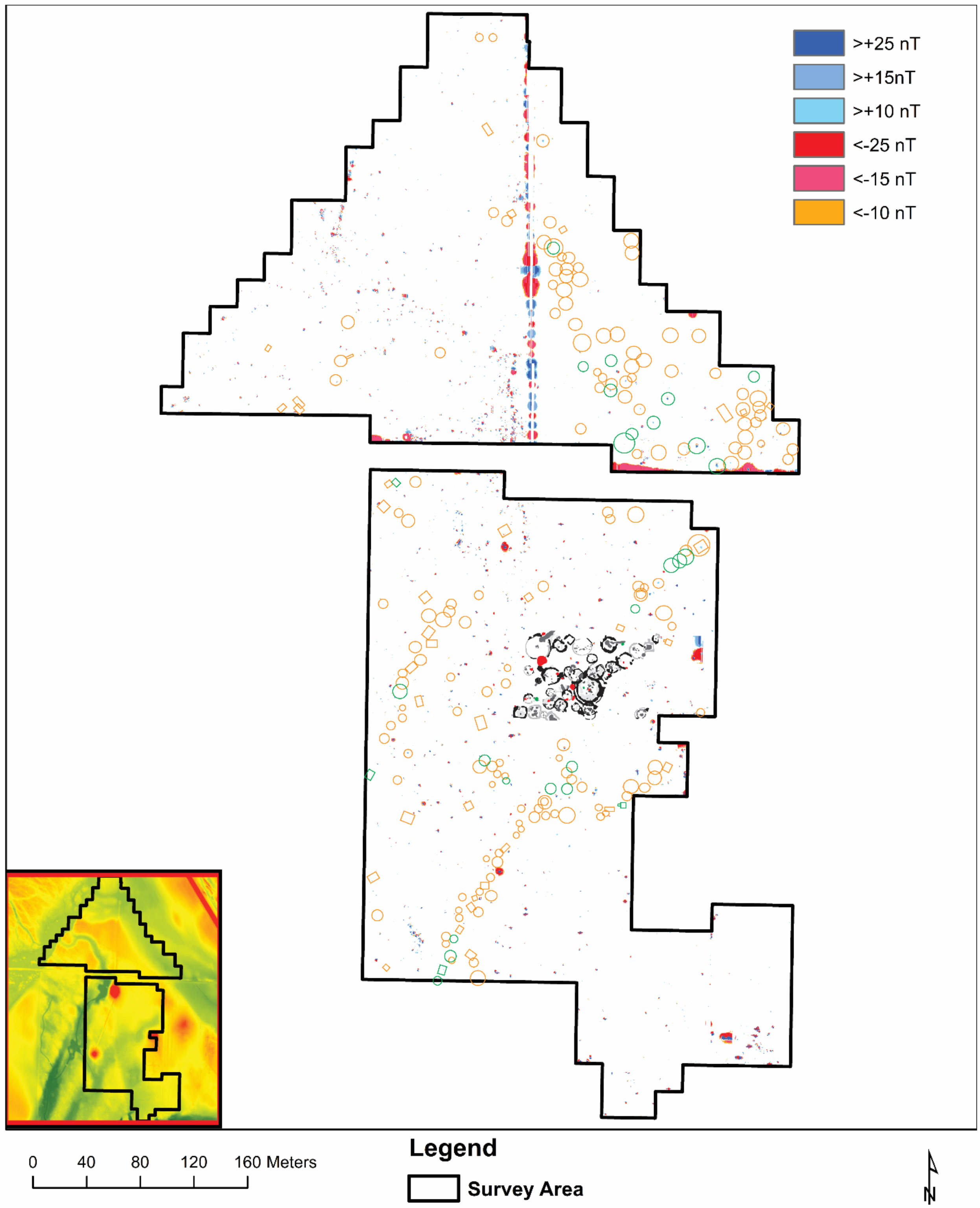

Figure 5.26 – Structures for both areas surveyed in this study. Linear patterns as well as overlapping structures occur, suggesting both time depth and contemporaneity.

5.4.3 Delineation of Space and Occupation

The site appears to have some clear delineations of space (Figures 5.25, 5.26). Firstly, areas adjacent to topographical lows were preferred for structure placement (see Figures 5.19, 5.20). This could be due to the proximity of water as some of these areas are associated with old oxbow lakes. However, other ecological reasons may exist. There may even be important ceremonial reasons for this arrangement. The placement of ceremonial structures next to borrow areas and Mound F may have represented an area of interaction or transition between the three worlds, often referred to as an *axis mundi* (see Brown 2012; Sabo 1998:160-161). The central placement of these possible ceremonial structures may indicate that Dee Ann Story's (1997) concept of an "inner precinct" may have some merit at the Crenshaw site. The placement of the structures around the topographically low areas left the high areas available for other activities. While anomalies do occur in these areas, they are relatively few. The areas suspected to contain domestic structures are set apart from suspected ceremonial structures. However, the occasional possible ceremonial structure is seen around these areas as well.

Given the patterns and placement of possible structures within the survey area, it is nearly certain that additional structures exist east, west, and north of the survey area. The only reason why it is not expected to the south is because Second Old River, when it was active, likely destroyed the original southern portion of the site. The linear patterning and overlapping structures strongly suggest Crenshaw was a village, at least at one point in time. There is enough evidence of domestic structures with appropriate patterns that it is considered very unlikely that these structures were limited to Fourche Maline times. Therefore, it is interpreted that Crenshaw was likely a village during Early Caddo times, but this may have continued into Middle Caddo times. Given all of this information and comparisons to other sites in the Caddo Area, Crenshaw appears to be among the heaviest occupied sites in the Caddo Area, if not the heaviest. The most comparable site is likely George C. Davis (Story 1997; Walker 2009) but given that no comparable large scale excavations have taken place at Crenshaw and that much of the Crenshaw site remains untested with geophysical techniques, it likely outpaces the activity documented elsewhere. While this could potentially be due to overinterpretation in this analysis, this is considered unlikely due to the linear and overlapping patterns which strongly reinforce the interpretations. The strong similarity to the George C. Davis site (e.g. Walker 2009:Figure 4.21) also provides additional support for the interpretations related to the number of structures, the overlapping nature of them, and the timing being consistent with the Early Caddo period.

While this study focused on structures, there is some evidence of delineation of space related to burials. Cemeteries 1 and 4 (see Figure 1.1) overlapped with a portion of the North Area near some possible structures. It is important to note that the locations of the cemeteries are estimated (Samuelsen 2009:39-40). Some of the small areas of high magnetism could be related to burials, particularly in the topographically lower areas. There are also some magnetic anomalies consistent with metal in the general area of Cemetery 4 (Appendix F19). Importantly, the geophysical results have been somewhat verified by this previous work which uncovered at least one burned structure in the area where many possible structures have been interpreted based on the gradiometry. A trench was dug 9 m northwest of the Cemetery 4 where burned cane continued in every direction. About 9 meters northwest of the metal anomalies is a linear pattern of high magnetism that cuts through one of the possible structures. This is an apparent verification of the geophysical interpretations in this area which were made prior to rectifying this information.

5.5 Conclusions

Crenshaw's settlement patterning was clearly not a variant of the Terán-Soule model. It had a nucleated settlement pattern at one time. It does not compare well with the Middle to Late Caddo settlement pattern documented at Battle (McKinnon 2013), which only had evidence of small use areas relative to the evidence at Crenshaw. While the presence of ceremonial structures might initially be considered support for the Terán-Soule model, there is simply too much activity for the site to be considered "vacant" or "nearly vacant." Even if the evidence of interpreted domestic structures were excluded, there would have been a significant population at Crenshaw just to maintain the ceremonial activities at the site.

The precise date for when the population dispersed cannot be determined using geophysical techniques alone. However, given the strong evidence of occupation and ceremonialism at the site, it is hypothesized that the Caddo did not disperse from Crenshaw until A.D. 1200. Large-scale articulated burials are less common after that time at Crenshaw (Wood 1963). This would be more consistent with interpretations at some other Caddo sites, like George C. Davis (Early 2004; Girard 2012; Story 1997, 1998). Therefore, the settlement patterns in the Great Bend Region of the Red River during the Early and/or Middle Caddo periods are not well represented by the Terán-Soule model. The settlement patterning at Crenshaw was clearly different than what was documented at Battle. This also implies that the degree of habitation at some mounds sites were greater or lesser during the same time period, suggesting a more complex system than can be described by individual mound sites. It is hypothesized that the Middle Caddo period represented a transition away from the more nucleated settlement pattern of the Early Caddo period, ending up resembling the more dispersed farmstead model of Late Caddo times. This transition seems to have coincided with the adoption of maize (see Chapter 4) and changes in burial patterns to incorporate a more dispersed populace (see Chapter 3). This would explain the increased use of skull and mandible burials as represented in the skull-and-mandible cemetery during this time. However, the site was still clearly occupied by at least a small resident population responsible for the rituals and ceremonies that occurred during the Middle Caddo period.

5.6 Acknowledgements

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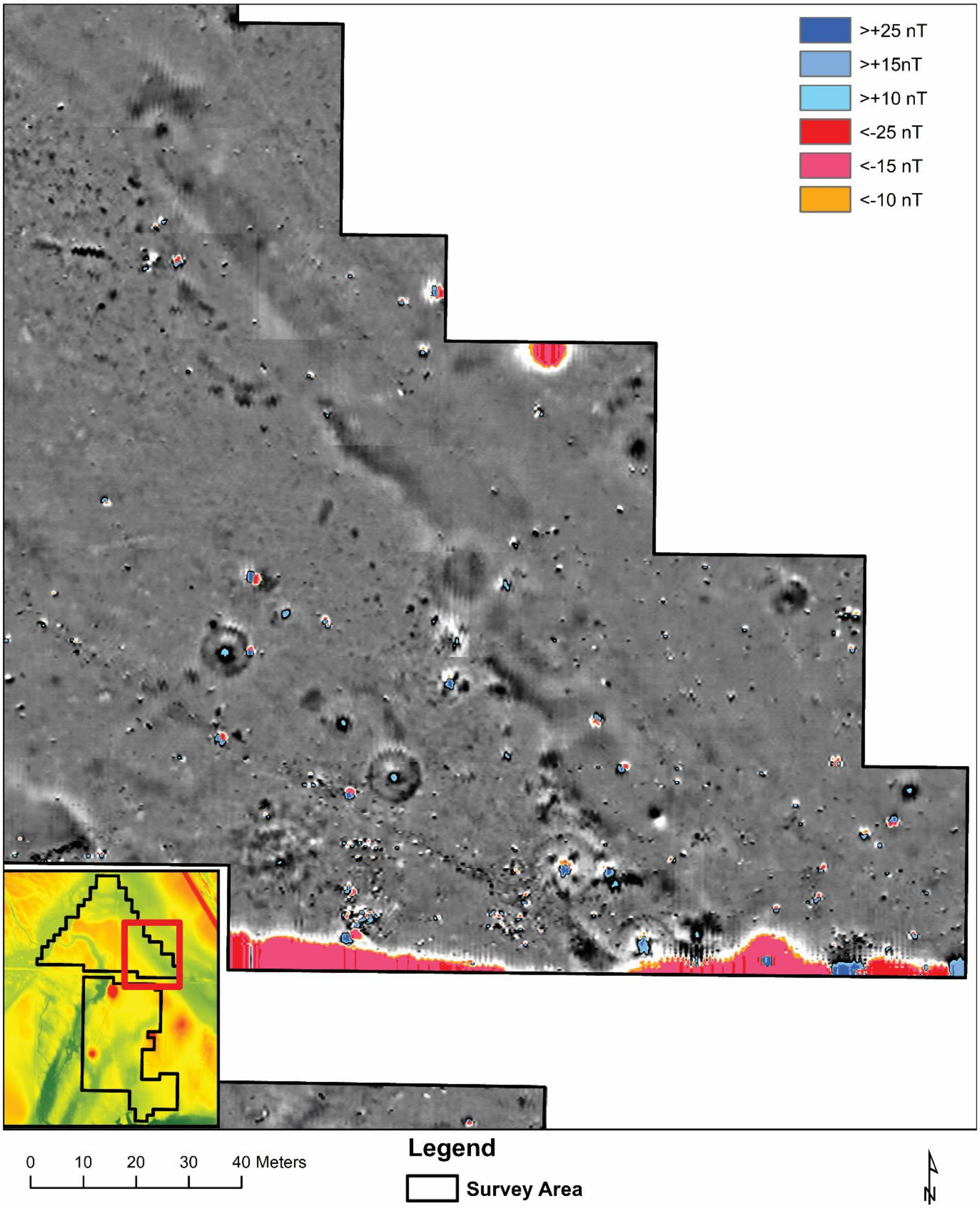
Appendix



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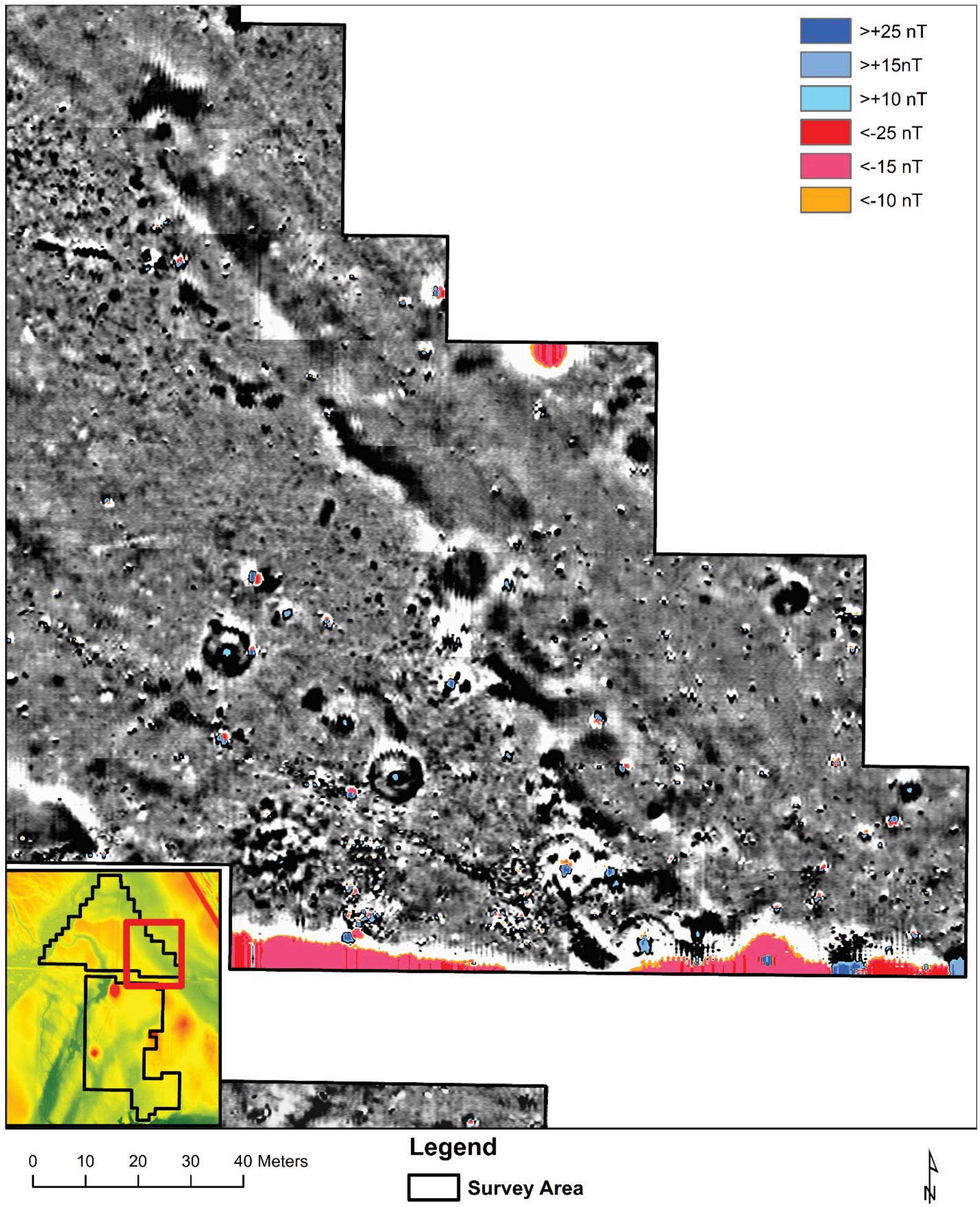

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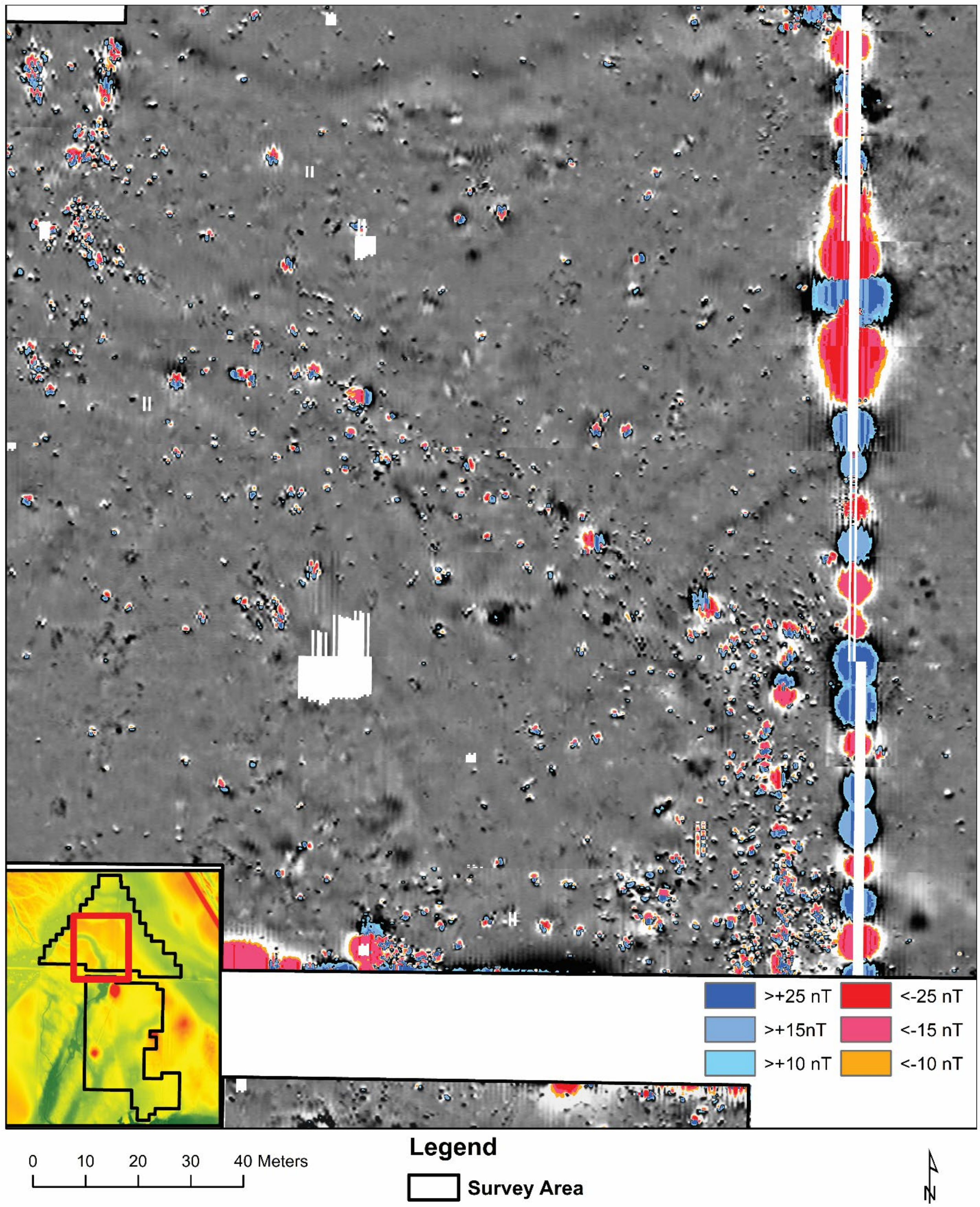

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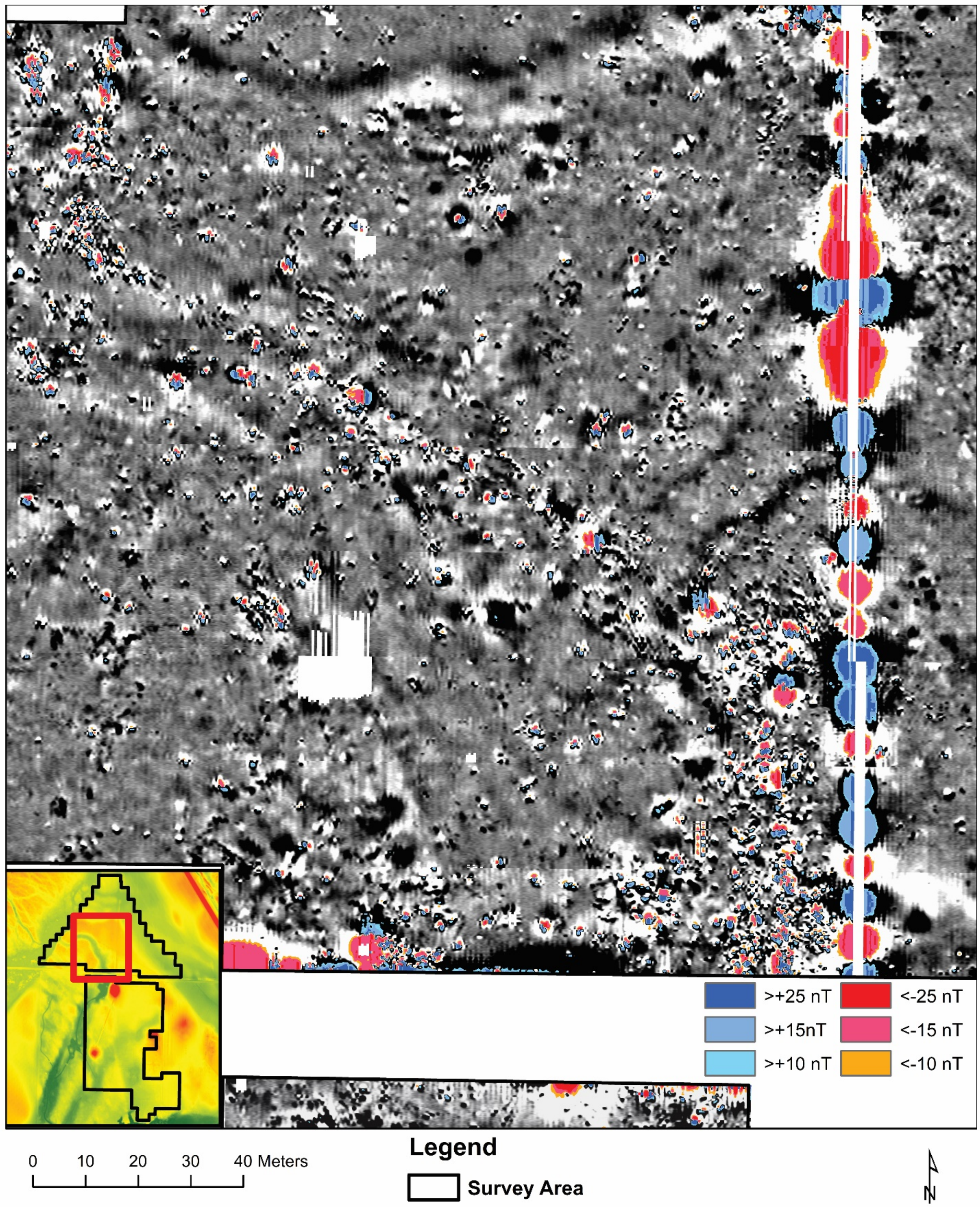

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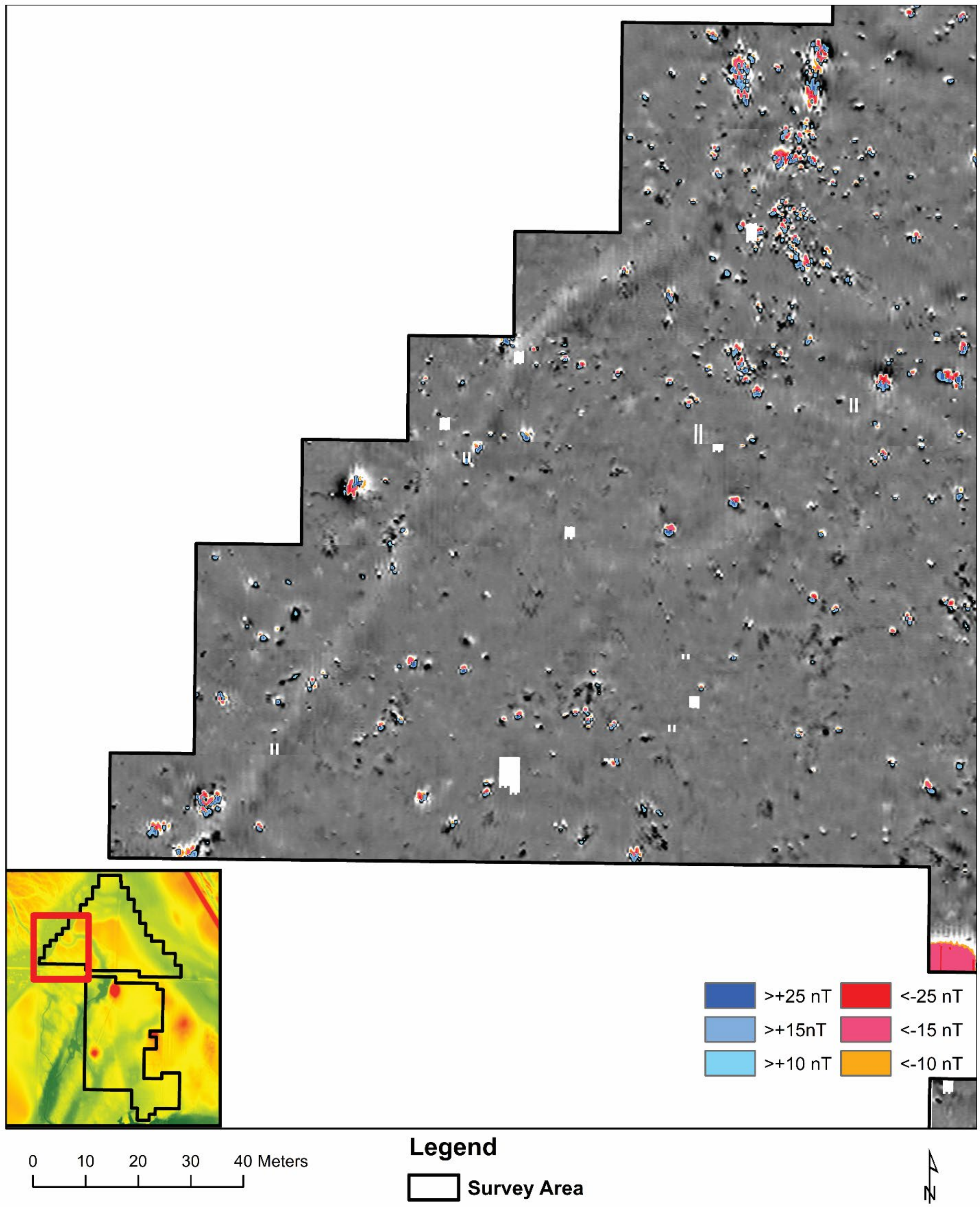

