

SPATIAL AND GEOMORPHOLOGICAL ANALYSIS  
OF MAMMOTH LOCALITIES IN  
WESTERN OKLAHOMA

By

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Abstract: Up until recently research on Paleoindian archaeology has focused on Clovis hunters and the demise of 35 genera of megafauna at the end of the Pleistocene. However, with increasing evidence of Pre-Clovis settlement many megafaunal sites older than Clovis are now under scrutiny. In this endeavor, geoarchaeology plays a key role, particularly with assessing the stratigraphic and geomorphological aspects of sites suspected of being Pre-Clovis. This Thesis looks at, and analyzes three mammoth sites in western Oklahoma; Helena, Grandfield, and Foss. These sites were analyzed on a geologic, geomorphologic, hydrologic, anthropologic, and soil pedogenic basis. Understanding of soils and their developmental processes can help give us a better understanding of the landscape and the environment in which they were formed. These sites were then compared to known sites Domebo, Hajny, and Burnham, all of which have had both an absolute date and an in depth soil analysis. The purpose of the comparison is to try and apply relative dating to a site when absolute dating is not obtainable, either due to funding, or technical issues that prevent obtaining a reliable date. It has been hypothesized that older mammoth finds should be found in higher terraces, while those of younger age, possibly with archaeological significance, should be found in lower terraces near flood plains. The three mammoth sites studied through this research are associated with lower terraces regardless of age. This example shows how complex the relationship is between site age and site distribution in the landscape. This research shows also how important is to evaluate soil development for estimating relative ages. This approach in turn is important for assessing late Pleistocene paleontological sites with potential association with Pre-Clovis human populations.

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## CHAPTER I

### INTRODUCTION

#### *Introduction*

At the end of the Late Pleistocene, somewhere between 13,000 and 10,000 years before present, North America's megafauna experienced a mass extinction episode that saw the loss of 35 genera of large mammals. These genera included three of the most common Proboscideans on the continent: the Columbian mammoth (*Mammuthus columbi*), the woolly mammoth (*Mammuthus primigenius*), and the American mastodon (*Mammut americanum*) (Table 1.1).

The south-central and southwestern portions of Oklahoma, like Northwest Texas, have a large number of reported sites containing the fossil remains of Proboscideans (Figures 1.1, 1.2, and 1.3). Some of these findings have been found in association with Paleoindian artifacts (i.e., Domebo, Burnham and Cooperton) (Table 1.2). A large number of other findings are not associated with hum artifacts, but it is not known if they were contemporaneous with humans, in part because their ages are unknown. Thus, the general spatial attributes of Proboscidean sites with and without human evidence have never been analyzed. Therefore, the study presented in this thesis will employ GIS and geoarchaeological techniques to address issues of age of sites, and possible relations with Paleoamerican peoples. Such an analysis will require

geoarchaeological techniques and GIS to analyze attributes such as landform, associated soil development, possible age, as well as taphonomic aspects (e.g., bone breakage and distribution).

The study presented here will analyze the distribution patterns and geoarchaeological attributes of three Proboscidean findings, Helena, Grandfield, and Foss.

Table 1.1: Mammoth Classification and Comparison.		
(Northcutt, 2007)		
<b>ORDER:</b> Proboscidea		<b>Max. Height At Shoulder</b>
<b>FAMILY:</b> Elephantidae		
<b>GENUS:</b> <i>Mammuthus</i>		
<b>Species:</b>	<b>Common Name:</b>	
<i>imperator</i>	Imperial mammoth	
<i>columbi</i>	Columbian mammoth	13 - 14 feet
<i>jeffersoni</i>	Jefferson’s mammoth	12 feet
<i>primigenius</i>	Wooly mammoth	11 feet
<i>exilis</i>	Dwarf mammoth	9 feet
		6.5 feet or less
<b>GENUS:</b> <i>Loxodonta</i>		
<b>Species:</b>	<b>Common Name:</b>	
<i>africana</i>	Modern African elephant	11.5 feet
<b>GENUS:</b> <i>Mammut</i>		
<b>Species:</b>	<b>Common Name:</b>	
<i>americanus</i>	American mastodon	7 - 10 feet

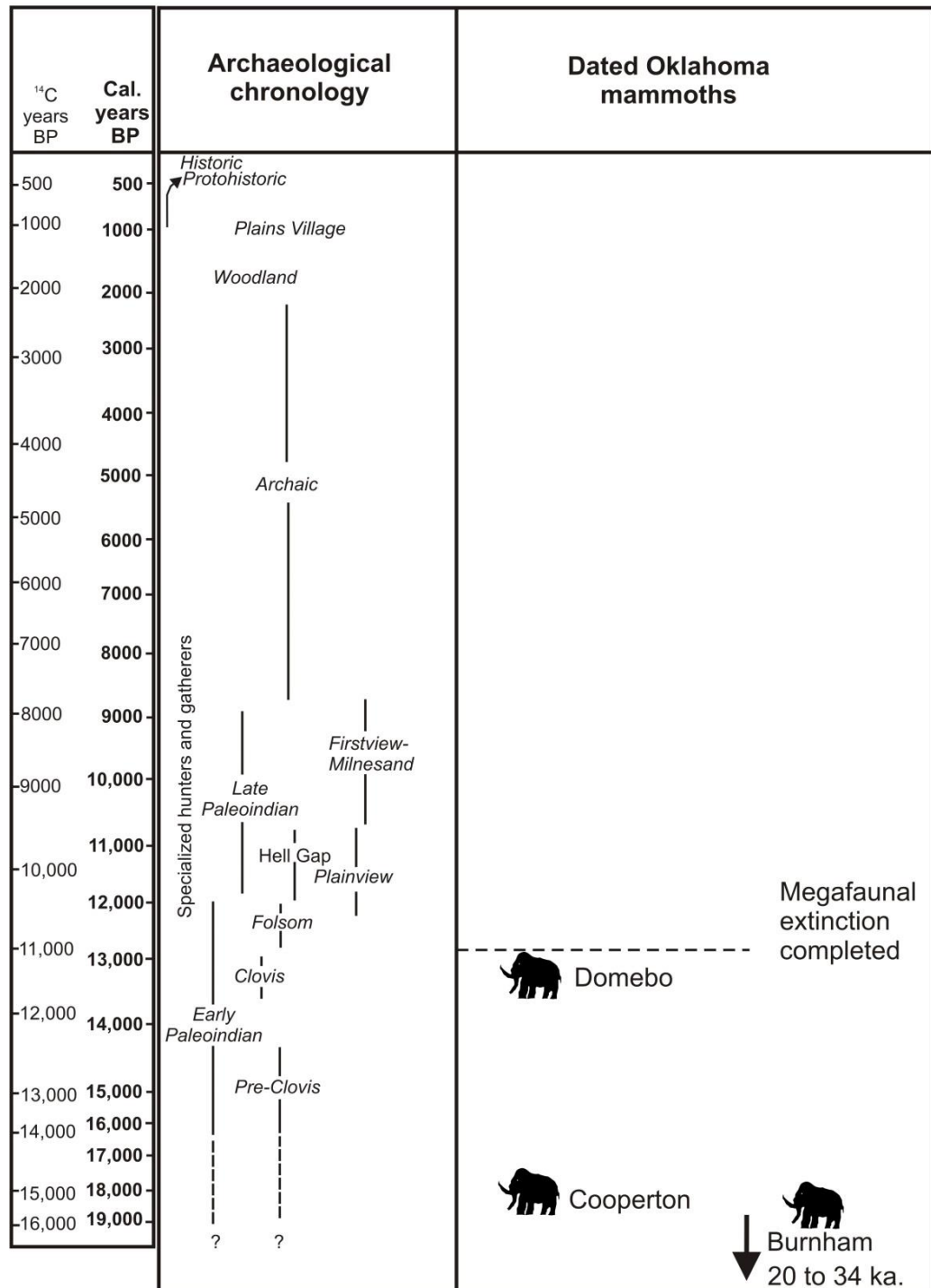


Table 1.2: Chronology. Source: Cordova et al. (2011).

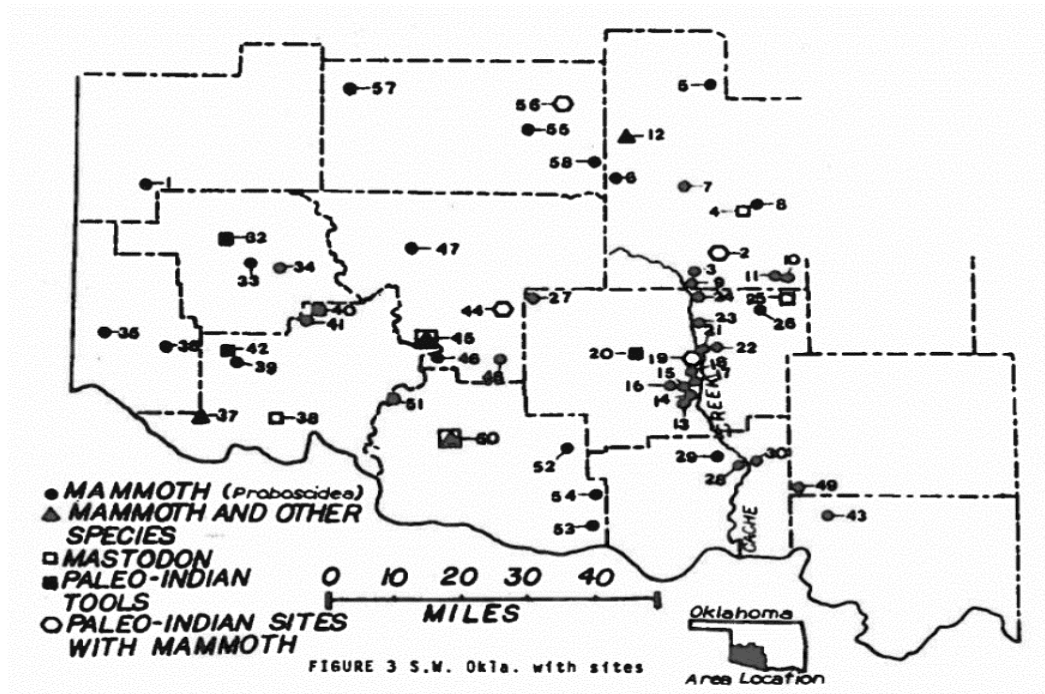


Figure 1.1. Fossil sites in Southwestern Oklahoma. Source: Northcutt (2007).

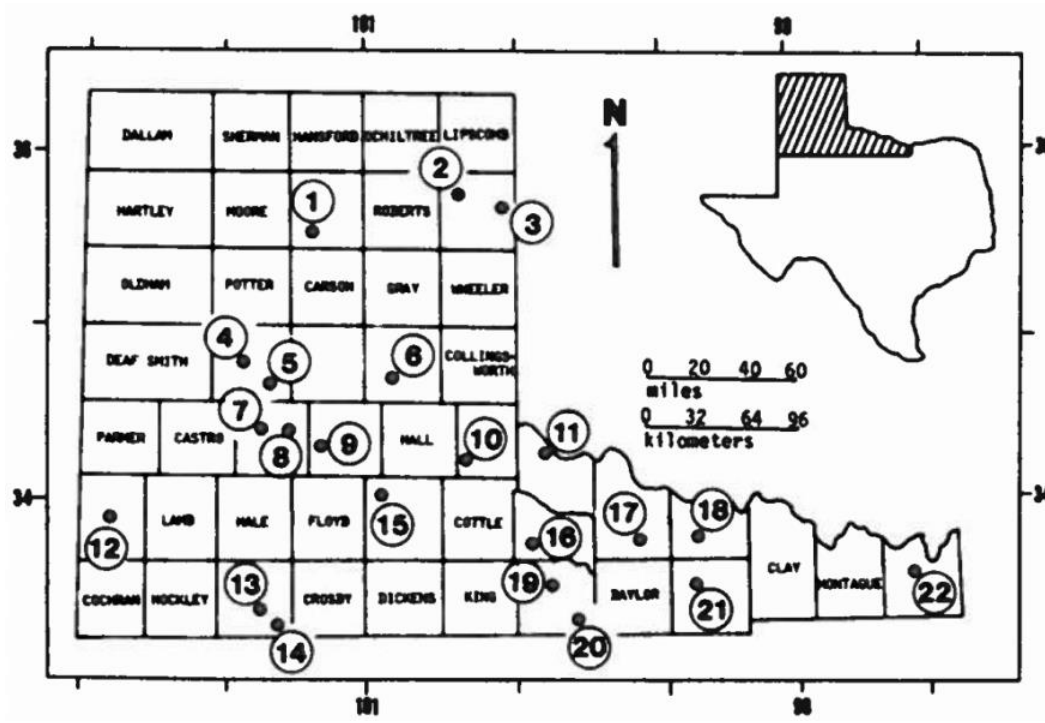


Figure 1.2. Fossil sites in Northwestern Texas. Source: Dalquest and Schultz (1992).

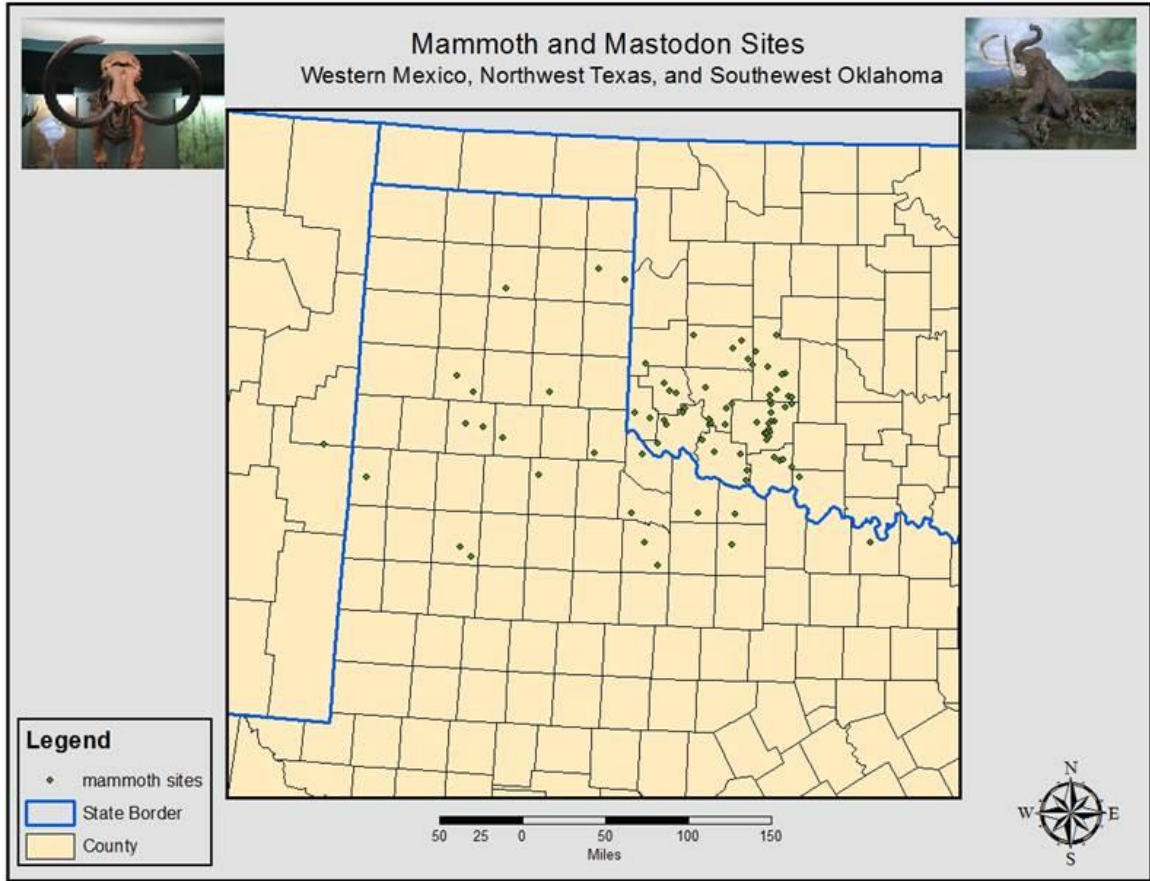


Figure 1.3. Georeferenced image of figures 1.1 and 1.2 in ArcMap 10.1.

### *Problem Statement*

Although a few findings are associated with lacustrine and palustrine environments, as in the case of Lubbock Lake Landmark (Baker, 2010-11) and Blackwater Draw (Holliday and Allen, 1987), fossils of Pleistocene Proboscideans and other megafauna in the Southern Osage Plains (Figure 1.4) are often found in fluvial sedimentary environments (Retallick, 1966; Wyckoff et al., 1992; Dalquest and Schultz, 1992, and Northcutt, 2007). In Oklahoma, older fossil remains seem to be at higher positions on the landscape or older terraces (Wyckoff et al., 1992), while younger fossil remains are found at lower positions on the landscape or younger terraces closer to the modern floodplain. Therefore those sites most likely associated with Clovis and Pre-Clovis should be closer to the floodplain, as is the case of Domebo (Retallick, 1966). To test this

hypothesis this study used GIS to record and georeference known fossil sites, and geoarchaeological techniques to study the geomorphology and soils of selected sites. I argue that due to a lack of absolute dates, this geoarchaeological approach should help establish relative dates which in turn could point to those sites most likely associated with Pre-Clovis and Clovis. This can be done by looking for patterns in the landscape, and then comparing those landscapes with known archaeological sites. By doing this I hope to prove that there is a recurrent theme between the landscape and those sites that are Clovis, those that are pre-Clovis, and those that predate humans.

This research has three objectives:

1. Analyze the geomorphic location of the studied sites Helena, Grandfield, and Foss in relation to alluvial terraces and other features in the landscape.
2. Analyze soil profiles in each of the localities to establish a relative chronology of the mammoth findings.
3. Analyze the three studied sites Helena, Grandfield, and Foss in relation to other mammoth findings in Western Oklahoma.

Objectives 1 and 2 aim at reviewing the hypothesis stated by Wyckoff et al. (1992) in relation to the age of mammoth findings and their location to alluvial terraces. Objective 3 refers to the comparative aspects between the studied sites and those sites in Oklahoma that have associations with humans.





Figure 1.4. Great Plains Regions of the United States. Source: Mandel (2000).

### *Study Area*

While the majority of mammoth and mastodon localities are in southwestern Oklahoma and northwestern Texas (Figures 1.1, 1.2, and 1.3) there are several sites throughout the state of Oklahoma, most of which are west of Interstate 35 (Figure 1.5). In order to obtain a thorough analysis of the area my research focused on three specific sites: Helena (Alfalfa County), Foss (Custer County), and Grandfield (Tillman County) (Figure 1.5). While these sites were sites of opportunity for this research, they were evenly spaced out across Western Oklahoma. This allowed for a very representative study of the various landscapes and climate regimes of Western Oklahoma. The geomorphic characteristics of these three sites will be compared to one another

and to other important mammoth localities that are similar in environment, landscape, and geomorphology.

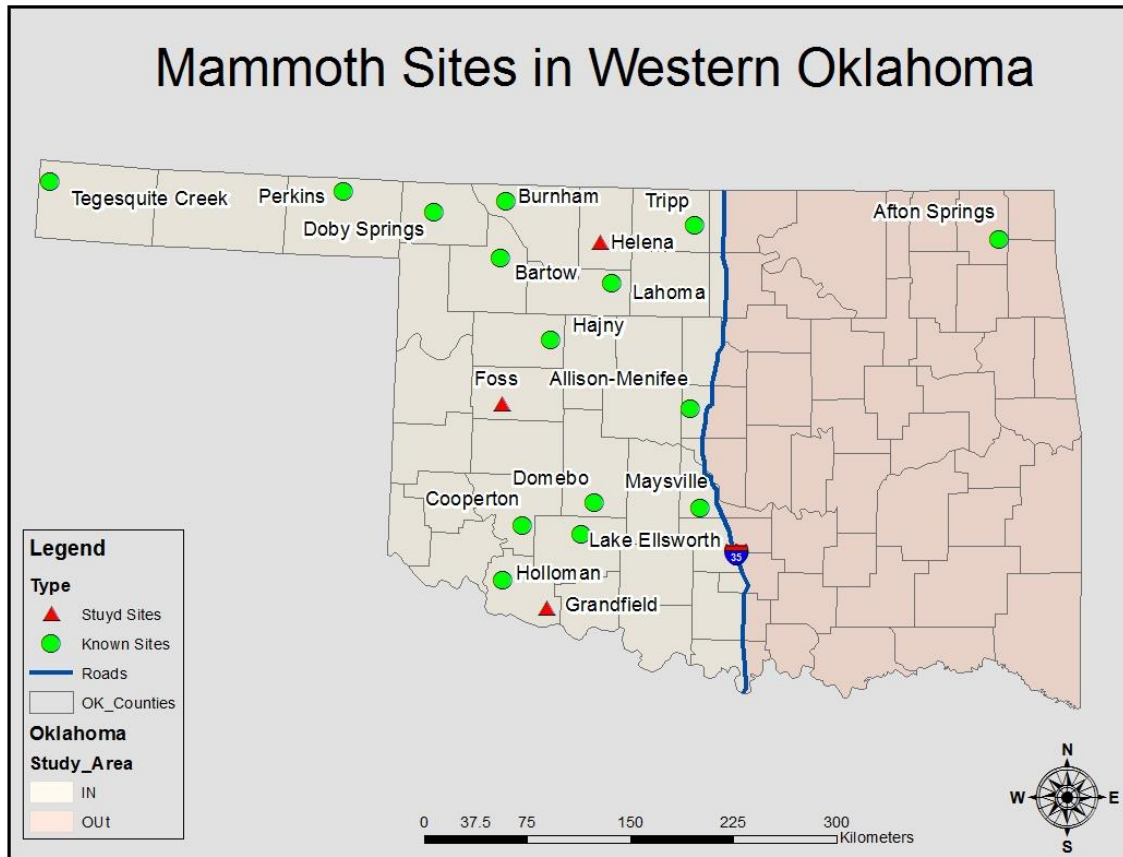


Figure 1.5. Mammoth sites in Western Oklahoma with absolute dates. Modified from Wyckoff et al (1992).

## CHAPTER II

### LITERATURE REVIEW

#### *Early Proboscidean-Human Relations and the Extinctions of Megafauna.*

In recent years, the debate over the extinction of the North American megafauna at the end of the Pleistocene has merged with the debate on the first inhabitants of the continent. More specifically, the debate has centered on Proboscideans (e.g., mammoths and mastodons) because their remains have been more closely associated with human habitation and tools (Haynes, 2009). It is for this reason that the central focus of the research presented in this thesis is the archaeological approaches and hypotheses regarding the early contacts between humans and Proboscideans in North America.

It was long believed among 20<sup>th</sup> century archaeologists that the Clovis hunters were the first inhabitants of North America, namely the Clovis First hypothesis. Along with this paradigm the idea that Clovis hunters brought about the demise of mammoths, mastodons, and other megafauna developed, resulting in the “overkill” hypothesis (Martin, 1973). This begs the question how small groups of hunter gatherers could have traveled such vast distance in such a

short period of time; crossing and adapting to various biomes as they moved. According to Whitley and Dorn (1993), that what Martin (1973) and Haynes (1966) proposed was not just improbable but impossible and unrealistic given the geographic extent of the sites across the continent and the fact that some sites have not been discovered.