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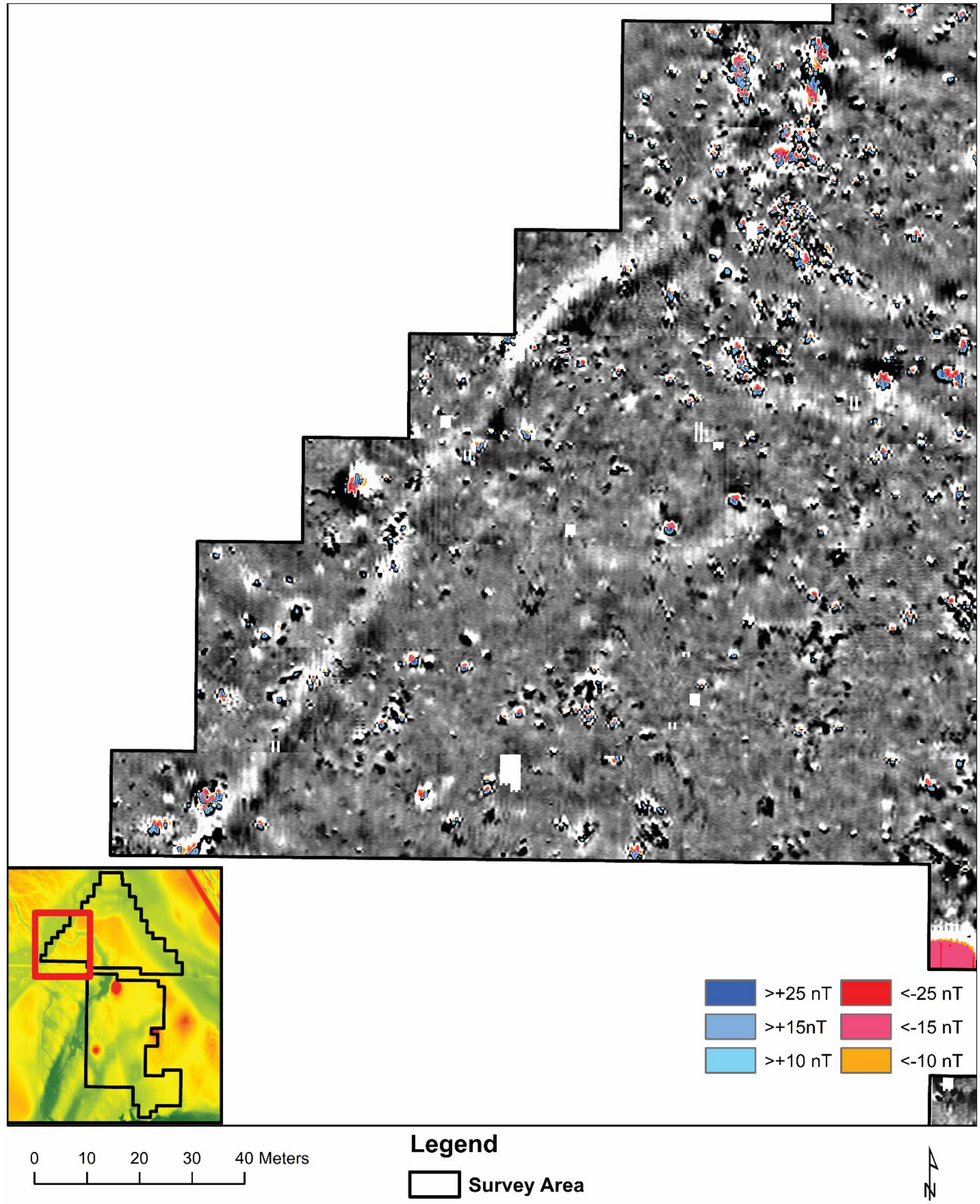

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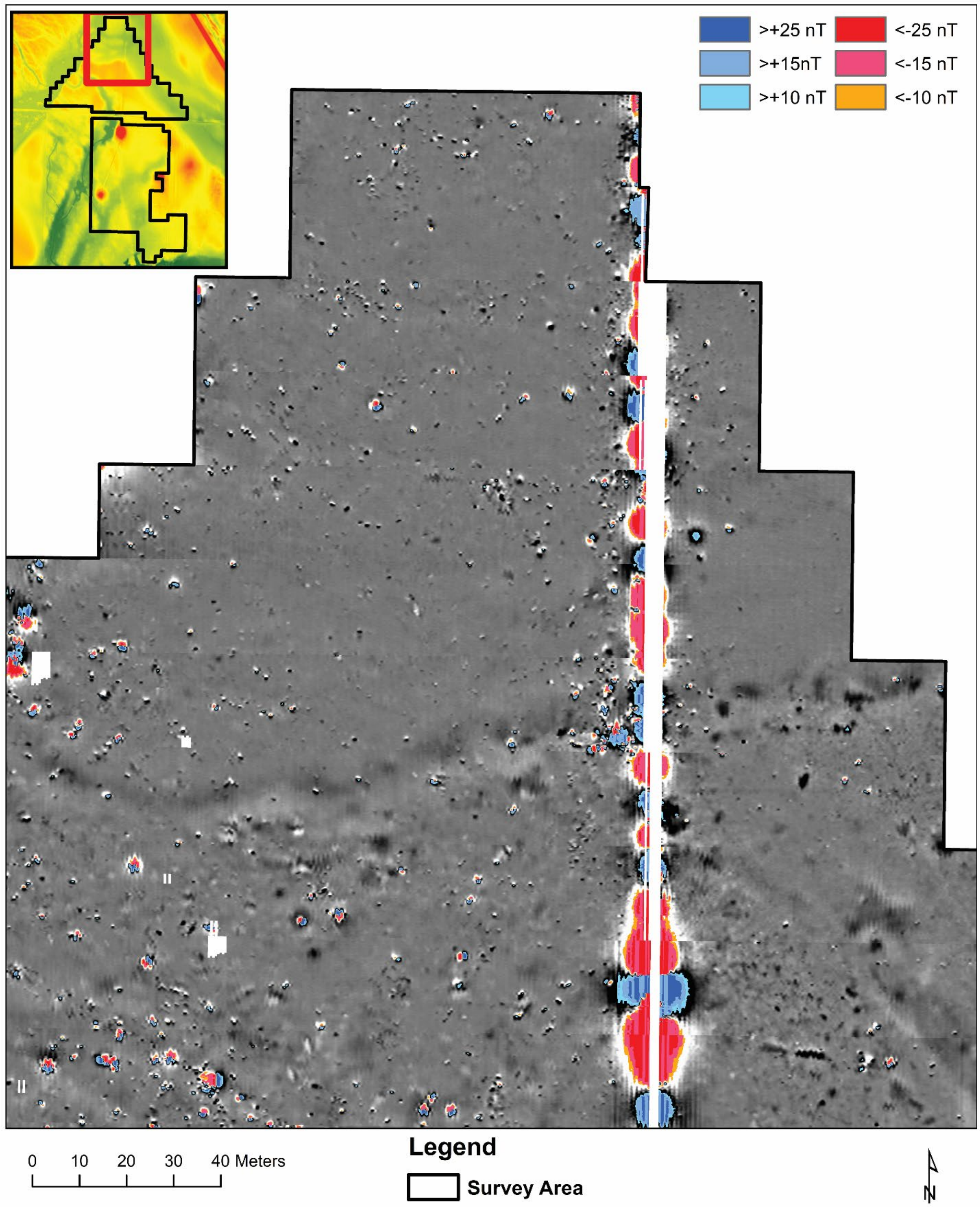

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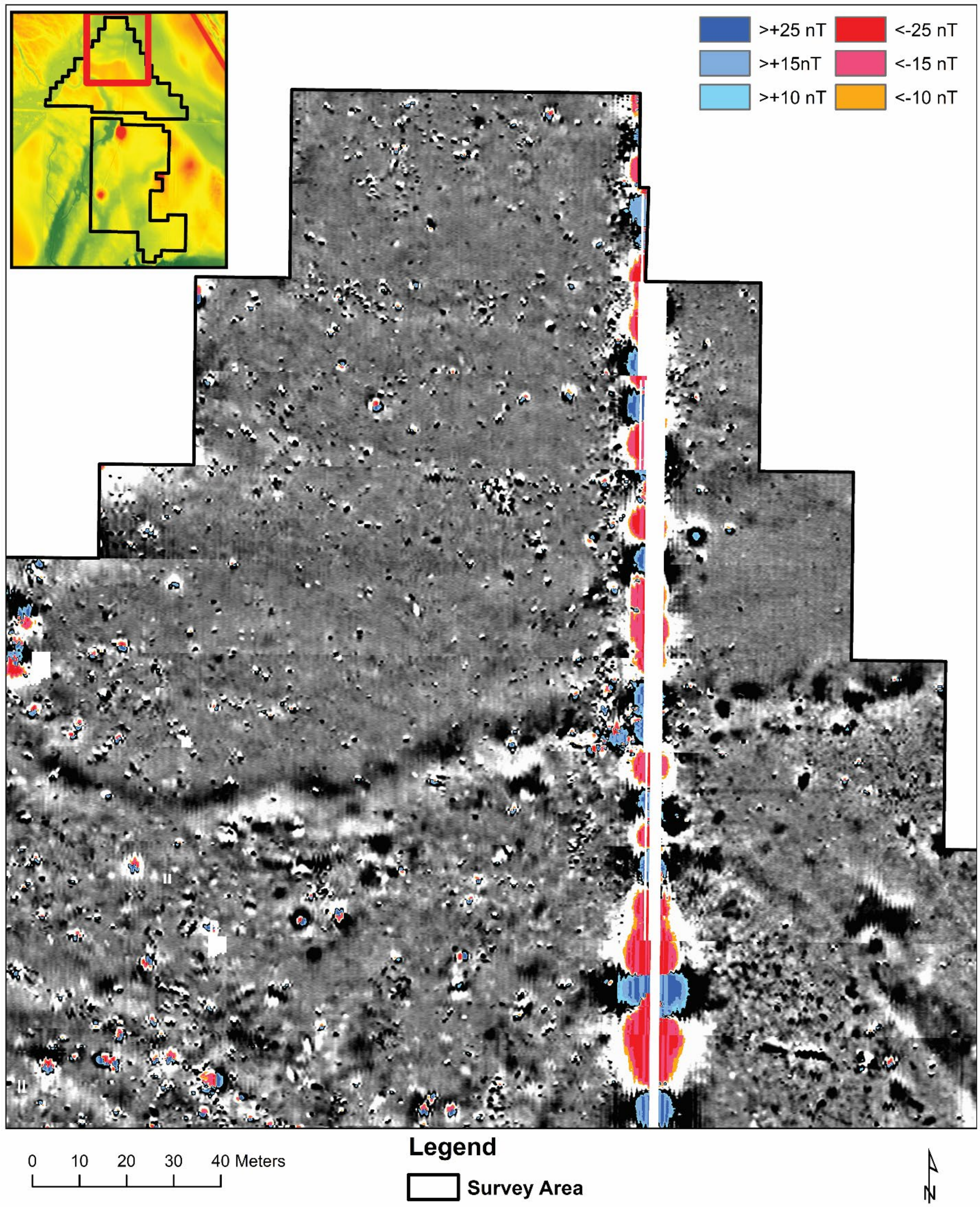

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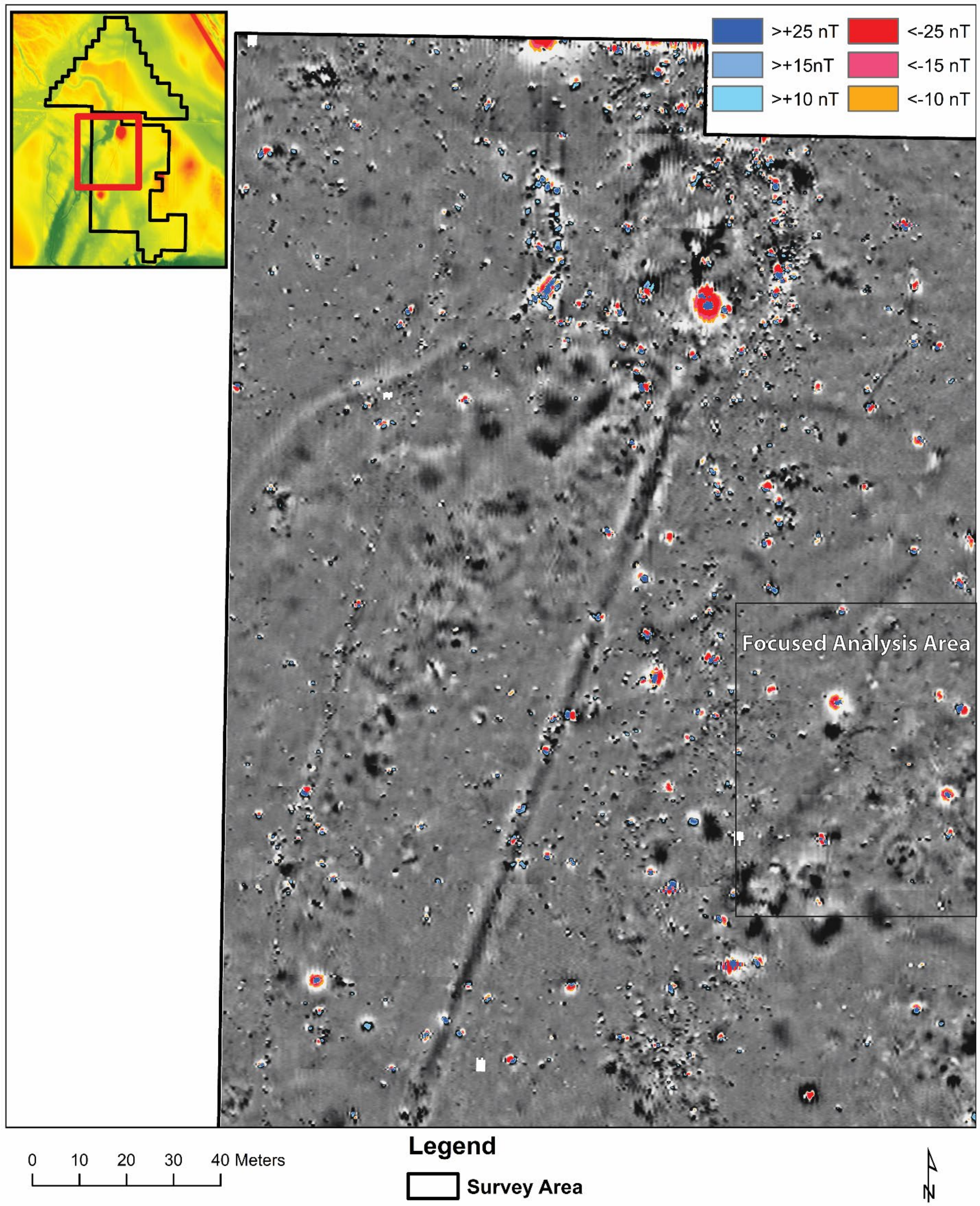

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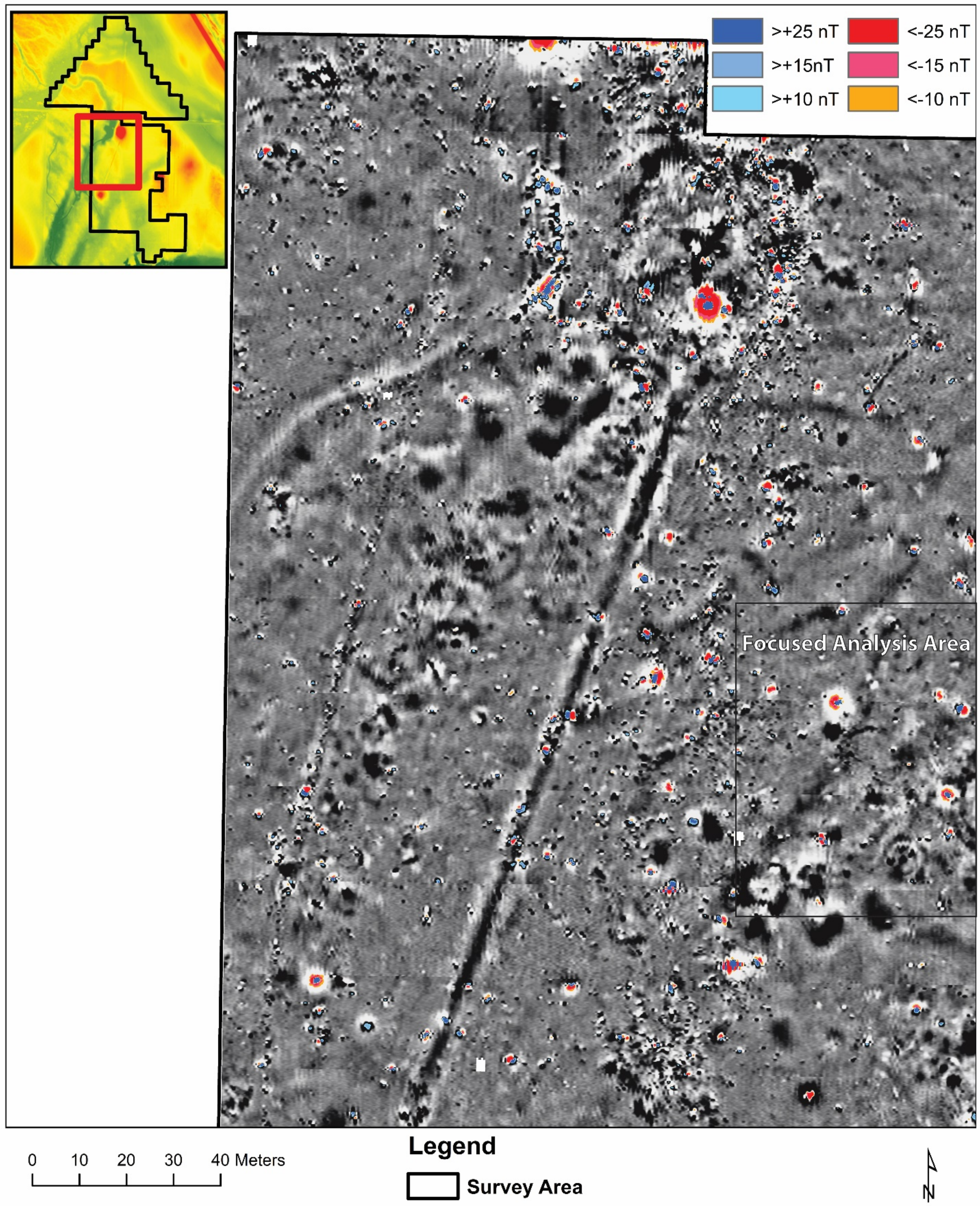

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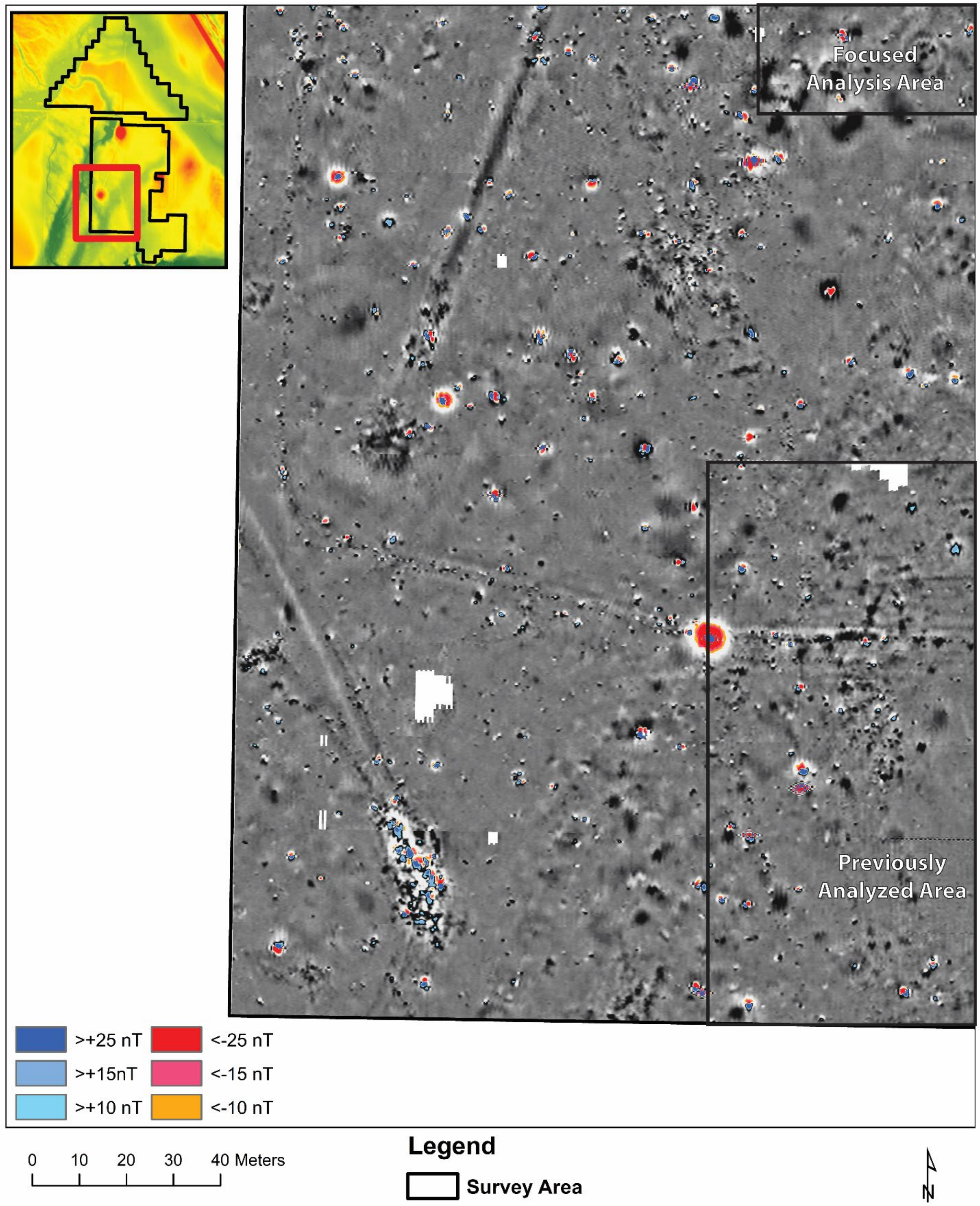

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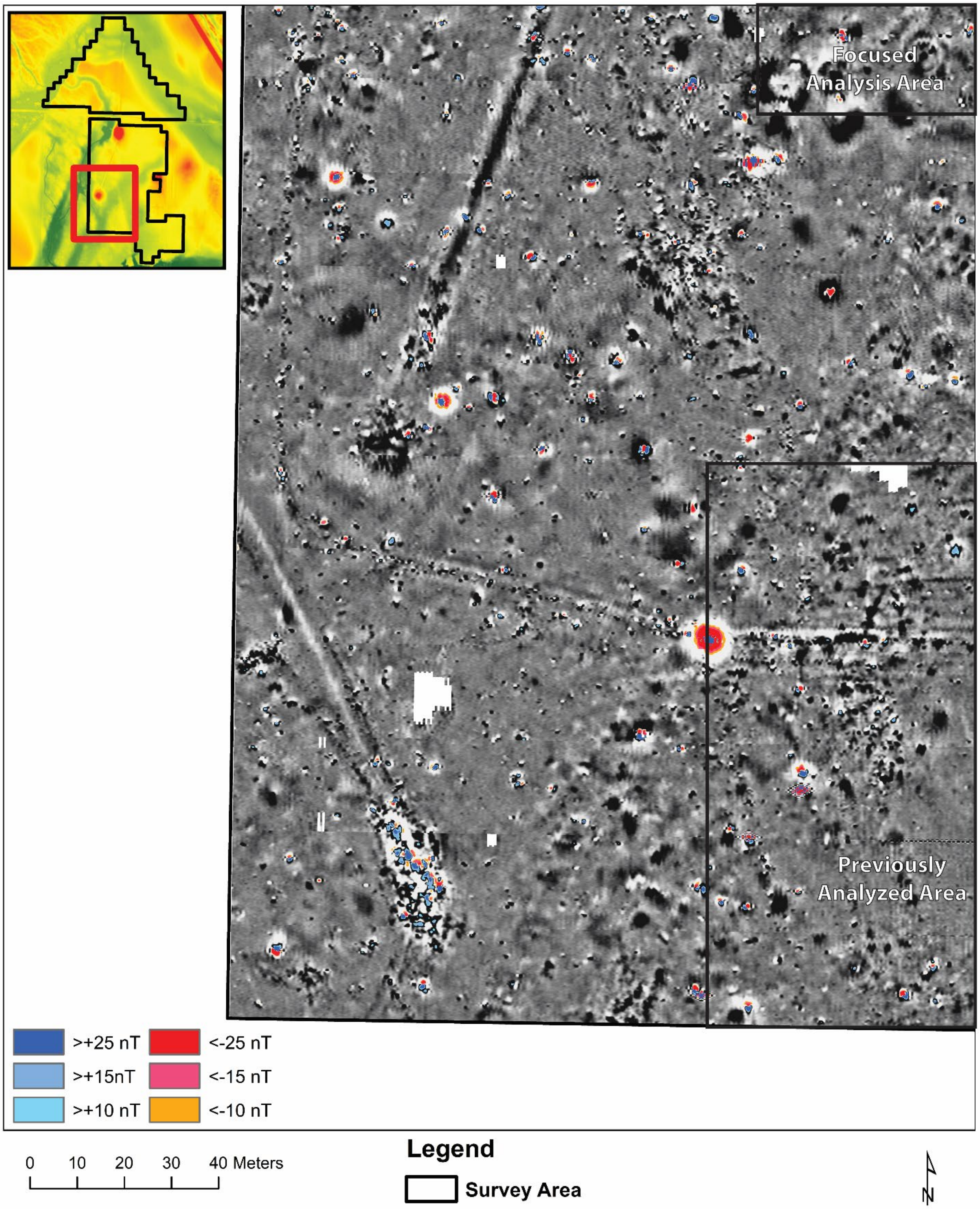

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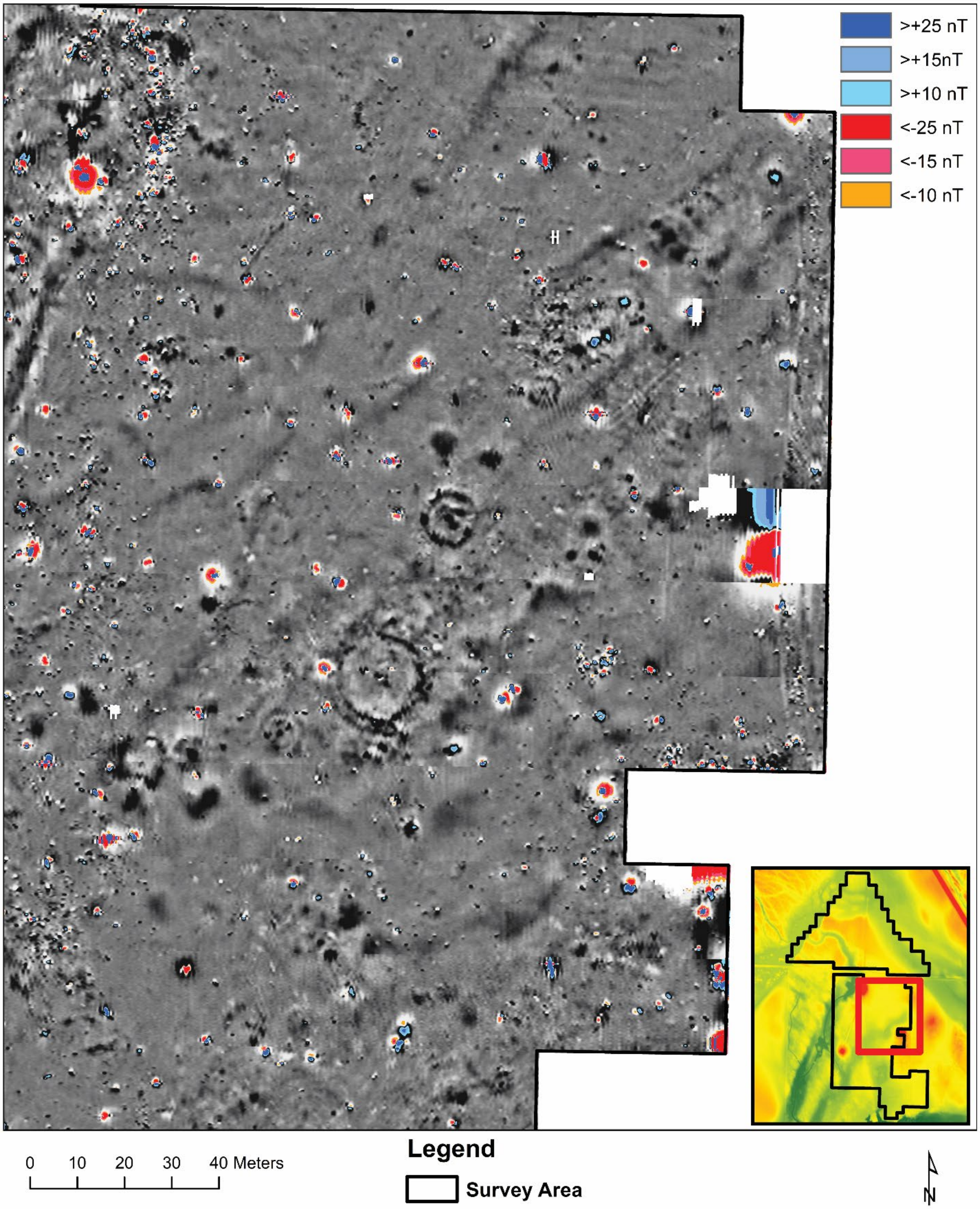