Whitley and Dorn (1993) note that Martin's model explained the migration of Clovis across North America in about 1000 years, while the Haynes model explained that the migration could have taken as little as 500 years. Martin's model was based on population growth, while Haynes model was based more on distance traveled. Whitley and Dorn (1993) argue that both of these models are severely flawed. They argue that Martin's assumed population growth rate of 3.4 percent/year is too large for nomadic hunter gatherers; and in fact studies on known nomadic groups show that they have minimal fertility rates. The problem with the Haynes model is the amount of time it would have taken to colonize North America. The Haynes model predicts that colonization would have happened at a rate of 6.4 km per year. The authors argue that this rate is over inflated and would have been closer to 1km per year, which would have allowed for acclimation and adaptation to the various biomes they encountered during colonization. It should be noted that the Haynes rate was based on the colonization of North America only. This becomes especially important with the recent discovery of Clovis age sites in Argentina.

However, based on the discovery of Clovis-equivalent age sites in South America we are left with one of two scenarios (Whitley and Dorn, 1993). The first scenario, based on the Clovis First hypothesis, is that growth rates and spread would have had to be exponentially much larger and quicker, which is unlikely based on known ethnographic data on African tribes. The second scenario leads us to believe in a new hypothesis in which Clovis technology was passed on to already existing groups or tribes

At the end of the 20<sup>th</sup> century the evidence of inhabitants previous to Clovis came to change some of the ideas regarding the extinctions, and overall the relation between humans and megafauna. Pre-Clovis sites abound now in the United States, and the whole North American

continent (Adovasio and Page, 2002; Goebel et al., 2008). But there is no lower limit in the chronology of the so called Pre-Clovis, since dates of sites vary (Meltzer, 2009).

The answer to the very early human origins in the continent may be in “The Mammoth Steppe Hypothesis” developed by Steven and Kathleen Holen, (2013). The Holen’s hypothesize that small groups of people moved into North America between 28,000 and 26,000 years ago, before the Last Glacial Maximum, or more probably toward the end of OIS3. However, this hypothesis has not been widely accepted, based on the argument that people would not have had the resources or knowledge to create the resources needed to survive above 60 degrees latitude, where weather conditions were more formidable. Furthermore, no genetic evidence exists to support an exit from Asia before 30 thousand years (ka) (Goebel, Waters, and O’Rourke, 2008). The Holens propose that the warmer than normal temperatures before the LGM would have made travel further north possible. One such site that backs up this hypothesis is the Yana Rhino Horn site, which is located in western Beringia (Siberia Russia) at 71 degrees latitude, and has been dated at ca. 27,000 radiocarbon years Before Present (yr. BP) (Holen and Holen, 2013). It is hypothesized that a land bridge existed during the Last Glacial Maximum which connected the North American Continent to the Asian Continent. This land bridge between the two continents is believed by most scholars to be the route that North America’s first inhabitants used during colonization. The Holen’s go on to say that these first groups of people would have then been cut off from the technologies of the Old World when Canada became glaciated from coast to coast during the Last Glacial Maximum. Then once the ice retreated again around ca. 11,500 years yr BP a new group of people entered the North American Continent bringing with them Clovis technology which spread rapidly through the already populated Americas (Waters and Stafford, 2007).

So what archaeological and technological evidence is there to support the pre-Clovis hypothesis? Again, Steven and Kathleen Holen have conducted several experiments and studied several sites believed to be pre-Clovis. Seven of these sites lie in the Great Plains; La Sena,

Hamburger, Jensen, Shaffert, Lovewell I and II, and Kanorado. These sites all range in date from 12,000 to 20,000 yr. BP. Each of the sites shows human occupation in the form of modified mammoth bones (that is bones that have been broken to form tools or for the extraction of bone marrow). Steven and his wife have gone to great lengths to show how difficult it is to modify mammoth bones, especially large bones. The bones are only broken with several strikes from a heavy object. These strikes result in various types of notches and flakes, including spiral fractures. Spiral fractures are an important indicator in that they must be made while the bones are still green or relatively fresh; otherwise the bones simply shatter or splinter. All of the sites that the Holens studied showed modification and displacement of the long bones, while vertebrae and ribs were left untouched (Holen and Holen, 2012).

The above hypothesis would better fit with Martin's (1973) hypothesis that the disappearance of megafauna was due to "overkill", although not explained exactly in the ways the overkill was originally proposed, namely in the context of the Clovis First hypothesis. However, can the Overkill account for the extinction of 34 genera of megafauna in North America? To answer this question and to better understand the extinctions it is important to review the different hypotheses proposed to explain the extinctions.

### *Extinction Hypotheses*

There have been two main initial hypotheses that explain the cause of the extinctions: overkill and climatic change. Afterwards, however, other hypotheses have been proposed. Martin (1973) first proposed the "overkill" hypothesis, which explained the extinctions due to overkill of fauna by Clovis hunters. He hypothesized that with man's arrival to North America, Proboscideans had not adapted defense techniques against human hunting and were therefore easy prey. He further states that the mass extinction of mammoths and mastodons would have only taken a few thousand years (Martin, 1973; and G. Haynes, 2002). The second hypothesis, the one putting the blame on climatic change, states that the Younger Dryas event, which saw the partial return of

glacial like conditions to North America, was responsible for the extinctions. Barnosky et al. (2004) believes that the Younger Dryas, which occurred near the end of the Late Pleistocene, changed environmental conditions. This change affected vegetation and foraging patterns of Proboscideans. This abrupt change in food supply availability drove the mammoths and mastodons to extinction. He further believes that the extinction of mammoths and mastodons occurred over a period of 50,000 years, and that the Younger Dryas was simply the final stressor (Barnosky et al., 2004; Koch and Barnosky, 2006; and Barnosky and Kraatz, 2007). While these are the two hypotheses accepted by mainstream archaeologists there have been other hypotheses over the years. Fiedel (2005), hypothesized that the extinctions occurred due to dogs used by Clovis hunters. The author believes the dogs carried disease which infected and wiped out the mammoths and other megafauna which preyed on them (hyperdisease). Firestone et al. (2007), hypothesized that an extraterrestrial impact such as a meteor caused the extinctions; similar, but with less force than the one associated with the KT boundary that saw the disappearance of the dinosaurs.

#### *Validity of Dates*

The debate over the extinctions stems from not knowing exactly how long it took for the Proboscideans and each of the other megafauna taxa to go extinct. One hypothesis is that the extinctions took only a few thousand years (Martin, 1973; G. Haynes, 2002; Faith and Surovell, 2007). The other hypothesis is that the extinctions may have occurred over a period of up to 50,000 years (Barnosky *et al.*, 2004; Koch and Barnosky, 2006; and Barnosky and Kraatz, 2007). This debate is fueled by the lack of radiocarbon dates and the validity of those dates that have been taken. Meltzer and Mead (1983) created a system for ranking the radiocarbon dates based on validity. This ranking system is based on the strength of association between the fossil and the object from which the radiocarbon date was acquired. Grayson and Meltzer (2002) used data from FAUNMAP, a spatial database that contains data on United States species going back

40,000 years, to test the hypothesis that Clovis hunting was responsible for the mass extinctions at the end of the Late Pleistocene. They found that of the 1922 fossil sites in North America, only 76 contained evidence of Clovis hunting. They then used Meltzer and Mead's (1983) ranking system to check for validity and found that of the 76 dates with evidence of Clovis hunting only 14 were considered valid, concluding there was not enough evidence to support extinction by Clovis hunting (Grayson and Meltzer, 2002).

According to McAndrews and Jackson (1988) one reason that it is so difficult to obtain valid radiocarbon dates is because of fossil contamination. They point out that, due to the size of mammoths and mastodons, their bones become encased in several different layers of sediment and soil. Chemical properties of these sediments and soils then leach into the bones over time, thus causing dates to be invalid. There is also a lack of dates because many sites go unregistered or unstudied. This is because archaeological budgets are limited and resources are only spent on those sites that are considered viable to our understanding of Paleoindians or the extinctions of the Late Pleistocene (Baker, 2010-11 and Baker, personal communication).

#### *Important Proboscidean Fossil Sites in the Great Plains*

The majority of research on the study of Late Pleistocene large mammals on North America, including the mammoths and mastodons, has largely been conducted by archaeologists and geologists. While this work has proven beneficial in our understanding of the period, it is lacking because it fails to paint a complete picture of what the landscape looked like, and fails to provide an accurate timeline for the time of the relation human-megafauna and the extinctions of the latter. This is because of either the lack of fossils or inconclusive information largely due to lack or scarcity of chronological data. However, geoarchaeology, a multidisciplinary approach that encompasses archaeology, geography and geology, offers a methodological strategy to fill the gaps left by previous research on Pleistocene megafaunal sites in the Great Plains.

Geoarchaeology uses sedimentology and soil taxonomy as its base tools. The use of



sedimentology and soil taxonomy provides a geographic insight that is often overlooked by researchers (Goldberg and Macphail, 2006). This multidisciplinary approach could prove beneficial in our understanding of what the landscape and environmental conditions were like at the end of the Late Pleistocene, as well as give us a better understanding of the amount of time that it took for the extinctions to occur. Geoarchaeology is not new to the study of the Late Pleistocene extinctions; however it has been used in a limited way. Geoarchaeological techniques are usually implemented at those sites that are considered important to our knowledge of the Late Pleistocene or archaeological sites that show anthropogenic influences such as Clovis hunting. But geoarchaeology offers insights into sites that are not necessarily associated with human influence, which is the key to evaluate whether a pre-Clovis megafaunal site is associated with human activities or not.

Examples of geoarchaeological work on megafaunal fossil sites with no apparent human relation are not uncommon. The Hot Springs Mammoth Site, South Dakota, was discovered in 1974 and while it is not associated with Clovis hunting geoarchaeological work has been done. This site is believed to contain the fossil remains of at least 100 mammoths as well as other species that went extinct during the Late Pleistocene (Agenbroad, 1994b). The site was, at one time, a natural sinkhole in which mammoths would become trapped and later die. This sinkhole is believed to have been active for hundreds if not thousands of years. Several attempts have been made to accurately date the site. However, only an estimation of 26,000 years before present is currently available (Agenbroad, 1994a). Laury (1994) documented both the geological stratigraphy and the sedimentology stratigraphy of the site. He noted that the site contains three sediment depositional episodes. His work showed that this was not a single event, but instead had been a death trap for hundreds if not thousands of years. He notes that the first infilling of sediments began rapidly and slowed over time, until it eventually filled completely (Laury, 1994).

The Waco Mammoth Site located on a terrace of the Brazos River in north-central Texas was discovered in 1978. This site while not associated with Clovis hunting, showed signs of herd

bunching (Fox et al., 1992; and Bongino, 2007). The herd died in a circular formation with the mature members surrounding the younger ones. According to Bongino (2007) radiocarbon, uranium series, and Optically Stimulated Luminescence (OSL) have been used to date the site. These tests have yielded ages from 28,000 years to 73,000 years before present. Bongino (2007) uses soil taxonomy and OSL to classify and date soil horizons at the site. His work showed that the site was composed of four allostratigraphic units and three terraces. Unit three, the unit in which the mammoth remains were found, was composed of loamy flood plain deposits (Bongino, 2007). According to Bongino (2007) the mammoths died by drowning from flood waters from the Bosque River. The evidence also showed that 22 mammoths were killed in two separate events. His research puts the age of these mammoth deaths between 53,000 and 73,000 years before present.

The Blackwater Draw site near Clovis, New Mexico was found in 1932. This was the first site in the United States in which Clovis projectile points were found in conjunction with a mammoth kill. This site, however, also contains artifacts from the Folsom and Archaic Periods. This excavation was the first interdisciplinary Paleoindian excavation in the United States. The artifacts and fossil remains of mammoths were found in a gravel pit (Haynes and Warnica, 2012). However, the majority of research carried out on the site has been archaeological.. More care has been given to the study of Clovis artifacts, than to the environment in which they were preserved (Grayson and Meltzer, 2002). F. Earl Green from Texas Tech University performed the stratigraphy and geochronology on the site; however Green's work was published by C. Haynes and Warnica (2012) after Green's death. Much of Green's work was performed quickly. This was because the site was a working rock quarry as well as an archaeological site. Heavy equipment used in the excavation of gravel disturbed and destroyed much of the landscape around the fossils before it could be properly studied. This site was once a spring-fed basin that was filled in by four separate depositional episodes (Haynes and Warnica, 2012). Green performed a detailed stratigraphic analysis of the sediments and soils at the Blackwater Draw complex.

Artifacts from the site have been dated between 10,000 and 11,000 years before present (Haynes and Warnica, 2012).

Lubbock Lake Landmark in the Texas Panhandle was discovered in 1936. This site contained several different genera of Late Pleistocene fauna as well as Paleoindian artifacts (Johnson and Holliday, 1987a). This site, like the Blackwater Draw site, was used by Paleoindians during different periods. However, this site is considered to be of Folsom age as no artifacts associated with Clovis have been found at the site. However, this site has been better preserved and analyzed than the Blackwater Draw site (Holliday, 1987). F. Earl Green was also responsible for much of the early work that went on at this site. This site, like those above, has an extensive sediment and soil analysis (Holliday and Allen, 1987). The site is composed of five geologic units and five paleosols; however, Holliday and Allen (1987) note that there may be as many as eight other buried paleosols. Deposition at Lubbock Lake dates back at least 11,000 years before present. The site started as a meandering stream, and was transformed into marsh and ponds over time. This analysis of both flora and fauna at this site has been comprehensive (Johnson and Holliday, 1987b).

#### *Sites Located in Western Oklahoma*

Oklahoma also has several sites that are important to the study of the Late Pleistocene extinctions. According to Smith and Cifelli (2000), there are 22 counties in Oklahoma with fossil sites. The Wichita Mountain area in Southwest Oklahoma is the focal point for several of these mammoth sites (Baker, 2010-11).

Baker (2010-11) first reported the excavations at the Grandfield Mammoth Site, which began in 2009 (see Figure 1.5). While the site yielded no data that showed any association with humans, it did give insight into what type of environment mammoth died in. Evidence found shows that the area may have been a shallow lake or wetland at one time and that the mammoth probably died due to drowning. While a soil analysis of the area was scheduled, it was never

done, leaving several unanswered questions such as possible age of the mammoth and environmental conditions at the time of death. Dr. Baker (2010-11) should be credited with doing an excellent job of documenting the dig step by step.

The Holloman site located near the town of Frederick in Tillman County was believed to be the first Paleoindian site found in Oklahoma. This site, located in a gravel pit, contains over ten species of extinct Late Pleistocene megafauna (Smith and Cifelli, 2000; Northcutt, 2007). However, artifacts believed to be Paleoindian in origin were later discovered to be much younger artifacts that had gotten mixed in with the fossilized remains through bioturbation. The fossil remains at the site are now believed to be around 500,000 years old, well before man came to North America.

The Domebo Mammoth Site, discovered in 1961, was the first archaeological site in Oklahoma that showed a definite association with Clovis hunting. Clovis projectile points and tools were found with the remains of the mammoth. Researchers estimate that the site is around 11,000 yr. BP, based on snail shell and pollen samples that were taken (Retallick, 1966). They hypothesized that the weather was more moderate with milder winter and summers than today's climate (Northcutt, 2007). The site is located on the Domebo Creek, a tributary of the Washita River. The creek runs through a canyon known as the Domebo Formation. The fossil bones were found on the lower bank of the Domebo Formation, which is composed of marsh sediments (Albritton, 1966). Unfortunately, further examination of this area is hampered due to policies set by the Bureau of Indian Affairs (Baker, per com).

The Cooperton site, discovered in 1961, is the oldest in Oklahoma that shows evidence of humans. However, the radiocarbon dates taken at the site date it as old as 20,000 years before present, making this site a Pre-Clovis site (Northcutt, 2007). The fossil remains were found in a gully near a farm pond that consisted of alluvium that was four feet thick. The deposits are believed to be from Glen Creek which originated in the Wichita Mountains. The deposits consist of alluvium material composed of medium to coarse sand with pebbles and cobbles. This

site is one of the few sites in which a soil analysis was performed. The analysis showed that the landscape underwent several cycles of soil formation which can only happen in a stable environment (Anderson, 1975).

The Hajny Mammoth site was discovered in 1985 and is believed to date between 140,000 to 160,000 years ago. However, uranium/thorium series which was used for the dating was experimental at the time the analysis was done (Smith and Cifelli, 2000). The bones were discovered while quarrying for gravel. The bones were in blue clay that contained snail shells and was believed to be spring deposits. These deposits are situated between terrace 1 and 2 of the five terraces bordering the Canadian River. Since no Paleoindian artifacts were found, the site was excavated by geologists rather than archaeologists. While they did an excellent geologic and soil analysis of the site, they used heavy digging equipment, which destroyed several specimens (Wyckoff *et al.*, 1992).

There are several more sites located throughout the state that could yet prove important to our understanding of mammoths and other megafauna that went extinct during the Late Pleistocene. The Afton site, located in Northeast Oklahoma, was discovered in 1901. This site contained 17 different genera of extinct mammals (Smith and Cifelli, 2000). This site is proof that more work is not only needed in the southwestern part of Oklahoma but throughout the state.

### *Summary*

Although for very long the extinctions have been attributed to Clovis hunters and climatic changes at the very end of the Pleistocene, research in the past two decades has produced a series of different views of the megafaunal extinctions. More and more studies on Pre-Clovis sites, as well as more chronological data are now changing our understanding of the relation between megafauna and humans and megafauna and climate.

Oklahoma is at the center of the mammoth-human debate because it contains both Clovis (Domebo Mammoth site), and pre-Clovis (Cooperton Mammoth site) sites, and a series of other

sites that are likely to precede Clovis, as is the case of the Helena Site (See Chapter 4). This thesis will not only look at Oklahoma mammoth sites as a whole but also in a cultural context. Comparisons for similarities may lead us to better understand the rise of America's first culture, and eventually the extinctions of mammoths

## CHAPTER III

### METHODOLOGY

#### *Field Research Strategy*

Due to the vast amount of research involved in this project, various types of collection methods were employed, including archival, soil description, and laboratory testing. Field analyses such as color were not done in the field due to the poor lighting because of the inclination of the sun's rays and cloudiness during the fall and winter months. However, color was determined in the lab. Recording of other soil properties such as structure, texture, and consistency were done in the field. The locations of sites were recorded as GPS coordinates using the Garmin "Oregon 650t". Soil sections and their horizons were photographed using a Nikon D40 camera, and soil samples were taken for further examination at the lab.

Field work was conducted at three sites in western Oklahoma: Helena, Grandfield, and Foss Reservoir. At the Helena Mammoth site the description of soils was conducted on three profiles of the site once the excavation of the mammoth was completed (see chapter 4). At the Grandfield Mammoth site the description of only one soil was conducted, because the digging of the original trench had exposed a tusk. Therefore, a second trench had to be opened downhill from the mammoth remains, where a soil profile was described (chapter 5). Work on the soil profiles at

the Foss Reservoir Mammoth site were carried out on the walls of a trench dug by Dr. Lee Bement. The entire work, including the soil descriptions had to be done in 5 hours due to time constraints imposed by the nature of the work (see chapter 6).

### *Archival Research*

Archival research for this study was carried out at the Great Plains Institute in July 2013 for the purpose of confirming mammoth sites and creating a database of those known localities and their findings. This part of the research was in large part based on information that Northcutt (2007) had compiled. Debra Baker of the institute facilitated access to documents and artifacts that the institute maintains. Step one in the process was to conduct a computer search for accession numbers that the institute had given to mammoth finds.

After compiling the list of accession number, individual files were accessed and reviewed for information relevant to this research. Those files that did contain descriptive information were then taken to the museum collections area and matched with the artifacts. Those files that could not be matched with artifacts were not used in this research. Debra Baker informed me that one of the past curators had taken several of the artifacts with them upon their dismissal. It should also be noted that the reason many of the files did not contain descriptive information is because while the site may have been reported, that report may not have been corroborated.

While archival research yielded a vast amount of data; much of the data could not be verified. Problems in verification were either due to a lack of proper documentation, or missing artifacts. It also became apparent early on that much of the data needed was maintained by other institutions. Access to this data proved to be difficult if not impossible to obtain. However, for the purpose of this research I was able to obtain more data than I ever thought was possible.



### *Database and Dissemination*

While searches of databases yielded information, much of this information was only precursory and contained very little usable data. This is due to two major obstacles; the first is that institutions differ on how information is maintained. During my research it became evident that sites had various names depending on which institution the data came from. The second was dissemination of data. This again was dependent on the institution, some institutions were more willing to disseminate data than others. However, after having been involved in several excavations during this research project I have come to understand the hesitancy institutions and individuals have for releasing or disseminating information. Safeguarding of information on known sites is important in maintaining the integrity of the site for future research as well as to prevent looting. While I had planned on releasing my data to online databases such FAUNMAP, MIOMAP, and NEOTOMA, I have in recent light reconsidered, and concluded that this would not be prudent to future research endeavors. Not only is the anonymity of site important, but also the protection of the rights of those individuals on which these sites are located. The data I have collected and compiled will be released to those pertinent individuals once it has been completed (see Appendix A).

### *Soil Profile Descriptions*

The most integral part of this research is based on soil development and geomorphology. This analysis is vital in completing the three objectives of this research: analyze the geomorphic location of the studied sites in relation to alluvial terraces and other features in the landscape; analyze soil profiles in each of the localities to establish relative chronology of the mammoth findings; and analyzing the three studied sites in relation to other mammoth findings in Western Oklahoma. In this study all soil descriptions are based on criteria proposed by Birkeland (1999), except for texture description, which was based on the “Guide to texture by feel” (USDA, 2013) (Figure 3.1). While this type of analysis is not quantitative in nature, it is however an accepted

method throughout the archaeology community when there is a lack of resources for absolute dating. However, field methods should be corroborated with a more in depth quantitative lab analysis if possible. It should be noted that field methods are extremely subjective in that there is a difference in which individuals see and feel things. The following characteristics were analyzed and recorded at the site: horizon, depth, structure, boundary; and any other special features such as calcium carbonate, pores, roots, and slickensides. Many of the special features would later be confirmed in the lab. Samples of each horizon were taken at the site so that the rest of the analysis could be conducted in a lab where environmental conditions remained constant. Along with verifying special features, the following characteristics were analyzed: color (wet and dry), pH., consistence, and effervescence using HCl.

There were three horizons that underwent more intense laboratory procedures, two from the Grandfield site and one from the Foss site. This was due to the large amount of clay they contained clay that had undergone pedogenesis and was extremely hard; therefore, performing a satisfactory texture analysis could not be completed using the “Guide to texture by feel” (USDA, 2013). These samples were weighed and crushed. Thirty-five percent HCL was used to remove all of the carbonates; the samples were then decanted. To remove the clays sodium hexametaphosphate and de-ionized water were added to the sample and placed in a sonicator; then more de-ionized water was added. The sample was left standing for one hour so that all the sands and silts would settle to the bottom. This step was repeated until the water became clear. De-ionized water was then added to the silt and sand and then passed through a 63-micron mesh. The materials in the mesh were the sands. Then the silts were de-ionized. The sands and the silts were both then dried and weighed; these weights are then subtracted from the original weight of the sample in order to obtain the amount of clay that was removed from the sample. These percentages were then compared to the soil texture triangle (USDA, 2013) (Figure 3.2).

### *OSL Dating*

Optically Stimulated Luminescence (OSL) samples were taken from sediments at the three studied localities. Two samples were taken from Helena, HM-2, and HM-3; one from Grandfield; and one from Foss. The samples taken from Helena and Grandfield were from the same layers where the mammoth remains were embedded. The Foss sample was taken from within the skull area of the mammoth. Due to a lack of funds only the Helena Mammoth sample has been sent out for laboratory dating. The other samples will be sent out at a later date should funds become available. OSL dating was at one time considered only applicable to aeolian sediments, but recently has become an accepted form of absolute dating for fluvial sediments. OSL dating can be used instead of radiocarbon dating when carbon is no longer present (Huntley and Lamothe, 2001).

One of the major advantages that make OSL dating so attractive is that it can be used in dating materials as old as 1 million years; whereas radiocarbon dating can only be used for dating deposits no older than about 50 ka. B.P. OSL dates come from testing the amount of radiation that is trapped in the unconformities of sand grains such as quartz and feldspar. Sunlight releases this trapped radiation resetting the OSL clock back to zero. Once the material is reburied the radiation begins to build and the clock starts once again. There are however several shortcomings to OSL dating: incomplete zeroing or bleaching, grain size, scatter, preheating, quartz vs. feldspar, and anomalous fading (Wallinga, 2002).

According to Wallinga (2002) incomplete zeroing or bleaching occur when the OSL signal is not completely reset before deposition, an incomplete reset can result in an overestimation of the age of the materials being dated. However, the luminescence charge in soils is zeroed once exposed to sunlight, which can give an underestimation of age, or no age at all. This is why it is important when taking OSL samples to make sure that the soils being tested do not get subjected to sunlight. This was accomplished at the Helena, Grandfield and Foss Mammoth sites by driving a 1-foot long and 2-inch wide PVC pipe into the sediments. Each end of the pipe is taped

off so that sunlight can't reach the soils inside. Incomplete zeroing or bleaching goes hand in hand with grain size. It has long been accepted that lighter materials floating at the top of a channel were likely to be more accurate than heavier sands at the bottom of a channel due to the penetration of sunlight. Therefore, heavier sands may not undergo complete zeroing or bleaching. However, this has recently proven to be inaccurate as testing has shown that the more reliable dates come from coarser grains.

Preheating results in thermal transfer that can also cause an overestimation of age. Thermal transfer happens when light that is trapped in light insensitive traps is released into those traps that are light sensitive. It is important to note that a comparison of dates should be made using several preheating ranges for fluvial deposits. Scattering is when there are inconsistencies of radiation among individual grains. This is common as finer material which settles slowly out of fluvial environments. The clock starts ticking as each grain settles, and is no longer exposed to sunlight. Therefore each grain will have different dates based on when it was last exposed to sunlight (Wallinga, 2002).

The most significant part of OSL dating is whether to test quartz grains or feldspar grains. Quartz grains are good for testing deposits up to 50ka, while feldspar grains are good for testing older deposits that may be as old as 1ma. This is due to the fact that quartz bleaches more quickly in fluvial environments than feldspar, and is therefore more accurate (Huntley and Lamothe, 2001; Wallinga, 2002). Charges in feldspar are more intense and therefore easier to date than those charges in quartz. Charges in feldspar can be measured even when other minerals are present. Corrections for thermal transfer are less for feldspar grains than for quartz grains; therefore, preheating becomes less of a problem (Huntley and Lamothe, 2001). Huntley and Lamothe (2001) agree with Wallinga (2001) in that quartz grains zero quicker than feldspar are therefore more accurate. Huntley and Lamothe (2001) also point out that quartz is also more resistant to weathering than feldspar. However, the most significant issue with using feldspar is anomalous fading which can cause an underestimation of age. Anomalous fading is the process

by which the electron used to measure luminescence is lost due to unknown reasons over the period of a couple of days. Details on the measurement of age of a sample in HM-2 (Helena locality) are in Appendix C. More issues on the OSL dating of this sample are mentioned in the Discussion section.

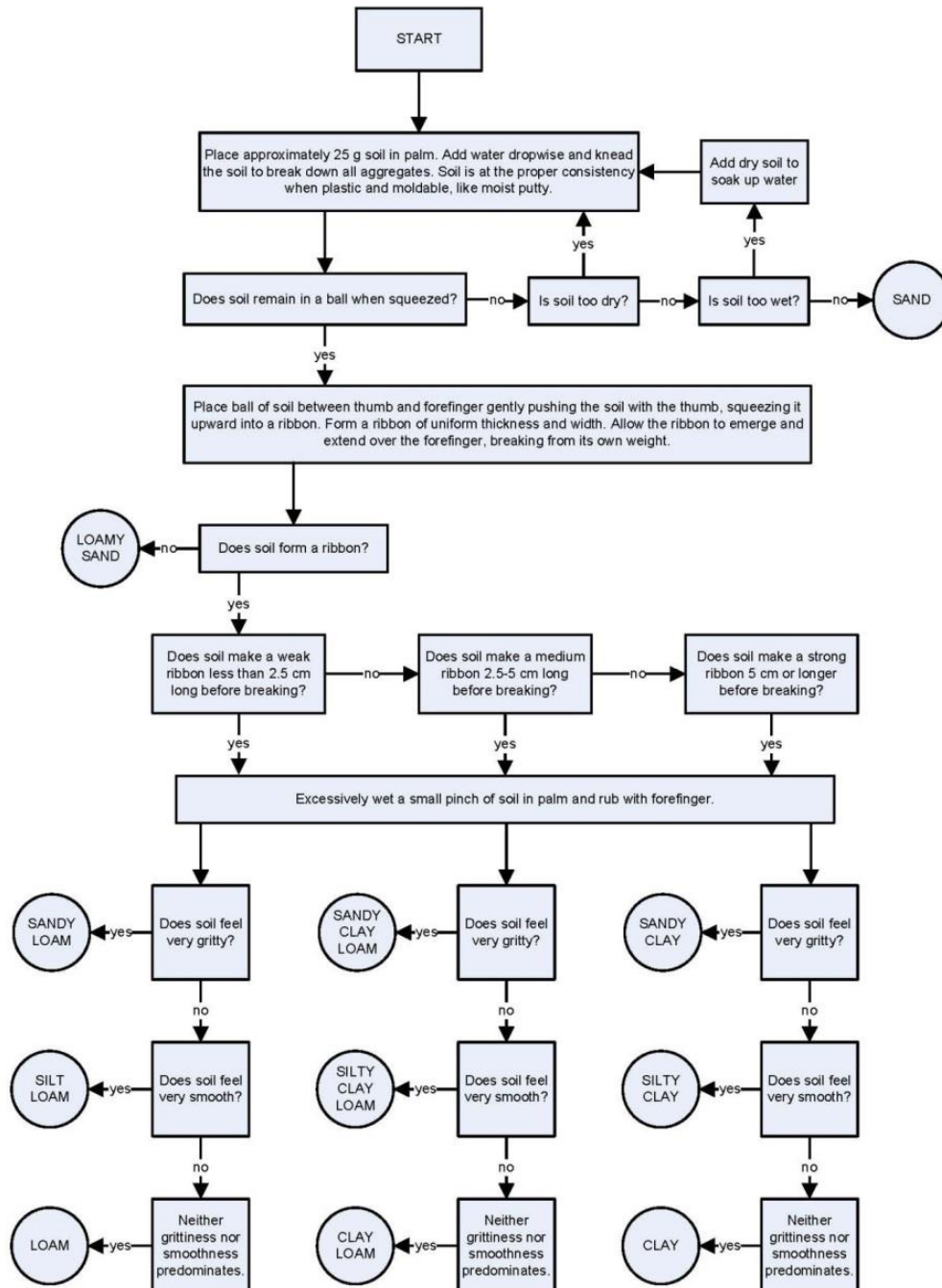


Figure 3.1. Guide to texture by feel. Source: USDA (2013).

## Soil Textural Triangle

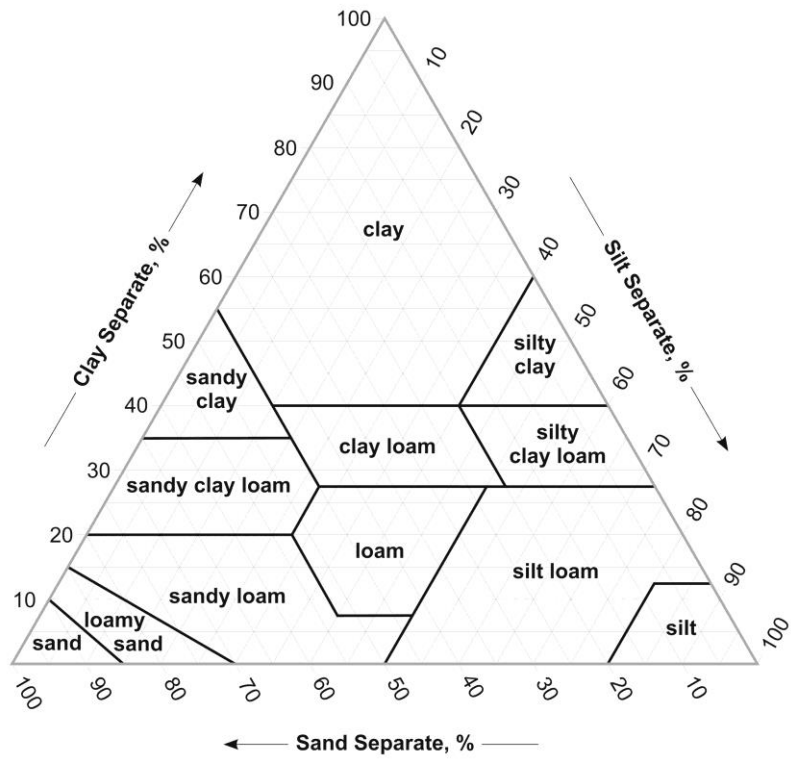


Figure 3.2. Soil Texture Triangle. Source: USDA (2013).

## CHAPTER IV

### HELENA MAMMOTH SITE

#### *Introduction*

The Helena Mammoth Site is located two miles northwest of the town of Helena in Alfalfa County, Oklahoma (Figure 4.1). The mammoth remains were found in early July of 2013 by Access Midstream, a natural gas provider, while installing a high pressure gas line. Excavation of the mammoth began at the site in early September and lasted until the end of October. Once the mammoth remains were excavated, stratigraphic and soil profile descriptions were conducted in order to place the finding in a geomorphological and temporal context. Three soil profiles were described within the site. They are named here HM-1, HM-2, and HM-3. Additionally, a general assessment of the landscape allowed placing the findings in the broader geomorphological context.

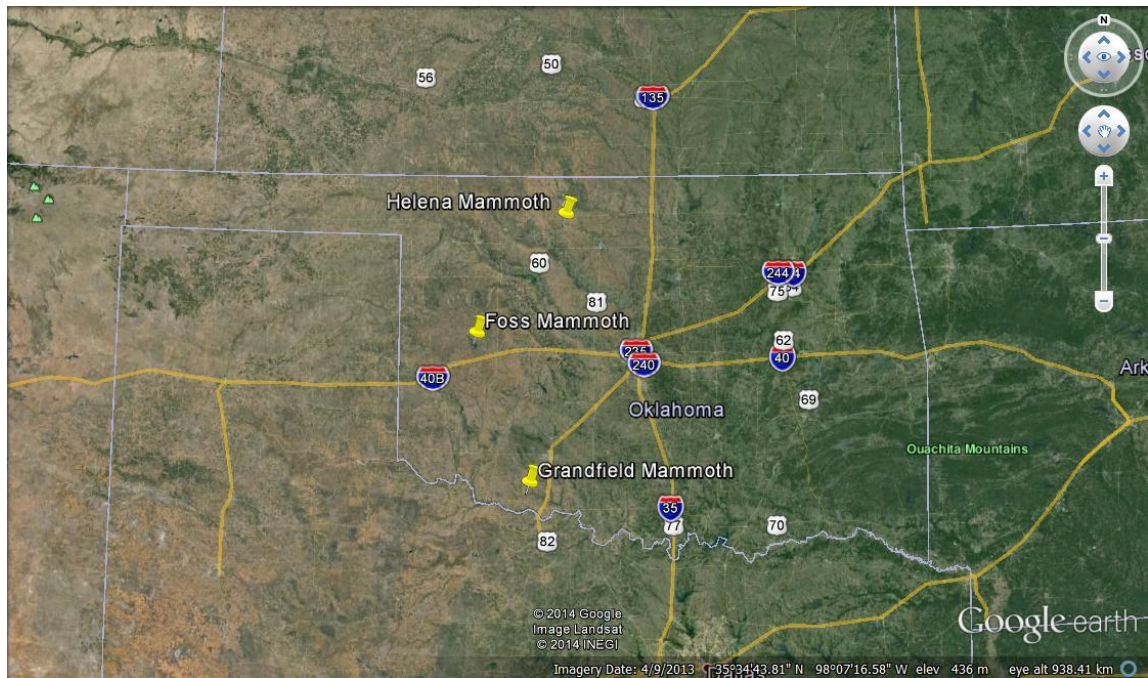


Figure 4.1. Google image of Oklahoma with study sites.

### *Geomorphology*

The Helena Mammoth Site is located on the lowest terrace of a stream valley composed of three terraces (Figure 4.2). The surface of Terrace 3, the highest of the terraces present at the site, is located at an elevation of approximately 428 meters. The surface of terrace 2 sits at an elevation of approximately 425 meters. Terrace 1, which is the one with the mammoth site, is located at an elevation of approximately 419 meters. The geomorphology of the area has been changed by anthropogenic influences such as leveling for agricultural terracing, ditches, and roads (Figures 4.3 and 4.4). Additionally, small erosion dams have been built along the floodplains of the streams, which resulted in a number of ponds and modern alleviation. The USDA (2014), Web Soil Survey has classified the soil of the Helena Mammoth site as belonging to the Grant Nash complex (Figure 4.5).



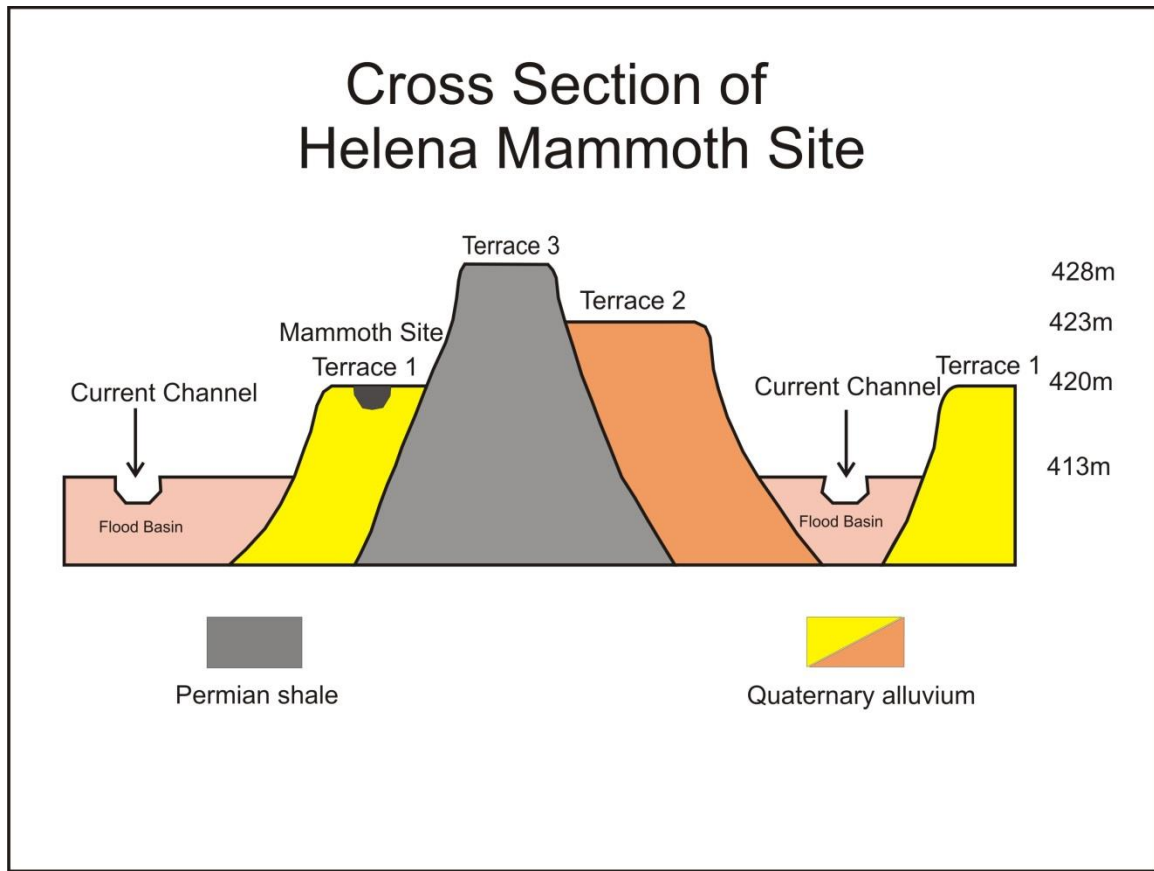


Figure 4.2. Cross section of Helena Mammoth site.

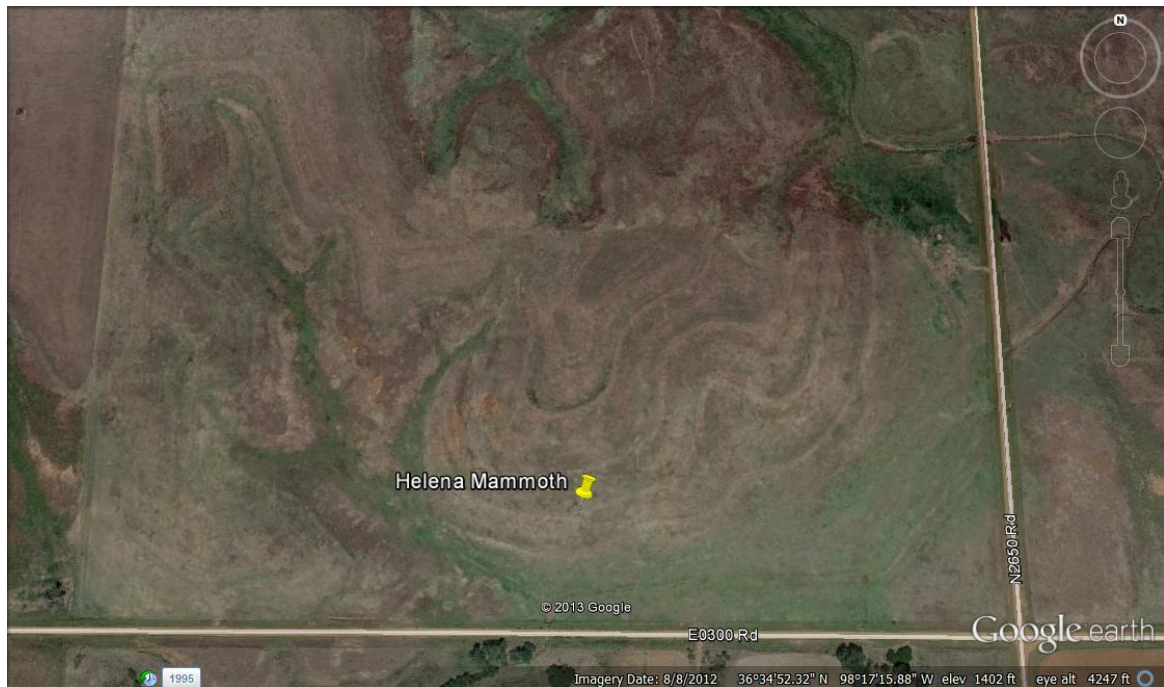


Figure 4.3. Google image of Helena Mammoth site.

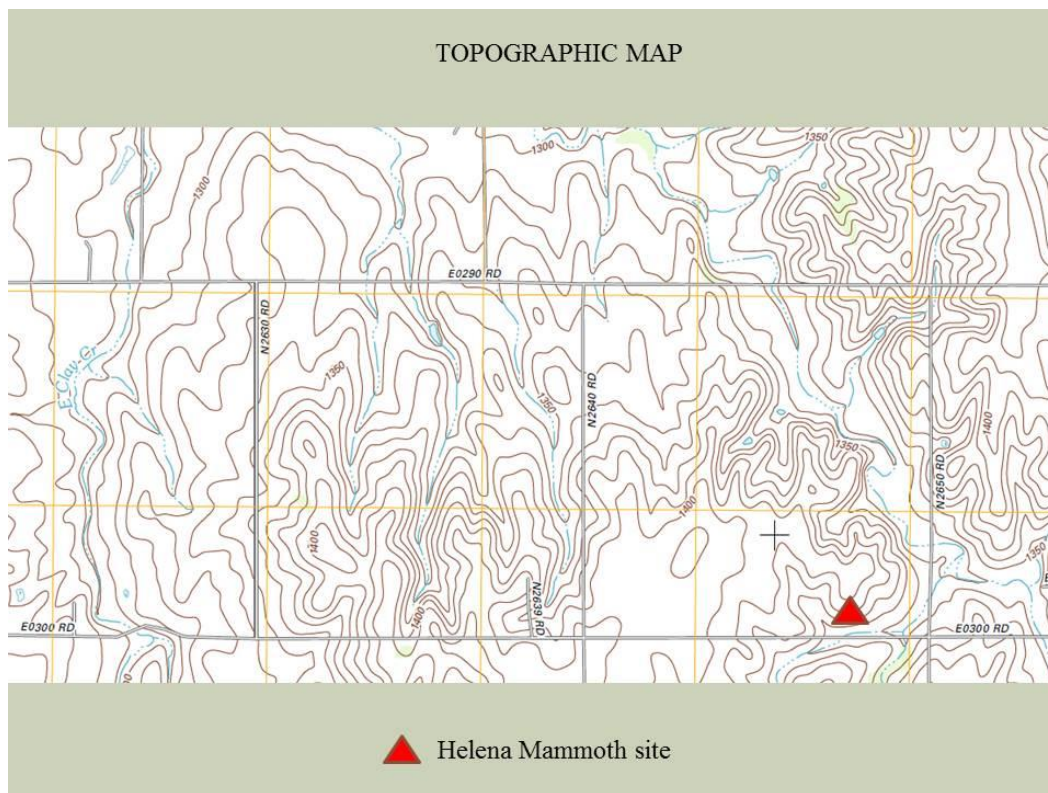
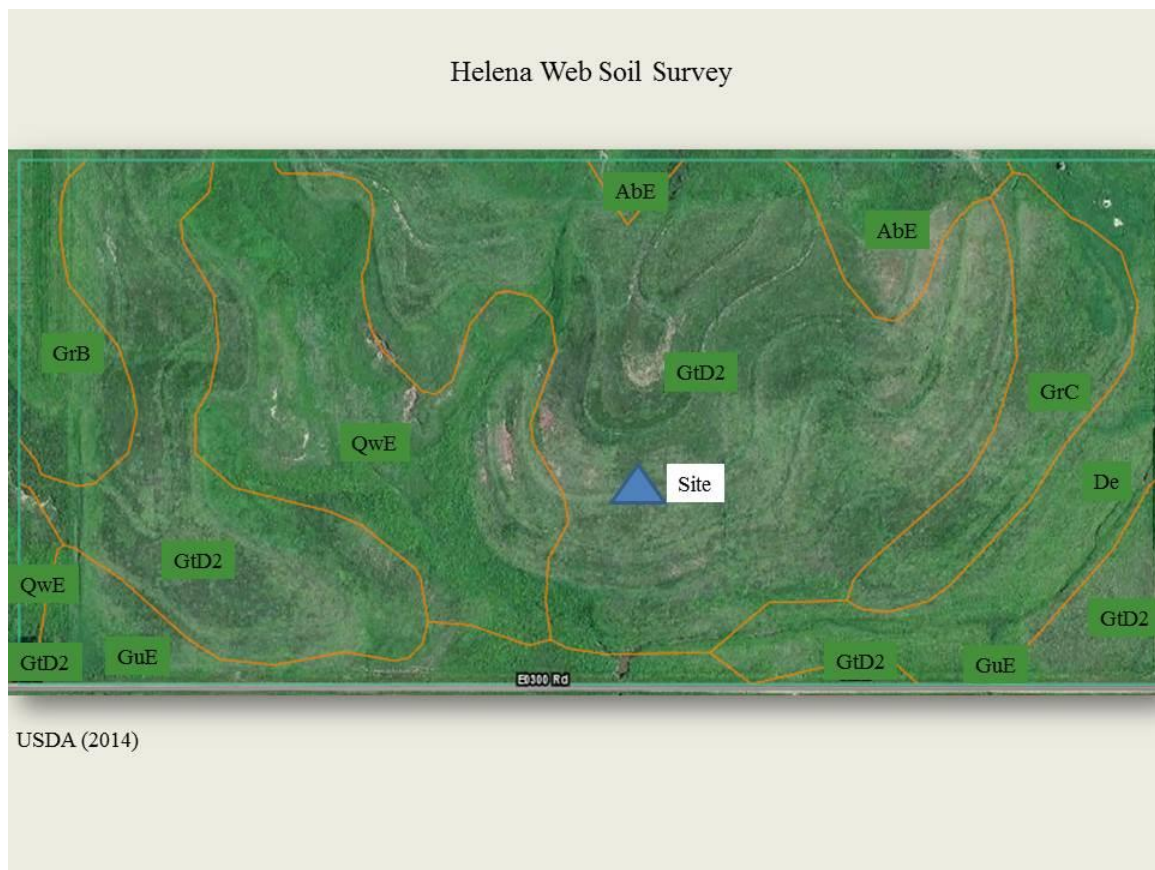


Figure 4.4. Helena Mammoth area topographic map. Source: USGS (2014).