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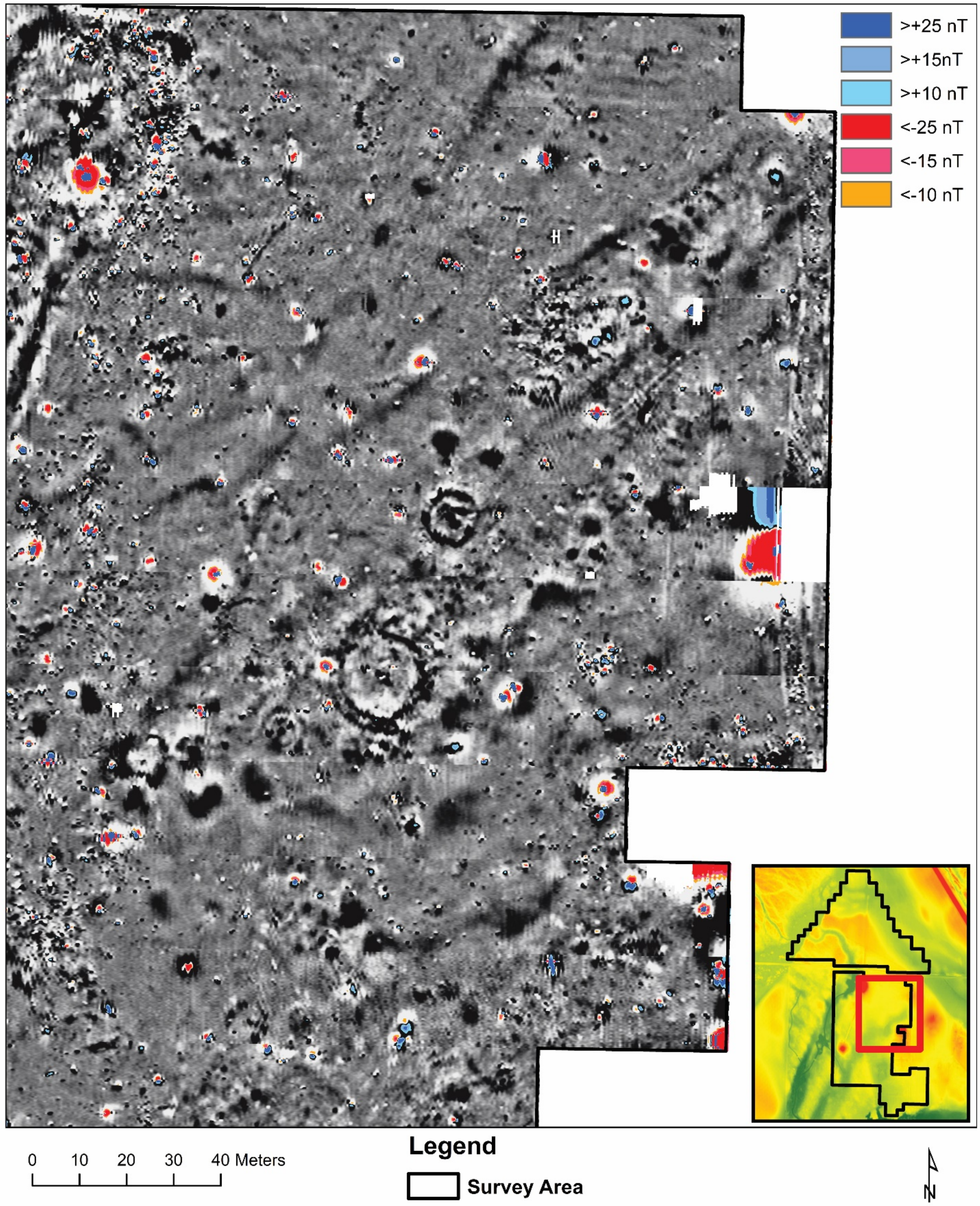

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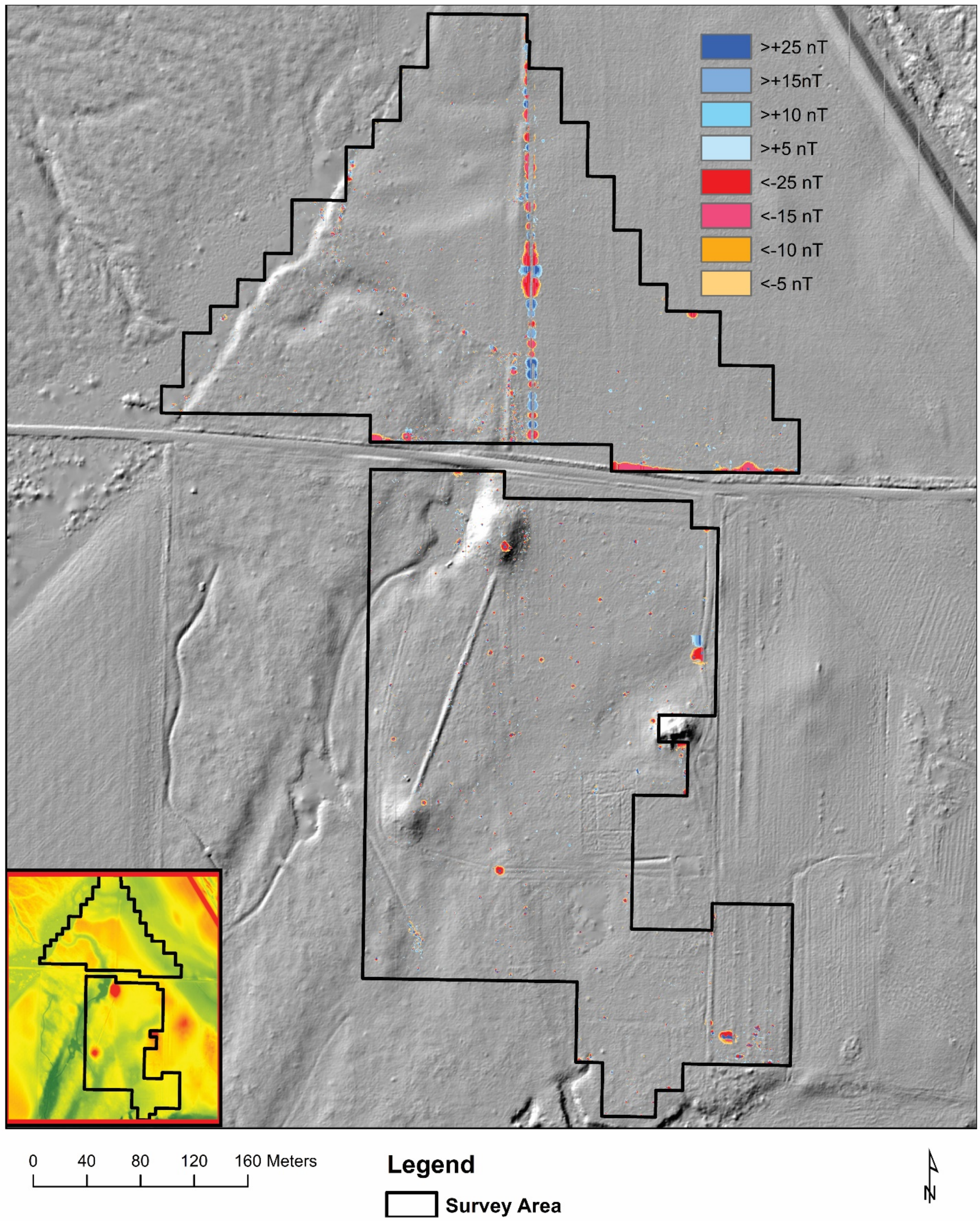
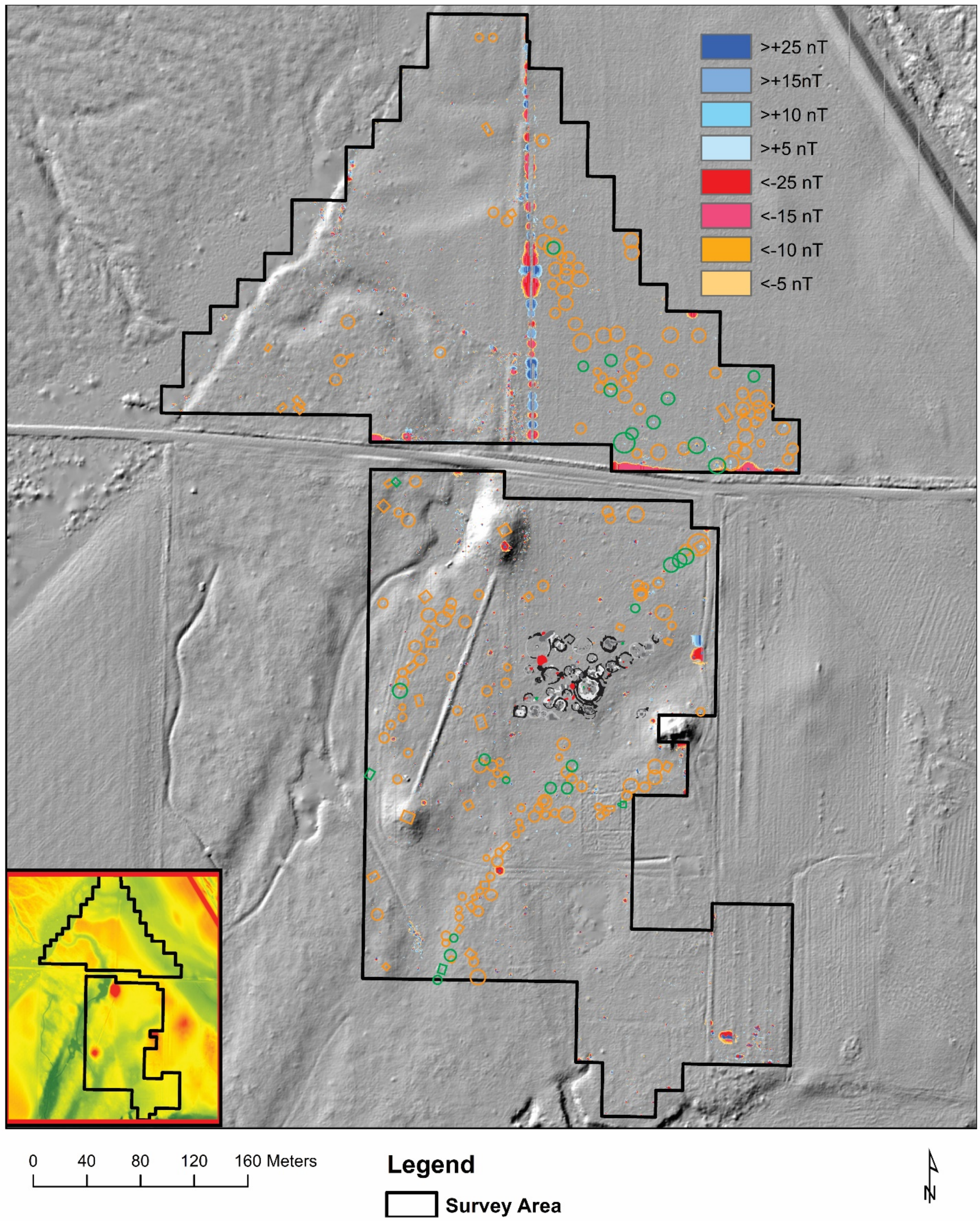
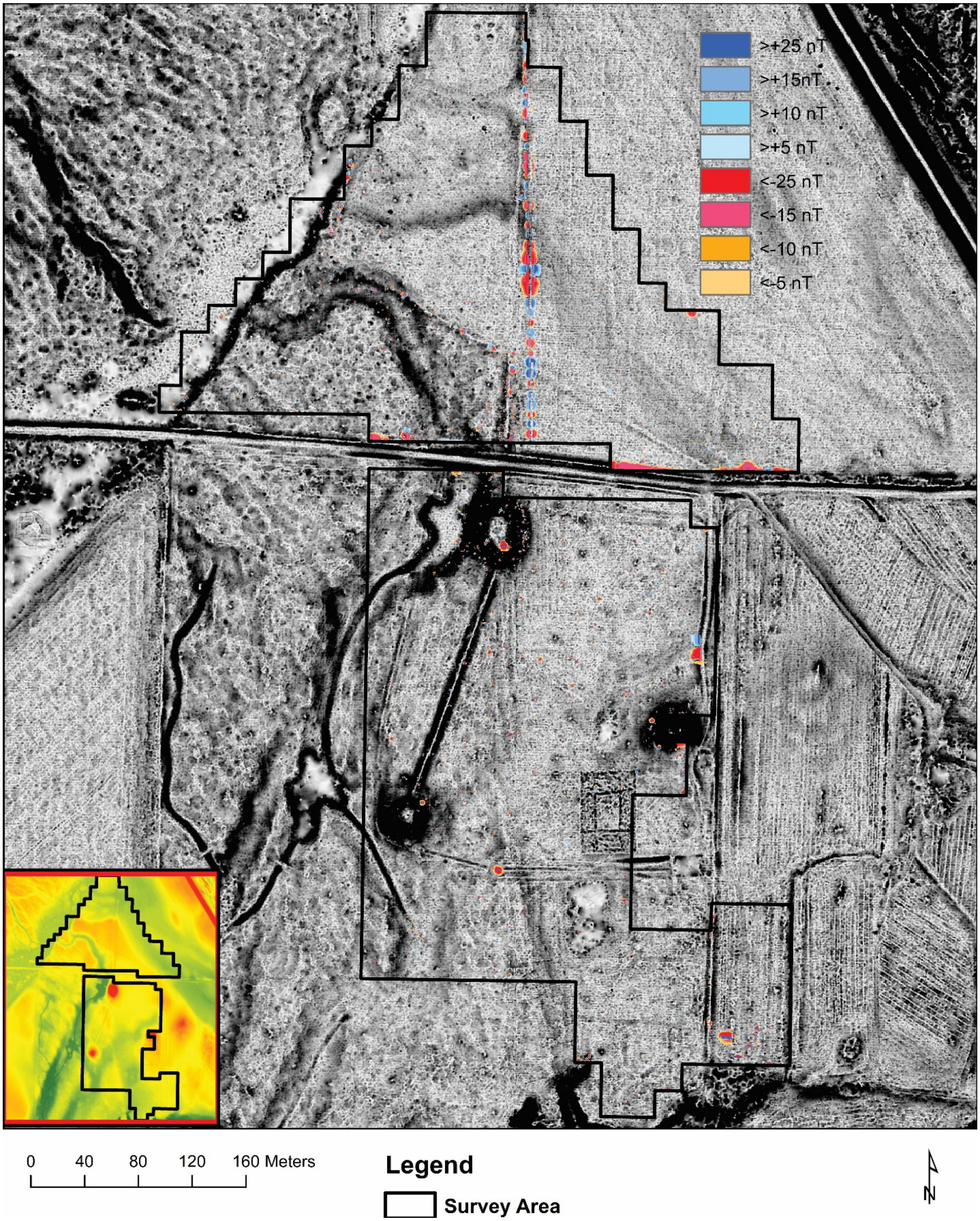


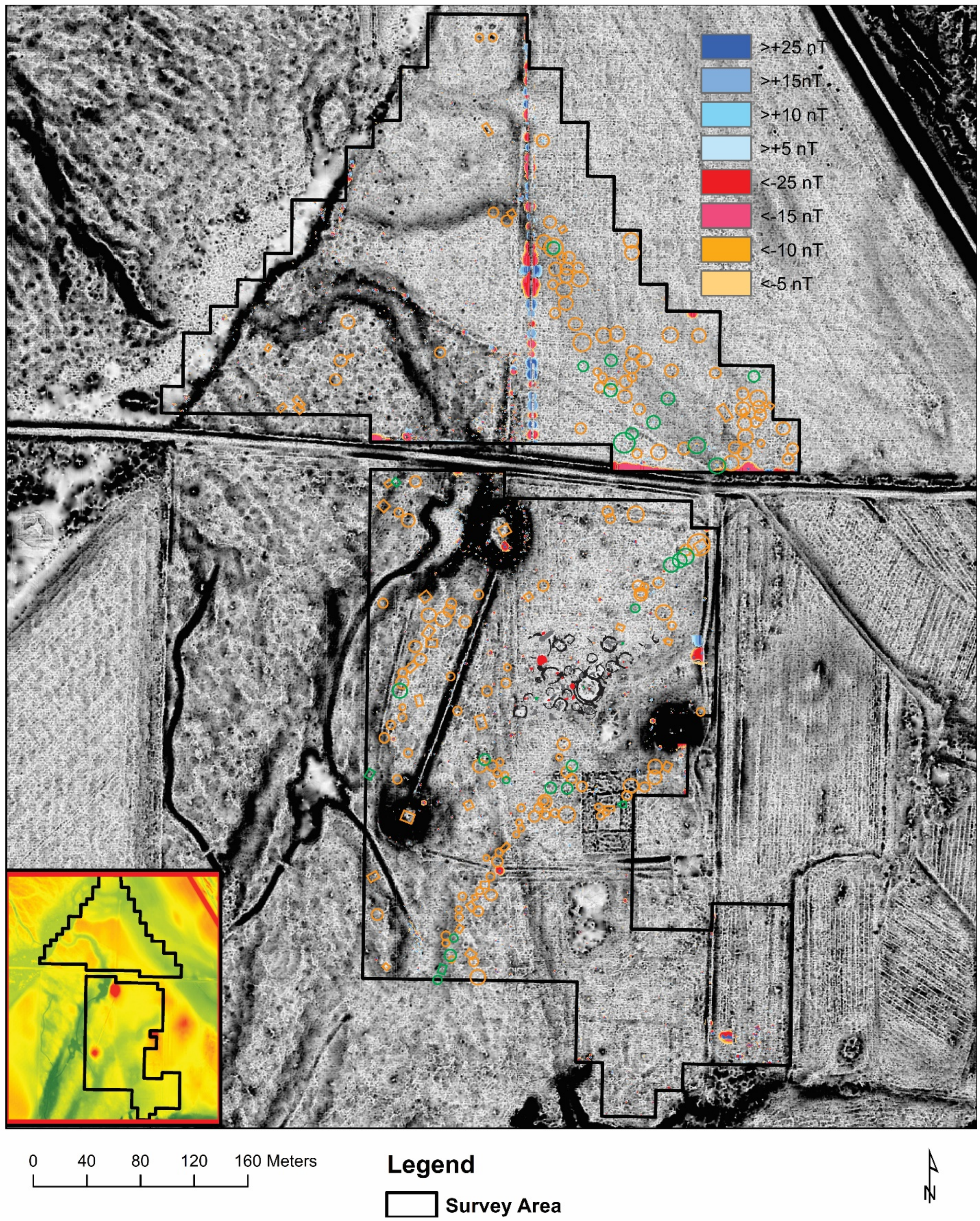
F15 – Unmarked hill shade based on LiDAR data. Many anomalies are related to historic activity (e.g. fences, roads, and agricultural activity) or the presence of trees.



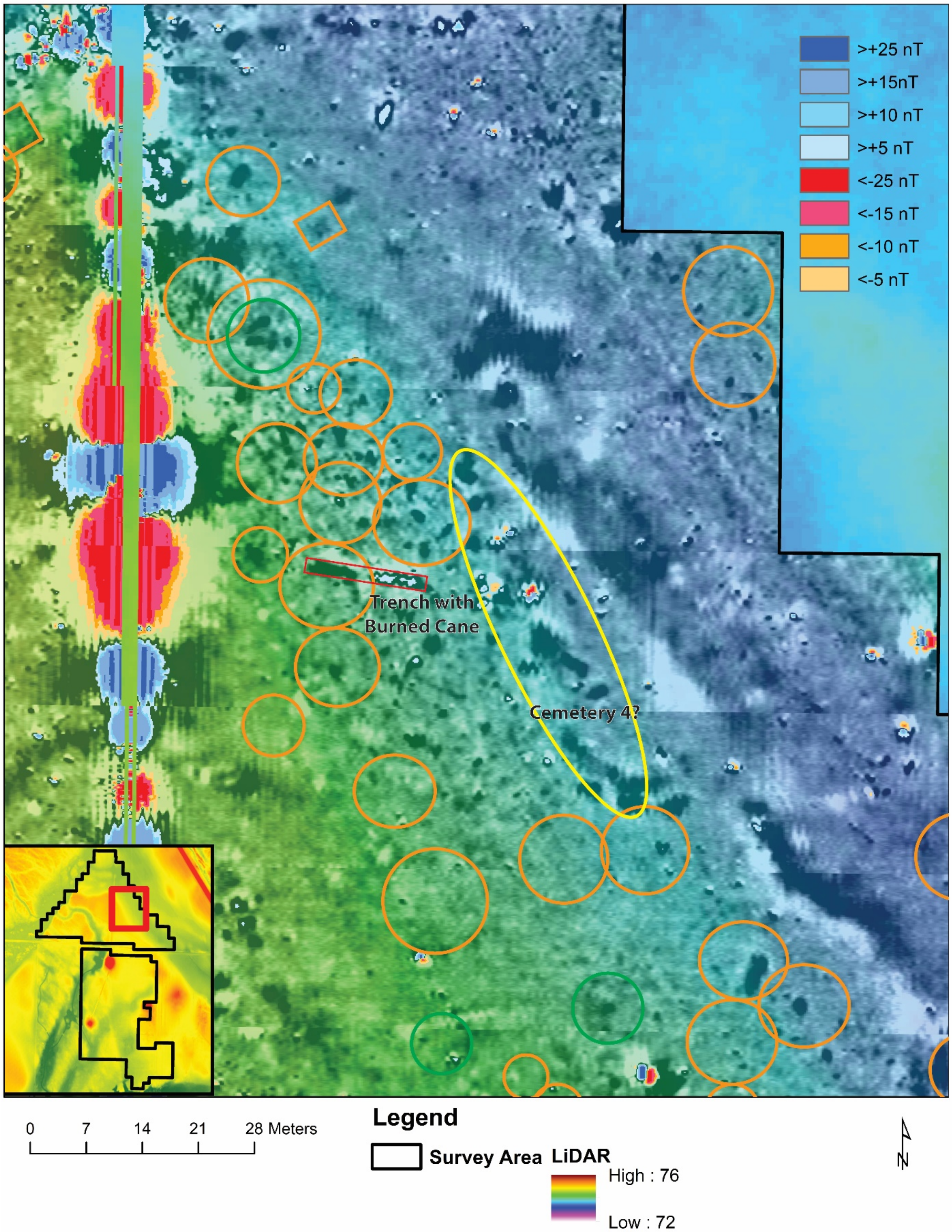
F16 – Marked hill shade based on LiDAR data. The two northmost possible structures are verified by these data. Two additional anomalies appear in the same area. This patterning of four anomalies may decrease the likelihood of these anomalies being ancient as they resemble dug silos.



F17 – Unmarked sky view factor based on LiDAR data. Many anomalies are related to historic activity (e.g. fences, roads, and agricultural activity) or the presence of trees.



F18 – Marked sky view factor based on LiDAR data. The two northmost possible structures are verified by these data. Two additional anomalies appear in the same area.



F19 – Marked area around Cemetery 4. Location of Cemetery 4 is estimated but is consistent with metal and high magnetism anomalies. A trench 9 m NW of the cemetery uncovered burned cane in every direction, consistent with a linear pattern of high magnetism through a possible structure.

Chapter 6: Reconsiderations of Biological Traits at the Crenshaw Site

John R. Samuelsen, Heidi S. Davis, Ashley E. Shidner, Nicole E. Smith-Guzmán, and Teresa V. Wilson

Abstract

Previous research concluded that the skull-and-mandible cemetery at the Crenshaw site reflected foreign victims of warfare based in part on biological traits of the remains. This study reassesses these conclusions by comparing to and documenting similar traits among a larger nearby local population from the Millwood Reservoir area along the Little River. Several issues with the original documentation were discovered during this process, causing some of the remains from Crenshaw to be reassessed for some traits. Because of the concentration on these traits in previous work, traits that were documented included tooth chipping, cranial modification, auditory exostoses, agenesis, supernumerary teeth, and cusps of Carabelli. The comparison to these remains and a broader analysis of the literature showed that the skulls at Crenshaw are consistent with what would be expected for Caddo remains from the Middle Caddo period (A.D. 1200-1500) in southwest Arkansas. In particular, reanalysis of tooth chipping and cranial modeling showed that the skulls had similar amounts and types as local populations. The mandibles were also generally consistent with local populations. However, they had greater amounts of tooth chipping compared to local populations and the skulls. A statistical analysis and a review of photographs suggest that some of this additional chipping may be due to postmortem damage, either prior to burial or afterward. If the difference were due to diet, it could suggest they are foreigners, but could also suggest that those without the proper status for articulated, bundle, or skull burial had a harsher diet or lifestyle.

Keywords: chipping, biological traits, cranial modification, auditory exostoses, warfare

6.1 Introduction

Previous presentations and reports have suggested that the people in the skull-and-mandible cemetery areas at Crenshaw are the result of warfare based in part on biological traits (Akridge 2011, 2014; Burnett 2010; Schambach 2014; Schambach et al. 2011; Zabecki 2011). In the best-case scenario, the skulls and mandibles would have been compared to a large nearby comparison population of known Caddo people. Unfortunately, this was not possible at the time since only a very small population of known Caddo people were excavated from Crenshaw and curated in the University of Arkansas Museum (UAM). Zabecki (2011:46) recognized this and emphasized this potential problem in her conclusions. While summary volumes and articles have been produced which could aid in this regard, they often have limited applicability to the question at hand since they include people from many areas or do not cover the traits in question (Jeter et al. 1989; Rose et al. 1998; Story et al. 1990). The conclusions that the skulls and mandibles are victims of warfare rest partially on interpretations about particular nonmetric dental and cranial traits (Schambach et al. 2011; Zabecki 2011). Zabecki (2011) used traits such as auditory exostoses, tooth chipping, agenesis of the third molar, supernumerary teeth, and cusps of Carabelli to detect differences between skull and mandible clusters while cranial modification played a major role in overall conclusions (Schambach et al. 2011).

Interpretations related to the skull-and-mandible cemetery for each of these traits will be reconsidered. This will be done in conjunction with the existent literature, the analysis of human remains in the Millwood Reservoir, and a limited reanalysis of some of these traits among populations buried at Crenshaw. This is done with recognition of the problems inherent in equating biological characteristics with ethnicity.