<b>Helena Soil Legend</b>		USDA (2014)
Map Unit Symbol	Map Unit Name	
AbE	Wisby sandy loam, 5 to 15 percent slopes	
De	Buttermilk silt loam, 0 to 1 percent slopes, rarely flooded	
GrB	Grant Silt loam, 1 to 3 percent slopes	
GrC	Grant silt loam 3 to 5 percent slopes	
GtD2	Grant-Nash complex, 3 to 8 percent slopes, eroded	
GuE	Grant-Port complex, 0 to 12 percent slopes	
QwE	Quinlan-Woodward complex, 5 to 30 percent slopes	

Figure 4.5. Helena Mammoth web soil survey map. Source: USDA (2014).

### *Hydrology*

The stream network in the area is of dendritic type. This basin is located close to the interfluvium between Arkansas River basin, whose course runs approximately 45 kilometers to the

north, and the Cimarron River, whose main channel runs approximately 37 kilometers to the south (Figure 4.6). The basin at the study site is composed of a fifth order stream system. The first stream that runs in close vicinity to the site has no name. This stream joins up with Clay Creek approximately 16 kilometers to the northwest, on the southwestern edge of the Salt Plains National Wildlife Reserve. Clay Creek then flows into the Salt Fork of the Arkansas River, which then joins the Arkansas River. The Arkansas River is a tributary of the Mississippi River.

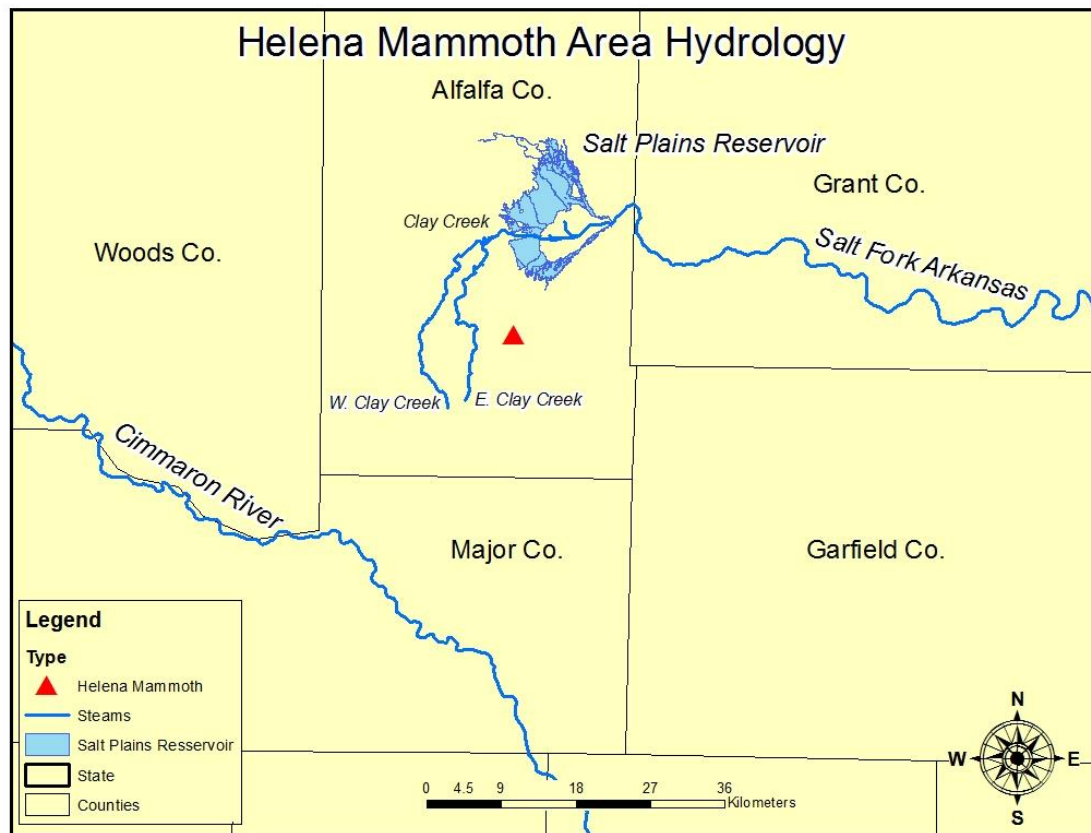


Figure 4.6. Helena Mammoth area hydrology.

According to Ward and Carter (1999), the Salt Fork of the Arkansas River was once a part of the Arkansas River. However, the Arkansas River has meandered further north leaving an abandoned channel, and making the Salt Fork of the Arkansas River a tributary. There is also an abandoned channel between the Salt Fork of the Arkansas River and the Cimarron River (Figure



4.7). Therefore, this area would have been more prone to flooding due to the larger volume of water transported by the ancestral streams of the Arkansas and Cimarron rivers.

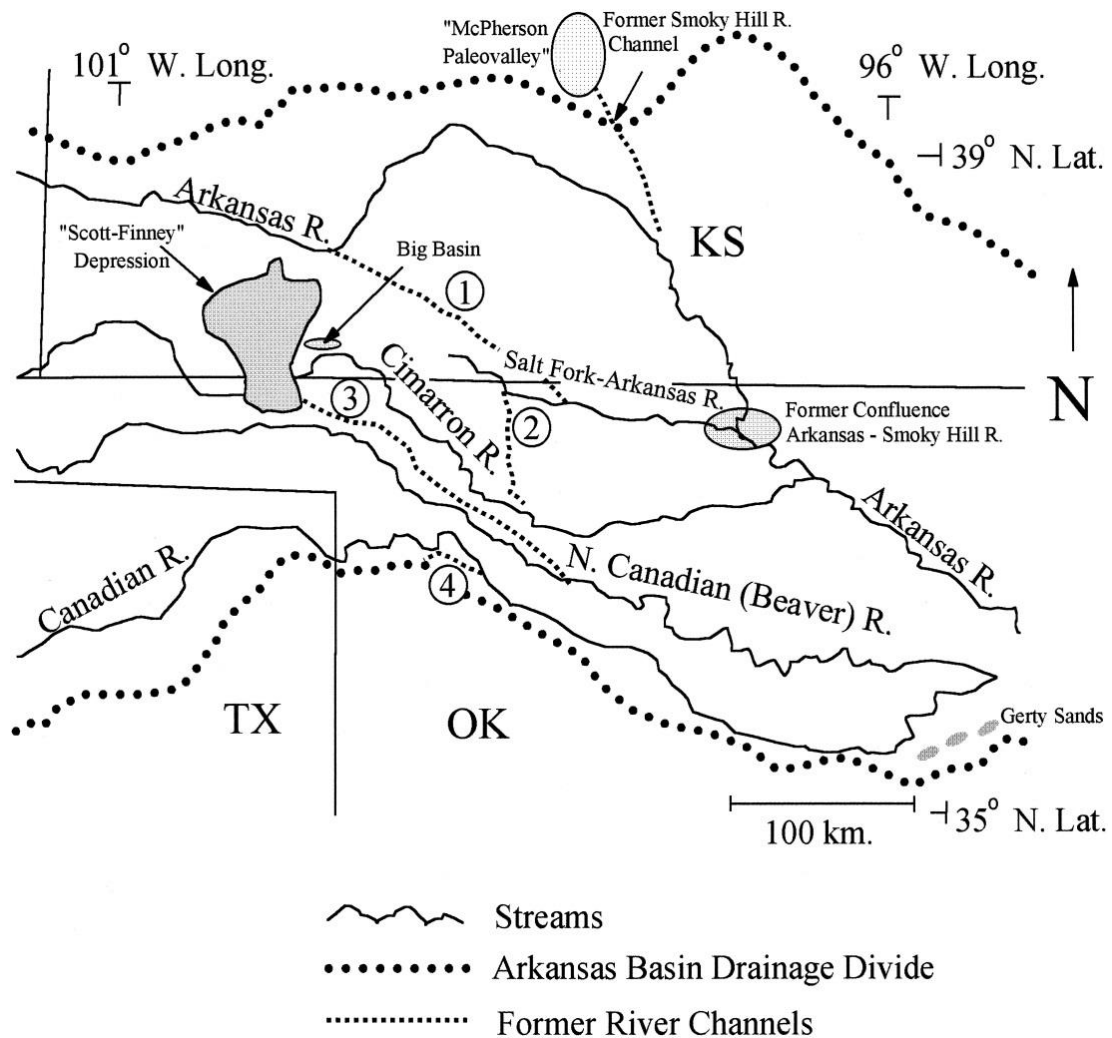


Figure 4.7. Abandoned channel of Arkansas River. Source: Ward and Carter (1999).

### Geology

While many of Oklahoma's Quaternary deposits have not been mapped in detail, these deposits abound, particularly along the main river valleys. The reason that these deposits have not been mapped in detail is because they are in the form of soils and not major formations or

bedrock. This is just one of the reasons that soil analysis and geomorphology become so necessary in a study of Pleistocene megafaunal remains.

The Pleistocene deposits in the Helena Mammoth Site area lie unconformable on Permian shale. Because shale is impermeable water cannot pass through it, but instead settles in small perched water tables throughout the basin (Figure 4.8).

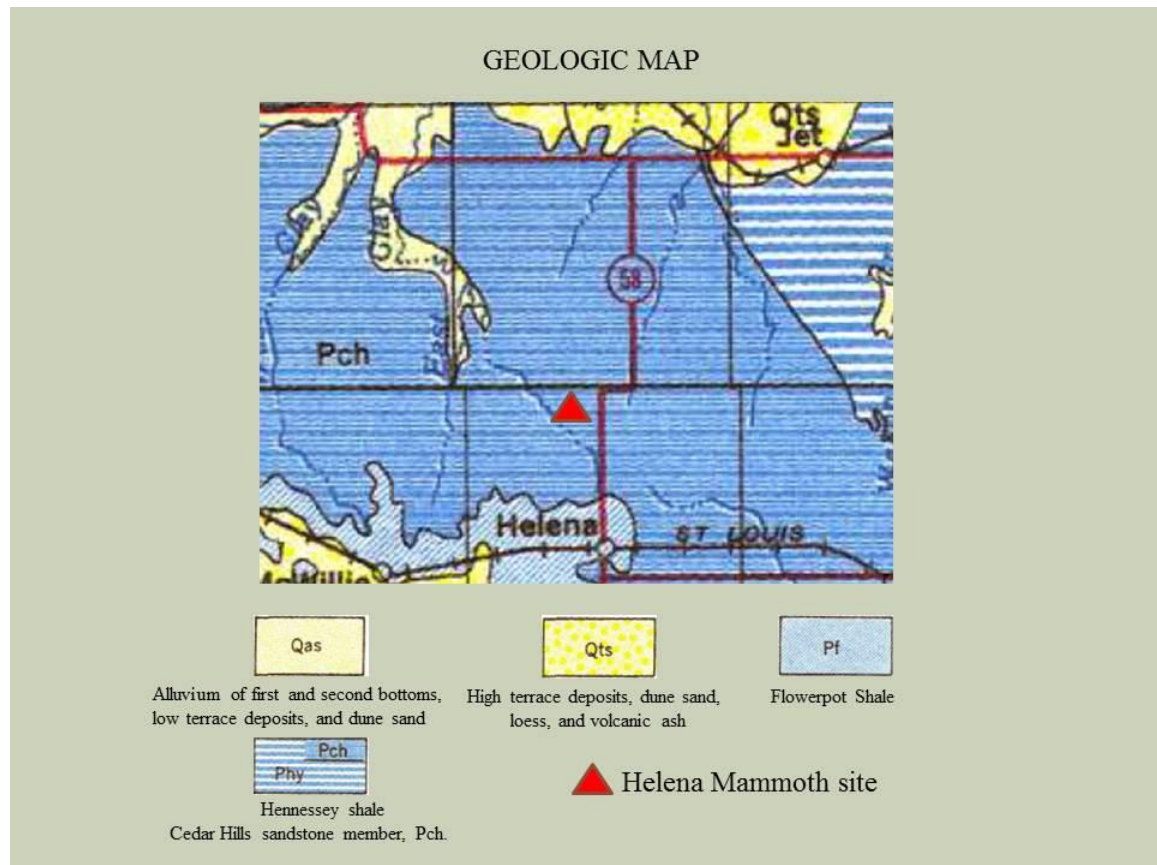


Figure 4.8. Helena Mammoth area geologic map. Source: OGS (2014).

### *Soil Profile Descriptions*

Three soil profiles were described on sections exposed in the excavation area (Figure 4.9). The HM-1 profile contains soils developed on sediments of Terrace 3, which lies just outside and to the north and west of the excavation area. HM-1 contains six different horizons developed on sediments of two different depositional events (Appendix B, table 1). These soils are defined as

Haplustoll soils, soils which have minimum horizon expression and associated with varying lengths of dryness. These soils are common to grass lands (Birkland, 1999). The topmost horizon, the Ap horizon, is a non-structured loam that consisted of roots, some pores and stage-I calcium carbonates. This horizon diffuses into Bk horizon below it. The Bk horizon has mild to medium pedogenesis and is composed a medium sub-angular blocky loam that contains pores and stage I calcium carbonate filaments. There is a clear horizontal boundary between the Bk horizon and the 2ACb below it. The structure of the 2ACb horizon consists of a coarse sub-angular blocky sandy clay loam. This horizon also has few pores and calcium carbonates; the calcium carbonate was brought up from the horizon below it possibly by plowing. There is a clear horizontal boundary between the 2ACb horizon and the 2Bk1 horizon which consists of coarse sub-angular blocky clay loam. The 2Bk1 horizon also has pedogenic properties in the form of pores, and stage I and II calcium carbonates. This horizon diffuses into the 2Bk2 horizon which consists of a coarse sub-angular blocky loam. The pedogenic properties of this horizon are similar to the 2Bk1 horizon above in that it contains pores, and stage I and II calcium carbonates. However, the 2Bk2 also has manganese mottles. The 2Bk2 diffuses into the lowest horizon analyzed the 2C horizon. The 2C horizon consists of loam with a medium to coarse sub-angular blocky structure. This horizon has some visible carbonates in stage I, as well as manganese layers and mottles at various depths (Figure 4.10, 4.11, and 4.12).

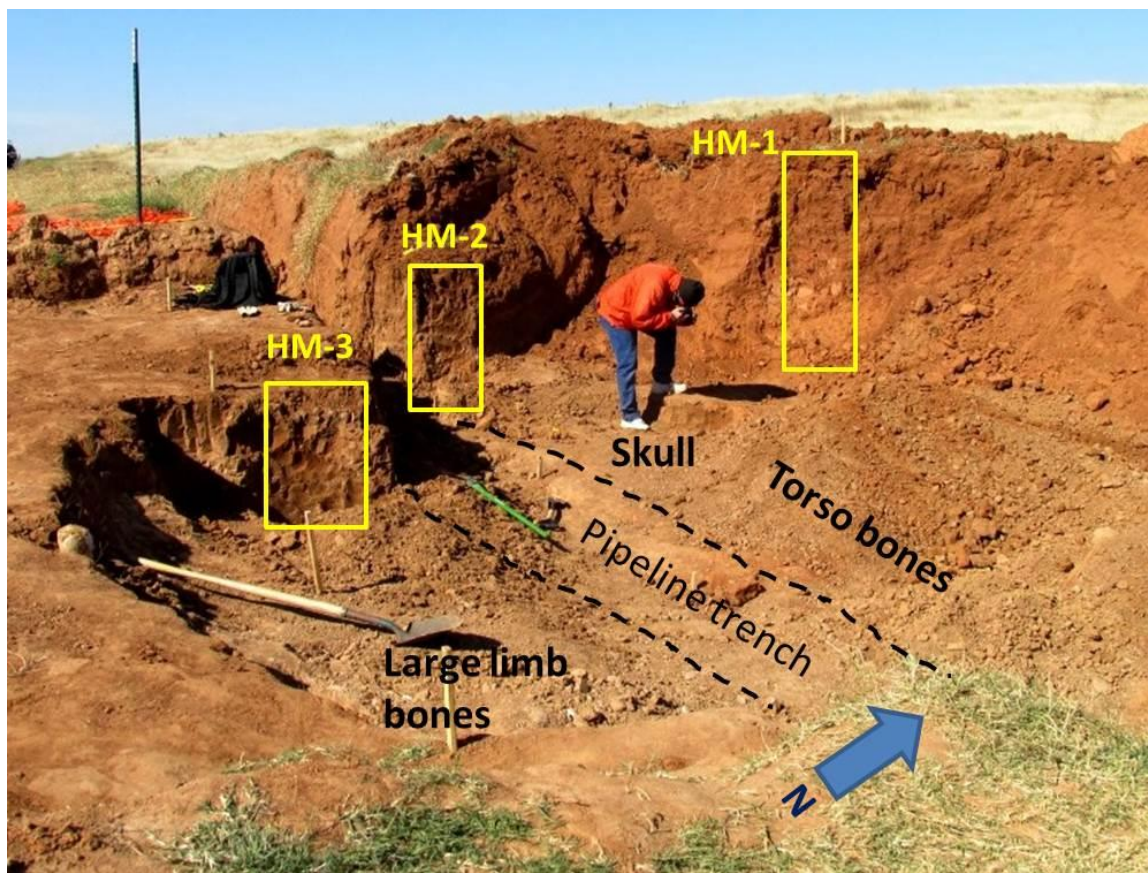


Figure 4.9. Helena Mammoth site excavation area and soil profiles. Photo by Carlos Cordova (2013).



# HM-1

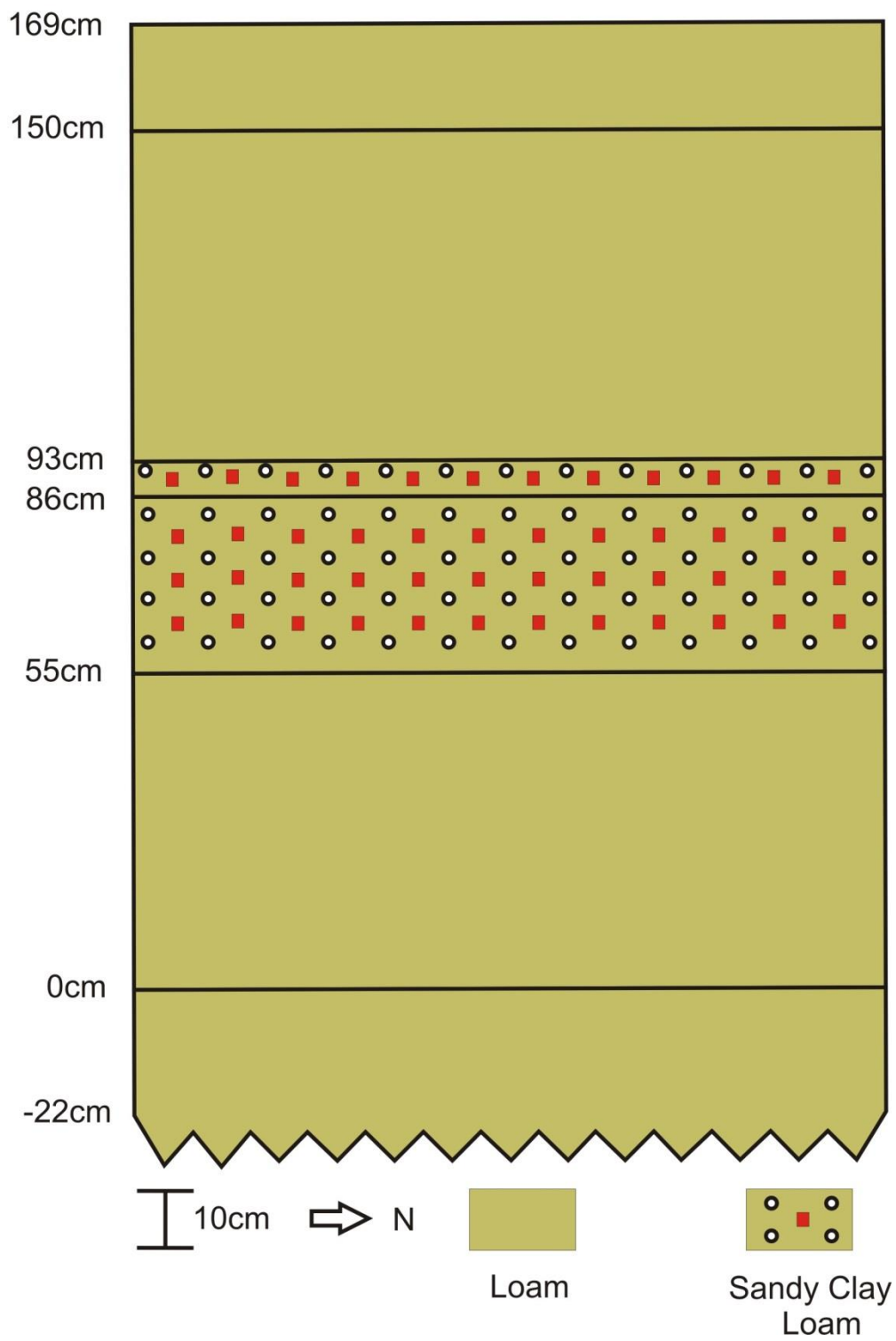


Figure 4.10. HM-1, horizons by texture.