At the time the project was executed, the U.S. Army Corps of Engineers maintained ownership of the Millwood Reservoir material and was seeking to repatriate the human remains and associated burial furniture to the Caddo Nation. During this process, John R. Samuelsen of the Arkansas Archeological Survey requested that these remains be studied to record the relevant biological characteristics for comparison to Crenshaw. Permission to study the human remains was received on August 19th, 2013 from the U.S. Army Corps of Engineers through Rodney Parker (District Archeologist & Tribal Liaison of the Little Rock District) and the Caddo Nation's Tribal Historic Preservation Office. Subsequently, a volunteer team of biological anthropology graduate students at the University of Arkansas was assembled under the guidance of Jerry C. Rose to do the documentation and aid in the writing of a report. September and October 2013 were spent organizing the group and outlining the appropriate procedures and data forms. Analysis began in November 2013 and was completed at the end of February 2014. Graduate students working on the project included Alissa M. Bandy, Elizabeth T. Brandt, Heidi S. Davis, Amanda Ederle, Ashley E. Shidner, Nicole E. Smith-Guzmán, and Teresa V. Wilson. Davis, Shidner, Smith-Guzmán, and Wilson contributed to this report.

The analyses followed the *Standards for Data Collection from Human Skeletal Remains* by Buikstra and Ubelaker (1994). During analysis and comparison with Crenshaw, it became clear that there were issues with a few pieces of previously collected data that had a large effect on the outcome of the study. These pieces were looked at in depth to resolve any issues. Finally, all of this information was placed in proper archaeological context, including their relative placement through time to detect potential changes in practices.

6.1.1 The Millwood Reservoir

From 1952 to 1954, Edward H. Moorman, Benton C. Poynor, and Edward B. Jelks of the River Basin Surveys, National Parks Service (NPS), surveyed 66 archaeological sites in the area surrounding the proposed Millwood Reservoir. This was done through a program administered by the NPS, the Smithsonian Institution, the U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation to salvage archaeological and paleontological resources that might be impacted by the building of the Millwood Dam on the Little River. The resulting report (Jelks 1954) outlined what future work should entail to salvage the archaeological resources in the Little River Basin in southwest Arkansas.

The UAM conducted most of the salvage work in the 1960s through a cooperative agreement with the Southeast Region of the NPS. Michael P. Hoffman and James A. Scholtz of the UAM and J. Fred Bohannon of the NPS led excavations on those sites that were recommended by Jelks (1954) for intensive or exploratory excavations. These sites include Mineral Springs (3HO1), Old Martin Place (3LR49/13), Miller's Crossing (3SV10), Hutt (3HE3), Stark (3LR14), Bell (3HO11), White Cliffs (3LR12), Beard Lake (3HE4), and Graves Chapel (3SV15). Hoffman's (1971) dissertation serves as a report for this work, although Bohannon (1973) separately published a report on the excavations at Mineral Springs. Hoffman (1970) also published a report with the results of the Hutt, Stark, and Beard Lake site excavations. These works have served as the large part of our knowledge of the Little River region archaeology and significantly contributed to our understanding of the Great Bend region as well. It is recognized that the Little River region has much in common with the Great Bend region. For example, when describing the Haley phase (A.D. 1200-1500), Early and Schambach (1982:107) describe the two regions together and note that they have great similarity in material culture. Hoffman (1971) also repetitively makes this point about these regions from Late Fourche Maline through at least Middle Caddo times (see also, Schambach 1982:139).

The excavations often included the collection of human remains from burial sites. Since their disinterment in the 1960s, most of the remains have been curated in the UAM. A few remains were transferred to the UAM in 1986 from the Texas Archaeological Research Laboratory (TARL). In the 1990s, the UAM undertook a project to ensure it was complying with the Native American Graves Protection and Repatriation Act (NAGPRA). This resulted in the basic documentation of all human remains in the UAM, including those from the Millwood Reservoir. The resulting data are stored in the UAM's Standard Osteological Database (SOD) for future research purposes.

Noticeably missing was any nonmetric dental and cranial traits data. These can be important for evaluating biological relations between skeletal samples (Buikstra and Ubelaker 1994; Kelley and Larsen 1991; Lee 1999; Schambach et al. 2011; Taylor and Creel 2012). However, the conclusions about genetic dissimilarities from studies using such data have been challenged on the basis that differences in skeletal samples during one time period could simply reflect genetically diverse founding populations (Perttula 2013a). In other words, without well-developed studies of earlier populations, we do not know how genetically diverse we should expect a given population to be. Therefore, if differences are found between groups, it is difficult to know if these are due to differences in ethnicity, recent migrations, or diverse founding populations.

6.2 Methods

Data collection focused on traits previously used to detect differences between the skeletal samples at Crenshaw. These included cranial modification, auditory exostoses, and dental nonmetric traits such as agenesis, supernumerary teeth, cusps of Carabelli, and tooth chipping. Cranial modification is the modification of the shape of the human skull due to pressure during skull growth and development. Auditory exostoses, or "surfer's ear," are boney growths in the ear which can be important for identifying cold water activities, such as fishing (Crowe et al. 2010; Frayer 1988; Jenkins 2013; Kennedy 1986; Okumura et al. 2007). Agenesis is the congenital absence of teeth in some individuals. For example, an adult with agenesis of the first right mandibular molar would only have 31 teeth at full development rather than 32. Supernumerary teeth are teeth that develop in addition to the typical 32. Cusps of Carabelli are extra cusps sometimes found on maxillary molars.

While the degree of tooth wear for this population was originally recorded, it did not discriminate between wear due to chipping or grinding. This is because different types of wear are not recorded during skeletal documentation using the *Standards for Data Collection from Human Skeletal Remains* forms (Buikstra and Ubelaker 1994). Tooth chipping was documented in this project as it was a particularly important trait previously used to discern ethnic differences at Crenshaw (Schambach et al. 2011).

6.3 Results and Discussion

6.3.1 Auditory Exostoses

It is important to note that auditory exostoses and tooth chipping are primarily behavioral in nature. While it could be said that certain people might be biologically predisposed to tooth chipping (wear) or auditory exostoses, the general understanding is that such traits are caused by a combination of environmental factors and activities or practices, not by genetics (Buikstra and Ubelaker 1994:47-55; Crowe et al. 2010; Frayer 1988; Jenkins 2013; Kennedy 1986; Okumura et al. 2007; Smith-Guzmán and Cooke 2019). Unlike genetics, behaviors can change relatively quickly through time. Both Powell (1977) and Zabecki (2011) interpreted auditory exostoses as a genetic marker and made interpretations that one cluster of skulls, the Rayburn Cluster, was foreign in part due to the high frequency of auditory exostoses within the cluster. When it is considered that auditory exostoses are largely behavioral, it could simply indicate that this group represented people with a subsistence strategy more dependent on fishing or some other cold water related activity.

The occurrence of auditory exostoses in the Millwood Reservoir population was documented and showed a lack of evidence for auditory exostoses. Only 15 individuals could be documented for both ears, 10 for one ear, and 36 could not be documented due absence or compacted dirt. Two of the 15 and 1 of the 10 were subadults who would not be expected to develop auditory exostoses. This does suggest that auditory exostoses were not common in the Little River region. However, different people may do more or less fishing or other cold water related activities within the same community. For example, those living along the major rivers might spend much more time fishing than those living further away or in the uplands. Since fishing is not an unexpected activity for the Caddo, the Red River in this area gets cold enough to cause auditory exostoses five to six months of the year, and auditory exostoses are seen at known Caddo or Fourche Maline sites such as Cedar Grove (3LA97) and Jones Mill (Bennett 1986; Rose 1984), they cannot be used as clear evidence that the human remains are foreign to the region. The Rayburn Cluster was not the only cluster to have multiple people with auditory exostoses present. This suggests that multiple clusters had a similar cold-water practice, such as fishing (see Chapter 4). The fact that the vast majority of assessable skulls (>90%) at Crenshaw did not have auditory exostoses (Harvey et al. 2014) is consistent with the populations in the Millwood Reservoir area, Cedar Grove, and Jones Mill when taken as a whole.

6.3.2 Tooth Chipping

Since tooth chipping is a result of practices, such as food preparation, changes in diet or other activities could lead to large differences in the amount of tooth chipping seen among different cultures and through time. Burnett (2010) noted that many teeth in the skulls and mandibles were chipped and suggested that they could represent peoples to the west who practiced hot rock cooking. However, Perttula (2013b) shows that this practice stopped well before Caddo times, ruling out this explanation.

One documented example in southwest Arkansas is from Jones Mill where Bennett (1986:102) reported that chipping was present and hypothesized that this was due to the accidental inclusion of nut hulls in processed food. Similar to the discussion about auditory exostoses, it might be expected that different families or sub-groups might have different diets and result in differences in the appearance of such traits, particularly around A.D. 1300 when maize was being adopted as a staple by the Caddo (Wilson and Perttula 2013).

Schambach et al. (2011) argued the Crenshaw skulls and mandibles have severe amounts of chipping when compared to locals and concluded that they were not Caddo. This was due to two main points. (1) The teeth among the skulls and mandibles were more chipped than the expected local remains, particularly in Mounds C and F. (2) It was believed to be atypical of Caddo populations due to the lack of previous documentation.

Zabecki (2011:46-48) states that the chipping of teeth among the skull-and-mandible deposits was more common than it was for those individuals from Mound F, Cemetery 5, and one portion of Mound C, considered to represent the population. This was interpreted to mean that the populations in the skull-and-mandible deposits were different populations since the diet or tools used in preparing the food must have been different. However, there was an important detail overlooked in these conclusions. The populations from Mound F were 50% subadults while subadults made up only 6% of the skull-and-mandible deposits (Zabecki 2011:Table 3.3). Cemetery 5 had a small sample size, but similarly had a larger sample of subadults at 20%. In general, the proportion of chipped teeth increases with the proportion of adults to subadults. Wilson (1995) has shown that tooth wear increases with age, particularly when comparing adults and subadults (see also, Buikstra and Ubelaker 1994:47). In addition, older individuals are more likely to have antemortem tooth loss, possibly further skewing contexts with high numbers of subadults toward lower chip counts when counted on a per tooth basis. Finally, Zabecki (2011:46) noted that chipping must have been rare in the Caddo area because no one had noted it before. However, the lack of previous identification among a Caddo population may simply be due to the way wear had previously been documented. That is, without specificity as to what type of wear it was (standard forms do not separately document chipping). It should be recognized, though, that it was previously noticed at Jones Mill (Bennett 1986:102).

The Millwood remains provided an opportunity to evaluate the possibility that local Caddo populations have less chipped teeth through the documentation of the nearby Caddo group. While documenting the Millwood remains, one important issue was discovered with the previous documentation at Crenshaw. The previous conclusions that the local Crenshaw population did not have chipped teeth rested heavily on the lack of chipped teeth from Mound C. When the documentation forms for Mound C were reexamined, it became clear that an oversight had occurred. Barbara Farley had created tooth documentation forms for the remains from Mound C but had only documented the tooth she had selected for isotope processing. She generally selected among the most preserved teeth (no chipping). When she did this documentation, she only documented the chipping on that one tooth per individual. When these sheets were later examined for the original project, the rest of the teeth were not analyzed for chipping and, due to this oversight, were all scored as having no chips. Therefore, the teeth from Mound C were redocumented alongside the Millwood remains to make sure the records were accurate. Upon reanalysis, it became clear that Mound C individuals had many chipped teeth, and that this was missed during the original documentation (Appendix T1).

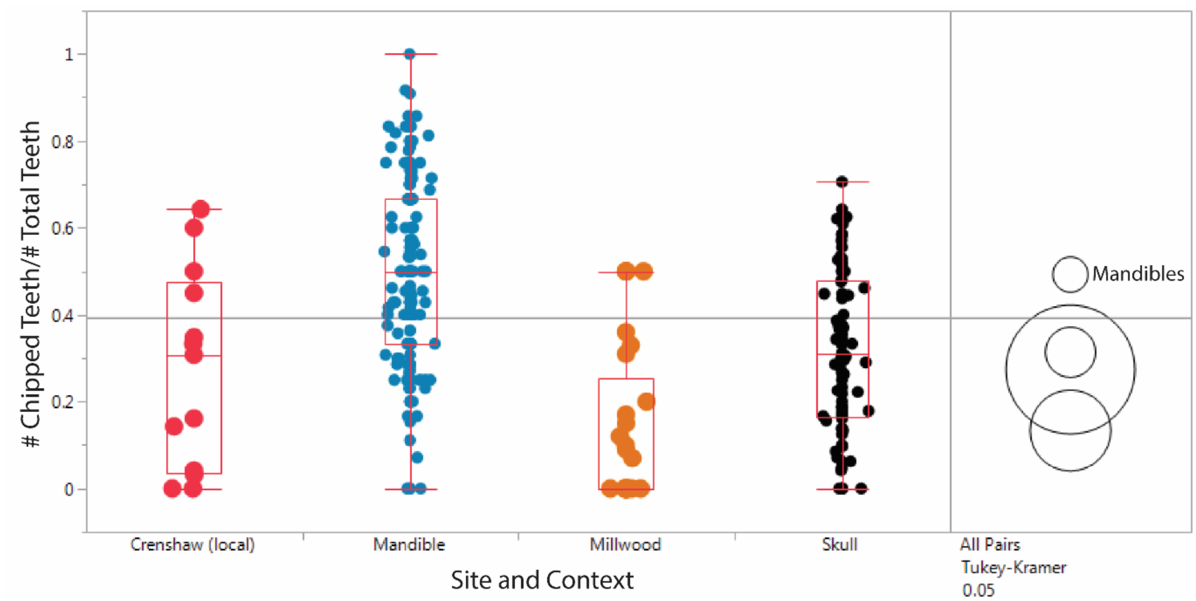


Figure 6.1 – Comparison of ratio of number of chipped teeth to number of total assessable teeth from adult Millwood remains, expected locals at Crenshaw, Crenshaw skulls, and Crenshaw mandibles. The expected locals at Crenshaw are not statistically different from the Crenshaw skulls or the Millwood remains. The Crenshaw mandibles are significantly different from all other groups ($p<0.002$). The two groups that are the most similar are the expected Crenshaw locals and the Crenshaw skulls.

The results of the documentation of the Millwood remains show that chipping was also present among those populations. A few individuals were excluded from analysis due to data problems, such as the lack of documentation about chipping or wear. Individuals had to have at least two teeth present to be included in the analysis. Since adults and subadults should be expected to be different, they were compared separately. For adults, a comparison of expected Crenshaw locals, the Millwood remains, skulls, and mandibles on the basis of the ratio of chipped teeth per total teeth (to account for preservation) showed that the expected locals at Crenshaw and the Millwood Reservoir compared favorably, but the Millwood Reservoir individuals tended to have less chipping (Figure 6.1). This mostly pre-Middle Caddo population (less maize consumption) may have less tooth chipping if the chipping is encouraged by increased caries. Unexpectedly, the skulls were statistically the same as the local Crenshaw group. The only group that was inconsistent with all others was the mandible cluster group, having more chipping on average ($p<0.002$). Given the concerns about two individuals from Mound C (slope) by Schambach et al. (2011), they were not included in the local group in this analysis. If they were, the Crenshaw local population would have even higher chipping ratios. For subadults, the results were essentially the same (Figure 6.2). The local Crenshaw group, the Millwood Reservoir group, and the skull cluster group were statistically the same. The mandible clusters were significantly different from the other groups, having greater amounts of chipping ($p<0.0001$).

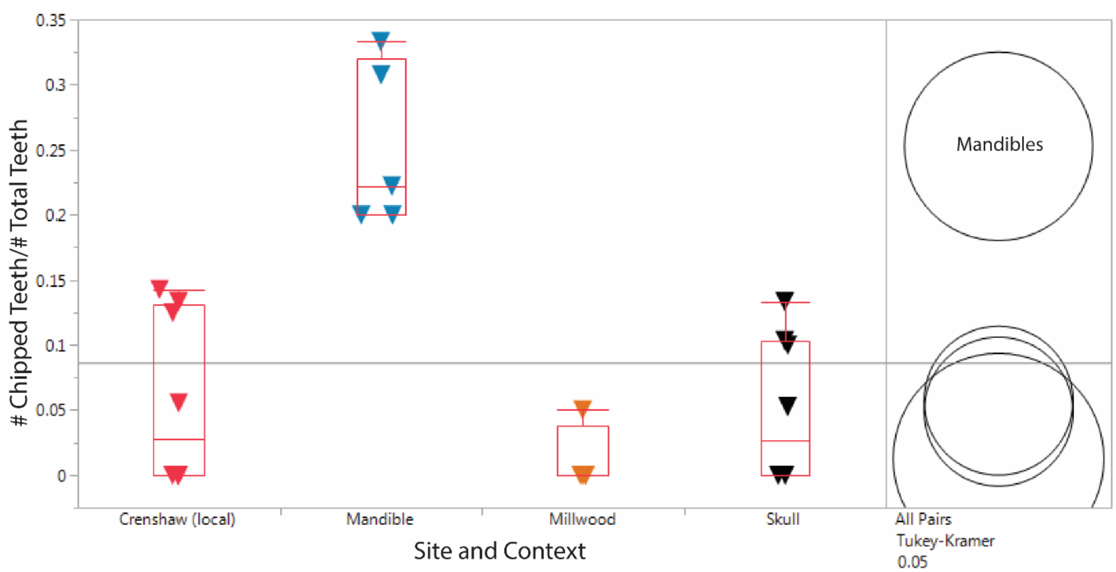


Figure 6.1 – Comparison of ratio of number of chipped teeth to number of total assessable teeth from subadult Millwood remains, expected locals at Crenshaw, Crenshaw skulls, and Crenshaw mandibles. Again, the expected locals at Crenshaw are not statistically different from the Crenshaw skulls or the Millwood remains. The Crenshaw mandibles are significantly different from all other groups ($p<0.0001$). The two groups that are the most similar are the expected Crenshaw locals and the Crenshaw skulls.

This indicates that the only group that has chipping inconsistent with the known locals is the mandible cluster group. If we assume that this is due to a different diet (meaning a different population), then that means that the mandibles are a different population than the skulls and the skulls might be locals. However, the lead and strontium isotope data (see Chapter 3) show that the skulls and mandibles have nearly the exact same range of ratios. This suggests that they were coming from the same region or regions, making this explanation unlikely. Therefore, alternative explanations for the highly chipped teeth among the mandible clusters should be examined.

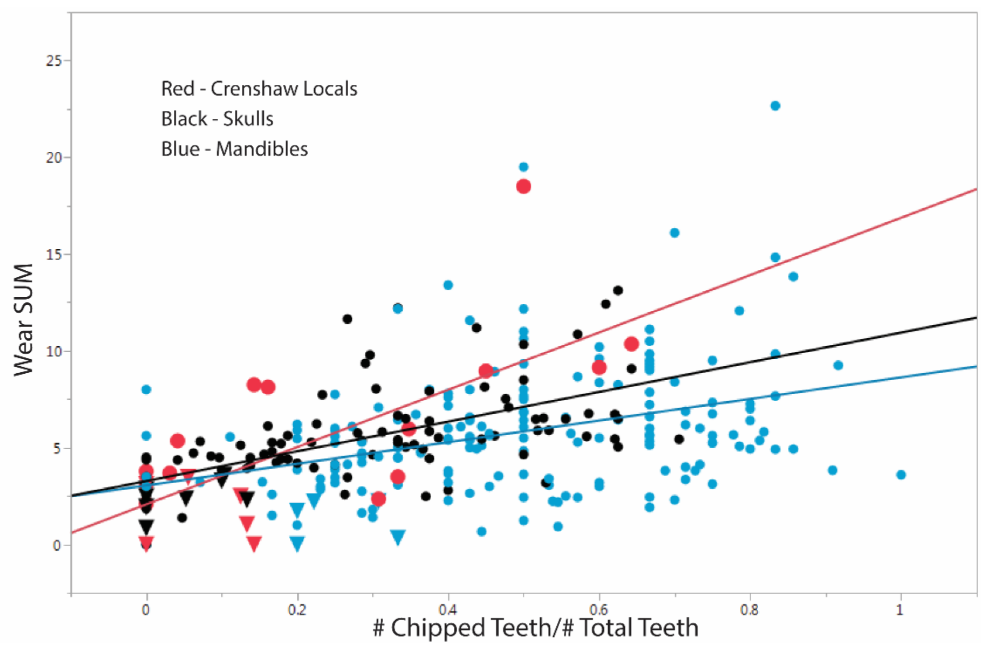


Figure 6.3 – Comparison of wear sum scores (i.e. age) and tooth chipping. Wear sum scores were created by summing all wear scores from all teeth and dividing by the total number of teeth. The correlation between wear and chipping is strongest among the locals (R=0.7), less strong among the skulls (R=0.59), and very weak among the mandibles (R=0.36) relative to the other two groups.

To help evaluate this difference, the chipping data was compared with wear scores to determine if the chipping correlated with wear (i.e. age) as would be expected if the chipping was due to diet. Regression lines show that each group correlates chipping and wear differently (Figure 6.3). The correlation between wear and chipping is strongest among the locals (R=0.7), less strong among the skulls (R=0.59), and very weak among the mandibles (R=0.36) relative to the other two groups. There are two potential explanations for this. (1) They represent different groups of people with different diets, lessening the strength of the correlation. (2) The chipping is due to a postmortem process. The first explanation is unlikely due to the consistent severity of chipping and similarity of chipping among subadults. This does not look like a bunch of different populations mixing together. Therefore, this provides evidence that the additional chipping of the teeth in the mandible clusters may not be due to age or diet but may be caused by postmortem damage as originally suggested by Zabecki (2011:48). This would explain why there is such a large difference between the skulls and mandibles and explain why even subadults among the mandibles have relatively high rates of chipping. There are multiple potential explanations for this. Perhaps the separation of the mandible from the cranium could cause damage to the teeth. If the mandibles were kept for a long period of time, carried around, and used in rituals, it might lead to postmortem chipping and grinding.

It is notable that there are 29 skull clusters and 8 mandible clusters. Despite this, most people are represented by their mandibles. The large number of mandibles collected and the clustering of them together suggests that the mandibles were collected over a large area (see also, Samuelsen 2016) and may have been kept together for some time before they were finally deposited. It is possible that they were placed together in a bag which may have been carried over long distances so the mandibles could be collected. In such a situation, the mandibles would be constantly hitting and grinding against each other as they were transported. This could potentially cause postmortem damage of the teeth that would not be reflected in other remains. There are also a variety of potential ceremonies or rituals that could cause postmortem damage to the teeth.

Some photographs of the West Skull Area (WSA) Cluster 2 mandibles were evaluated and this revealed a large amount of evidence of postmortem damage to the teeth. Although this was not a complete reanalysis, much of the chipping was due to this postmortem damage. Some chipping was due to carious lesions weakening enamel. Some appeared to be typical antemortem chipping. Therefore, the differences between the mandibles and other remains could be due, in part, to the postmortem damage. This, combined with the lack of a correlation between the chipping and wear (i.e. age), suggests that the differences in chipping may not be due to differences in diet. The chipping may be exacerbated by damage to the teeth prior to deposition, during excavation, or during handling. In any case, they would be much more exposed to potential damage compared to skulls, which would have provided better protection for the teeth.

Regardless, the evidence presented here suggests that the skulls and the expected locals at Crenshaw had similar amounts of chipping present when adults and subadults are compared separately. The mandibles are different, but the differences may be due to postmortem damage. Even if the chipping were antemortem and a different diet were the cause of the additional chipping in the mandibles, this could represent foreigners, but could also reflect a harsher diet or lifestyle for those without the status or family connections to receive a skull, bundle, or articulated burial.

6.3.3 Agenesis, Supernumerary Teeth, and Cusps of Carabelli

In contrast, dental nonmetric traits such as agenesis, supernumerary teeth, and cusps of Carabelli all have evidence of a direct genetic link (Khambete and Kumar 2012; Kraus 1951; Goose and Lee 1971; Mostowska et al. 2003; Vastardis 2000; Vieira et al. 2004). It is also important to note that genetic traits can be most strongly represented in familial heredity. This means that differences between two small subgroups, such as two skull clusters, could just as easily be explained by the two groups being different families as it could be explained by them being different populations. For example, Powell (1977) and Zabecki (2011) both make note of the high degree of agenesis (37.5%) among the Rayburn Cluster and compare that to the lower overall frequency (5%) among the Caddo as a whole (see Rose et al. 1998). This can be variable, though, as none of the Millwood Reservoir individuals had evidence of agenesis. The fact that agenesis is so common in the Rayburn Cluster is most suggestive that they are part of a family unit. Showing that agenesis is not as common for other clusters or the Caddo as a whole is an important point. However, if these clusters represent family units, it should be expected that their biological traits will most closely match within clusters. The presence of multiple instances of dental nonmetric traits such as these can be most clearly seen in family units when it is relatively rare in the population as a whole (Khambete and Kumar 2012; Mostowska et al. 2003). Therefore, it is dangerous to compare such a small sample of a potential family to the population as a whole to make conclusions about ethnicity. Zabecki (2011:48) alluded to this potential problem in her comparisons.

Khambete and Kumar (2012) clearly document how familial heredity is reflected in high rates of supernumerary teeth. In their study, they found that supernumerary teeth were twice as likely to appear in men as in women and cases with multiple supernumerary teeth are most likely due to genetic factors. Importantly, they note that in one population between 90% and 98% of supernumerary teeth occurred in the maxilla, complicating comparisons using this trait when only mandibles are present. Similarly, Nanda (1951) recognized differences between the rate of maxillary and mandibular agenesis of the third molar. Buikstra and Ubelaker (1994:85) note that such correlations can be population dependent, further complicating analyses. This suggests that sex, familial heredity, and differences between maxilla and mandibular human remains could all be important variables to consider for some traits. In other words, comparisons between people using such traits are complex and multivariate. Therefore, comparisons between two groups, such as skulls and mandibles, need to account for the possibility that some of these traits may be more likely to appear in skulls than mandibles if the trait tends to appear in the maxilla. Also, when differences between two groups are seen, other variables, such as sex, need to be considered as potential sources of these differences.

Interestingly, 25% of the eight skulls from the Rayburn Cluster had cusps of Carabelli. This matches the rest of the 97 skulls with observable maxilla dentition, which had 24% with a cusp of Carabelli present (Zabeck 2011:44-45). It is just as important to highlight where the groups are similar as it is to highlight where they are different, as this could be seen as evidence that they have similar genetic backgrounds. Zabecki (2011:45) highlighted the fact that no dental genetic markers, such as supernumerary teeth, could be singled out to show a genetic difference between the clusters. While Zabecki (2011:44) noted a low number of supernumerary teeth among all populations at Crenshaw (about 1%), it is worth noting that they may be much more likely to appear in maxilla than mandibles (Khambete and Kumar 2012), but is population dependent. Since the vast majority of the individuals are only represented by their mandibles, this could skew the results towards lower representations of supernumerary teeth. However, it is worth noting that three of the four examples of supernumerary teeth at Crenshaw were found in mandibles (Zabecki et al. 2011). The other example is not noted as to whether it was maxillary or mandibular. Rose et al. (1998:Table 6-1) showed that the number of supernumerary teeth among the Caddo varies wildly from drainage to drainage. The Ouachita drainage (8.1%) seems to have greater numbers of supernumerary teeth than the Red River area (4.2%), which is higher than the Arkansas drainage (1.9%) and Spiro area (1.8%). Since supernumerary teeth are so rare, it is unclear if these are large enough sample sizes to be representative of these regions. Additionally, it is not stated which sites are used to make up these totals. So, it is unclear what portion of the Red River area is made up of sites from communities in east Texas and Oklahoma or even Crenshaw itself. Only one individual in the Millwood Reservoir area had a possible supernumerary tooth, suggesting the low numbers present among the Crenshaw skulls and mandibles are consistent with local populations.