# HM-1

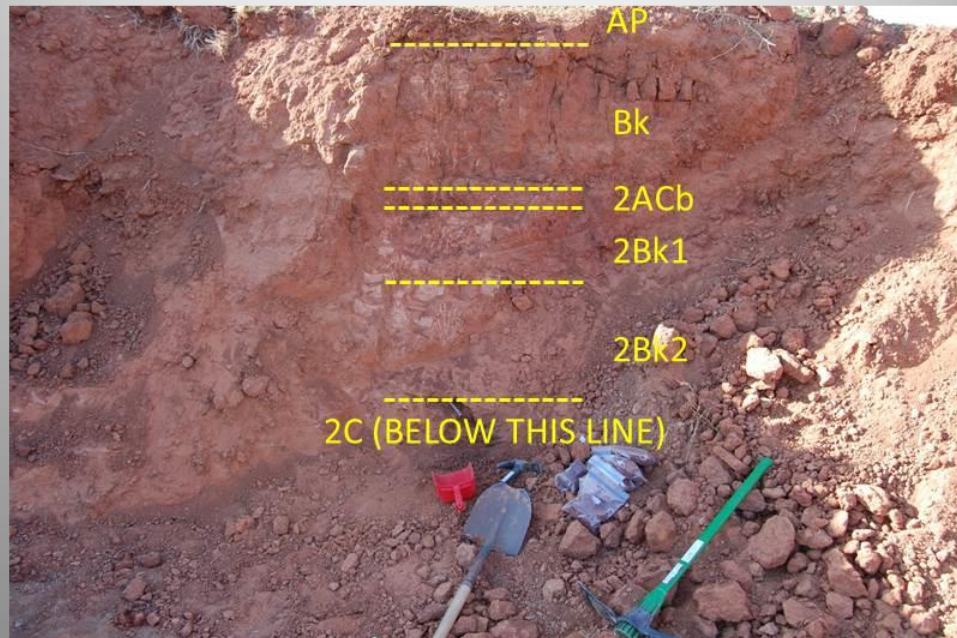


Figure 4.11. HM-1, soil horizons.

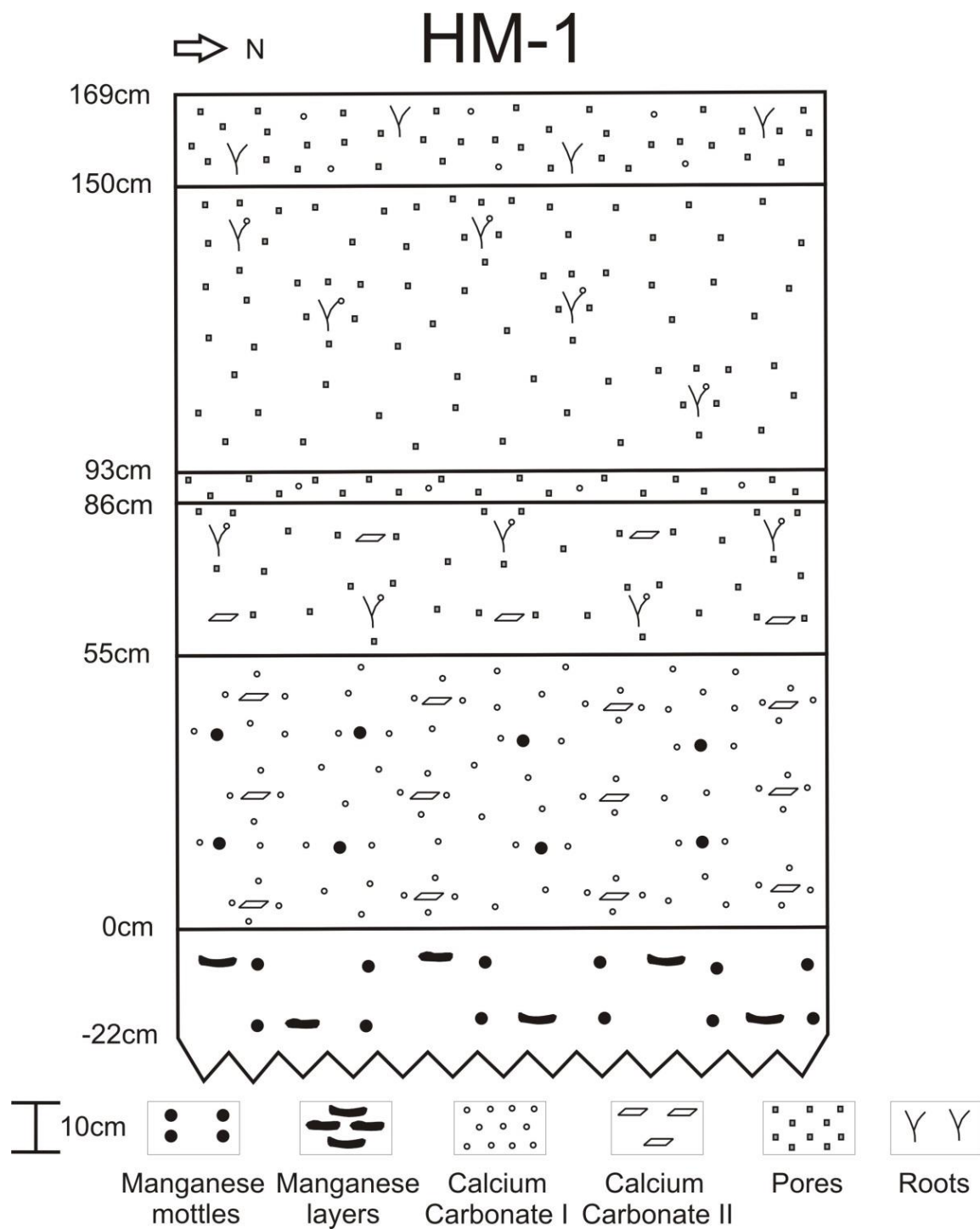


Figure 4.12. HM-1, pedogenic properties.

The HM-2 soil profile is situated just west of the excavation area in close proximity to where the skull was found. HM-2 consists of five different horizons and three separate depositional

events (Appendix B, table 2). It should be noted that for the purposes of the excavation that the upper two meters of soil were removed. The upper most Ap horizon had no structure and consisted of a silt loam; it also contained roots and pores. This horizon diffused into the Bk horizon below. The Bk horizon is a silt loam with a medium sub-angular blocky structure. It has pores and minor calcium carbonate content. The Bk horizon diffuses into the underlying 2Bk, which has a coarse sub-angular blocky silt loam; this horizon has mild pedogenesis in the form of few pores and root filaments with stage I calcium carbonates. The 2Bk horizon has horizontal lamination. There is a clear horizontal boundary between the 2Bk and the 2Cu horizon beneath it. The 2Cu is comprised of colluvium depositional material. It is comprised of a non-structured loam; however, it tested for medium calcium carbonates which were deposited. There is a clear horizontal boundary between the 2Cu horizon and the 3Cu horizon, which was the last horizon analyzed. The 3Cu horizon is comprised of a non-pedogenically altered loam with horizontal laminations (Figures 4.13, 4.14, and 4.15).

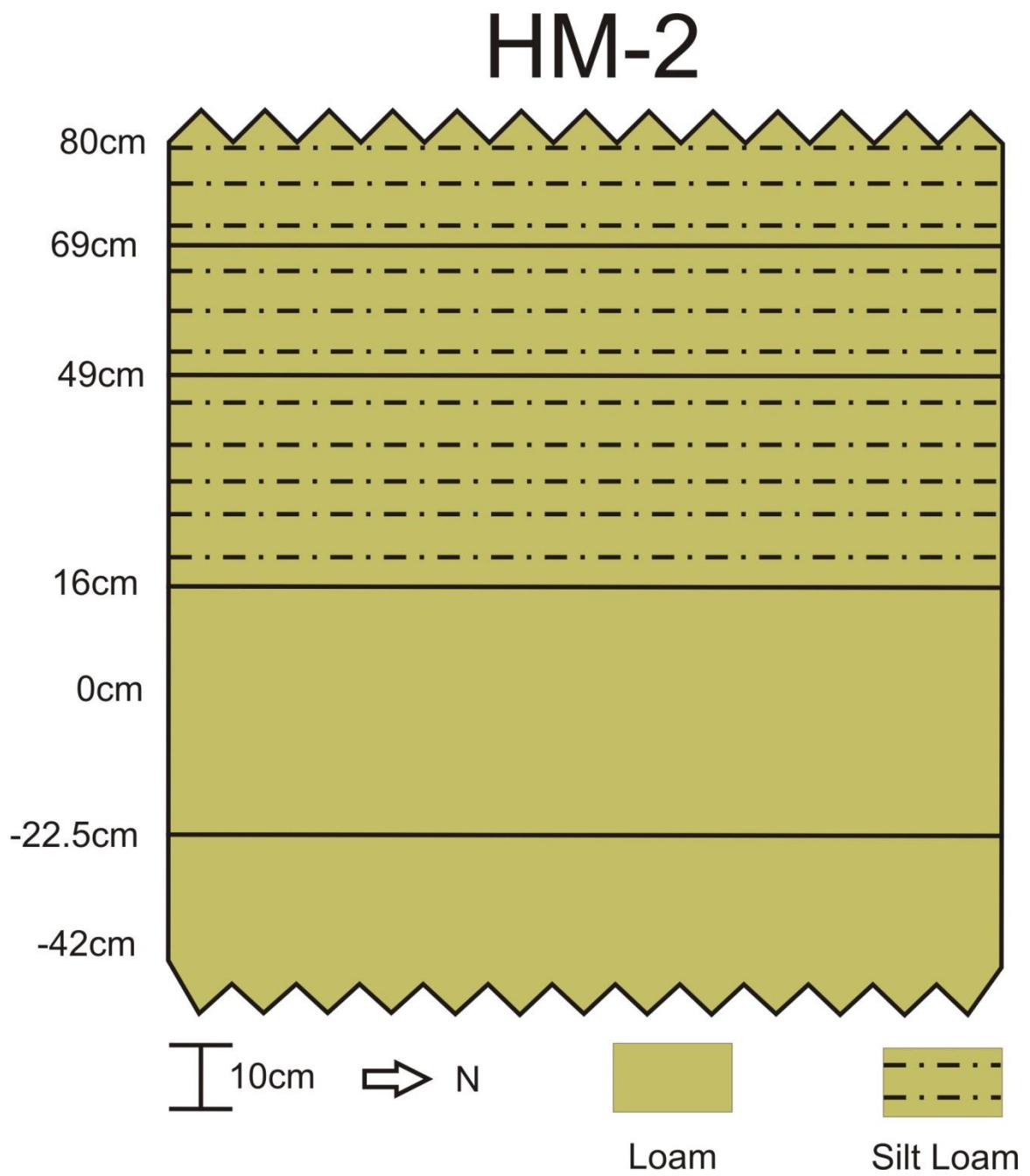


Figure 4.13. HM-2, horizons by texture.

## HM-2

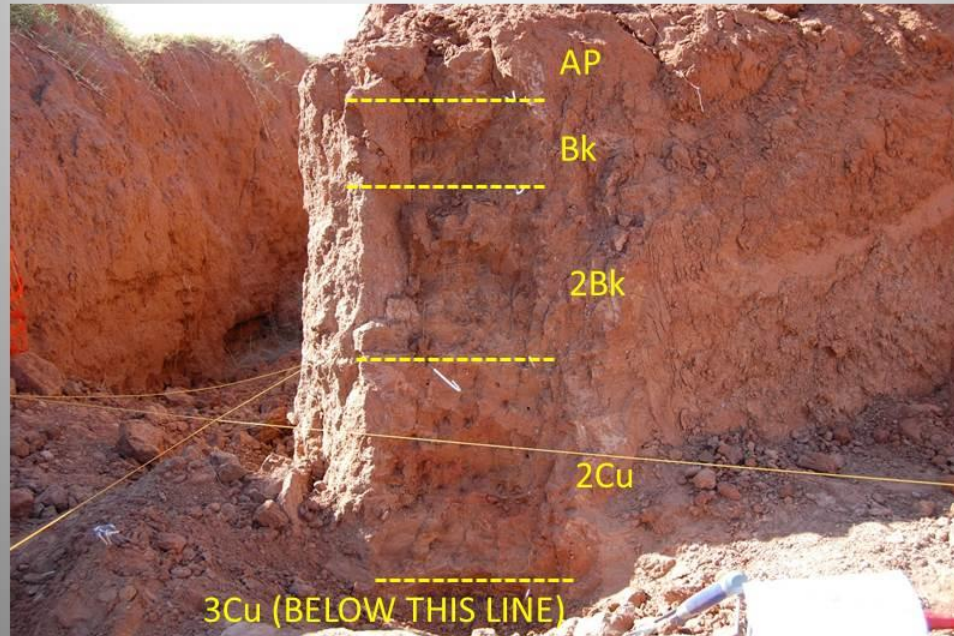


Figure 4.14. HM-2, soil horizons.



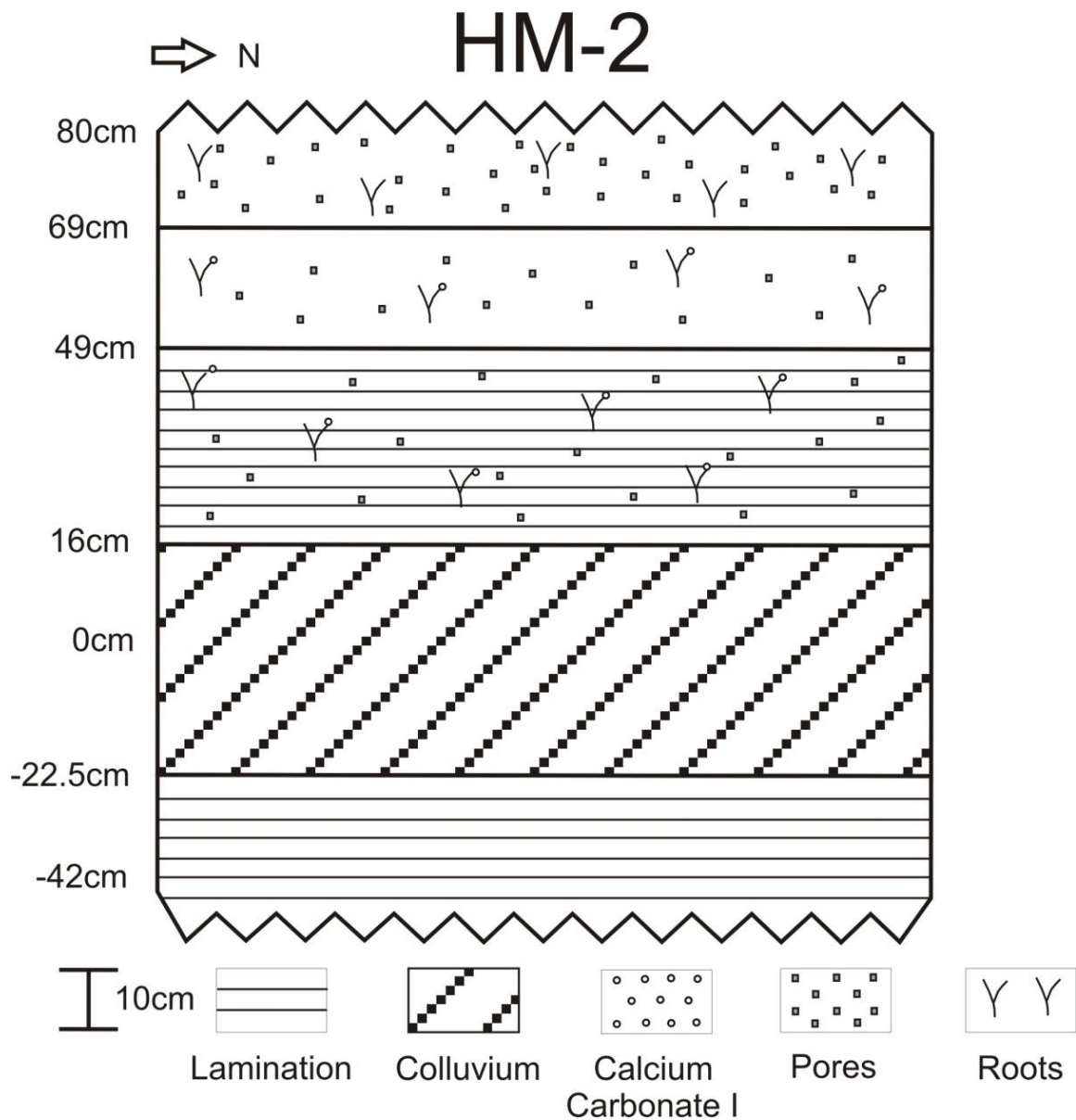


Figure 4.15. HM-2, pedogenic properties.

Section HM-3 is situated south of the gas pipeline trench and to the west of the broken large bones. HM-3 comprises three separate horizons and two depositional events (Appendix B, table 3). It should be noted that the upper meter of soil was removed for the excavation. The uppermost horizon is the Bk, which was comprised of fine sub-angular blocky silt loam. This horizon has pores and very minor traces of calcium carbonates. There is a clear horizontal

transition between the Bk horizon and the Cu horizon beneath it. The Cu horizon has no structure and consists of loam that has some lamination and reworked calcium carbonates in cracks. There is a clear horizontal boundary between the Cu and the 2Cu horizon below it. The 2Cu horizon was the last horizon analyzed, and consists of a non-structured loam. This horizon has both horizontal and cross-bedded laminations (Figures 4.16, 4.17, and 4.18).

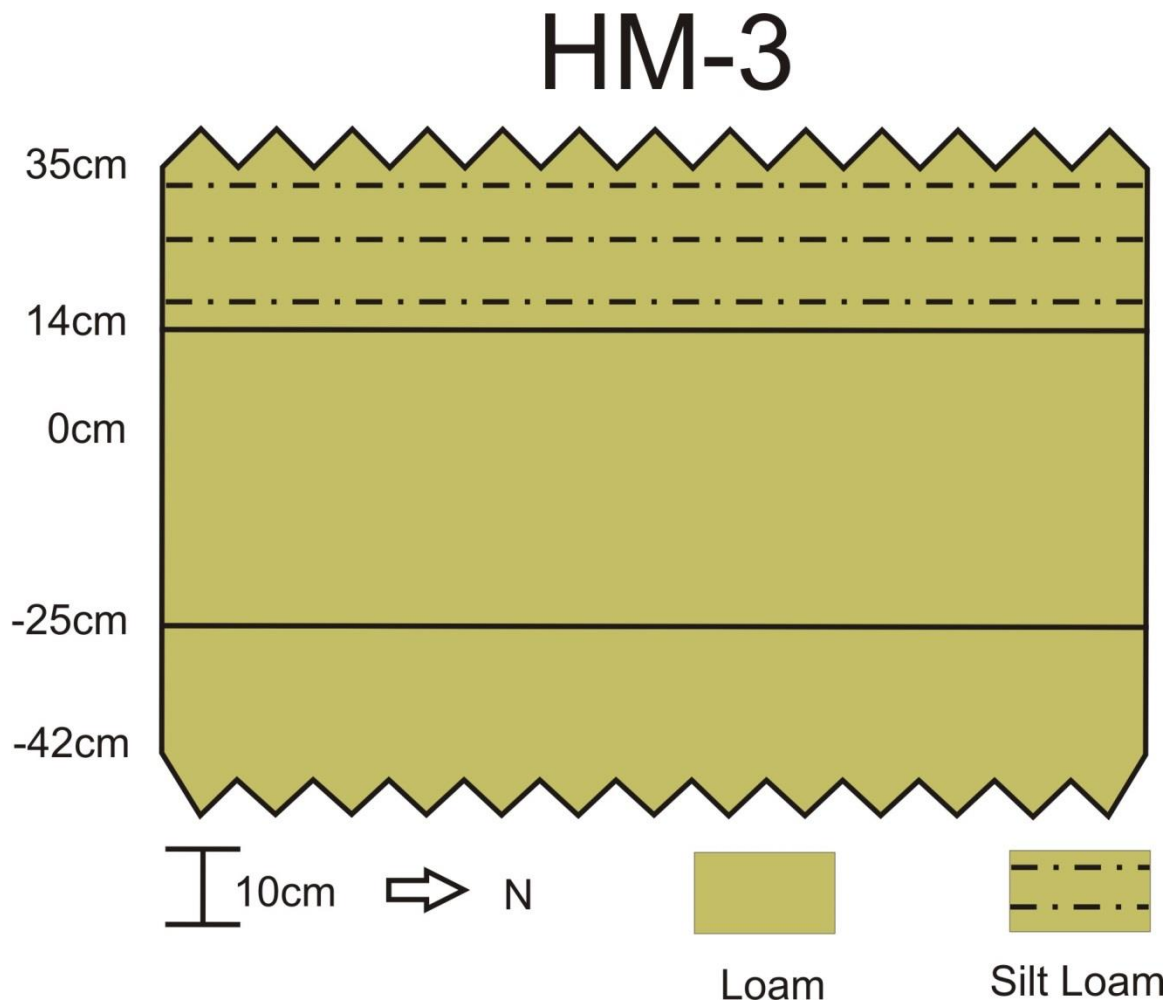


Figure 4.16. HM-3, horizons by texture.



## HM-3

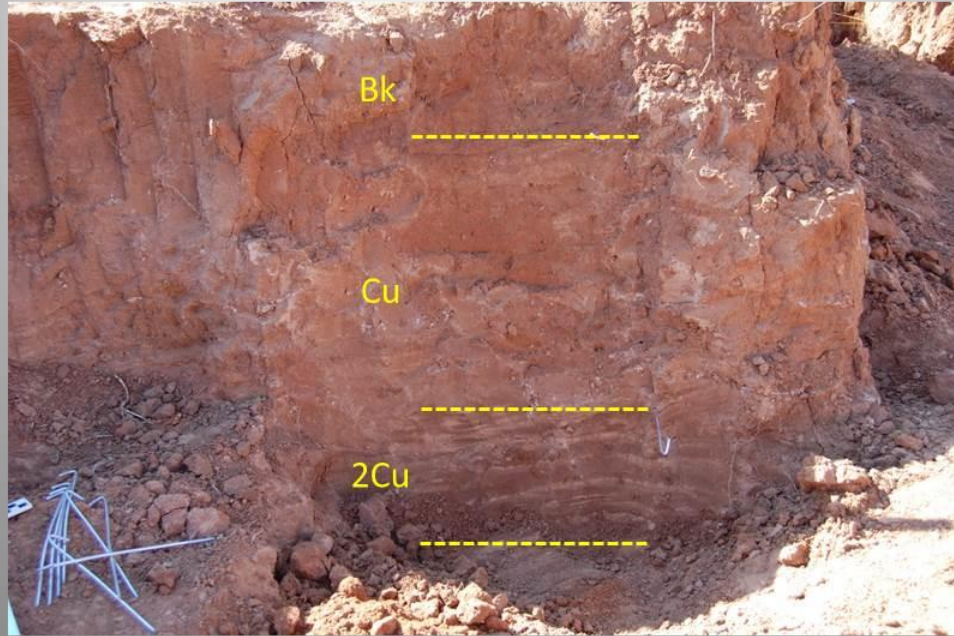


Figure 4.17. HM-3, soil horizons.

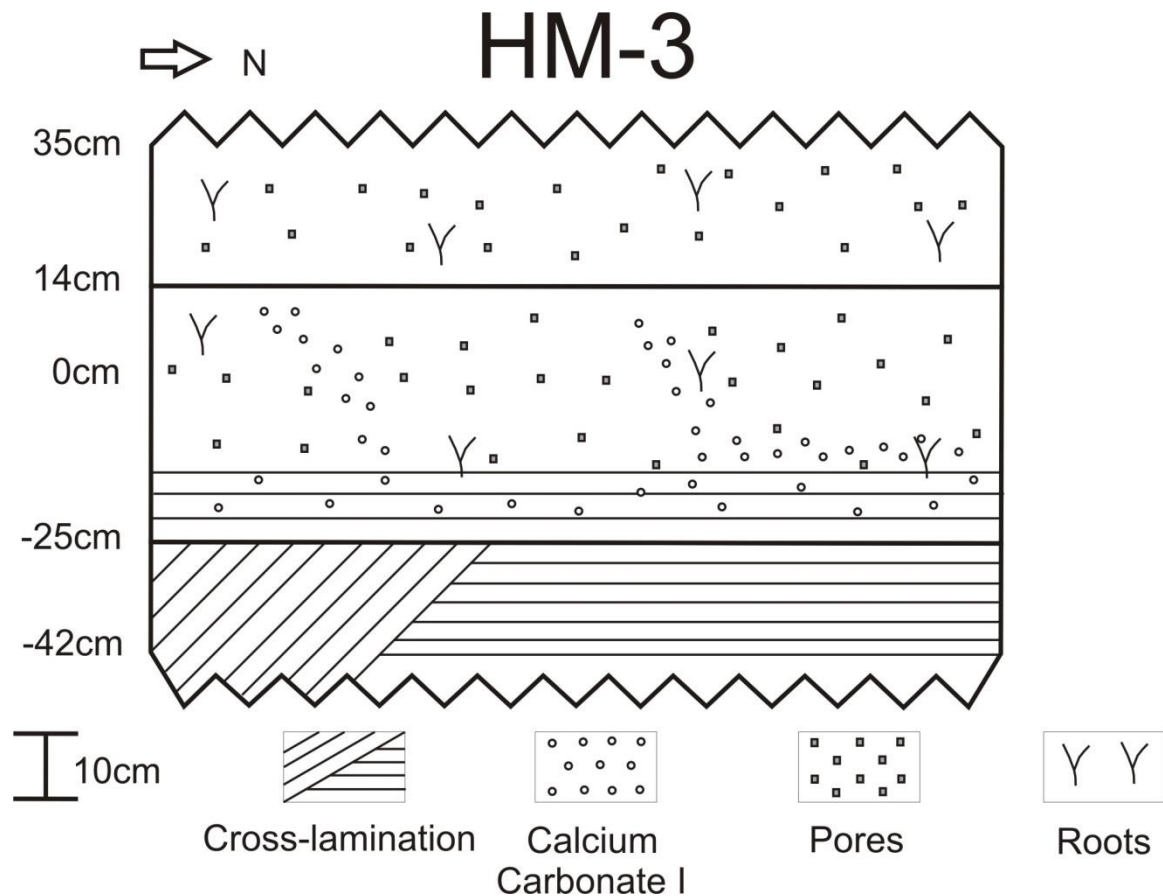


Figure 4.18. HM-3, pedogenic properties.

### *Anthropogenic Influences*

While the Helena mammoth site was not originally believed to have archaeological significance; there are some indications that this might be the case. This comes not in the form of tools or butchering marks, but in the form of possible bone breakage. It is hypothesized that some of the long bones may have been broken by humans. This hypothesis is based on spiral fractures and nick points on several of the bones. Spiral fractures and nick points can only be made while the bones are still green or semi-fresh; no more than a few years old depending on environmental conditions (Holen and Holen, 2013). However, no tools have yet been discovered. It is also possible that these bones could have been broken later by scavengers looking for possible materials to make tools. It is also quite possible that because these bones were

deposited in a wet environment, such as an oxbow lake; they may have stayed pliable. They could have then been broken during a future cataclysmic depositional episode. However, this is unlikely due to the fact that several pieces of long bones have been found in conjunction with the skull. The long bones were also the only bones that were broken by forces other than stress from overlying soil. While the long bones were broken, smaller less dense bones such as the ribs and vertebrae remained intact similar to that of the Lamb Spring site located south of Denver, Colorado (Holen and Holen, 2012). Further research is needed before an absolute reason for the spiral fractures and the position of the long bones to the skull can be known.

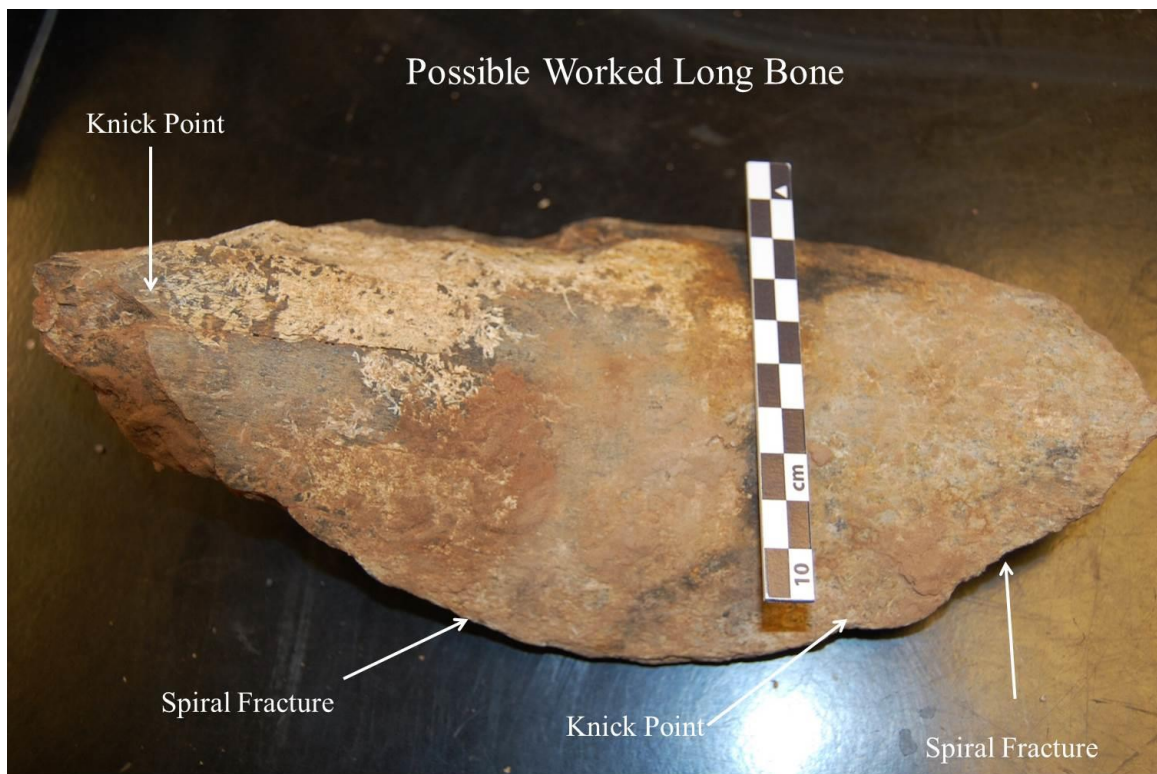


Figure 4.19. Long bone with possible spiral fractures

## *Discussion*

The Helena Mammoth site is situated on the lowest of three terraces. Based on the presence of manganese this site is associated with an alluvial environment such as an oxbow lake. The water table had periods of stability due to presence of well-defined manganese layers (2). The soils of the site were largely composed of loam which had undergone pedogenesis. According to Birkeland (1999), the soils of the Helena Mammoth site are classified as weakly developed based on the lack of clay, and only stage I calcium carbonates. However, the terrace adjacent to the site (terrace 3) is considered moderately developed because it contains clay and stage II calcium carbonates. Another indication of development is that terrace 3 has a hue of 2.5YR based on the Munsell soil color book, which is redder than those of terrace 1 which has a hue of 5YR.

This was further substantiated by OSL testing conducted by Ronald Goble at the University of Nebraska Lincoln (2014), which dated the deposits at  $51.0 \pm 4.6$  ka at 50C. and  $52.5 \pm 5.4$  ka at 225C. Because the quartz grains were flooded with electrons, feldspars had to be tested. Flooded quartz grains occur in samples that are older than the 50 ka, which is the maximum possible age for quartz. The test used was the single aliquot (an aliquot is a sample) regenerative method prescribed by Murray and Wintle (2005), the dates were then corrected for anomalous fading which had a drop off of .02 over 100 hours. In the single aliquot method the grain is tested and then reradiated in order to test how quickly and how much radiation the grain can hold.

Due to the fact that there may be an anthropogenic influence on the long bones of the site, and the soil deposits tested were from below the mammoth remains, more testing is needed. Because the mammoth remains were located in the 2Cu horizon while the skull was located in between the 2Cu and 2Bk horizon it is suggested that a piece of long bone found next to the skull be dated by other means in order to obtain a valid date for the mammoth.

## CHAPTER V

### GRANDFIELD MAMMOTH SITE

#### *Introduction*

The Grandfield Mammoth Site is located eight miles northeast of the town of Grandfield in Tillman County, in southwestern Oklahoma (Figure 4.1). The site is in the basin of the Deep Red Creek, which is a tributary of the Red River. The Wichita Mountains are approximately 70 kilometers north, and the Red River is approximately 15.5 kilometers to the south. The mammoth remains were found in 2005 by a local resident, who noticed an object protruding from the ground in the ditch adjacent to a county road (Figure 5.1). Personnel from Cameron University excavated several bones that were eroding from the bank of the ditch. In 2009 and 2010 Cameron University and the Institute of the Great Plains partnered together in an attempt to excavate the rest of the mammoth from the ditch. While a vast majority of the mammoth's bones were excavated between 2005 and 2010, the skull was never located (Baker, 2010-11).

In January 2014, faculty and students of Oklahoma State University went to the site with Ground Penetrating Radar (GPR) equipment in the hopes of locating the skull. While GPR did locate several areas of interest, it did not reveal a particular location where the head was located.



The day the GPR was run, the city of Grandfield supplied a backhoe for the purpose of cutting a profile adjacent to the excavation site. Although the cut was meant to expose a profile for soil studies, the backhoe exposed a tusk. This suggests that the mammoth's skull may be under the field next to the road. Because of the discovery of the tusk, the backhoe was moved to the south of the excavation site, where the soil profile for GM-1 is located.

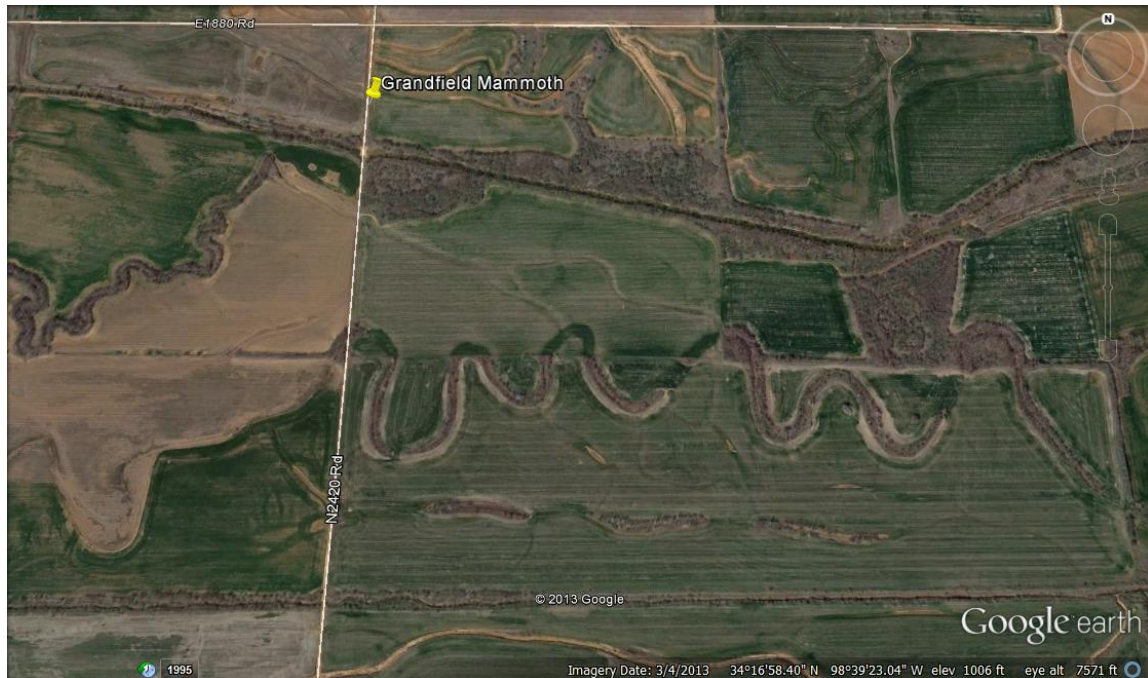


Figure 5.1. Google Image of Grandfield Mammoth site.

### *Geomorphology*

The Grandfield Mammoth Site lies on a low terrace north of Deep Red Creek. Two terraces lie south of the flood basin. Terrace 1 which is where the mammoth remains were located sits at an elevation of 316 meters above the sea level, terrace 2 to the south of the area sits at an elevation of 327 meters, and the flood plain lies at an elevation of 306 meters. The mammoth remains were located approximately half way up terrace 1, and sat an elevation of approximately 308 meters (Figures 5.2 and 5.3). The geomorphology of the area has been changed do to anthropogenic use in the form of agriculture and the extraction of gravel for use in road building.

However, the overall area has retained most of its original terrace morphology. The USDA (2014), Web Soil Survey has classified the soil of the Grandfield Mammoth site as being Burford clay loam (Figure 5.4).

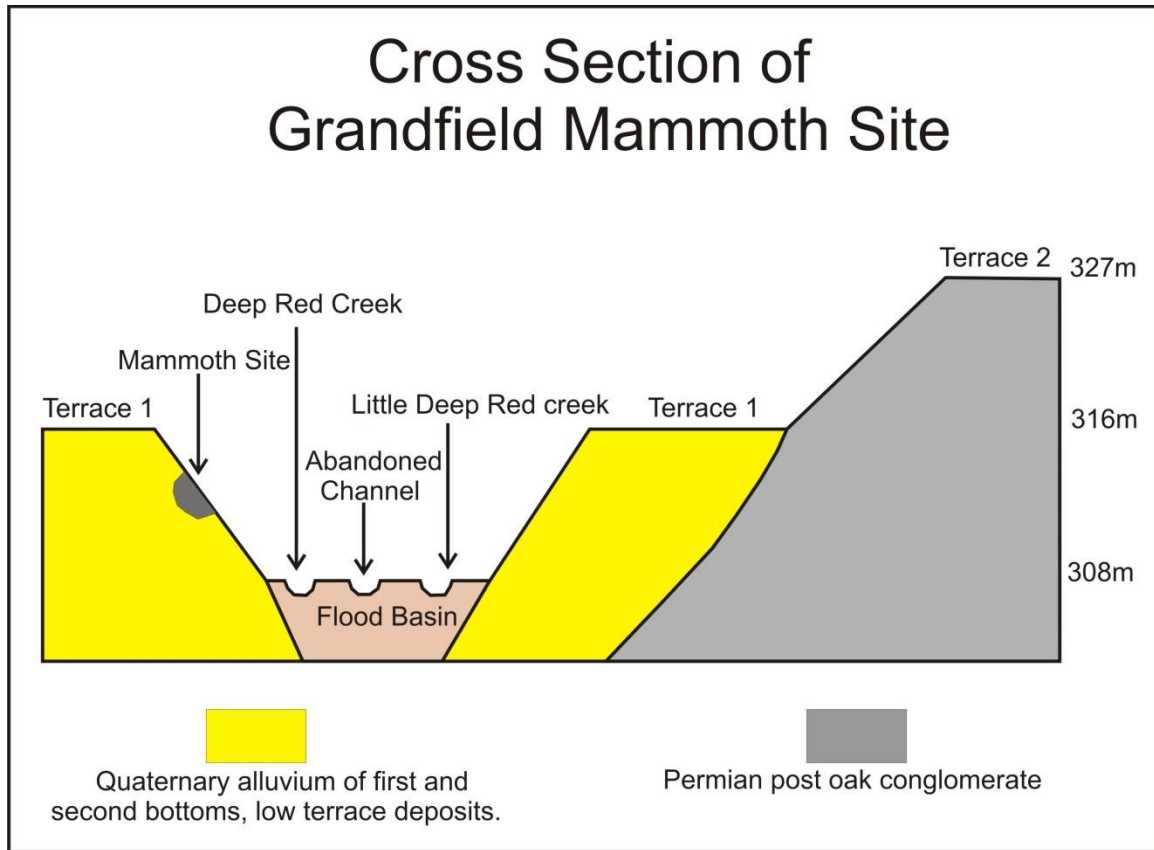


Figure 5.2. Cross section of Grandfield Mammoth site.

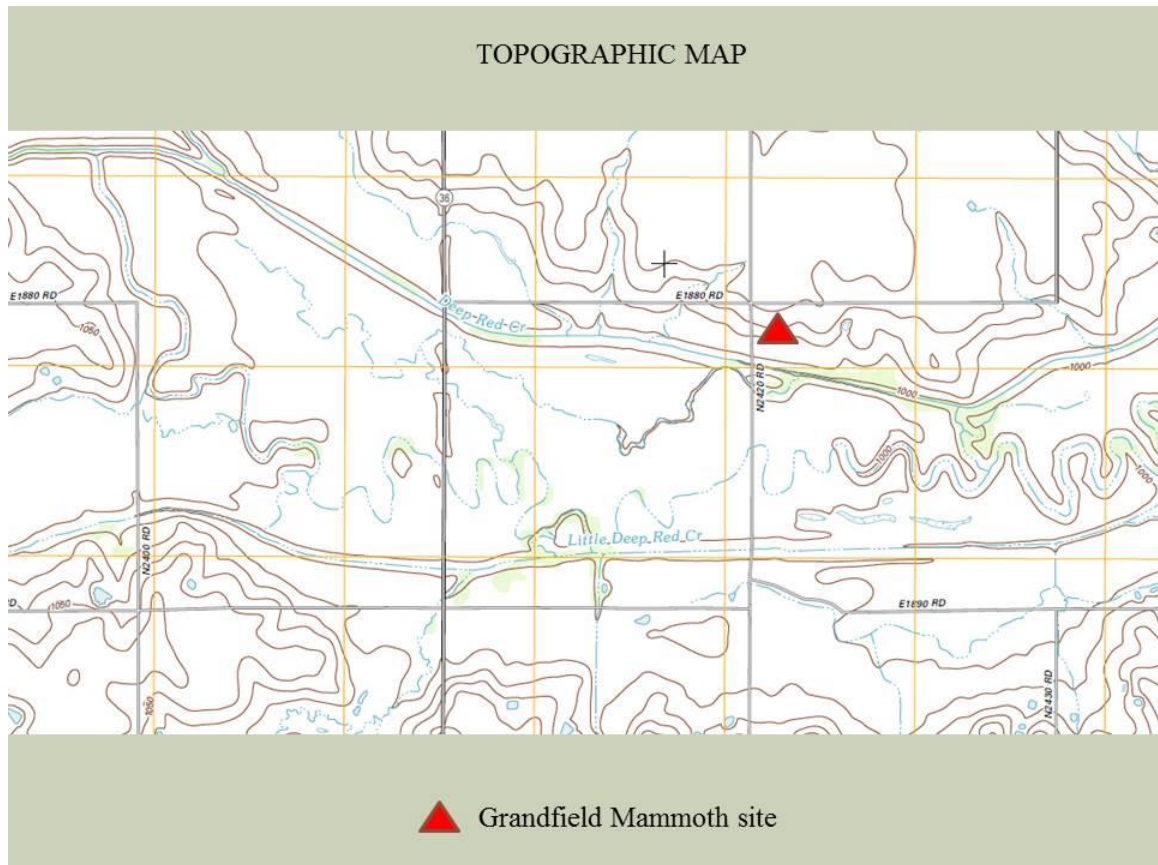


Figure 5.3. Grandfield Mammoth area topographic map. Source: USGS (2014).



# Grandfield Web Soil Survey



USDA (2014)

Grandfield Soil Legend		USDA, 2014
Map Unit Symbol	Map Unit Name	
As	Wheatwood silt loam, 0 to 1 percent slopes, occasionally flooded	
Ca	Clairemont silty clay loam, 0 to 1 percent slopes, channeled, frequently flooded	
FdA	Foard silt loam, 0 to 1 percent slopes	
Mc	Miller clay, 0 to 1 percent slopes, occasionally flooded	
PIT	Pits	
Po	Port silty clay loam, 0 to 1 percent slopes, occasionally flooded	
Tfb	Tillman and Foard soils 1 to 3 percent slopes	
VeC2	Vernon clay, 3 to 5 percent slopes, eroded	
WeC	Burford clay loam, 3 to 5 percent slopes	

Figure 5.4. Grandfield Mammoth web soil survey map. Source: USDA (2014).

### *Hydrology*

One of the interesting aspects of this site is the changes streams have undergone in this area. The area is comprised of a dendritic stream system that extends to the Red River. The Deep Red Creek basin is drained by two different fifth-order streams. The flood plain to the south of the site contains three channels; the channel closest to the site is Deep Red Creek. Little Deep Red Creek lies adjacent to the terrace opposite of the one containing the mammoth remains. An abandoned channel of the Deep Red Creek lies between the Deep Red Creek and the Little Deep Red Creek in the flood basin. These two streams drain into West Cache Creek which then merges with Cache Creek, which in turn merges with the Red River (Figure 5.5).

There are several large gravel pits in the immediate area of the site. The gravel contains fragments of bivalve shells and mammal remains, some of which include mammoths and horses. The gravels are capped by silt with a soil similar to the characteristics of the soil that caps the mammoth remains at GM-1. The gravels and the size of the pits suggest that they were deposited by a stream with much more energy than the present stream in the valley (Deep Red Creek), which in turn poses the hypothesis that this may have been a paleo-channel of the Red River.

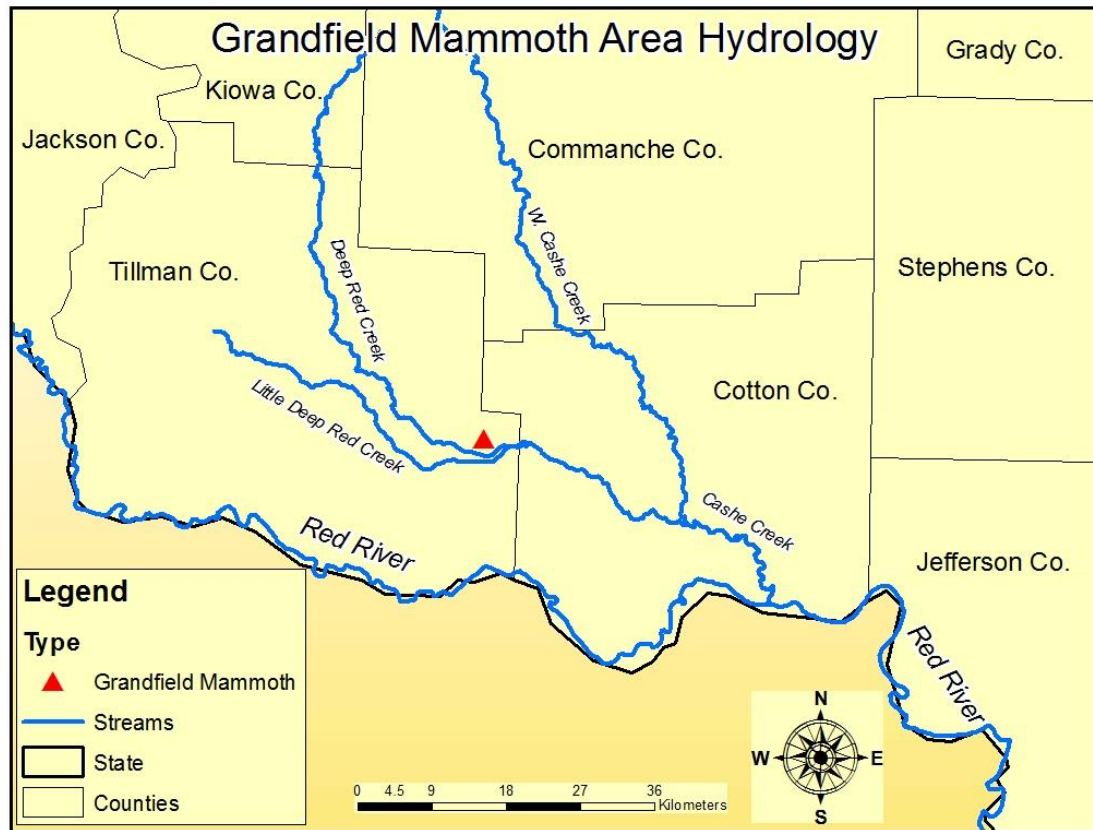


Figure 5.5. Grandfield Mammoth area hydrology.