6.3.4 Cranial Modification

Like auditory exostoses and tooth chipping, cranial modification is largely the result of behavior, not genetics. It is also important to note that cranial modification is generally done intentionally. The exception is occipital flattening, or cradle boarding, which can be a side effect of babies frequently lying on hard, flat surfaces. The general lack of cranial modification among the skulls at Crenshaw was cited by Schambach et al. (2011:69-70) as an indicator that these people were not Caddo. Specifically, they suggested they were not Caddo due to the lack of cranial modification among the vast majority of the skulls and the presence of occipital flattening among those that did have cranial modification. They cited Derrick and Wilson (1997) which noted high amounts of cranial modification during the Middle Caddo period in east Texas, the same time that the skull-and-mandible cemetery was created. However, this was complicated by several factors. First, most people during the Early Caddo period had no cranial modification in East Texas and it is uncertain when within in the Middle Caddo period such a change to higher rates of cranial modification took place.

Second, the large degree of cranial modification from the Middle Caddo period in that dataset was derived almost entirely from two sites on the western edge of the Caddo area, Sanders (41LR2) and Womack (41LR1) (see Derrick and Wilson 1997). The suggestion that the

Great Bend region Caddo should have similar rates and types of cranial modification as people much further up the Red River in east Texas is unsupported. Derrick and Wilson (1997:141-142) themselves caution against making the conclusion that these two sites on the western frontier of the Caddo area are a representative sample for the Middle Caddo period. Third, Derrick and Wilson's (1997:Table 1) data suggest a fair amount of intraregional variation in the types of cranial modification present. Specifically, all five types of cranial modification as well as the absence of cranial modification are shown to be present in the Red River drainage. It is uncertain how much of this variation is due to time, space, or other factors such as clans or kinship.

Fourth, Schambach et al. (2011) compared the skulls at Crenshaw to the Great Bend region Caddo at Cedar Grove, Haley, and McClure, but did not identify the time and context differences between some populations. While six individuals in mound burials at Haley and McClure are reported to have had parallelo-fronto-occipital cranial modification, it is difficult to know if this represents the general population or just those who had appropriate status to be placed in mound burials. The two individuals with modification at Haley seem to date to the Middle Caddo period (A.D. 1200-1500) based on associated artifacts. The four people with modification at McClure were interred with ceramic types such as Belcher Engraved. This suggests they are from ca. A.D. 1500-1680, later than the skulls and mandibles at Crenshaw. While McClure does demonstrate that cranial modification was taking place, the small sample size from mound contexts from a later time period may show that cranial modification was practiced more during the Late Caddo period in the region, particularly among those who were buried in mounds. The two individuals from Haley are more comparable to the skulls and mandibles at Crenshaw, but they are similarly from a mound and only represent two individuals from the site. These individuals also might be the product of selection bias. That is, C. B. Moore may have collected the skulls due to the presence of cranial modification, while those without it were left behind. We do not know what percentage of the population these two individuals represent, but it is likely only a small number.

Cedar Grove is a Late Caddo to Historic Caddo (A.D. 1680-1860) non-mound site and most people had no cranial modification present (Rose 1984). One individual had parallelo-fronto-occipital cranial modification. The lack of cranial modification among most of the skulls at Cedar Grove was suggested by Schambach et al. (2011:69-70) to be due to time, but it is more likely due to regional differences. That is, this could suggest the Great Bend region Caddo never fully adopted a single type of cranial modification for the vast majority of the population like at Sanders and Womack (Derrick and Wilson 1997). Schambach et al. (2011:69-70) suggest that cranial modification was waning during this time period as an explanation. However, this directly contradicts the east Texas data. During the Late and Historic Caddo periods, nearly every example from east Texas had some type of cranial modification (Derrick and Wilson 1997:Figure 4). This shows that cranial modification was not practiced nearly as much in the Great Bend region as it was in east Texas during the Late to Historic periods, indicating that the lack of cranial modification is at least partially due to regional differences. Also, Rose (1984) identified a skull with occipital flattening among the Cedar Grove skulls and Farley (2011) identified four people at Cedar Grove with occipital flattening. This suggests that occipital flattening may not only be a local form of cranial modification (possibly associated with cradle boarding), but a common form during the Late to Historic Caddo periods in the Great Bend region. It also demonstrates that multiple forms of cranial modification were present at one relatively small site. Therefore, the fact that the latest skull cluster at Crenshaw, the Rayburn Cluster, may also have had occipital flattening should not be used to suggest they are foreign.

Fifth, bioarchaeological studies from nearby areas to the northeast were not consulted. For example, the non-mound Hardman site (3CL418) had a detailed bioarchaeological study on 20 individuals from Middle to Late Caddo times (Burnett 1993). Despite the detailed analysis, no evidence of cranial modification was detected. Three of these individuals from the end of the Middle Caddo period were discovered as headless bodies with evidence that the heads were severed. These three individuals were placed together with pots potentially replacing their heads. While warfare is one explanation, it is not well supported. Burnett (1993:182-183) notes that there was no evidence of violent trauma with the rest of the skeletons and instead suggests an alternative hypothesis that this might have been part of a local burial practice associated with differences in status. Interestingly, there is also a headless body from the Haley site containing ceramics consistent with the Middle Caddo period (Moore 1912:528-530).

Finally, by the time the skulls at Crenshaw were analyzed by Zabecki (2011), many had become significantly fragmented. This makes identification of cranial modification difficult since the skull shape cannot be properly observed. It is unclear how many skulls did not have any cranial modification and how many could not be assessed for cranial modification (i.e. too fragmented). This has the potential to inflate the percentage of skulls without cranial modification since skulls that could not be assessed would be counted as having no cranial modification. Similarly, this could cause an underrepresentation of the different types of cranial modification that may have originally been present.

The Millwood Reservoir skeletal samples were analyzed for cranial modification but were also detrimentally affected by preservation factors. A reassessment of cranial modeling at Crenshaw was performed based on photographs taken in the field whilst the cranial fragments were still held in place by soil debris. Given the importance of the Rayburn Cluster on the previous conclusions, they were reassessed for cranial modification.

Due to the state of the cranial fragments, 55 of the 63 individuals in the Millwood Reservoir sample could not be assessed for intentional cranial modeling. Of the eight individuals that could be assessed, two date to the Middle Caddo period or later while six date to earlier periods. Only one individual out of these eight showed evidence of cranial modeling. This individual was between the ages of 25-29 years old and dated to the Middle Caddo period, contemporaneous with the skull-and-mandible deposit. This individual exhibited parallelo-fronto-occipital flattening. This provided apparent confirmation of Schambach et al.'s (2011)

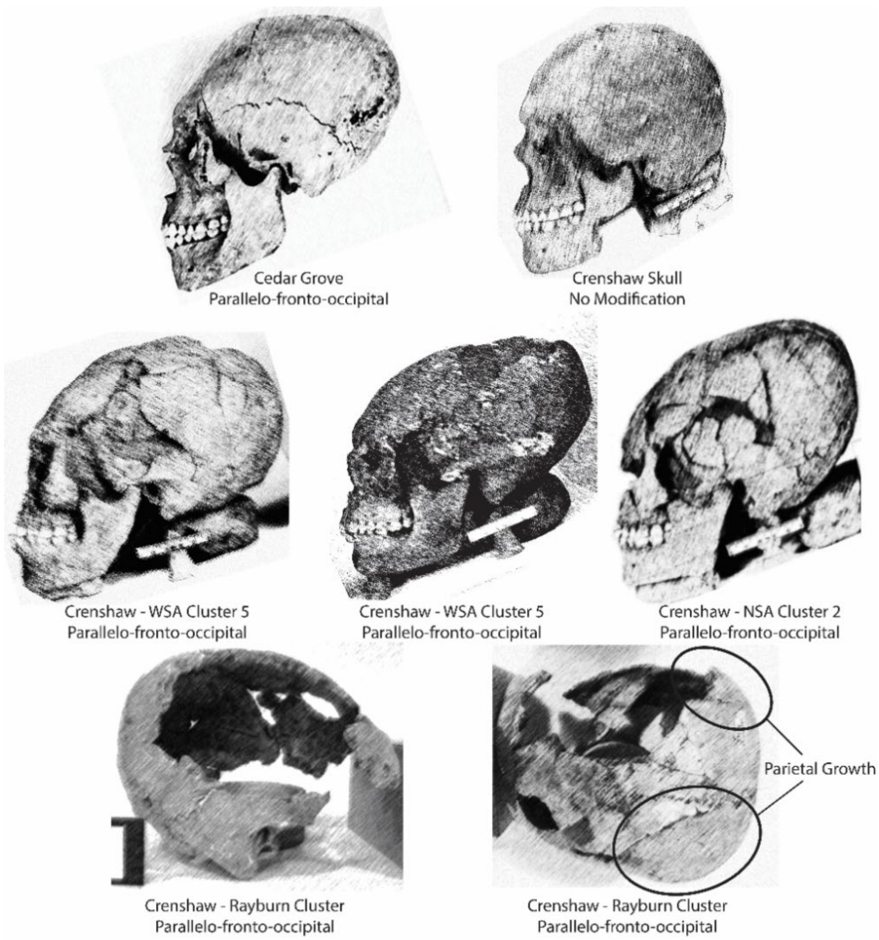


Figure 6.2 – Selected examples from Cedar Grove and the Crenshaw skulls showing parallelo-fronto-occipital modification and no modification (digital drawings based on photographs).

hypothesis that such cranial modeling should be present among the skulls at Crenshaw if they were local. The lack of modeling among the earlier population suggests that cranial modeling was not practiced in this area until the Middle Caddo period. Thus, some time of transition should be expected.

The Crenshaw sample was first reanalyzed using photographic evidence before being verified with the remains. The examination of cranial photographs from the WSA and North Skull Area (NSA) identified five individuals with evidence of cranial modeling out of 45 individuals that could be assessed (Figure 6.4). This means 11% had cranial modification in the WSA and NSA, 13% had cranial modification in the Millwood reservoir (although from a variety of times), 9% had cranial modification at Cedar Grove if not counting occipital flattening, and none had modification at Hardman. All individuals with modification at Crenshaw were estimated to be of adult age (20-50 years old), with sex estimations of two females, two males, and one of indeterminate sex all of whom were dated to the Middle Caddo Period (A.D. 1275-1303). Three individuals had intentional cranial modeling reflecting a tabular parallelo-fronto-occipital style (83-377-6-1, 83-377-6-2, and 83-377-25-1), one individual appeared to only have frontal flattening (83-377-7-1), and one individual had fronto-vertico-occipital flattening (83-377-24-3). When the remains were directly reassessed, this was confirmable in 4 of the 5 individuals. The other was too fragmentary.

The Rayburn Cluster reassessment showed that the remains consisted of four individuals with parallelo-fronto-occipital cranial modeling, one had slight occipital flattening, two had no modeling, and one was not assessable. This strongly contradicts the previous conclusions that this cluster represents foreigners since this is the style of modeling found in the Millwood population and the style Schambach et al (2011) argued should be present in a local population.

This analysis does not show any indication that these two groups are wholly different. Instead, it appears that intentional cranial modeling was practiced by some of the individuals in the group, but not all, and that both groups used parallelo-fronto-occipital modeling. Finally, taken as a whole, no cultural differences can be clearly identified or are even indicated between these two groups on the basis of cranial modeling.

6.3.5 Demography

Many other studies have considered demography at Caddo sites (Burnett 1993; Harmon and Rose 1989; Harvey et al. 2014; Rose 1984; Rose et al. 1998). These reports generally show a low frequency of infant and child remains and a tendency for slightly more males than females to be buried at the sites (Rose 1984).

Table 6.1 – Age designations at Millwood and among the Crenshaw skulls

	Adult*		0-19		20-35		35-50		50+		Total	
Site	n	**(%)**	n	**(%)**	n	**(%)**	n	**(%)**	n	**(%)**	n	**(%)**
Millwood	39	(72.2)	8	(14.8)	5	(9.3)	2	(3.7)	0	(0.0)	54	(100.0)
Crenshaw	9	(9.2)	10	(10.2)	47	(48.0)	32	(32.7)	0	(0.0)	98	(100.0)
Total	48	(31.6)	18	(11.8)	52	(34.2)	34	(22.4)	0	(0.0)	152	(100.0)

*Adults of indeterminate age.

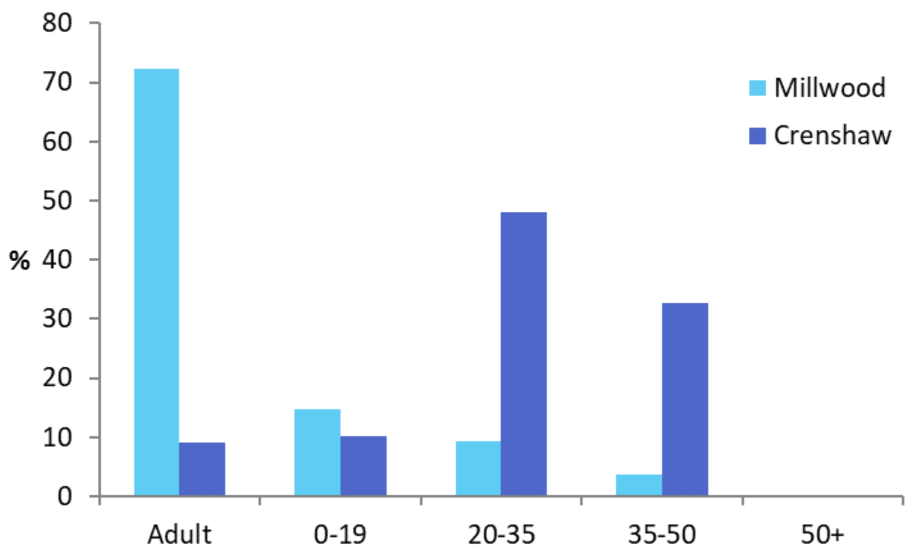


Figure 6.5 – Percentage-based age distributions for Millwood and among the Crenshaw skulls.

Several observations can be made from the demographic data collected from the individuals recovered from the Millwood Reservoir (Table 6.1). Given the problems with the sexing of mandibles, only skulls from Crenshaw and the Millwood Reservoir were compared (Figure 6.5). The proportion of individuals that fell into the youngest age category (0-19 years), consisting mainly of infants, children, and adolescents, was similar to that of other Caddo burials, in which a dearth of infants and children has been noted in this area (Hoffman 1971:559–560; Rose 1984).

Table 6.2 – Sex designations at Millwood and among the Crenshaw skulls

	Female		**Probable female**		**Ambiguous**		**Probable male**		**Male**		**Total**	
Site	n	**(%)**	n	**(%)**	n	**(%)**	n	**(%)**	n	**(%)**	**n**	**(%)**
Millwood	4	(13.8)	6	(20.7)	7	(24.1)	11	(37.9)	1	(3.4)	29	(100.0)
Crenshaw	0	(0.0)	20	(23.8)	26	(31.0)	29	(34.5)	9	(10.7)	84	(100.0)
Total	5	(4.4)	26	(22.8)	33	(28.9)	40	(35.1)	10	(8.8)	114	(100.0)

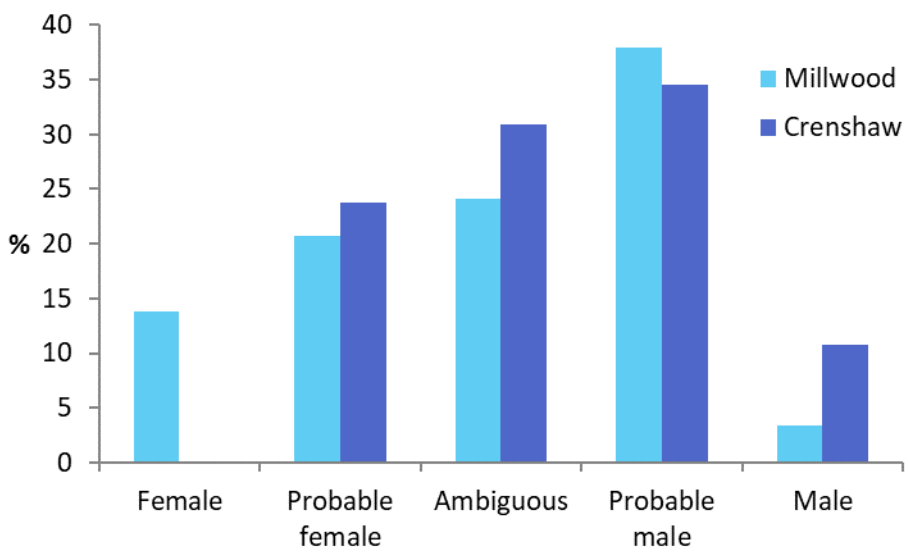


Figure 6.6 – Percentage-based sex distributions for Millwood and the Crenshaw skulls.

Of the adults of determined sex, males and females were of similar proportion, with slightly more males than females in the sample population from Millwood (Table 6.2). This sex distribution was similar to that reported by Zabecki (2011) for the skulls recovered from the

Crenshaw site (Figure 6.6). The demographic data do not reveal any substantial differences in the age and sex distributions between the Millwood and Crenshaw individuals. Statistical analysis with a Pearson's χ^2 test confirmed the lack of a significant difference between the two populations in terms of sex distribution. Therefore, there is no evidence to suggest the Millwood individuals represent a population distinct from the Crenshaw individuals based on demography. Conversely, this lack of demographic difference does not mean the people at Crenshaw originate from the Millwood Reservoir population. It does at least suggest that there is nothing particularly unusual about the demographics among the skulls at Crenshaw.

6.4 Conclusion

Human remains from the Millwood Reservoir area and the Crenshaw site were documented for several biological traits. This provided a better comparison population to the Crenshaw skulls and mandibles than was available for Schambach et al.'s (2011) analyses. This analysis and comparisons to the literature show that some previous analyses were problematic due to a range of issues including oversights during documentation, comparisons between potentially related individuals to larger populations to infer ethnicity, missing references to relevant previous documentations, and problematic assumptions about some behaviorally and genetically induced traits. Several traits previously used to suggest that the skulls and mandibles were not derived from local populations have been reassessed. The results of the comparisons between these different groups show that there are no clear differences between the local populations and the Crenshaw skulls. The conclusions that the skulls and mandibles are not local have been contradicted in several ways. The one exception is that the mandibles have more chipped teeth than all other groups, including the skulls. This is suggested to possibly be due to postmortem damage related to the way they were collected, excavated, or treated in ceremonies.

6.5 Acknowledgements

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Appendix

T1 – Data related to chipped teeth and wear combined with SOD data.

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-19M			Adult				No
83-377-9M			Adult				No
83-377-2			Adult				No
69-66-589-3	Rayburn	Skull	Adult	0.09	4.56	35	Yes
69-66-589-4	Rayburn	Skull	Adult	0.40	2.80	15	Yes
69-66-589-5	Rayburn	Skull	Subadult	0.00	2.84	32	Yes
69-66-589-7	Rayburn	Skull	Adult	0.22	3.96	27	Yes
69-66-589-8	Rayburn	Skull	Adult	0.23	7.73	30	Yes
83-376-1	Mound F	Crenshaw (local)	Adult	0.14	8.25	14	Yes
83-376-2	Mound F	Crenshaw (local)	Subadult	0.00	2.67	15	Yes
83-376-3	Mound F	Crenshaw (local)	Adult	0.04	5.35	24	Yes
83-376-5-3	Mound F	Crenshaw (local)	Adult				No
83-376-4	Mound F	Crenshaw (local)	Adult				No
83-376-6	Mound F	Crenshaw (local)	Subadult	0.13	1.03	15	Yes
83-376-6-2	Mound F	Crenshaw (local)	Subadult	0.00	3.12	18	Yes
83-376-7	Mound F	Crenshaw (local)	Adult	0.00	3.78	12	Yes
83-376-7-1	Mound F	Crenshaw (local)	Subadult	0.06	3.48	18	Yes
83-376-8	Mound F	Crenshaw (local)	Adult	0.35	5.96	23	Yes
83-376-9	Mound F	Crenshaw (local)	Subadult		3.53		No
83-376-10-1	Mound F	Crenshaw (local)	Subadult		0.00		No
83-376-10-2	Mound F	Crenshaw (local)	Adult	0.00	2.10	7	Yes
83-376-11	Mound F	Crenshaw (local)	Subadult	0.13	2.50	8	Yes
83-377-2-1	WSA 01	Skull	Adult	0.00	4.50	4	Yes
83-377-2-2	WSA 01	Skull	Adult			0	No
83-377-2-3	WSA 01	Skull	Adult			0	No
83-377-2-4	WSA 01	Skull	Adult	0.30	8.04	23	Yes
83-377-2-5	WSA 01	Skull	Adult	0.27	11.64	15	Yes
83-377-2-6	WSA 01	Skull	Adult	0.00	3.50	10	Yes
83-377-2-7	WSA 01	Skull	Adult	0.33	12.21	15	Yes
83-377-2-8	WSA 01	Skull	Adult	0.63	13.13	8	Yes
83-377-3-1	WSA 02	Mandible	Adult	0.75	7.33	12	Yes
83-377-3-2	WSA 02	Mandible	Adult	0.25	5.89	8	Yes
83-377-3-3	WSA 02	Mandible	Subadult	0.20	1.73	15	Yes
83-377-3-4	WSA 02	Mandible	Adult	0.50	9.33	8	Yes
83-377-3-5	WSA 02	Mandible	Adult	0.60	8.36	10	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-3-6	WSA 02	Mandible	Adult	0.30	1.40	10	Yes
83-377-3-7	WSA 02	Mandible	Adult	0.43	8.00	7	Yes
83-377-3-8	WSA 02	Mandible	Adult	0.44	6.10	9	Yes
83-377-3-9	WSA 02	Mandible	Adult			0	No
83-377-3-10	WSA 02	Mandible	Adult	0.50	4.83	6	Yes
83-377-3-11	WSA 02	Mandible	Adult	0.70	16.10	10	Yes
83-377-3-12	WSA 02	Mandible	Adult	0.07	3.21	14	Yes
83-377-3-13	WSA 02	Mandible	Adult	0.20	3.87	15	Yes
83-377-3-14	WSA 02	Mandible	Adult	0.36	4.82	11	Yes
83-377-3-15	WSA 02	Mandible	Adult	0.25	3.88	16	Yes
83-377-3-16	WSA 02	Mandible	Adult	0.80	7.00	10	Yes
83-377- 3-17	WSA 02	Mandible	Adult	0.33	3.08	12	Yes
83-377-3-18	WSA 02	Mandible	Adult	0.69	3.81	16	Yes
83-377-3-19	WSA 02	Mandible	Adult	0.83	0.00	6	No
83-377-3-20	WSA 02	Mandible	Adult	0.36	6.71	14	Yes
83-377-3-21	WSA 02	Mandible	Adult	0.54	2.23	13	Yes
83-377-3-22	WSA 02	Mandible	Adult	0.50	2.43	14	Yes
83-377-3-23	WSA 02	Mandible	Adult	0.40	2.27	15	Yes
83-377-3-24	WSA 02	Mandible	Adult	0.46	8.92	13	Yes
83-377-3- 25	WSA 02	Mandible	Adult	0.50	1.24	2	Yes
83-377-2-26	WSA 02	Mandible	Adult	0.71	6.18	14	Yes
83-377-3-27	WSA 02	Mandible	Adult	0.73	6.00	15	Yes
83-377-3-28	WSA 02	Mandible	Adult	0.29	2.75	14	Yes
83-377-3-29	WSA 02	Mandible	Adult	0.00	7.00	4	No
83-377-3-30	WSA 02	Mandible	Adult	0.20	1.00	10	Yes
83-377-3-31	WSA 02	Mandible		0.00	0.00	7	No
83-377-3-32	WSA 02	Mandible	Adult	0.33	4.47	15	Yes
83-377-3-33	WSA 02	Mandible	Adult	0.00	2.75	12	No
83-377-3-34	WSA 02	Mandible	Adult	0.20	5.47	15	Yes
83-377-3-35	WSA 02	Mandible	Adult	0.50	7.50	10	Yes
83-377-3-36	WSA 02	Mandible	Adult	0.40	3.67	15	Yes
83-377-3-37	WSA 02	Mandible	Adult	0.67	9.50	6	Yes
83-377-3-38	WSA 02	Mandible	Adult	0.00	6.86	14	No
83-377-3-39	WSA 02	Mandible	Subadult	0.22	2.22	9	Yes
83-377-3-40	WSA 02	Mandible	Adult	0.38	8.00	16	Yes
83-377-3-41	WSA 02	Mandible	Adult	0.71	6.88	7	Yes
83-377-3-42	WSA 02	Mandible	Adult	0.67	1.92	12	Yes
83-377-3-43	WSA 02	Mandible	Adult	0.40	5.46	15	Yes
83-377-3-44	WSA 02	Mandible	Subadult	0.33	0.33	6	Yes
83-377-3-45	WSA 02	Mandible	Adult	0.45	0.00	11	No