### *Geology*

As in most of Oklahoma, the geological maps only show two types of Quaternary deposits: fluvial and eolian. The area of the GM-1 finds is in the maps simply classified as Quaternary alluvium of first and second bottoms, and low terrace deposits (Figure 5.6). The higher terraces are reported as the Permian Post Oak Conglomerate. However, the Tillman County Soil Survey shows differences in soil that can be linked to the age of each terrace and older surface. Thus, the floodplain has a poorly developed soil that falls within the suborder of Entisols. The area where the find was located was a paleo-channel that had cut through the surrounding conglomerate.



Figure 5.6. Grandfield Mammoth area geologic map. Source: OGS (2014).

### *Soil Profile Description*

The GM-1 profile is located a few meters south of the tusk exposed by the backhoe (Figure 5.7). The soil profile includes five different horizons developed on sediments of two depositional events (Appendix D, table 1). These soils are defined as Argustoll soils, soils which have an Argillic horizon and associated with varying lengths of dryness. These soils are common in grass lands which contain a significant amount of clay (15 to 40 percent) (Birkland, 1999). The Ap horizon is the upper most horizon and consist of loam. The horizon tested for moderate effervescence to HCL. This is due probably to plowing into the underlying Btk. There is a diffuse boundary between the Ap and Btk horizon. The Btk horizon consists of very hard clay with stage II calcium carbonates, roots, abundant pores, slickensides, and manganese mottles. The boundary between this horizon and the Btk2 beneath it is clear wavy. The Btk2 horizon

consists of very hard clay with abundant pores, calcium carbonates (stage I/II), root marks, and manganese mottles. The boundary between the Btk2 and the C horizon beneath is clear wavy. The C horizon consists of sandy loam with laminations, very few small pores, calcium carbonate (stage I or II, and very little manganese. The boundary between this horizon and the 2C horizon beneath is clear. The 2C horizon consist of sandy loam with pores, worm holes, calcium carbonates (stage I/II), and a gravel lens (Figure 5.8, 5.9, and 5.10).

Because the clays in the Btk and the Btk2 horizons made the peds so hard, field tests were not appropriate in determining texture. Therefore, more extensive lab tests were needed in order to determine. The Btk horizon consists of 14 % sand, 24% silt, and 62% clay. The Btk2 horizon consists of 22% sand, 34% silt, and 44% clay.

## Grandfield Mammoth Site Map

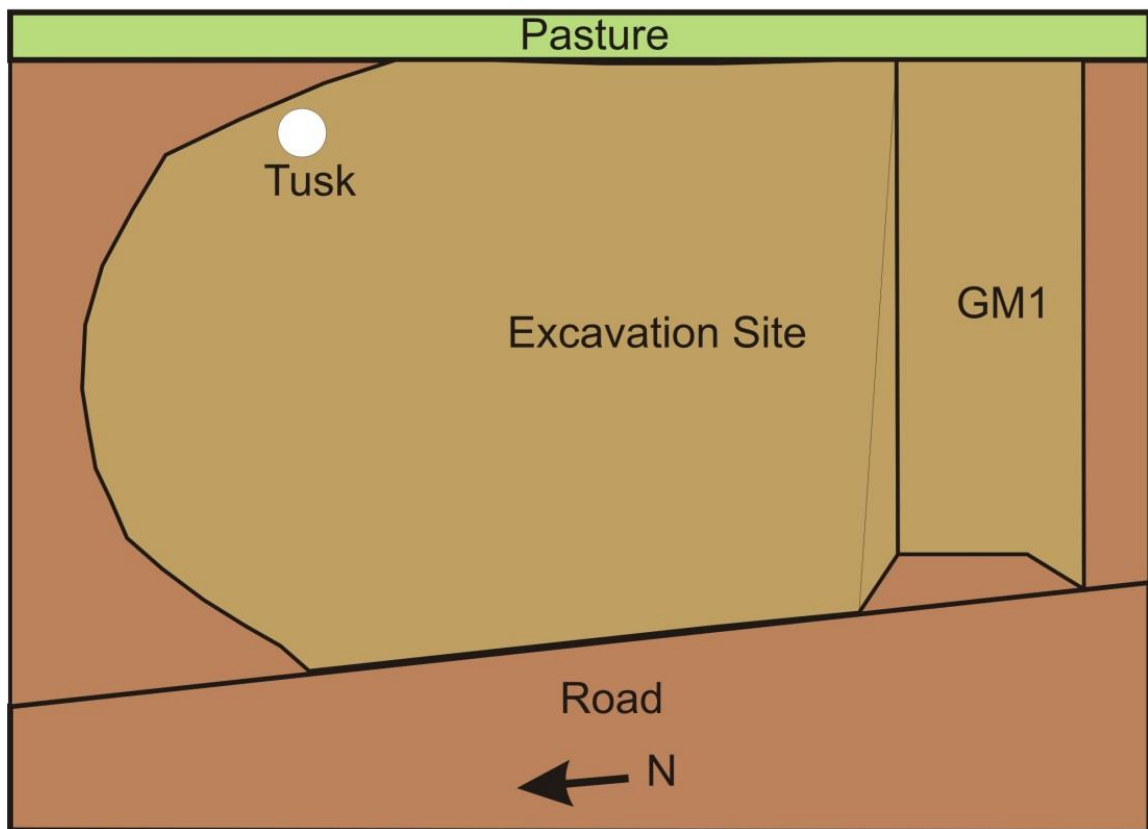


Figure 5.7. Grandfield Mammoth site map.

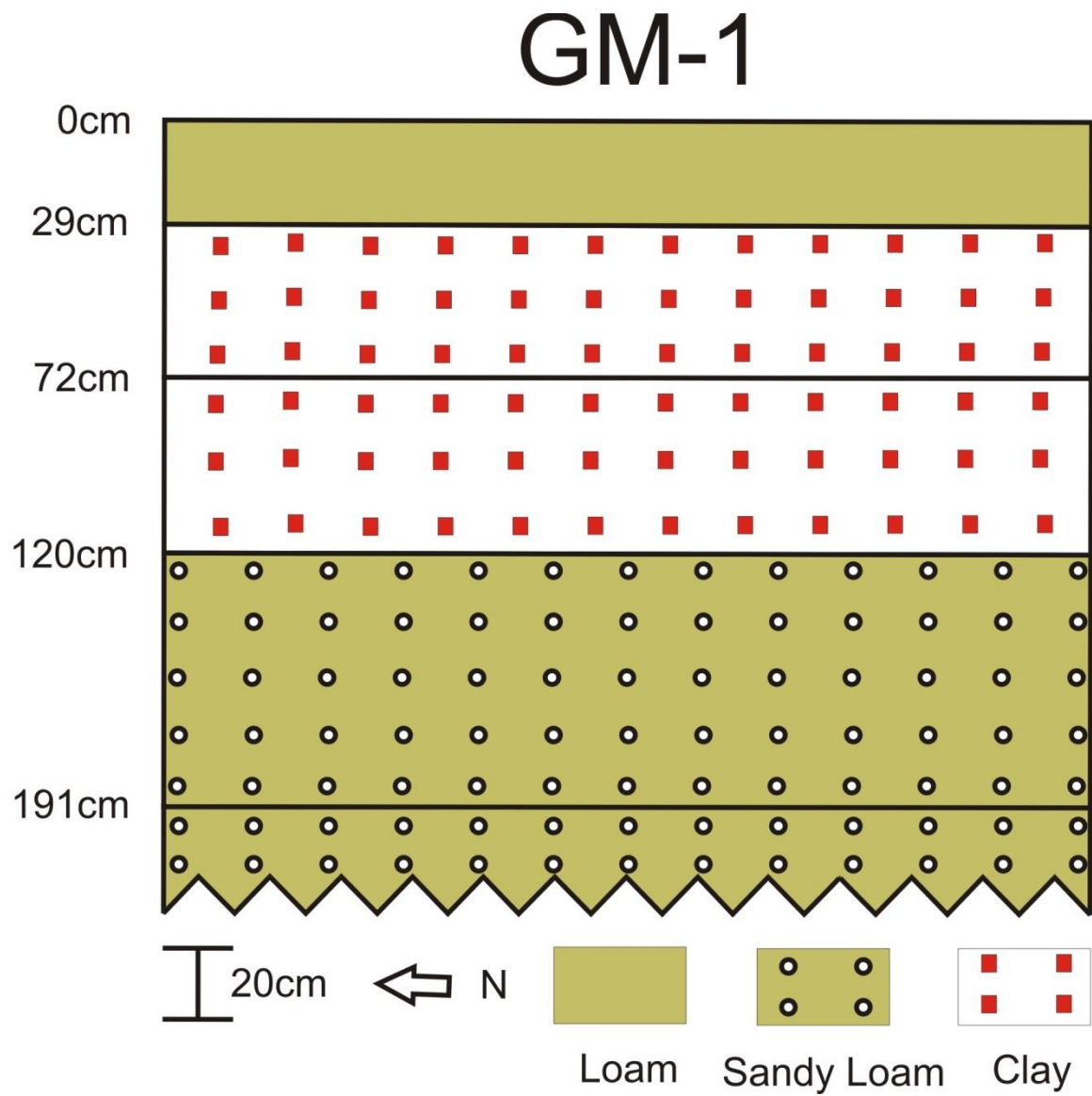


Figure 5.8. GM-1, horizons by texture.



## GM-1

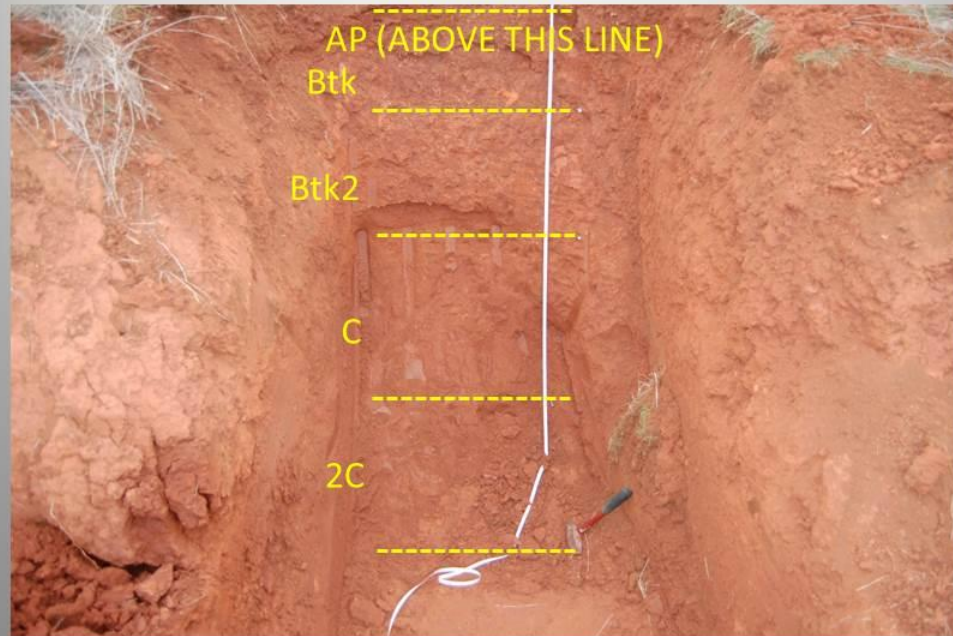


Figure 5.9. GM-1, soil horizons.

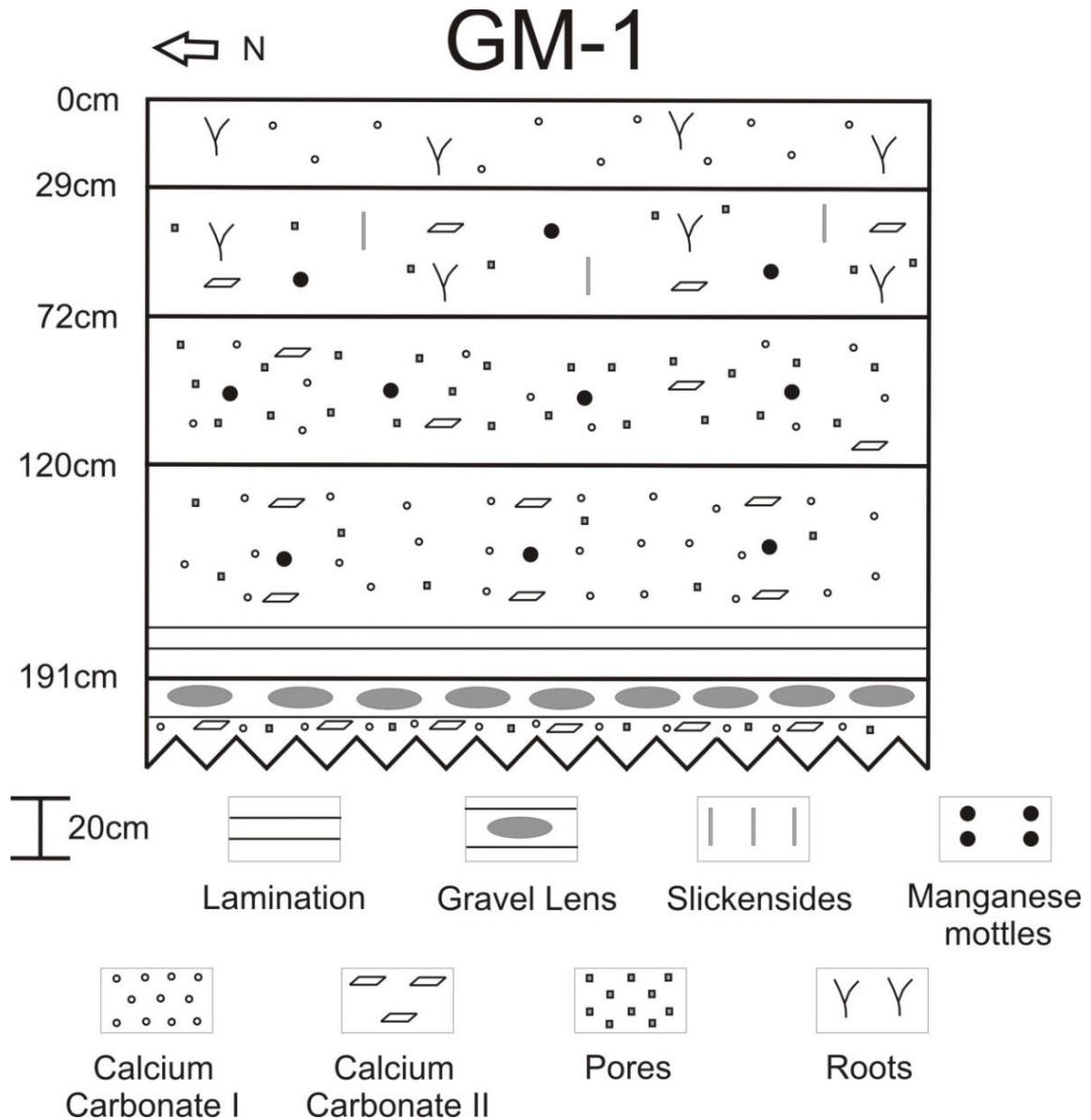


Figure 5.10. GM-1, pedogenic properties.

### Discussion

The Grandfield Mammoth site is situated on the lower of two terraces. Based on the presence of manganese mottles this site is associated with an alluvial environment such as a paleo-channel. The soils of the site were largely composed of loam and clay which had undergone pedogenesis. Because of agricultural use the Btk horizon extended into the AP horizon above. According to Birkeland (1999), the soils of the Grandfield Mammoth site are classified as moderately



developed due to the thickness of the Btk horizons which are largely composed of clay and contain stage II calcium carbonates. Grandfield like terrace 3 of the Helena site has a hue of 2.5YR based on the Munsell soil color book, which is redder than more weakly developed soils.

## CHAPTER VI

### FOSS MAMMOTH SITE

#### *Introduction*

The Foss Mammoth Site is located in the Foss Reservoir area, approximately 23.3 kilometers northwest of Clinton, Custer County, Oklahoma (Figures 6.1 and 6.2). The site was exposed as the waters of the reservoir receded during a 3-year drought period, exposing the mammoth remains for the first time since the reservoir was built in 1961. The mammoth remains at this locality comprised only a skull upside down and one of its tusks. The remains were found in 2013 by a local resident, who destroyed much of the find while trying to remove sections of exposed tusk and teeth.

The U.S Department of Interior's Bureau of Reclamation, in conjunction with the Oklahoma Archaeological Survey, removed the skull in December of 2013. The skull was in very poor condition, -due to years of being submerged in the waters of the reservoir. The digging of the pit around the skull, the description of soil profiles, and the removal of the skull took place over approximately a four and half hour period. Two profiles were described: FM1 on the east wall of the pit, and FM2 on the south side of the pit (Carlson et al., 2014).



Figure 6.1. Google image of Foss Mammoth site in association with Foss Reservoir.

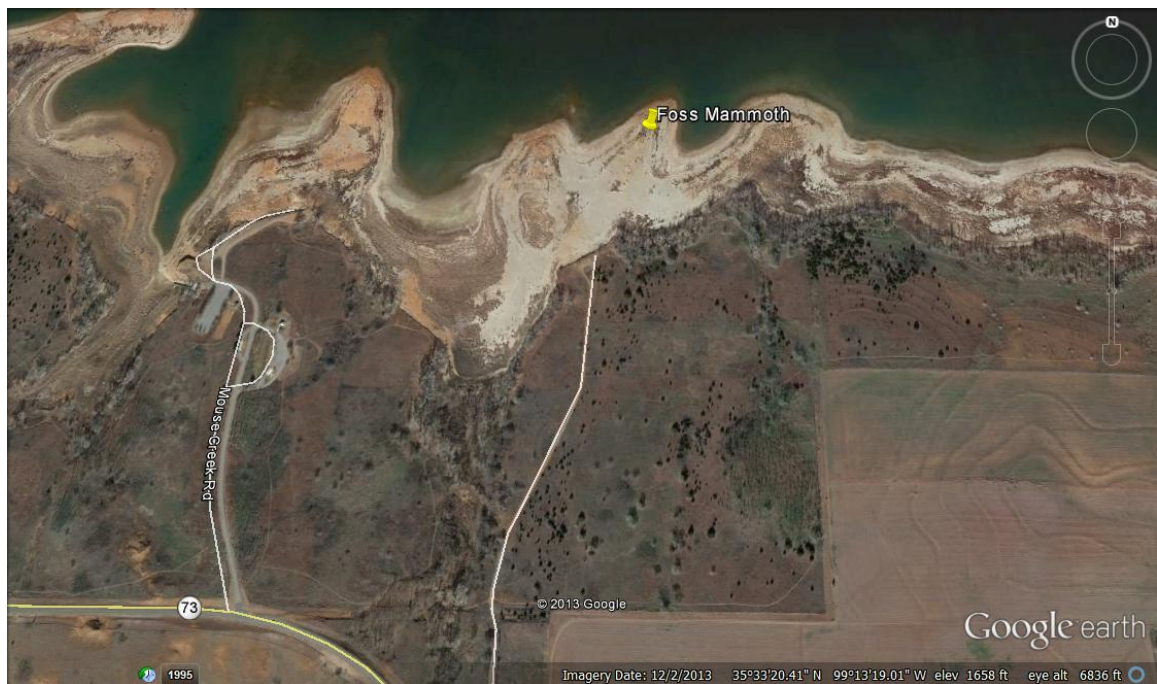


Figure 6.2. Google image of Foss Mammoth site.

### *Geomorphology*

The Foss Reservoir mammoth site area is surrounded by several structural terraces and bluffs. The mammoth remains were found in the flood basin during a period of low water. The area has undergone mass weathering and erosion. There are several dams and reservoirs in the surrounding area (Figures 6.3 and 6.4). The area adjacent to the reservoir has undergone major changes due to anthropogenic influences such as the building of the dam for the reservoir, and terrace building for farming and recreational uses. The USDA (2014), Web Soil Survey has classified the soil of the Foss Mammoth site as “water” since the classification was done when the water level was much higher (Figure 6.5).

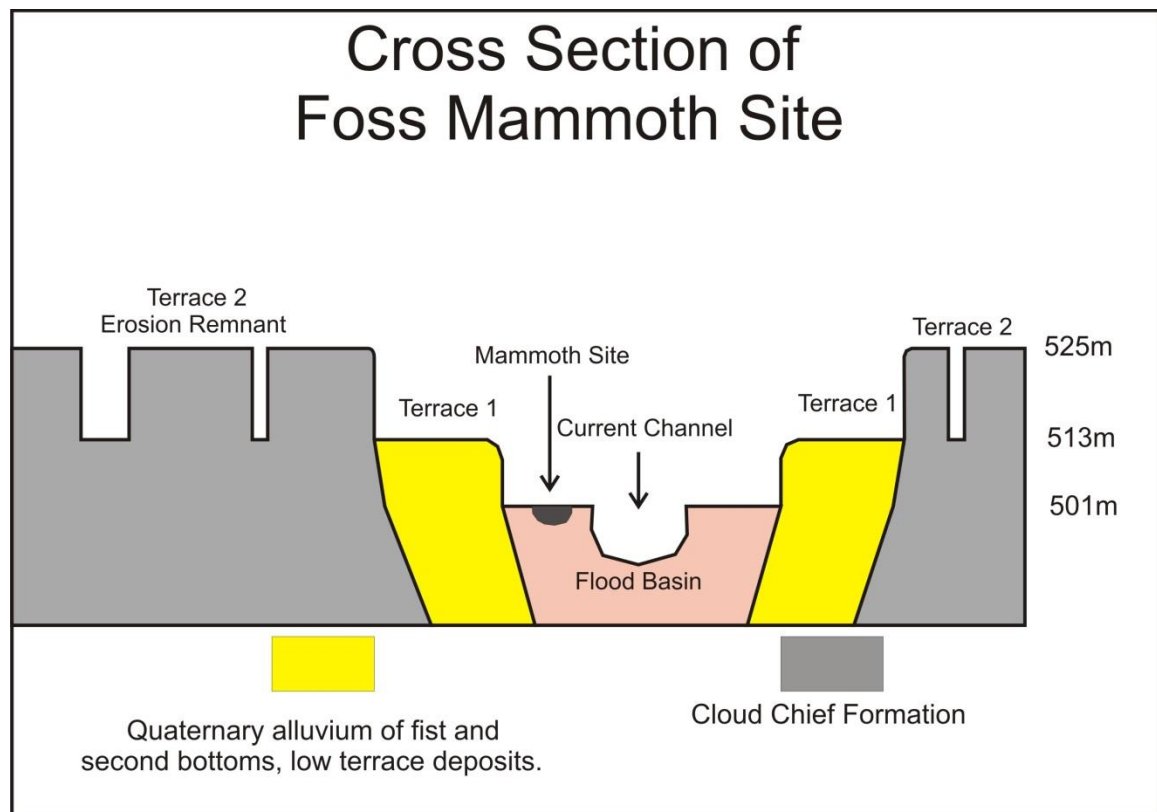


Figure 6.3. Cross section of Foss Mammoth site.