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-3-46	WSA 02	Mandible	Adult	0.36	4.73	11	Yes
83-377-3-47	WSA 02	Mandible	Adult	0.73	3.82	11	Yes
83-377-3-46	WSA 02	Mandible	Adult	0.00	12.33	3	No
83-377-3-48	WSA 02	Mandible	Adult	0.71	4.00	7	Yes
83-377-3-49	WSA 02	Mandible	Adult	0.67	2.44	9	Yes
83-377-3-50	WSA 02	Mandible	Adult	0.67	5.67	3	Yes
83-377-2-51	WSA 02	Mandible	Adult	0.17	1.50	12	Yes
83-377-3-52	WSA 02	Mandible	Adult	0.50	10.63	8	Yes
83-377-3-53	WSA 02	Mandible	Adult	0.33	0.00	9	No
83-377-3-54	WSA 02	Mandible	Adult	0.00	6.00	6	No
83-377-3-55	WSA 02	Mandible	Adult	0.44	0.67	9	Yes
83-377-3-56	WSA 02	Mandible	Adult	0.75	3.13	8	Yes
83-377-3-57	WSA 02	Mandible	Adult	0.57	8.67	7	Yes
83-377-3-58	WSA 02	Mandible	Adult	0.40	5.40	5	Yes
83-377-3-60	WSA 02	Mandible	Adult				No
83-377-3-59	WSA 02	Mandible	Adult	0.20	6.20	5	Yes
83-377-3-60x	WSA 02	Mandible	Adult			0	No
83-377-3-61	WSA 02	Mandible	Adult	0.86	4.93	14	Yes
83-377-3-62	WSA 02	Mandible	Adult	0.63	6.44	8	Yes
83-377-3-63	WSA 02	Mandible	Adult	0.79	12.07	14	Yes
83-377-3-64	WSA 02	Mandible		1.00	0.00	2	No
83-377-3-65	WSA 02	Mandible	Adult	0.67	5.33	12	Yes
83-377-3-66	WSA 02	Mandible	Adult	0.00	3.33	7	No
83-377-3-67	WSA 02	Mandible	Adult	0.50	19.50	4	Yes
83-377-3-68	WSA 02	Mandible	Adult	0.33	6.44	9	Yes
83-377-3-69	WSA 02	Mandible		0.00	0.00	3	No
83-377-3-70	WSA 02	Mandible	Adult	0.40	3.20	5	Yes
83-377-3-71	WSA 02	Mandible	Adult	0.17	2.58	12	Yes
83-377-3-72	WSA 02	Mandible	Adult	0.55	0.92	11	Yes
83-377-3-73	WSA 02	Mandible	Adult		17.33	0	No
83-377-3-74	WSA 02	Mandible		0.00	5.00	5	No
83-377-3-75	WSA 02	Mandible	Adult	0.45	5.73	11	Yes
83-377-3-76	WSA 02	Mandible	Adult	0.67	9.33	3	Yes
83-377-3-77	WSA 02	Mandible	Adult	0.67	10.50	3	Yes
83-377-3-78	WSA 02	Mandible	Adult	0.75	5.25	4	Yes
83-377-3-79	WSA 02	Mandible	Adult	0.91	0.67	11	No
83-377-3-80	WSA 02	Mandible	Adult	0.50	3.63	8	Yes
83-377-3-81	WSA 02	Mandible	Adult	0.83	9.83	12	Yes
83-377-3-82	WSA 02	Mandible	Adult	0.57	2.43	7	Yes
83-377-3-83	WSA 02	Mandible	Adult	0.81	5.38	16	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-3-84	WSA 02	Mandible	Adult	0.43	2.64	14	Yes
83-377-3-85	WSA 02	Mandible	Adult	0.33	3.31	12	Yes
83-377-3-86	WSA 02	Mandible	Adult	0.29	4.24	14	Yes
83-377-3-87	WSA 02	Mandible	Adult	0.75	0.00	4	No
83-377-3-88	WSA 02	Mandible	Adult	0.70	2.30	10	Yes
83-377-3-89	WSA 02	Mandible	Adult	0.67	5.13	15	Yes
83-377-3-90	WSA 02	Mandible	Adult	0.50	6.42	12	Yes
83-377-3-91	WSA 02	Mandible		0.50	0.00	4	No
83-377-3-92	WSA 02	Mandible	Subadult	0.20	0.00	5	Yes
83-377-3-93	WSA 02	Mandible		0.00	8.00	13	No
83-377-3-94	WSA 02	Mandible	Adult	0.53	3.07	15	Yes
83-377-3-95	WSA 02	Mandible	Adult	0.91	3.83	11	Yes
83-377-3-96	WSA 02	Mandible	Adult	0.92	9.25	12	Yes
83-377-3-97	WSA 02	Mandible	Adult	0.47	3.53	15	Yes
83-377-3-99	WSA 02	Mandible	Adult	0.25	3.19	16	Yes
83-377-3-100	WSA 02	Mandible	Adult	0.82	0.00	11	No
83-377-3-101	WSA 02	Mandible	Adult	0.56	5.73	16	Yes
83-377-3-102	WSA 02	Mandible	Adult	0.29	1.63	7	Yes
83-377-3-103	WSA 02	Mandible	Adult	0.75	6.75	16	Yes
83-377-3-104	WSA 02	Mandible	Adult	0.25	5.25	4	Yes
83-377-3-105	WSA 02	Mandible	Adult	0.56	2.50	9	Yes
83-377-3-106	WSA 02	Mandible	Subadult	0.31	2.23	13	Yes
83-377-3-107	WSA 02	Mandible	Adult	0.79	5.07	14	Yes
83-377-3-108A	WSA 02	Mandible	Adult	0.00	22.40	5	No
83-377-3-108B	WSA 02	Mandible	Adult	0.00	0.00	3	No
83-377-5-1	WSA 04	Skull	Adult	0.07	5.32	28	Yes
83-377-5-2	WSA 04	Skull	Adult	0.46	5.62	13	Yes
83-377-5-3	WSA 04	Skull	Adult	0.06	4.72	32	Yes
83-377-5-4	WSA 04	Skull	Adult	0.06	4.72	32	Yes
83-377-6-1	WSA 05	Skull	Adult	0.38	7.91	24	Yes
83-377-6-2	WSA 05	Skull	Adult	0.52	5.89	27	Yes
83-377-6-3	WSA 05	Skull	Adult	0.45	8.14	29	Yes
83-377-6-4	WSA 05	Skull	Adult	0.20	4.20	30	Yes
83-377-6-5	WSA 05	Skull	Adult	0.62	5.45	29	Yes
83-377-7-1	WSA 06	Skull	Adult	0.29	5.37	28	Yes
83-377-7-2	WSA 06	Skull	Adult	0.34	6.50	32	Yes
83-377-7-3	WSA 06	Skull	Adult	0.00	6.73	16	No
83-377-7-4	WSA 06	Skull	Subadult	0.10	3.30	20	Yes
83-377-7-5	WSA 06	Skull	Subadult	0.00	1.95	16	Yes
83-377-7-6	WSA 06	Skull	Adult	0.17	5.27	30	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-7-7	WSA 06	Skull	Subadult	0.05	2.37	19	Yes
83-377-8-1	WSA 07	Skull	Adult	0.63	6.50	8	Yes
83-377-9-1	WSA 08	Mandible	Adult	0.00	5.62	13	Yes
83-377-11-1	WSA 09	Mandible	Adult	0.83	4.92	12	Yes
83-377-11-2	WSA 09	Mandible	Adult	0.40	13.40	5	Yes
83-377-11-3	WSA 09	Mandible	Adult	0.45	3.00	11	Yes
83-377-11-4	WSA 09	Mandible	Adult	0.30	1.80	10	Yes
83-377-11-5	WSA 09	Mandible	Adult	0.70	8.40	10	Yes
83-377-11-6	WSA 09	Mandible	Adult	0.20	5.90	10	Yes
83-377-11-7	WSA 09	Mandible	Adult	0.40	6.00	5	Yes
83-377-11-8	WSA 09	Mandible	Adult	0.25	4.00	16	Yes
83-377-14-1	WSA 10	Skull	Adult	0.50	4.64	14	Yes
83-377-14-3	WSA 10	Skull	Adult	0.39	5.52	31	Yes
83-377-14-4	WSA 10	Skull	Adult	0.34	5.03	32	Yes
83-377-15-1	WSA 11	Skull	Adult		2.50		No
83-377-16-1	WSA 12	Skull	Subadult		0.00		No
83-377-16-2	WSA 12	Skull	Adult	0.64	9.07	28	Yes
83-377-16-3	WSA 12	Skull	Adult	0.19	5.28	32	Yes
83-377-16-4	WSA 12	Skull	Adult	0.59	6.76	29	Yes
83-377-17	WSA 13	Skull	Adult	0.37	4.93	30	Yes
83-377-19-1	WSA 14	Mandible	Adult	0.82	5.82	11	Yes
83-377-19-2	WSA 14	Mandible	Adult	0.50	6.80	6	Yes
83-377-25-1	NSA 02	Skull	Adult	0.37	2.48	27	Yes
83-377-19-3	WSA 14	Mandible	Adult	0.40	7.17	5	Yes
83-377-19-4	WSA 14	Mandible	Adult	0.33	12.17	6	Yes
83-377-19-5	WSA 14	Mandible	Adult	0.40	7.80	5	Yes
83-377-19-6	WSA 14	Mandible	Adult	0.43	5.00	14	Yes
83-377-19-7	WSA 14	Mandible	Adult	0.43	6.40	14	Yes
83-377-19-8	WSA 14	Mandible	Adult	0.27	6.09	11	Yes
83-377-23-2	WSA 15	Mandible	Adult	0.83	14.83	6	Yes
83-377-23-3	WSA 15	Mandible	Adult	0.67	9.17	6	Yes
83-377-23-4	WSA 15	Mandible	Adult	0.33	5.00	3	Yes
83-377-23-5	WSA 15	Mandible	Adult	0.43	11.57	7	Yes
83-377-23-6	WSA 15	Mandible	Adult	0.67	9.00	9	Yes
83-377-23-7	WSA 15	Mandible	Adult			0	No
83-377-23-8	WSA 15	Mandible	Adult	1.00	3.60	5	Yes
83-377-23-9	WSA 15	Mandible	Adult	0.50	8.00	2	Yes
83-377-23-10	WSA 15	Mandible	Adult	0.50	12.17	6	Yes
83-377-23-11	WSA 15	Mandible	Adult	0.50	6.88	8	Yes
83-377-23-12	WSA 15	Mandible	Adult	0.57	5.29	14	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-23-13	WSA 15	Mandible	Adult		0.00	0	No
83-377-23-14	WSA 15	Mandible	Adult	0.25	6.00	8	Yes
83-377-23-17	WSA 15	Mandible	Adult	0.25	6.00	8	Yes
83-377-23-15	WSA 15	Mandible	Adult	0.67	9.83	12	Yes
83-377-23-16	WSA 15	Mandible	Adult	0.86	13.83	7	Yes
83-377-23-18A	WSA 15	Mandible	Adult	0.83	22.67	6	Yes
83-377-23-18B	WSA 15	Mandible	Adult	0.63	8.25	8	Yes
83-377-23-20	WSA 15	Mandible	Adult	0.25	3.46	12	Yes
83-377-23-21	WSA 15	Mandible	Adult	0.27	4.13	15	Yes
83-377-23-22	WSA 15	Mandible	Adult	0.00	8.00	2	Yes
83-377-23-23	WSA 15	Mandible	Adult	0.25	5.58	12	Yes
83-377-23-24	WSA 15	Mandible	Adult	0.75	5.63	16	Yes
83-377-23-25	WSA 15	Mandible	Adult	0.67	7.87	15	Yes
83-377-23-26	WSA 15	Mandible	Adult	0.67	6.60	9	Yes
83-377-23-27	WSA 15	Mandible	Adult	0.50	7.67	6	Yes
83-377-23-28	WSA 15	Mandible	Adult	0.43	5.57	14	Yes
83-377-23-29	WSA 15	Mandible	Adult	0.50	6.07	14	Yes
83-377-23-30	WSA 15	Mandible	Adult	0.29	4.71	7	Yes
83-377-23-31	WSA 15	Mandible	Adult	0.67	5.63	9	Yes
83-377-23-32	WSA 15	Mandible	Adult	0.33	3.53	15	Yes
83-377-23-33	WSA 15	Mandible	Adult	0.29	4.57	14	Yes
83-377-23-34	WSA 15	Mandible	Adult				No
83-377-23-35	WSA 15	Mandible	Adult	0.44	5.11	9	Yes
83-377-23-36	WSA 15	Mandible	Adult	0.80	6.40	15	Yes
83-377-23-37	WSA 15	Mandible	Adult	0.40	7.60	5	Yes
83-377-24-1	NSA 01	Skull	Adult	0.33	5.41	27	Yes
83-377-24-2	NSA 01	Skull	Adult	0.53	6.53	19	Yes
83-377-24-3	NSA 01	Skull	Adult	0.14	4.48	29	Yes
83-377-24-4	NSA 01	Skull	Adult	0.48	7.08	25	Yes
83-377-24-5	NSA 01	Skull	Adult	0.19	5.63	32	Yes
83-377-25-2	NSA 02	Skull	Adult	0.00	4.38	8	Yes
83-377-25-3	NSA 02	Skull	Adult	0.17	4.80	30	Yes
83-377-27-1	WSA 16	Skull	Adult	0.38	6.38	8	Yes
83-377-27-2	WSA 16	Skull	Adult	1.00	16.00	1	No
83-377-29-1	WSA 17	Skull	Adult	0.19	4.41	32	Yes
83-377-29-2	WSA 17	Skull	Adult			0	No
83-377-29-2-1	WSA 17	Skull	Adult	0.50	10.33	2	Yes
83-377-29-3	WSA 17	Skull	Adult	0.14	4.07	29	Yes
83-377-30	NSA 03	Skull	Adult	0.26	2.58	19	Yes
83-377-32-1	WSA 18	Skull	Adult	0.30	9.79	27	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-32-2	WSA 18	Skull	Adult	0.00	2.27	30	Yes
83-377-32-3	WSA 18	Skull	Subadult	0.00	2.48	31	Yes
83-377-32-4	WSA 18	Skull	Subadult	0.00	0.86	14	Yes
83-377-32-5	WSA 18	Skull	Adult	0.16	6.12	31	Yes
83-377-32-6	WSA 18	Skull	Adult	0.27	3.47	30	Yes
83-377-32-7	WSA 18	Skull	Subadult	0.10	3.59	29	Yes
83-377-32-8	WSA 18	Skull	Adult	0.53	5.90	30	Yes
83-377-32-9	WSA 18	Skull	Adult	0.30	4.63	30	Yes
83-377-32-10	WSA 18	Skull	Adult	0.17	4.24	29	Yes
83-377-34-1	WSA 19	Skull	Adult	0.00	2.53	30	Yes
83-377-34-3	WSA 19	Skull	Adult	0.00	0.00	2	Yes
83-377-34-2	WSA 19	Skull	Adult	0.38	5.84	32	Yes
83-377-35-1	NSA 04	Skull	Adult				No
83-377-35-2	NSA 04	Skull	Adult				No
83-377-36-1	NSA 05	Skull	Adult	0.48	7.52	21	Yes
83-377-36-2	NSA 05	Skull	Adult	0.53	3.19	17	Yes
83-377-36-3	NSA 05	Skull	Adult	0.44	5.44	9	Yes
83-377-36-4	NSA 05	Skull	Adult	0.28	5.76	25	Yes
83-377-70-38	WSA 28	Mandible	Adult	0.56	6.56	9	Yes
83-377-70-39	WSA 28	Mandible	Adult	0.23	2.85	13	Yes
83-377-39-1	NSA 06	Mandible	Adult	0.40	3.80	5	Yes
83-377-70-40	WSA 28	Mandible	Adult	0.71	3.36	14	Yes
83-377-40-1	NSA 07	Mandible	Adult	0.00	3.00	2	Yes
83-377-41-1-1	NSA 08	Skull	Adult	0.56	6.48	27	Yes
83-377-41-1-2	NSA 08	Skull	Adult	0.00	1.85	12	Yes
83-377-41-2	NSA 08	Skull	Adult	0.58	5.58	24	Yes
83-377-41-3	NSA 08	Skull	Adult	0.13	5.13	16	Yes
83-377-41-4	NSA 08	Skull	Adult	0.57	10.86	14	Yes
83-377-41-5	NSA 08	Skull	Adult	0.13	3.93	30	Yes
83-377-41-6	NSA 08	Skull	Adult	0.62	6.72	29	Yes
83-377-41-7	NSA 08	Skull	Adult	0.52	6.47	31	Yes
83-377-41-8	NSA 08	Skull	Adult	0.71	5.43	17	Yes
83-377-41-9	NSA 08	Skull	Adult	0.18	4.41	28	Yes
83-377-55-1	WSA 20	Skull	Adult	0.29	9.35	31	Yes
83-377-55-1X	WSA 20	Skull	Adult			0	No
83-377-55-2	WSA 20	Skull	Adult	0.33	5.27	15	Yes
83-377-56-1	WSA 21	Skull	Adult	0.10	3.83	30	Yes
83-377-57-1	WSA 22	Skull	Adult	0.05	1.38	21	Yes
83-377-60-1	WSA 24	Skull	Adult	0.04	4.36	24	Yes
83-377-60-3	WSA 24	Skull	Adult	0.38	4.44	32	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-60-4	WSA 24	Skull	Subadult	0.13	2.30	30	Yes
83-377-61-1	WSA 25	Skull	Adult	0.35	5.16	31	Yes
83-377-61-2	WSA 25	Skull	Adult	0.44	11.19	16	Yes
83-377-61-3	WSA 25	Skull	Adult	0.33	6.66	30	Yes
83-377-62-1	WSA 23	Skull	Adult	0.10	4.48	31	Yes
83-377-62-2	WSA 23	Skull	Adult	0.25	4.13	32	Yes
83-377-65-1	WSA 26	Skull	Adult	0.50	8.50	8	Yes
83-377-69-1	WSA 27	Skull	Adult	0.63	5.04	24	Yes
83-377-69-2	WSA 27	Skull	Adult	0.16	4.66	32	Yes
83-377-69-3	WSA 27	Skull	Subadult		0.00	0	No
83-377-69-4	WSA 27	Skull	Adult	0.23	6.23	31	Yes
83-377-69-5	WSA 27	Skull	Adult	0.18	5.21	28	Yes
83-377-70-1	WSA 28	Mandible	Adult	0.67	6.00	6	Yes
83-377-70-2	WSA 28	Mandible	Adult	0.11	5.56	9	Yes
83-377-70-3	WSA 28	Mandible	Adult	0.50	11.00	4	Yes
83-377-70-3-1	WSA 28	Mandible	Adult	0.25	7.75	4	Yes
83-377-70-4	WSA 28	Mandible	Adult	0.60	5.50	5	Yes
83-377-70-5	WSA 28	Mandible	Adult	0.60	10.20	10	Yes
83-377-70-6	WSA 28	Mandible	Adult		15.00		No
83-377-70-7	WSA 28	Mandible	Adult	0.00		6	Yes
83-377-70-8	WSA 28	Mandible	Adult	0.45	5.64	11	Yes
83-377-70-9	WSA 28	Mandible	Adult	0.73	4.13	15	Yes
83-377-70-10	WSA 28	Mandible	Adult	0.43	6.57	7	Yes
83-377-70-11	WSA 28	Mandible	Adult	0.80	0.00	5	No
83-377-70-12	WSA 28	Mandible	Adult	0.31	7.08	13	Yes
83-377-70-13	WSA 28	Mandible	Adult	0.15	3.23	13	Yes
83-377-70-14	WSA 28	Mandible	Adult	0.80	7.27	15	Yes
83-377-70-15	WSA 28	Mandible	Adult	0.23	3.38	13	Yes
83-377-70-16	WSA 28	Mandible	Adult			0	No
83-377-70-17	WSA 28	Mandible	Adult	0.60	3.20	5	Yes
83-377-70-18	WSA 28	Mandible	Adult	0.42	6.08	12	Yes
83-377-70-24	WSA 28	Mandible	Adult		6.36		No
83-377-70-25	WSA 28	Mandible	Adult		0.89		No
83-377-70-26	WSA 28	Mandible	Adult	0.53	3.40	15	Yes
83-377-70-28	WSA 28	Mandible	Adult			0	No
83-377-70-29	WSA 28	Mandible	Adult			0	No
83-377-70-30	WSA 28	Mandible	Adult	0.67	7.22	9	Yes
83-377-70-31	WSA 28	Mandible	Adult	0.75	5.25	4	Yes
83-377-70-32	WSA 28	Mandible	Adult	0.60	3.00	5	Yes
83-377-70-33A	WSA 28	Mandible	Adult	0.75	9.50	4	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-70-33B	WSA 28	Mandible	Adult	0.60	9.60	5	Yes
83-377-70-34	WSA 28	Mandible	Adult	0.44	4.94	16	Yes
83-377-70-35	WSA 28	Mandible	Adult	0.00	3.50	3	Yes
83-377-70-36	WSA 28	Mandible	Adult	0.29	5.29	14	Yes
83-377-70-37	WSA 28	Mandible	Adult	0.25	4.13	8	Yes
83-377-70-41	WSA 28	Mandible	Adult	0.33	4.50	3	Yes
83-377-70-57	WSA 28	Mandible	Adult	0.25	0.00	8	No
83-377-70-58	WSA 28	Mandible	Adult	0.43	5.38	7	Yes
83-377-70-59	WSA 28	Mandible	Adult	0.78	5.67	9	Yes
83-377-70-60	WSA 28	Mandible	Adult	0.31	4.54	13	Yes
83-377-70-61	WSA 28	Mandible	Adult	0.23	3.00	13	Yes
83-377-70-19	WSA 28	Mandible	Adult	0.50	5.50	8	Yes
83-377-70-20	WSA 28	Mandible	Adult	0.80	4.93	15	Yes
83-377-70-21	WSA 28	Mandible	Adult	0.83	7.67	6	Yes
83-377-70-21-1	WSA 28	Mandible	Adult			0	No
83-377-70-22	WSA 28	Mandible	Adult	0.67	11.11	9	Yes
83-377-70-23	WSA 28	Mandible	Adult	0.55	2.18	11	Yes
68-633	Cemetery 6	Crenshaw (local)	Adult	0.60	9.14	5	Yes
69-66-490	Fea. 8a	Mandible	Adult	0.42		12	Yes
69-66-495	Mound C slope		Adult	0.77		13	No
69-66-495-1	Mound C slope		Adult	0.75		12	No
69-66-589-6	Rayburn	Skull	Adult	0.45	8.97	29	Yes
69-66-589-1	Rayburn	Skull	Adult	0.61	12.42	23	Yes
69-66-589-2	Rayburn	Skull	Adult	0.31	5.81	32	Yes
2009-718-1	Cemetery 5	Crenshaw (local)	Adult	0.03	3.69	32	Yes
2009-718-2A	Cemetery 5	Crenshaw (local)	Adult	0.50	18.50	2	Yes
2009-718-2B	Cemetery 5	Crenshaw (local)	Adult	0.16	8.13	31	Yes
2009-718-3A	Cemetery 5	Crenshaw (local)	Adult	0.45	8.96	20	Yes
2009-718-3B	Cemetery 5	Crenshaw (local)	Subadult	0.00	0.00	24	Yes
62-40-34	Mound C	Crenshaw (local)	Subadult	0.00	0.00	7	Yes
62-40-47	Mound C	Crenshaw (local)	Adult	0.31	2.35	13	Yes
62-40-49	Mound C	Crenshaw (local)	Adult	0.33	3.50	3	Yes
62-40-50	Mound C	Crenshaw (local)	Adult	0.64	10.36	14	Yes
62-40-58	Mound C	Crenshaw (local)	Subadult	0.14	0.00	7	Yes
62-40-59	Mound C	Crenshaw (local)	Adult				No
62-40-121	Mound C		Adult		5.20		No
62-40-48	Mound C	Crenshaw (local)	Adult		26.00		No
53-1-10-1	Mineral Springs	Millwood	Adult	0.00		4	Yes
53-1-10-2	Mineral Springs	Millwood	Adult	0.00		2	Yes
61-114-1	Bell	Millwood	Adult	0.36		28	Yes

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
62-53-190	Mineral Springs	Millwood	Adult	1.00		1	No
62-53-267	Mineral Springs	Millwood	Adult	0.10		21	Yes
62-53-269	Mineral Springs	Millwood	Adult	0.33		3	Yes
62-53-27	Mineral Springs	Millwood	Adult	0.50		8	Yes
62-53-289	Mineral Springs	Millwood	Adult	0.00		7	Yes
62-53-529	Mineral Springs	Millwood	Adult	0.00		21	Yes
62-53-539	Mineral Springs	Millwood	Adult	0.00		29	Yes
62-53-542	Mineral Springs	Millwood	Adult	0.00		23	Yes
62-53-543	Mineral Springs	Millwood	Adult	0.00		14	Yes
63-39-103	Old Martin Place	Millwood	Adult	0.00		2	Yes
63-39-165	Old Martin Place	Millwood	Adult	0.00		26	Yes
63-39-175	Old Martin Place	Millwood	Adult	0.31		16	Yes
63-39-204	Old Martin Place	Millwood	Adult	0.00		10	Yes
63-39-207-A	Old Martin Place	Millwood	Subadult	0.00		5	Yes
63-39-222-1	Old Martin Place	Millwood	Adult	0.00		7	Yes
63-39-234	Old Martin Place	Millwood	Adult	0.00		1	No
63-39-264	Old Martin Place	Millwood	Adult	0.00		22	Yes
63-39-274-1	Old Martin Place	Millwood	Subadult	0.05		22	Yes
63-39-276	Old Martin Place	Millwood	Adult	0.00		21	Yes
63-39-NONO-1	Old Martin Place	Millwood	Adult	0.00		11	Yes
63-39-NONO-2	Old Martin Place	Millwood	Adult	0.50		26	Yes
64-50-344	Graves Chapel	Millwood	Adult	0.50		2	Yes
64-50-NONO	Graves Chapel	Millwood	Adult	0.00		9	Yes
64-51-44	Unknown	Millwood	Adult	0.00		25	Yes
65-112-1-2	White Cliffs	Millwood	Adult	0.07		28	Yes
65-112-2-1	White Cliffs	Millwood	Adult	0.12		26	Yes
65-112-2-2	White Cliffs	Millwood	Adult	0.15		13	Yes
65-112-4	White Cliffs	Millwood	Adult	0.00		27	Yes
65-114-10	Miller's Crossing	Millwood	Adult	0.20		5	Yes
65-114-16	Miller's Crossing	Millwood	Subadult	0.00		11	Yes
65-114-23	Miller's Crossing	Millwood	Adult	0.17		6	Yes
65-114-5	Miller's Crossing	Millwood	Adult	0.50		2	Yes
65-114-7	Miller's Crossing	Millwood	Adult	0.00		7	Yes
65-114-8	Miller's Crossing	Millwood	Adult	0.00		13	Yes
69-66-589			Adult				No
83-377-14-2							No
83-377-18							No
83-377-23-38			Adult	0.27		15	No
83-377-27-M							No
83-377-29M			Adult				No

T1 (Cont.)

Accession Number	Context	Analysis Group	Age	Chipped Teeth /Total Teeth	Wear SUM	Num Teeth	Included in Analysis
83-377-32M							No
83-377-3-98			Adult	0.63		16	No
83-377-56-2			Subadult				No
83-377-60-2						0	No
83-377-70-27						0	No
83-377-70-M/MC							No
86-53-1	None	Millwood	Adult	0.50		18	Yes
86-53-2-A	Unknown	Millwood	Adult	0.09		11	Yes
86-53-3-1	Unknown	Millwood	Adult	0.00		13	Yes
86-53-4	Unknown	Millwood	Subadult	0.00		15	Yes

Chapter 7: Conclusion

John R. Samuelsen

7.1 Study Objectives

This study set out to accomplish seven objectives related to ancient human origins, warfare, ceremonialism, settlement patterning, and diet. Each objective also provided at least one line of evidence which could be used to evaluate the purposes behind the ritual burial of skulls and mandibles at the Crenshaw site. As outlined in Chapter 1, these represent independent lines of evidence, often based on independent theoretical backgrounds, that each help evaluate the questions surrounding the origins of the remains. If all these different lines of evidence agree, it provides a much more definitive answer than if there is disagreement between them. The chapters in this study each addressed one or more of these objectives.

(1) Develop and test a method utilizing the multivariate and linear nature of biologically available Pb isotope ratios from archaeological animal and human teeth to determine the geographic origins of skeletal elements. Chapter 2, written collaboratively with Adriana Potra, developed and tested the biologically available Pb method using prehistoric animal teeth from southwest Arkansas to construct a local background (Samuelsen and Potra 2020). Other types of samples were compared to, including expected local and foreign ancient human teeth, foreign prehistoric animal teeth, whole rocks, rock leachates, and soil leachates. The chapter successfully showed that the geographic origins of ancient human remains could be assessed using prehistoric animal teeth, but not whole rocks. Different contamination assessment methods were compared and trace element analysis (e.g. Kamenov et al. 2018) was recommended for future research.

(2) Furnish this new approach with a comparative multi-state map of biologically available Pb/Sr isotope ratios. (3) Demonstrate this method by analyzing the geographic origins

of the Crenshaw skull-and-mandible deposits and evaluate the prevalence and extent of interregional warfare at the intersection of the Southern Plains and Eastern Woodlands ca. A.D. 1200-1500. Chapter 3 utilized the method developed in Chapter 2 to construct a Pb and Sr isoscape using prehistoric animal teeth from Arkansas, Illinois, Louisiana, Mississippi, Missouri, Oklahoma, and Texas. The first large-scale Pb isoscape from prehistoric animal tooth enamel and the biologically available Pb method successfully distinguished the skulls and mandibles from most other areas. The combination of the Pb isoscape with the Sr isoscape helped distinguish areas where Pb isotopes were not definitive on their own. This established that the skulls and mandibles are local to southwest Arkansas (particularly sites surrounding Crenshaw) and are non-local to all other tested regions. The isoscapes created can be used by future researchers investigating similar issues in other regions. The correlation analysis of the trace element data from ancient human tooth enamel showed that the elements and thresholds established by Kamenov et al. (2018) were generally successful at identifying contamination, but that the use of some elements (particularly V) and universal thresholds may not be appropriate for some ancient populations. The analysis also showed that the total removal of the surface of the tooth successfully removed soil Pb contamination.

(4) Reevaluate the dietary isotopic evidence for the possibility of bison consumption to help evaluate if a Southern Plains origin for the skulls and mandibles is supported by carbon (C) and nitrogen (N) isotope ratios. Chapter 4 reanalyzed these data, includes auditory exostoses as a variable in analysis, and bases contamination thresholds only on C/N ratios. The analysis suggested that different clusters tended to have different diets, but that these diets were generally similar with other tested sites in the Southern Caddo Area. They were inconsistent with the Northern Caddo Area where bison was likely being consumed. There were statistically

significant differences between those in association with auditory exostoses and those with no such association. This suggests that the skulls and mandibles included clusters that had elevated C and N isotope ratios due to maize and fish consumption rather than bison consumption. Other interesting aspects of the data suggested that there is evidence of matrilocal intermarriage between clusters and that there was food sharing with articulated burials in Mound C. This would be consistent with Caddo lifeways which include matrilocality, matrilineal decent, and food sharing from the populous with ritual and community leaders (Sabo 1998). Taken with the results from Chapter 3, Chapter 4 also indicates that the Caddo had a varied diet depending on the family (or other grouping) and was in the midst of adopting maize as a staple during the Middle Caddo period (A.D. 1200-1500). The latest skull cluster (Rayburn) also had some of the strongest evidence of maize consumption, but some mandibles indicated even more consumption of maize. The diets of the mandibles generally suggested they had a smattering of diets consistent with the skulls except for one sample with a high N isotope ratio.

(5) Evaluate the geophysical evidence of settlement patterning at Crenshaw to test if it is consistent with the use of Crenshaw for ceremonies and the skull-and-mandible cemetery reflecting the ritual deposition of human remains from surrounding sites. Chapter 5 analyzed the results of a large-scale (~18 ha) gradiometry survey and unexpectedly showed evidence of both linear patterns of structures and overlapping structures in most of the study area. There are clear examples of numerous and large ceremonial structures, particularly near Mounds A and B. There are also linear patterns of less clearly defined possible structures that are interpreted to be domestic structures. The large number of these and the large number of overlapping structures indicates that Crenshaw had a nucleated settlement pattern at some point in time. Comparisons to previously excavated Caddo structures, comparisons to the George C. Davis site (Newell and

Kreiger 1949; Story 1997; Walker 2009), and comparisons to Middle to Late Caddo sites like Battle (McKinnon 2013) show that Crenshaw was among the most populated sites, if not the most, in the Caddo Area at one time. Interpretations based on this and other data conclude that Crenshaw had a nucleated settlement pattern until the beginning of the Middle Caddo period (A.D. 1200). This means that Crenshaw was a nucleated settlement during Early Caddo times, similar to interpretations about George C. Davis (Story 1997). The transition to a more dispersed settlement pattern is hypothesized to occur ca. A.D. 1200, just before the increased use of skull and mandible burials at Crenshaw. However, the site was still clearly occupied by at least a small resident population responsible for the rituals and ceremonies, including both articulated and disarticulated burials, that occurred during the Middle Caddo period.

(6) Reconsider the previous biological evidence (Schambach et al. 2011; Zabecki 2011) that suggested the skulls and mandibles were foreigners by reevaluating the data and literature. This includes a comparison to a separate population for biological traits in the Little River region around the Millwood Reservoir. Chapter 6, written collaboratively with Heidi S. Davis, Ashley E. Shidner, Nicole E. Smith-Guzmán, and Teresa V. Wilson, reevaluated the data and biological evidence for foreign populations among the skulls and mandibles and compared to populations in the Little River region. The results of this reevaluation show that many of the previous lines of evidence arguing that the skulls and mandibles were foreigners were based on unfortunate errors in documentation or in interpretations related to biological versus behaviorally induced traits. Other lines of evidence suggesting they were foreigners were contradicted with additional data.

First, photographs from the time of excavation were reviewed (before the skulls deteriorated) and showed that several of the skulls had cranial modification and that parallelo-fronto-occipital was the most common type represented. This suggests little difference between the skulls and what would be expected of local populations on the basis of cranial modification. Second, it was discovered that the lack of chipping of teeth in Mound C was due to a documentation error. This meant that the local population at Crenshaw did not lack chipping, but instead had a degree of tooth chipping comparable to the skulls. Third, some behavioral traits, like auditory exostoses, were previously interpreted to be genetic markers of foreign populations (Powell 1977; Zabecki 2011). However, these are primarily behavioral and are consistent with other populations in southwest Arkansas, including an example from Cedar Grove (Rose 1984). Overall, there is no evidence to suggest the skulls and mandibles are foreign populations except for increased tooth chipping of mandibles. However, a statistical comparison with age (i.e. wear) and a review of photographs suggested that this additional chipping of the mandibles was likely due to postmortem damage.

(7) Compare all datasets with the archaeological evidence from the Little River region sites nearest to Crenshaw to help explain the burial ceremonialism in this region during the Middle Caddo period (A.D. 1200-1500). This chapter will accomplish this objective.

7.2 Burial Ceremonialism and Comparisons to the Little River Region

Mortuary patterns were compared to the evidence from several Little River region sites in the vicinity of the Millwood Reservoir. Sites that were evaluated include Mineral Springs (3HO1), Old Martin Place (3LR49/13), Miller's Crossing (3SV10), Bell (3HO11), White Cliffs (3LR12), and Graves Chapel (3SV15) (Bohannon 1973; Hoffman 1971). These were some of the same sites that were sampled for Pb and Sr isotopes from animal tooth enamel (see Figure 2.3) and were some of the same sites that were evaluated for biological traits in Chapter 6.

7.2.1 Mortuary Structures

Hoffman (1971:230, 552, 559) suggested that the burned and mounded over structures at many of these sites represented a pattern of mortuary structures associated with the nearby off mound graves (Tables 7.1, 7.2). He uses these structures as part of his phase designation for the Early Caddo Miller's Crossing phase (Hoffman 1971:746). However, it is clear from the subsequently processed radiocarbon dates and the artifact assemblages at multiple sites that these potential mortuary structures were from Middle Caddo times while the graves dated to Fourche Maline and Early Caddo times with the exception of Mineral Springs (Bohannon 1973). That is, there is a pattern that shows significant Middle Caddo occupation and mortuary ceremonialism, but there were no bodies excavated from this time. This is despite the fact that there are clearly bodies from earlier times and significant effort was taken both by professionals and amateurs to locate later graves. This raises the question, where are all the bodies of the Middle Caddo occupants of these sites? While it is possible that this is due to selection and excavation biases, it is important to recognize that the pattern exists and to propose potential explanations.

Table 7.1 – Sites with burned structures previously interpreted to be charnel houses. Have occupations dating to the Middle Caddo period, but tend to lack burials from same time.

Site Name	Middle Caddo		Structure Date	Mounded	Burned	Basin Shape	Burial Dates	Skull Burial	Cremation	Bundle
	Artifacts	Burials								
Mineral Springs	Yes	Yes	Middle Caddo	Yes	Yes	Yes	1000-1500	Yes	Yes	No
Bell	Yes	No	Middle Caddo	Maybe	Yes	Yes	700-1200	Fragments	Maybe	No
Whitte Cliffs	Yes	No	Middle Caddo	Yes	Yes	Yes	700-1200	No	Yes	No
Old Martin	No	No	None				?.-1200	No	No	Yes
Miller's Crossing	No	No	Unknown	Yes	Yes	Yes?	1000-1200	Yes	No	No
Graves Chapel	Yes	No	Middle Caddo	Yes	Yes	No	700-1200	Skull + long bones?	No	Yes

Table 7.2 – Timing of interpreted mortuary structures from previous radiocarbon dates (Pearson et al. 1965; Valastro et al. 1972).

Site Name	Lab Numbers	Provenience	Conventional ^{14}C Age B.P.			Calibrated 1σ Range A.D. (Probability)				Calibrated 2σ Range A.D. (Probability)			
Mineral Springs	Tx-111(a), Tx-111(b) and I-982	Mound 8 - Stage 3 Structure	565	±	51	1314 1388	– –	1357 1420	(0.56) (0.44)	1297 1376	– –	1374 1435	(0.56) (0.44)
Bell	Tx-112 and Tx-583	Structure 1	640	±	57	1287 1347	– –	1322 1392	(0.44) (0.56)	1274	–	1410	(1.00)
White Cliffs	Tx-581	Mound 1 Structure	650	±	70	1281 1345	– –	1324 1393	(0.47) (0.53)	1256	– –	1423	(1.00)
White Cliffs	Tx-578	Mound 2 Structure	620	±	70	1294 1339	– –	1330 1397	(0.38) (0.62)	1273	–	1427	(1.00)
Graves Chapel	Tx-580	Mound A - Uppermost Structure	720	±	70	1223 1363	– –	1305 1385	(0.83) (0.17)	1181	–	1399	(0.99)

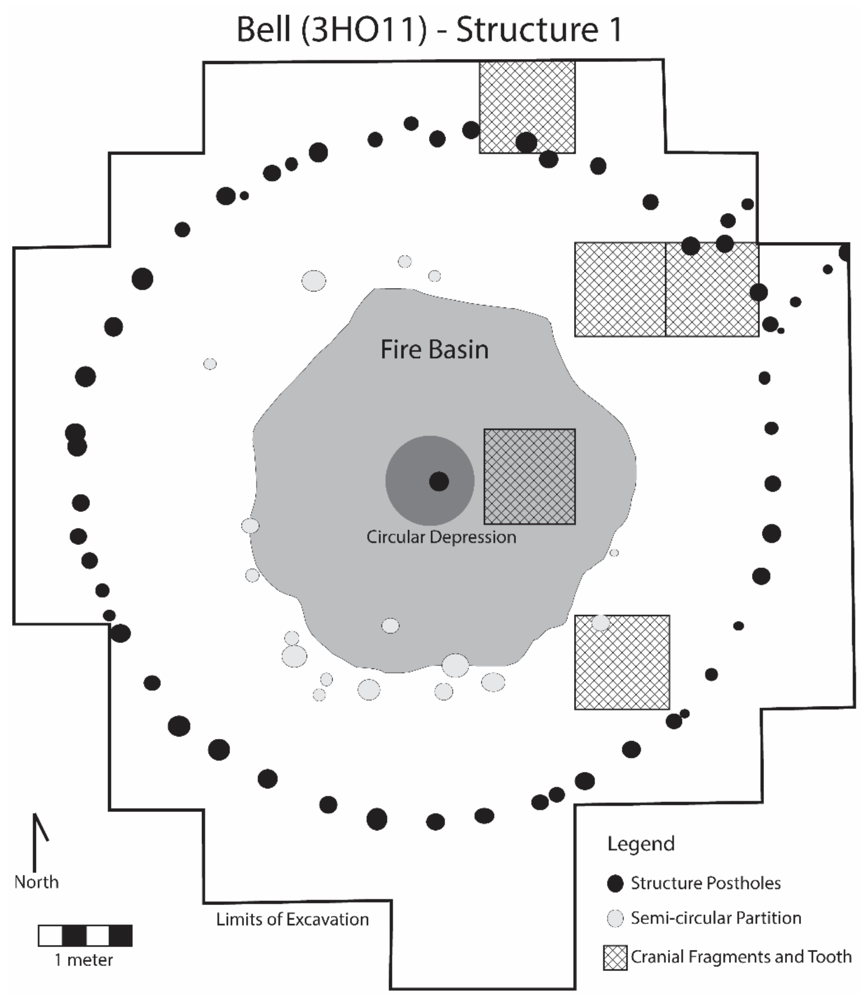


Figure 7.1 – Structure 1 at Bell (3HO11) with a central fire basin (after Hoffman 1971:Figure 39). The cranial fragments and tooth were found in five units. Interestingly, three of these units are between the fire basin and the entranceway, potentially indicating they were dropped while they were being taken in or out of the structure.

Hoffman's (1971:230) suggestion that some of these structures may be charnel houses or mortuary facilities is complicated due to the fact that they seem to have been kept clean or were cleaned out before they were burned. However, there is some evidence to support this conclusion. First, Structure 1 at Bell (Figure 7.1) had human cranial remains within a fire basin. Fire basins have a long history of being associated with secondary cremations and bundle burials (see Story 1990). Hoffman (1971:336-337) hypothesized that the cranial fragments may come from the intrusion of the fire basin on an underlying burial. However, the only burial under the fire basin is noted as having no portions missing (Hoffman 1971:334). This hypothesis also does not explain why only cranial fragments were present or why they were burned.

Second, these structures have significant evidence of being used for ceremonial purposes. This includes the apparent ritualized burning and burying/mounding over of the structures. While the structure at Bell seems to have been buried, the thickness of the covering layer was relatively thin and may not qualify as a "mound." Many of these structures also have extended entranceways. Third, those structures that were not as clean were associated with ceramic types that are typically deposited with burials, such as Haley Engraved or Haley Complicated Incised.

Finally, Robert E. Bell's (1984) descriptions of the Harlan phase and Harlan-style charnel houses (Kay and Sabo 2006) show clear similarities between these structures. He indicates that skull burials were associated with them in the Northern Caddo Area:

> The entranceway is usually marked by shallow parallel trenches or rows of post holes forming a short hall-like entrance passage into the interior… That these structures functioned as mortuaries is indicated by the general absence of debris or rubbish on the floors, as if the structure had been cleaned out prior to destruction, the absence of interior fire places, and the presence of postholes for closing the entranceway. The finding of human skull fragments in the mortuary area also supports this usage, and indicates that the clearing of the mortuary for interment elsewhere was not always complete.
>
> Excavations at the Harlan site indicate that mortuary structures were used for housing the dead. When the mortuary was filled (or for other cultural

> reasons), the contained remains were removed and buried in the nearby burial mound. After burial, the mortuary was burned and destroyed, covered over with earth, and a new one was constructed over the same spot. The burial remains found within the burial mound also support this idea. Many burials were apparently deposited at the same time and these occur in layers to indicate different burial episodes in mound construction. The skeletons are commonly disarranged and are often incomplete, suggesting various stages of decomposition of the body prior to burial…
>
> The burials contained within the mound were dominated by single flexed individuals, commonly in very poor condition and usually incomplete. Multiple burials, cremations, and bundle burials also occur with isolated bones or single skulls… (Bell 1984:229-231)

Bell's description of the Harlan structures (see also, Bell 1972:253-258) is very similar to the structures in the Little River region, particularly the structure at Bell. This structure even has post holes in the entranceway. The main difference is the presence of the fire basin. Hoffman similarly referenced Bell's statements that charnel houses at Harlan appear similar to these structures (Davis 1966:48-51). Many burned and buried structures are found all over the Southern Caddo Area and are not generally assigned with this function (Trubitt 2009). It is important to recognize that while some of these structures may represent charnel houses or mortuary structures, there may have been multiple uses for such structures. However, it is interesting that public building-oriented mound ceremonialism appears in this area (A.D. 1250-1300, see Schambach 1996:40-41) at the same time the skulls and mandibles appear at Crenshaw. Additionally, the smaller Little River region sites show that mound burial was not practiced during this time, despite it having been practiced during the Early Caddo period. Instead, these building-related mounds appeared, as did the skull-and-mandible cemetery at Crenshaw. This concurrent appearance could suggest that these structures were related to the transportation of remains from smaller mound sites to important ceremonial centers, possibly also explaining why mound burials decreased in many places during this time.

From another viewpoint, comparisons can be made between the Bell structure, an ash pit containing human cranial fragments exposed to fire, and the ash bed structure at Crenshaw. This structure (Jackson et al. 2012; Schambach 1996) was also an ash pit containing fragments disproportionately representing the cranium rather than the mandible. Notably, 109 of the 129 teeth (84.5%) recovered from the structure (Features 1 and 6) and all 16 recovered from the floor are maxillary teeth (Zabecki et al. 2011:C-177). The probability that 109 or more of the 129 teeth were from the maxilla is 2.22×10^{-16}. This was not a random occurrence. This suggests that both of these structures were used to process human skulls with additional processing of the cranium that left mandibles relatively intact. Zabecki (2011:48) indicates that the evidence supports the hypothesis that portions of the skulls at Crenshaw may have been smashed and taken elsewhere. It is further suggested here that additional processing of craniums led to the disproportional deposition of cranial fragments and maxillary teeth. This would explain why the mandibles do not have matching crania. It might also explain why the mandibles might have postmortem damage.

Some cranial fragments from both structures were exposed to fire, suggesting cremation or some other ritual burning practice was involved (Hoffman 1971:336; Zabecki et al. 2011:C-176). This could provide an explanation for the large ash basins in both structures. Fire basins were often found in close association at sites with secondary cremations and bundle burials during Fourche Maline times (Story 1990:279-292). Two particularly interesting examples at the Coral Snake Mound included Feature 30, a “badly crushed” unburned skull deposited with cremated remains, and Feature 4, an unburned mandible deposited with charred skull remains (Story 1990:286). A few of the people in the skull-and-mandible cemetery at Crenshaw also have evidence that they were exposed to fire before burial (Zabecki et al. 2011).

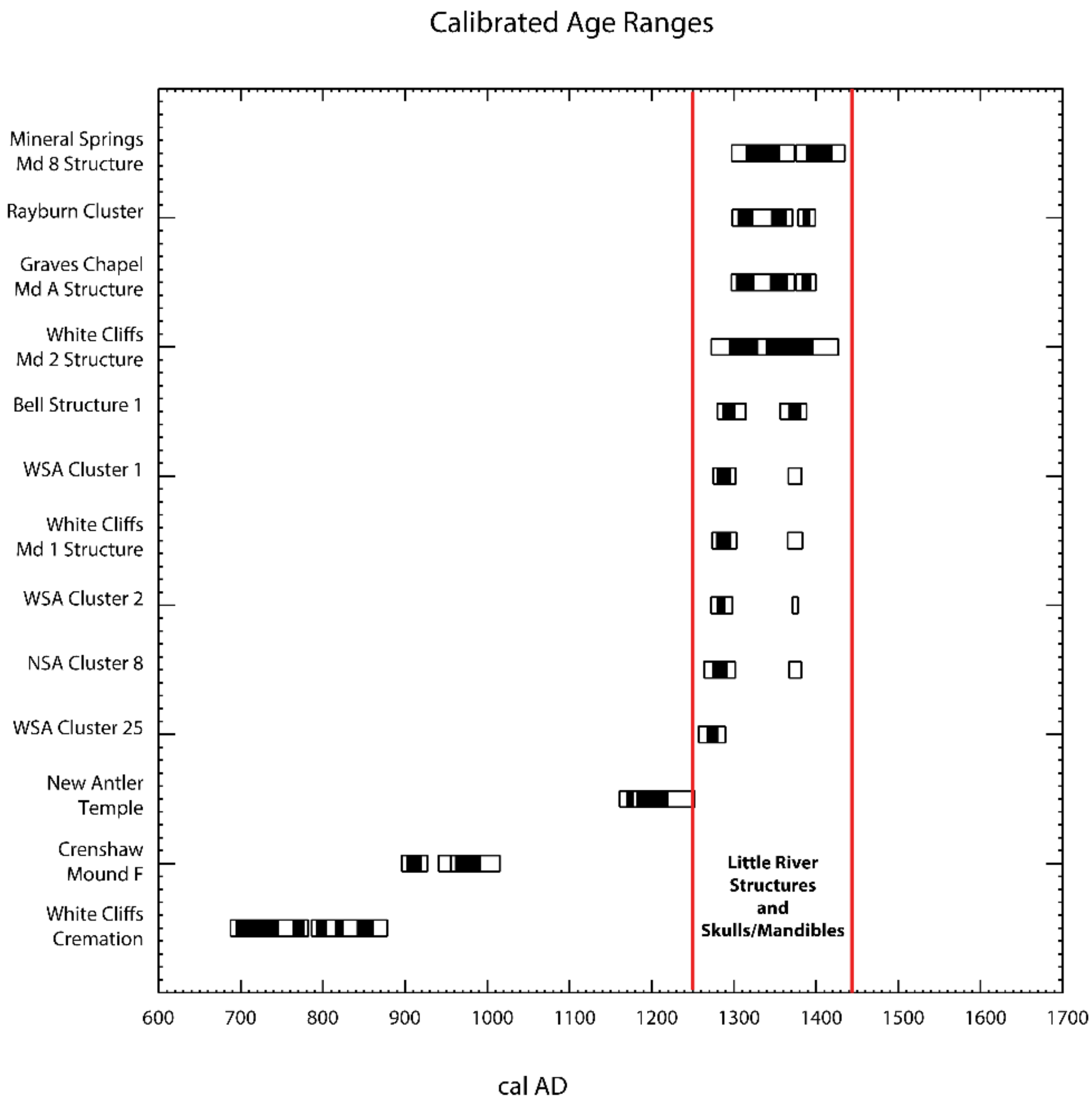


Figure 7.2 – Little River structures interpreted to be mortuary structures date to same time as the skulls and mandibles (Samuelsen 2014). This includes the structure from Bell with a fire basin and charred skull pieces. If a new date was produced (Table 7.3), that date was used, otherwise the old dates were used. Old dates include the dates from Mineral Springs and the structure from White Cliffs Mound 2. The dates from Mineral Springs represent an average of three dates from the same structure.

It is important to note here that the structure at Bell dates to A.D. 1274-1410 (2σ) based on an averaging of Tx-112 and Tx-583 (Pearson et al. 1965; Valastro et al. 1972). The skull-and-mandible cemetery at Crenshaw dates to A.D. 1253-1399 (Samuelsen 2014), making them contemporary. Sometimes, older radiocarbon dates are inaccurate. Therefore, additional dates from three structures were obtained through AMS analysis (Table 7.3). These dates confirm the original dates but have better accuracy. They show that these mortuary structures date to the same time as the skulls and mandibles at Crenshaw (Figure 7.2).

Table 7.3 – Newly processed AMS dates from structures and a cremation.

Site Name	Lab Number	Accession	Provenience	Material	Conventional ^{14}C Age B.P.			Calibrated 1σ Range A.D. (Probability)				Calibrated 2σ Range A.D. (Probability)			
Bell	D-AMS 022020	61-114-359	Center of fire basin in Structure 1	Charcoal (hickory nut)	663	±	22	1285 1366	– –	1302 1382	(0.53) (0.47)	1280 1356	– –	1314 1388	(0.52) (0.48)
White Cliffs	D-AMS 022021	61-114-1174	Roof fall in Mound 1 structure	Charcoal	686	±	20	1278	–	1297	(1.00)	1274 1365	– –	1303 1383	(0.80) (0.20)
Graves Chapel	D-AMS 022023	64-50-143	Beam in Mount A structure	Charcoal	612	±	23	1303 1344 1383	– – –	1325 1366 1394	(0.41) (0.40) (0.19)	1297 1376	– –	1374 1400	(0.78) (0.22)
White Cliffs	D-AMS 022022	65-112-3	Cremation	Human tooth root	1235	±	29	694 763 791 814 841	– – – – –	746 778 805 825 862	(0.51) (0.15) (0.11) (0.07) (0.15)	687 786	– –	782 878	(0.57) (0.43)

7.2.2 Explaining the Ritual Burial of Skulls and Mandibles

One possible explanation for the lack of graves associated with the Middle Caddo structures and occupations in the Millwood Reservoir is that some of the bodies were stored or processed in such structures but were not being buried at these sites. For example, there are many Middle Caddo graves at Mineral Springs and these people may represent the occupants of these other sites. If we assume that central place theory is correct, then this might be the best explanation. The multiple-mound Lockesburg site (3SV48) is another possibility, but is distantly up a tributary, the Cossatot River. What limited information is available suggests that most of the mounds contained burned structures. There were reports of a cremation and burials, but we currently do not know what time period they are from or how many there were. Crenshaw is another option if we consider that communities may have followed river channels. This type of spatial distribution was suggested for the Middle Caddo in the Mid-Ouachita region (Early 1982:219-222). It should also be noted that the Terán map showed the mound at the edge of the community, not the center (Sabo 2012). Crenshaw is the first large ceremonial center downstream and is located south of the intersection of the Red and Little Rivers. While there are not a large number of articulated Middle Caddo burials at Crenshaw, the large number of skull and mandible burials could potentially explain where these people were buried. Additionally, the overlap between the ash bed structure at Crenshaw (ca. A.D. 1190) and the Middle Caddo structure at Bell shows that some common mortuary practice was occurring in these areas related to burnt cranial fragments and fire basins. Given all of this information, it is possible that some of these people may have been processed in such a structure after death and their skull, mandible, or other remains sent to Crenshaw for final burial. This would still leave important questions. Such as, where are the rest of the bodies?

White Cliffs, which dates from the Late Fourche Maline period (A.D. 700-1000) to Middle Caddo, had one individual who was cremated and buried without any associated funerary objects. This is a constant problem for understanding the timeframe of cremation practices in southwest Arkansas. Cremations are often only relatively dated if they are placed near other burials that have associated funerary objects. This makes it unclear how late cremations can be expected to have been practiced in southwest Arkansas. A tooth was AMS dated to provide a direct measurement of when this individual was cremated and dated to A.D. 687-782 or A.D. 786-878 (2σ), consistent with other burials in the area. Cremation, therefore, has been shown to have been practiced at least as late as the Late Fourche Maline period in southwest Arkansas.

While there are examples of Early and Middle Caddo cremations, they are rare. If such large numbers of individuals were being cremated, we might expect to see cremations deposited around these sites. The lack of evidence of this could be due to sampling error or pothunter behavior since much of what we know from many sites is based on such reports. However, it is likely that any cremations were scattered or were similarly being carried elsewhere for burial. For example, Mound D at Crenshaw contained several cremations with many very small bone fragments, some including skull pieces. Most of these are seemingly from Caddo times since they were intrusive into the mound (Moore 1912:623; Schambach 1982:154; Wood 1963:61, 64-65). Middle Caddo cremations were documented at Mineral Springs in Burial 15, which also contained Middle Caddo ceramic types, such as Haley Engraved (Bohannon 1973). There are many other examples of cremations in the archaeological record in the Great Bend region, but many have not been critically assessed as to what time they were deposited. Cremation is but one possible explanation for where the rest of the bodies went after the separation of the skull or mandible. It appears that there were alternatives, such as the headless burials at Haley (Moore 1912) and Hardman (Early 1993). Articulated or bundle burials also seem to have been an option. Sites like Crenshaw, Mineral Springs, and Haley (to name a few) all had articulated burials during this same time but included much greater numbers of funerary objects than the burials that came before. This could suggest these represented ritual or community leaders or those that have obtained some sort of special status. The dietary evidence from Chapter 4 would support this interpretation in Mound C, given their diets reflect an averaging of the community's diet. Some burials at Crenshaw also reflect the collective burial of postcranial remains.

Mound F is one clear example of large-scale secondary burials including cranial and postcranial remains, but dates to ca. A.D. 895-1015. Clarence B. Moore's (1912:620-627) excavations at Crenshaw illustrate the secondary burial practices among the Early or Middle Caddo. He repeatedly found disarticulated remains in the mounds at Crenshaw, including skull burials with bodies that were clearly treated differently. For example, Moore's (1912:621) Burial 2 in Mound B "consisted of a layer of bones, including four skulls." This shows that skulls were being deposited in Mound B as assembled burials of disarticulated remains. Moore's (1912:622) Burial 4 in Mound B similarly represented the disarticulated remains of a single individual. Burial 3 is even more important:

> This great deposit of bones, which included seventeen skulls, was without arrangement save that the skulls were in two groups, one at the northwestern, and one at the southwestern, margin of the deposit; and that in one place there had been an attempt to pile the long-bones parallel and horizontal. Along the northeastern part of the deposit of bones were arranged ten earthenware vessels, one of which contained a mass of kaolin. (Moore 1912:621-622)

Burial 3 demonstrates that disarticulated postcranial remains were being treated differently from skulls. Skulls were being collected and placed together, or "clustered," while the rest of the remains were being scattered. It is also worth noting that the "skulls" were not described as "craniums" despite the disarticulated state of the postcranial remains. By contrast, in his description of Burial 13 in Mound D, he describes this individual as a "cranium" without other bones (Moore 1912:623). This could suggest that the mandibles were still attached in Burial 3 and that they Caddo either did not wait for the body to fully decompose or they used some sort of method to keep the cranium and mandible together after decomposition.

Based on Moore's (1912:620-622) description of the mound, it appears that each of the burials were within Mound B and not beneath it. This is important as all evidence suggests that this mound was only used during Early to Middle Caddo times (Samuelsen 2009:37-38; Wood 1963:6-29). The ceramic types figured by Moore include Haley Complicated Incised jar (Moore 1912:Figure 127) and a Foster Trailed Incised jar (Moore 1912:Figure 126) with many Haley Complicated Incised elements. These types are consistent with a Middle Caddo date. There were also two examples of Crockett Curvilinear Incised or Pennington Punctate Incised (Moore 1912:Figures 124, 125), indicating Early Caddo use as well. The burials excavated by Judge Harry J. Lemley (1936) and Glen Martin showed that the mound only contained Caddo material and that a Fourche Maline cemetery underlies the mound. So, it is possible that some of these burials could be earlier, but Moore makes no mention of digging to the pre-mound surface and the burial depths are much shallower than the mound height. Wood (1963:7, 9) similarly notes that Moore's excavations were "superficial" and never penetrated beneath the mound.

This is important as these disarticulated remains show an Early or Middle Caddo practice involving disarticulated remains with different treatment of the postcranial and skull remains. The large number of ceramics deposited with this burial represents nearly half of the collection from Moore's excavation of Mound B. Verification of the timeframe of this burial could be done by verifying the types present in this collection. Regardless, this suggests that charnel houses or some other mortuary facility would have been needed to store or process the remains before secondary deposition occurred and that these most likely would have existed during Early or Middle Caddo times, perhaps in a similar manner as the historic Choctaw "Bone-picker" practice (Swanton 1931:176-177) previously proposed for Fourche Maline burial practices by Story (1990:288-289):

> After the death of a Choctaw, the corpse, wrapped in a bear skin or rough kind of covering of their own manufacture, was laid out at full length upon a high scaffold erected near the house of the deceased, that it might be protected from the wild beasts of the woods and the scavengers of the air. After the body had remained upon the scaffold a sufficient time for the flesh to have nearly or entirely decayed, the Hattak fullih nipi foni, (Bone-picker) the principal official in their funeral ceremonies and especially appointed for that duty—appeared and informed the relatives of the deceased that he had now come to perform the last sacred duties of his office to their departed friend. Then, with the relatives and friends, he marched with great solemnity of countenance to the scaffold and, ascending, began his awful duty of picking off the flesh that still adhered to the bones, with loud groans and fearful grimaces, to which the friends below responded in cries and wailings…
>
> After he had picked all of the flesh from the bones, he then tied it up in a bundle and carefully laid it upon the scaffold; then gathering up the bones in his arms he descended and placed them in a previously prepared box, and then applied fire to the scaffold, upon which the assembly gazed uttering the

> most frantic cries and moans until it was entirely consumed. Then forming a procession headed by the Bone-picker the box containing the bones was carried, amid weeping and wailing, and deposited in a house erected and consecrated to that purpose and called A-bo-ha fo-ni, (Bone-house) with one of which all villages and towns were supplied. Then all repaired to a previously prepared feast, over which the Bone-picker, in virtue of his office, presided with much gravity and silent dignity.
>
> As soon as the bone-houses of the neighboring villages were filled, a general burial of bones took place, to which funeral ceremony the people came from far and near, and, in a long and imposing procession, with weeping and wailing and loud lamentations of the women, bore off the boxes of bones to their last place of rest, and there depositing them in the form of a pyramid they were covered with earth three or four feet in depth forming a conical mound. All then returned to a previously designated village and concluded the day in feasting… (Swanton 1931:176-177)

The gathering of human remains in a charnel house, one per town, family, or village, and eventual deposit at the Crenshaw could be reflected by the clustering of skulls and mandibles. That is, the clusters of several skulls together could be the remains of individuals from the same site or the same general area given a more dispersed settlement pattern, perhaps even the same family unit. This would certainly be consistent with the matching biological traits, dietary isotopes, and Pb and Sr isotopes within clusters. The mandibles might similarly represent this, but they were generally deposited in far larger numbers, perhaps indicating a practice closer to the Swanton's description of a large deposit of bones among all people from multiple areas. This could be seen as a later adaptation of the mass graves with over 40 individuals under Mound F and in similarly large-scale burial in Mound C (Durham and Davis 1975; Schambach 1982).

7.3 Synthesis

Taken as a whole, the evidence indicates that the skull-and-mandible cemetery is the result of a local burial practice (Chapter 3), occurred while the Caddo were adopting maize as a staple (Chapter 4), and occurred when a nucleated settlement pattern at Crenshaw began to give way to a more dispersed settlement pattern (Chapter 5). This is consistent with what is known about other contemporary and significant Caddo mound centers, such as George C. Davis (Story 1997, 1998). There is also little difference between expected local populations and the skulls and mandibles based on biological traits (Chapter 6). However, there are two issues that need to be addressed since they do not necessary fit perfectly with this narrative.

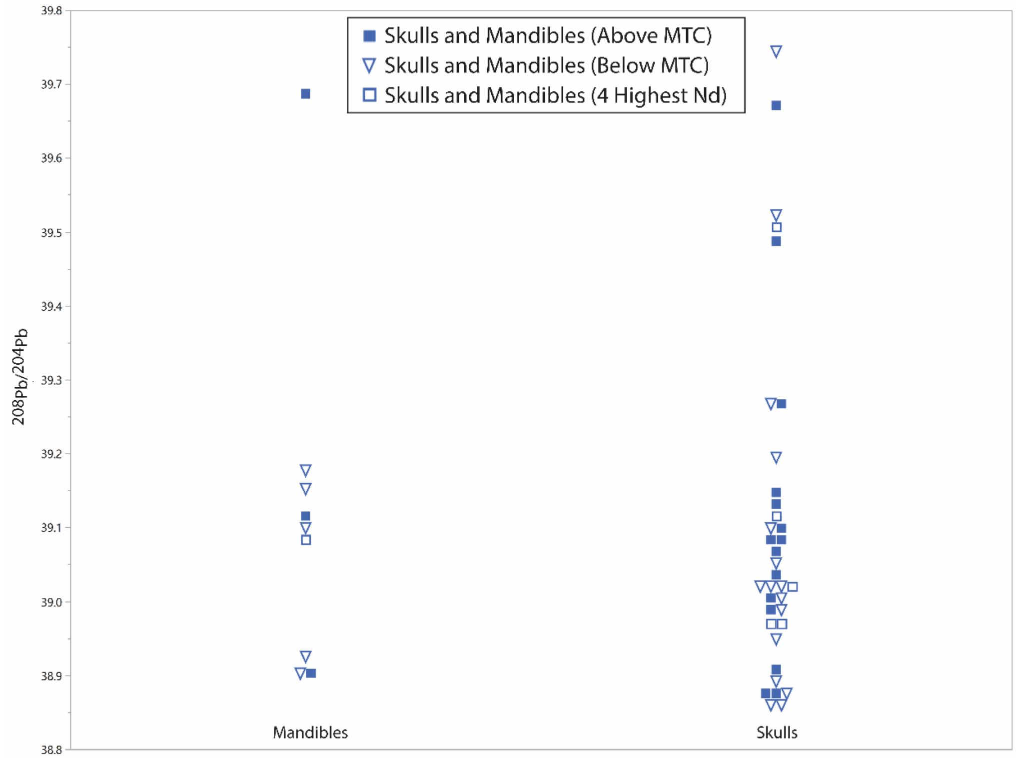


Figure 7.3 – Pb isotope comparisons between the skulls and mandibles. Both groups are consistent with southwest Arkansas and there is no significant difference between the two groups.

First, the mandibles had more tooth chipping than the skulls, Crenshaw locals, or Millwood remains. Chapter 6 showed this was most likely due to postmortem damage, either prior to or after burial. However, it would be prudent to consider the other evidence presented to test if there is any evidence that might suggest the skulls were local and the mandibles were not. The Pb and Sr isotopes processed in Chapter 3 show that there is no difference between the skulls and mandibles on the basis of Pb or Sr isotopes (Figures 7.3, 7.4). Considering both groups match the local range for southwest Arkansas and are not significantly different when compared to each other, it is considered unfeasible that the mandibles were coming from a different region or regions than the skulls. This is further supported by Figure 4.11 which shows that the diets represented by the mandibles were generally similar to the skulls with the exception of one sample with a very high N isotope ratio.

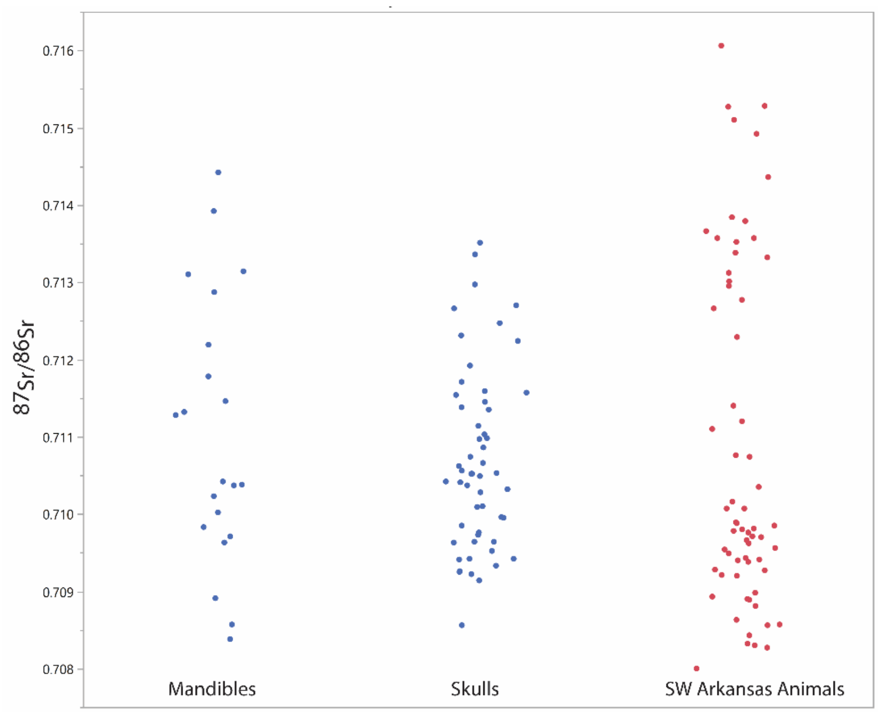


Figure 7.4 – The skulls, mandibles, and southwest Arkansas animals all have similar Sr isotope ratios. The mandibles have a slightly higher range than the skulls and the animals have a slightly higher range than the mandibles. This, combined with the Pb isotope evidence, suggests the mandibles are coming from the same general area as the skulls.

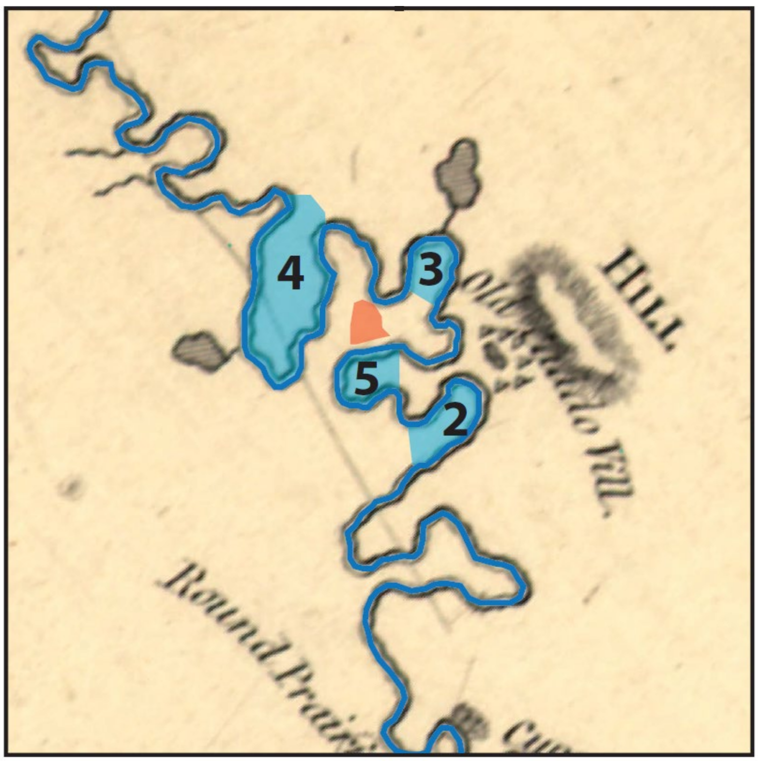
Second, it is still unclear if one of the issues described by Samuelsen (2016:132) has been resolved. Specifically, while the skulls and mandibles have been shown to be local and represent people from surrounding sites, it is unclear if this could mean "an expansion of the area that was part of the ritual community to preexisting sites" or if it could mean that it was "associated with a change to a more dispersed settlement pattern during this time." The description of the Middle Caddo sites in the Little River region could suggest the former, but the geophysical results have been interpreted to suggest the latter. To get a better understanding of the issue, the concept of the ritual landscape should be explored.

Those who contributed to this ritual, whether willing participants or not, could be seen as participating within a ritual landscape (Anschuetz et al. 2001). This ritual landscape could be defined as the area from which the ritual participants came. It is important to recognize that people have multiple identities, including identities associated with kin, clans, religious/ritual communities, social communities, and political communities (Fowler 2004). It may be the case for smaller groups that ritual and social communities are one in the same (Rappaport 1984). However, this is likely not the case for the ancient Caddo. For example, Sabo (1998) showed that Caddo hierarchies are different for social/political and ritual community leaders.

Rather than assume that the people participating in this ritual were part of one social/political/ritual community, it should be recognized that the ritual community and the social/political community around Crenshaw may have not been equivalent. This may be especially true if Crenshaw had special ceremonial standing compared to other mound sites in the region. As an analogy, the current equivalent of this concept is seen in people's selective attendance at particular places of worship, participation in religious communities, and interments at cemeteries. People will attend churches far from their political/social communities because of their religious importance or because of a special ritual event or holiday. People will similarly choose to be buried in particular cemeteries due to the prestige of being buried there, due to family ties, or because the cemetery's religious affiliation most closely matches their identity.

Historic records show that the area around Crenshaw was particularly important for the historic Caddo. The Kaddohadacho resided near the Great Bend during historic times (Early 2000). The Freeman and Custis expedition of 1806 traveled up the Red River from Louisiana with Caddo guides. When they neared Crenshaw, the Caddo guides stopped the expedition here to pay homage (Flores 1986). Clearly, this landscape held special meaning to the Caddo. The

“Old Caddo Village” at which they stopped is shown east of the Red River near Crenshaw in the 1806 expedition map (Figure 7.5). Crenshaw is west of the river, but it is possible this location east of the river had some connection to Crenshaw in the past. Perhaps this is where the community went when Crenshaw was abandoned. Regardless, this shows how particular locations on the landscape can have ritual significance and the area around Crenshaw seems to have been one of these ritual landscapes (see Flores 1986).



Freeman and Custis Expedition

Figure 7.5 – A.D. 1806 map from the Freeman and Custis expedition showing Crenshaw in orange west of the river and the “Old Caddo Village” east of the river (after Flores 1986). North is up. The numbers indicate current oxbow lakes which have been formed through time. Lower numbers indicate the oxbow lakes are younger, higher numbers are older.

To further emphasize the point, Caddo archaeologists have encountered issues when trying to correlate mound sites to communities. Sometimes, several mound sites are too close together to be easily explained by central place theory (Early 1982; Fields 2014; Schambach and

Early 1982:11-12). Early (1982:222) noted that Middle Caddo sites in the middle Ouachita River basin were often too close together for it to be consistent with such a model. Instead she notes the possibility that supporting populations may follow natural boundaries, such as river tributaries, or reside in the uplands. Describing settlement patterns, Hally (1996:97-98) argues that Mississippian mound centers spaced more than 31 km apart represent distinct chiefdom administrative centers while those less than 18 km apart represent primary and secondary centers of complex chiefdoms. Hally (1996:114-115) too grapples with the issue of closely spaced mound centers. He rejects the idea that they indicate periodic abandonment and relocation due to peaceful chiefly succession. Rather, he suggests they are due to factional competition where they pronounce a new chiefly lineage. This illustrates the view that mound centers are places of political/social power. However, while Caddo mound centers were social and political, they were more clearly centers of ritual power (Brown 2012; Sabo 1998, 2012). The spatial and temporal proximity of some Caddo mound centers may suggest that ritual communities and social/political communities were not a one to one comparison at all times and all places. In this case, it may suggest Crenshaw had obtained primary center status related to surrounding secondary centers during the Middle Caddo period.

Considering the issue at hand, the Pb and Sr isotopes can help evaluate this question as they could potentially reveal if the skulls and mandibles themselves were consistent with the sites in the Little River drainage. A comparison of just these sites and the skull-and-mandible cemetery showed that the isotope ratios are very similar (Figures 7.6, 7.7). A Pb isotope linear patterning analysis also showed that the animals from the Bell site, with the fire basin and skull pieces, appeared very similar to many of the skulls and mandibles (Figure 7.8), although the Sr isotope ratios tended to be on the low side. While this cannot definitively identify what sites the skulls and mandibles were coming from, this and the evidence from Chapter 5 suggests that the expansion of the practice during the Middle Caddo period may be due to both reasons. That is, Crenshaw may have been both changing settlement patterns towards a more dispersed model and incorporating existing sites within the ritual landscape. Chapters 2 and 3 show that the skulls and mandibles are generally inconsistent with the isotope ratios from two Mid-Ouachita region sites and sites in northwest Louisiana, suggesting that this practice was limited to sites closer to Crenshaw. Regardless of whether or not the occupations represented by the Little River Middle Caddo structures were being sent to Crenshaw, Mineral Springs, or some other site, it shows that the Caddo burial practices at the time required burial away from these sites and is consistent with the skulls and mandibles being from surrounding sites.

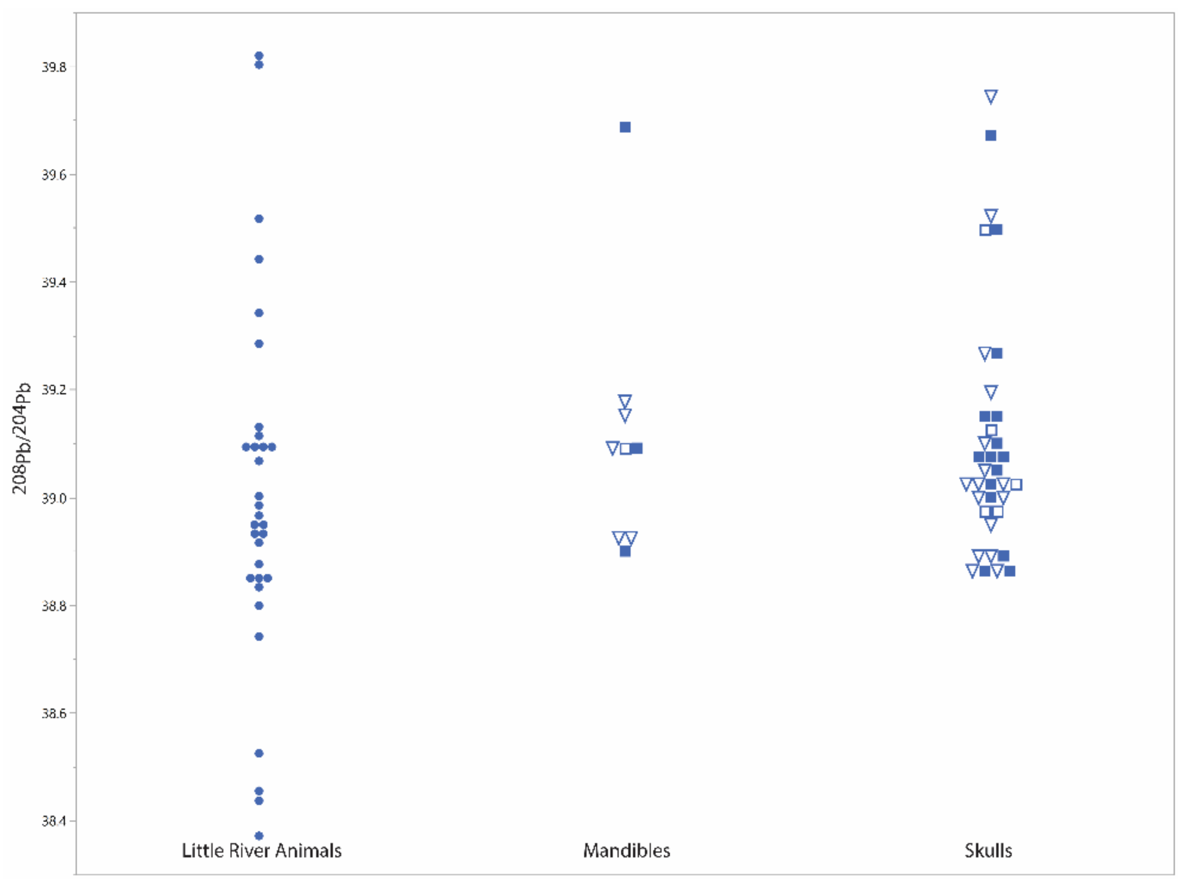


Figure 7.6 – Pb isotope ratio comparison of the skulls and mandibles to only the animals from the Little River sites analyzed (3HO11, 3LR49, 3SV15, and 3SV20). They are very similar.

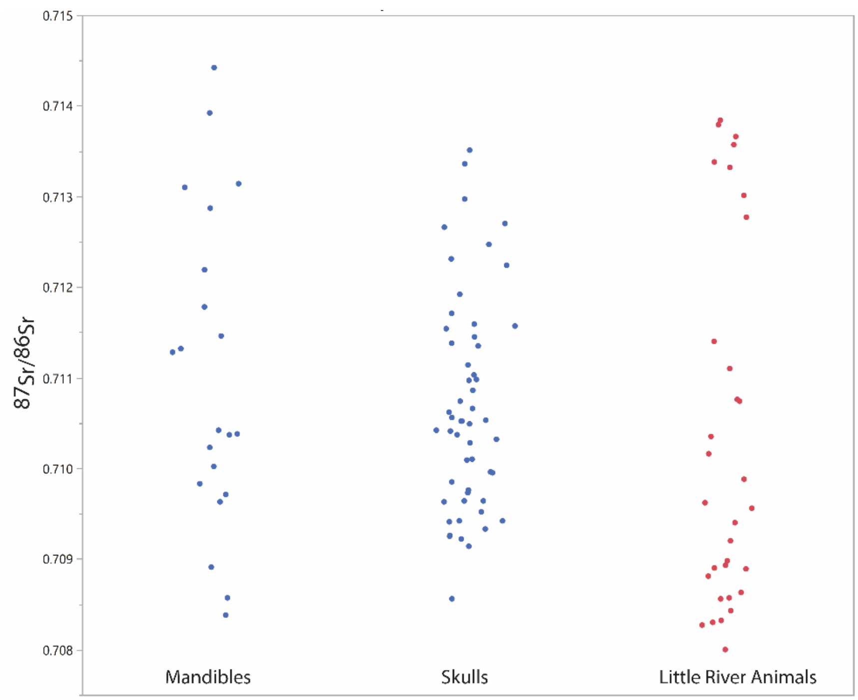


Figure 7.7 – Sr isotope ratio comparison of the skulls and mandibles to only the animals from the Little River sites analyzed (3HO11, 3LR49, 3SV15, and 3SV20). They are very similar.

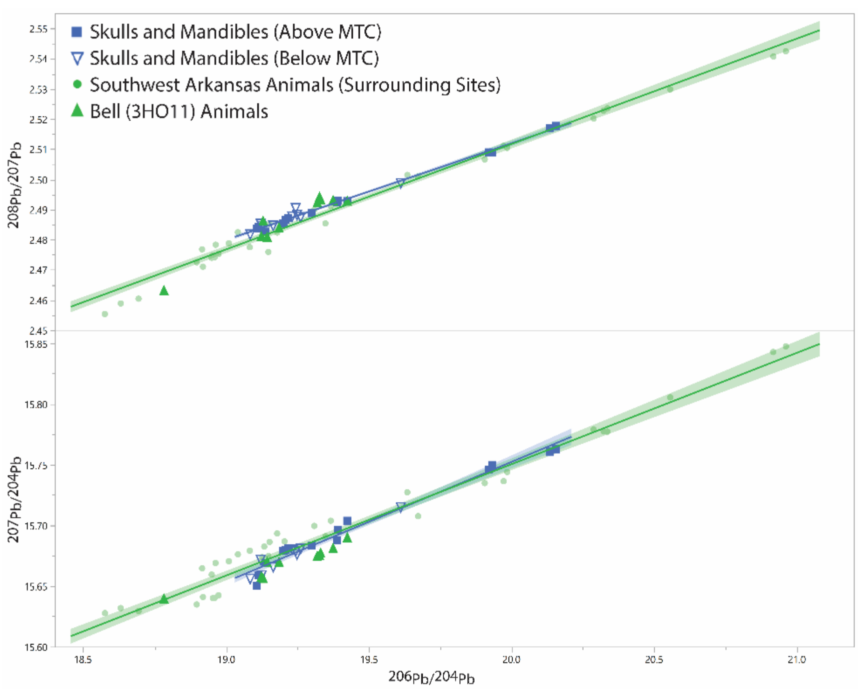


Figure 7.8 – Pb isotope linear patterning analysis shows that some of the skulls and mandibles are similar to the Bell site animals. This is the same site with the fire basin structure containing charred skull pieces. The Sr isotopes from Bell were on the low side, but still consistent with many of the remains.

7.4 Summary Conclusions

The evidence shows that there was a co-occurrence of the skull-and-mandible cemetery at Crenshaw, the adoption of maize, public building-oriented ceremonialism, potential charnel houses or crematoriums, and the lack of burials at occupied sites along the Little River at ca. A.D. 1200-1500. There is much evidence that secondary burials were occurring in this region during Early and Middle Caddo times which could be related to the transfer of the dead to sacred locations for final burial, such as Crenshaw or Mineral Springs. The data also suggest that while the practice of skull burial seems to have become dominant during the Middle Caddo period, examples can be seen during the Early Caddo period and earlier at multiple sites, including Crenshaw itself. Therefore, the practice of skull and mandible burial was simply expanded during the Middle Caddo period as part of a larger set of changes in the Caddo cultural system, including changes in diet, settlement patterns, ceremonialism, and the area of ritual influence.

This study evaluated the geographic origins of the Crenshaw skull-and-mandible cemetery to test if the ancient Caddo were committing large-scale acts of violence against neighboring regions. The inability to answer the questions surrounding the origins of this skull-and-mandible cemetery created starkly contrasting interpretations about the prevalence and extent of ancient warfare in the intersection between the Eastern Woodlands and the Southern Plains. The increased levels of violence in the Southern Plains and the Central and Lower Mississippi Valleys could have related to interregional warfare with the Caddo. However, the evidence indicates that the skull-and-mandible cemetery represents a local or regional burial practice associated with Crenshaw's increasing ritual influence over surrounding areas. This, combined with the lack of other evidence of violence, suggests that A.D. 1200-1500 in the Caddo Area presents a contrast with neighboring regions as a time and place of relative peace.

The evidence of warfare seen in these other regions is not the result of Caddo raiding parties. If interregional warfare was occurring at all, it does not appear to have involved the Caddo. This clearly changed sometime around European contact when tensions between the Caddo and other tribes boiled over. Instead, the practice of skull and mandible burial and potential storage or display of the remains in charnel structures is consistent with Native American practices related to ancestor worship.

The conclusions to this study provide scholars and the Caddo Nation of Oklahoma with a clear, research-based answer to the questions surrounding the cultural affiliation of the remains. While these conclusions should not be uncritically applied to other skull deposits, they do provide one cautionary tale that interpretations about violence should be evaluated with appropriate methods and evidence and with a critical eye for other explanations.

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