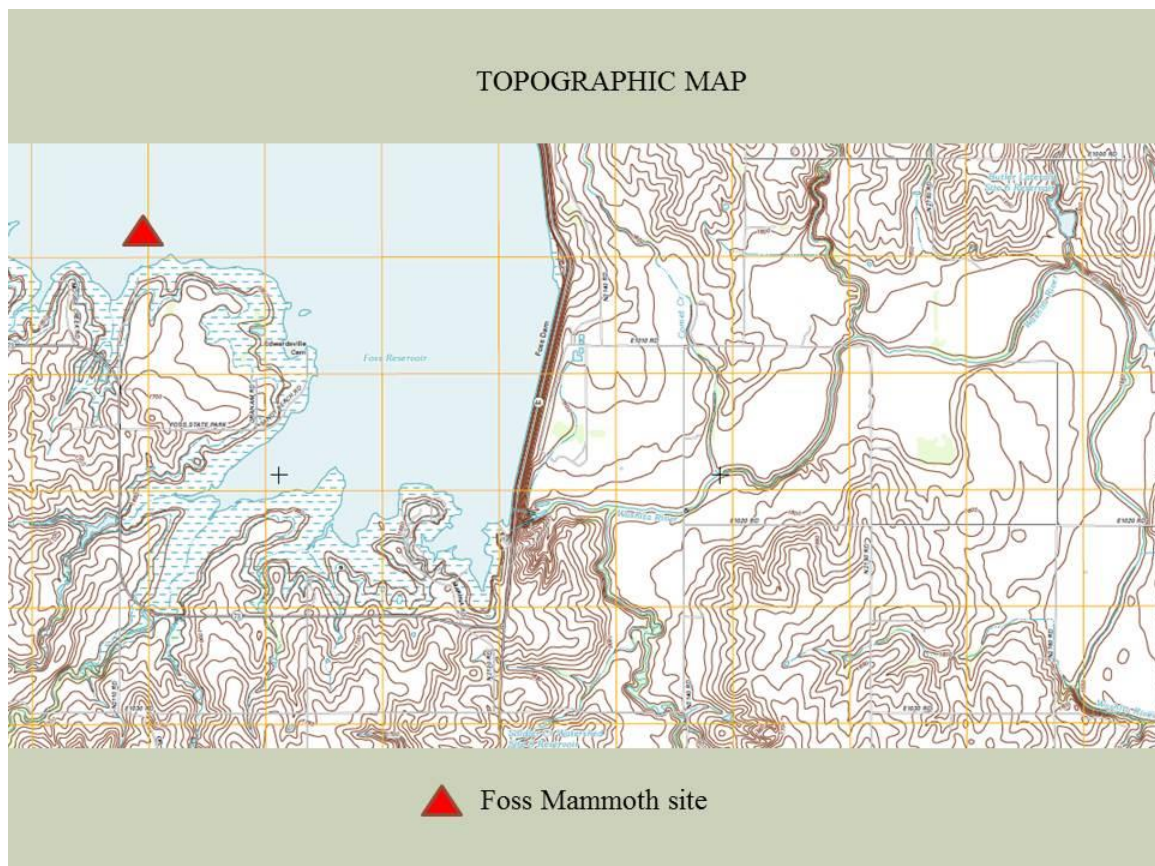
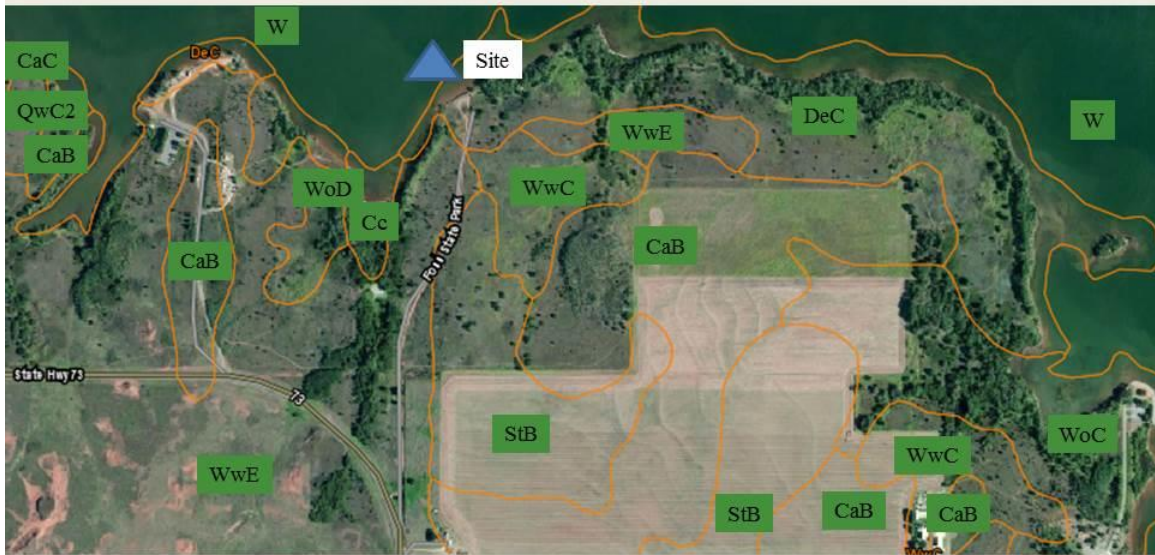


Figure 6.4. Foss Mammoth area topographic map. Source: USGS (2014).



## Foss Web Soil Survey



USDA (2014)

<b>Foss Soil Legend</b>		<b>USDA (2014)</b>	
<b>Map Unit Symbol</b>		<b>Map Unit Name</b>	
CaB		Carey silt loam, 1 to 3 percent slopes	
CaC		Carey and Woodward soils, 3 to percent slopes	
Cc		Clairemont silt loam, 0 to 1 percent slopes, occasionally flooded	
DeC		Devol fine sandy loam, 3 to 5 percent slopes	
QwC2		Quinlan-Woodward complex, 3 to 5 percent slopes, eroded	
StB		St. Paul silt loam, 1 to 3 percent slopes	
W		Water	
WoC		Woodward silt loam,, 3 to 5 percent slopes	
WoD		Woodward silt loam, 5 to 8 percent slopes	
WwC		Woodward-Quinlan complex, 3 to 5 percent slopes	
WwE		Quinlan-Woodward complex, 5 to 12 percent slopes	

Figure 6.5. Foss Mammoth web soil survey map. Source: USDA (2014).

### *Hydrology*

Because the area has been dammed and turned into a lake much of the landscape has either been transformed or covered by the lake. Therefore, being able to obtain a complete hydrological picture of the site is virtually impossible at this time. The damming has also caused the valley to silt up, erasing evidence of the terraces. In essence, the dammed area developed a new floodplain that dominates the topography of the site area. One thing of note, however, is that the skull was found on large gravels like those associated with a point bar. This would suggest that the skull was in an abandoned channel. This might be part of a buried terrace of age younger than Terrace 1, or an eroded section of Terrace 1 itself. However, these are only guesses based on what is visible today. It is not known whether this channel is an abandoned channel of the Washita River or one of its tributaries. Based on known information and analysis it can only be surmised that the skull is associated with a third order stream system. The Washita River flows into the Red River which then flows into the Mississippi River (Figure 6.6).

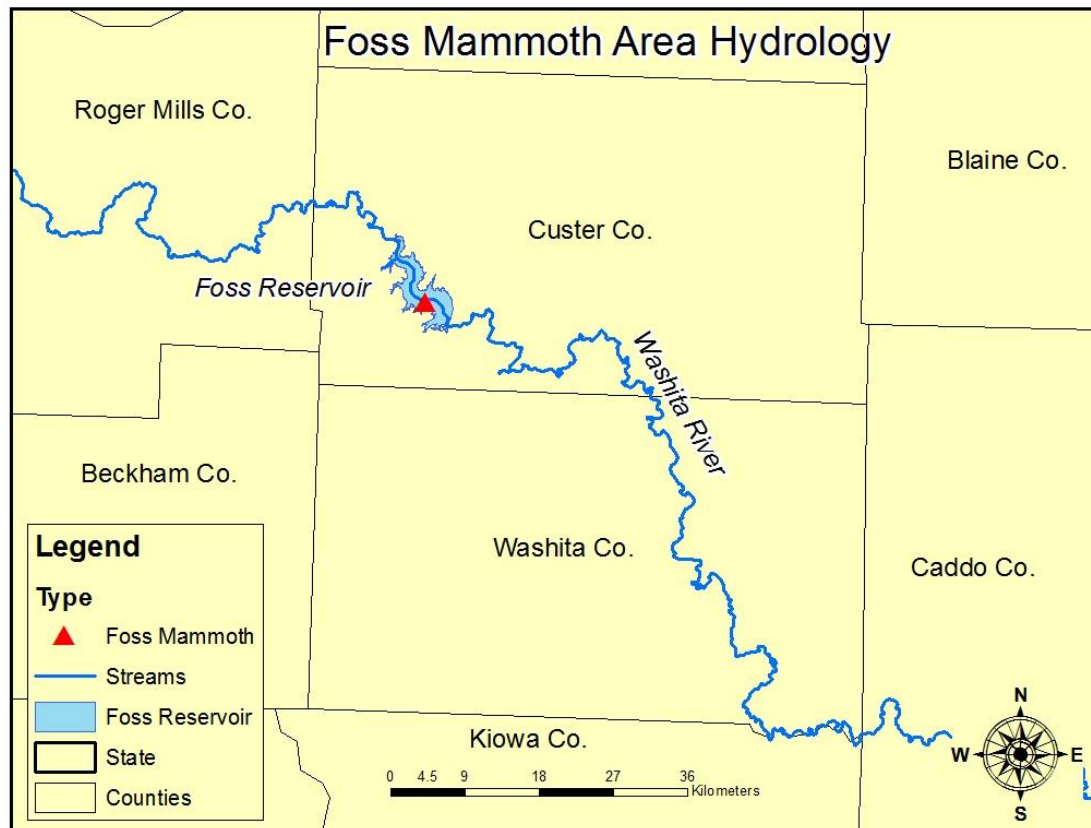


Figure 6.6. Foss Mammoth area hydrology.

### *Geology*

This area is comprised of several high terraces associated with various geologic formations. Terrace 1 which is adjacent and part of the flood plain sits at an elevation of 513 meters and is comprised of Quaternary deposits. Terrace 2 is a structural terrace of the Cloud Chief Formation with an elevation of 525 meters. As you move further away from the site there are also structural terraces of the Rush Springs Sandstone Formation (Prs), Doxy Member of the Quarter Master Formation (Pdy), and the Kiowa Formation (Kk). The terraces of the Cloud Chief Formation and the Quarter Master Formation are Permian in age; while the Kiowa Formation is Cretaceous in age (Figure 6.7).



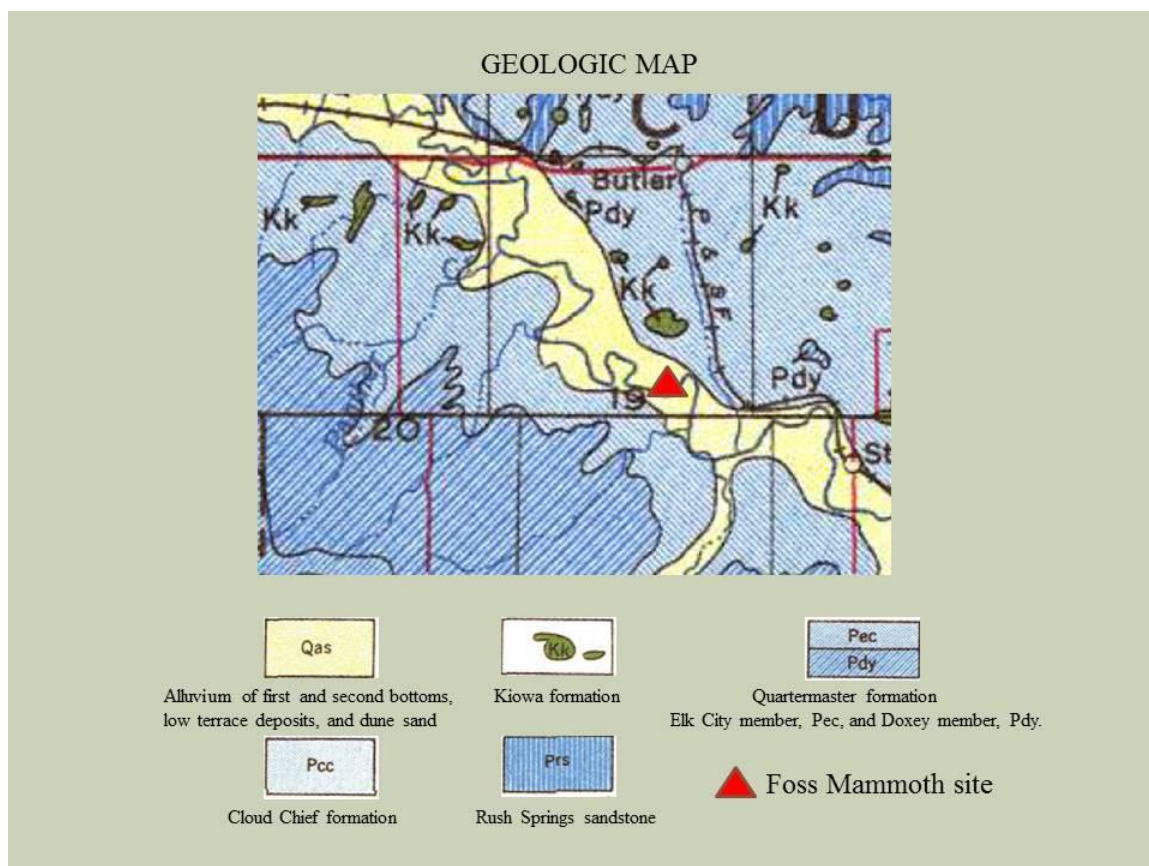


Figure 6.7. Foss Mammoth area geologic map. Source: OGS (2014).

### *Soil Profile Descriptions*

A soil profile description was conducted on the south and east walls of the excavation site (Figure 6.8). It should be noted that due to time constraints the soils and stratigraphy of the north and west walls of the excavation pit were not recorded.

Profile FM1 includes five different horizons all of which represent different depositional events (Appendix E, table 1). These soils are defined as Entisols soils, soils which are poorly developed due to a high erosion rate. These soils are common in floodplains (Birkeland, 1999). The AC horizon is the uppermost horizon, and consists of sandy loam. The horizon has fine and medium sands with fine angular blocky development. There is a diffuse boundary between the AC and the 2C beneath it. The 2C horizon is also a sandy loam with angular blocky

development. The horizon contains some pebbles, sandstone, and manganese. There is a diffuse boundary between the 2C and 3C horizon. The 3C horizon is composed of clay, and has angular blocky development. The horizon also has developed slickensides and contains manganese mottles. There is a diffuse boundary between the 3C and the 4C beneath it. The 4C is composed of sand with some sandstone, and has no pedogenic development. There is a diffused boundary between the 4C and the 5C horizons. The 5C horizon is composed of sand with some pebbles and sandstone. The horizon has no structure and tests mild for calcium carbonates. All the other horizons tested negative for calcium carbonates (Figures 6.9, 6.10, and 6.11).

The 3C horizon in profile FM-1 had such a hard consistency that texture could not be determined using field methods. Therefore, it was analyzed using those laboratory techniques outlined in the methodology chapter. Upon analysis in the lab it was determined to be comprised of 66% clay, 32% silt, and 2% sand.

## Foss Mammoth Site Map

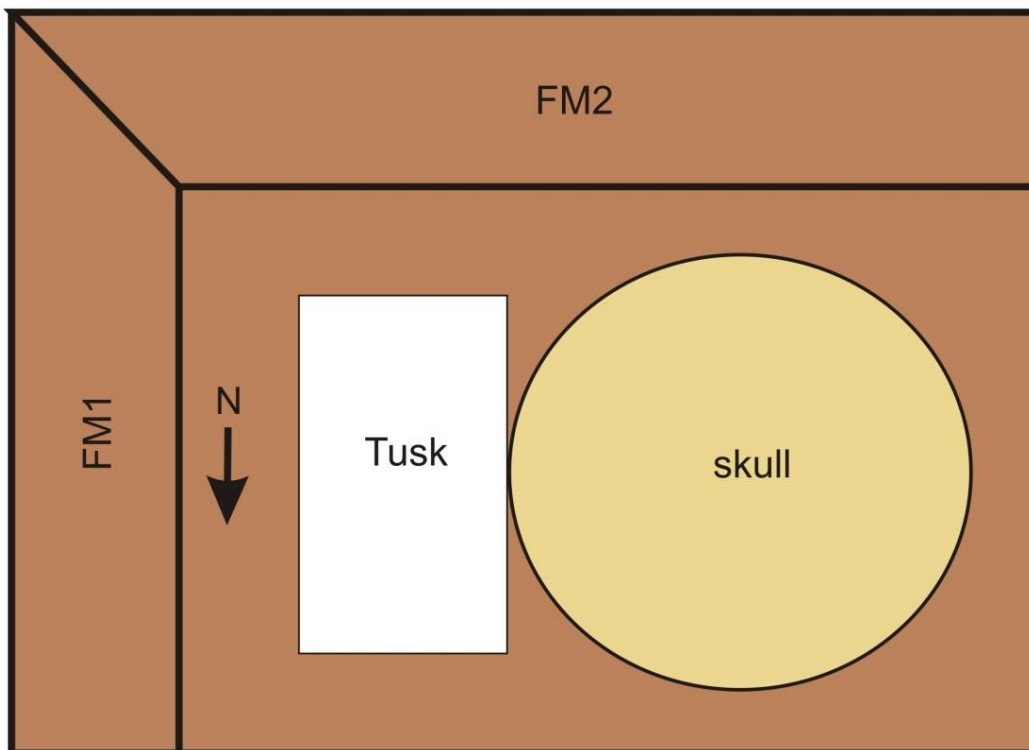


Figure 6.8. Foss Mammoth site map.

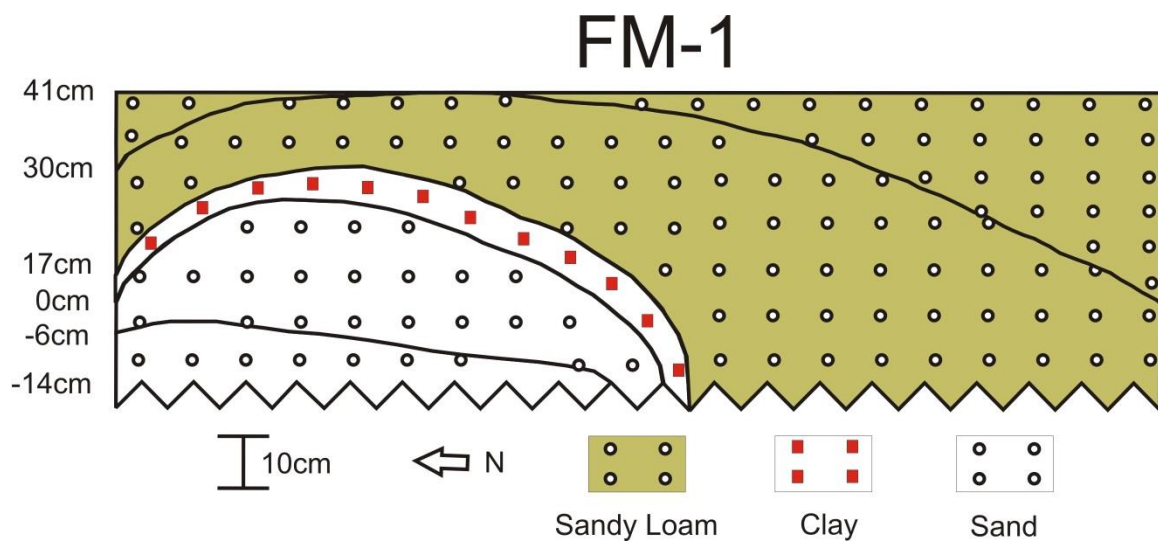


Figure 6.9. FM-1, horizons by texture.

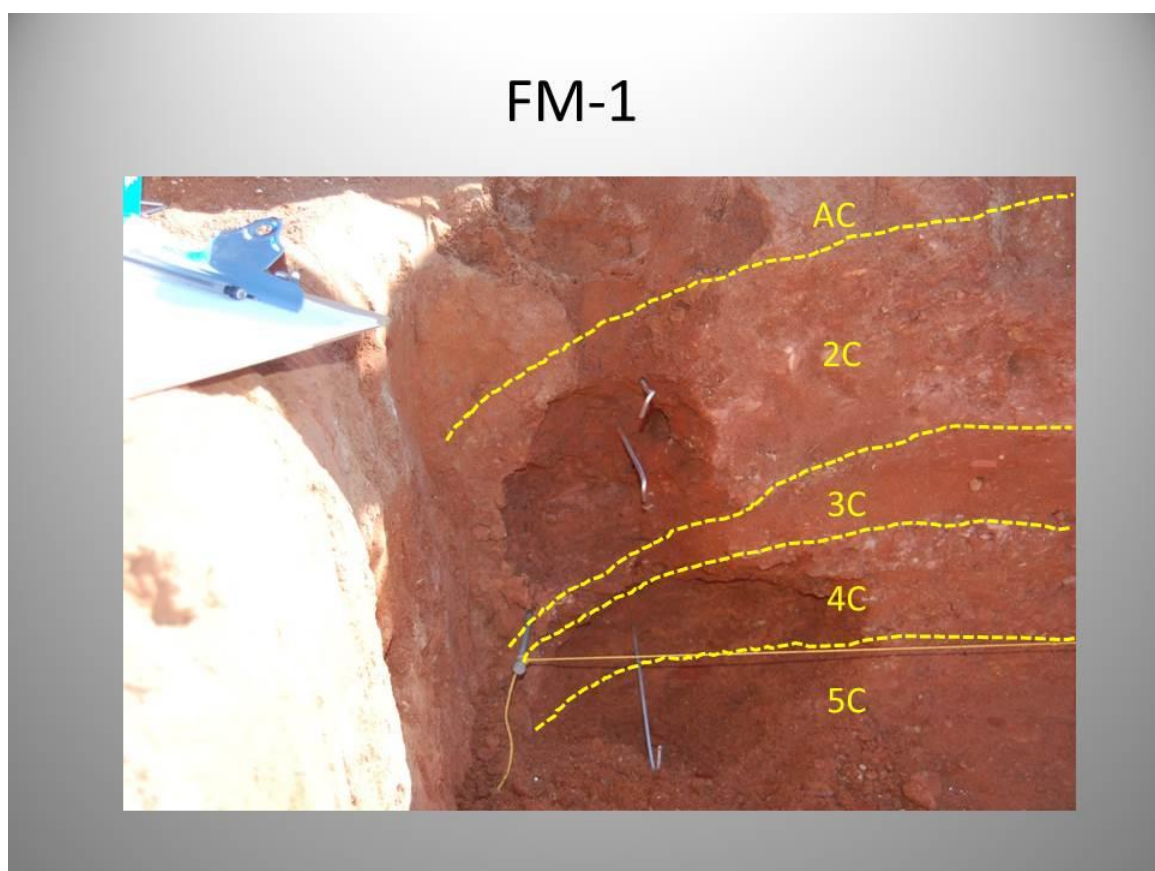


Figure 6.10. FM-1, soil horizons.

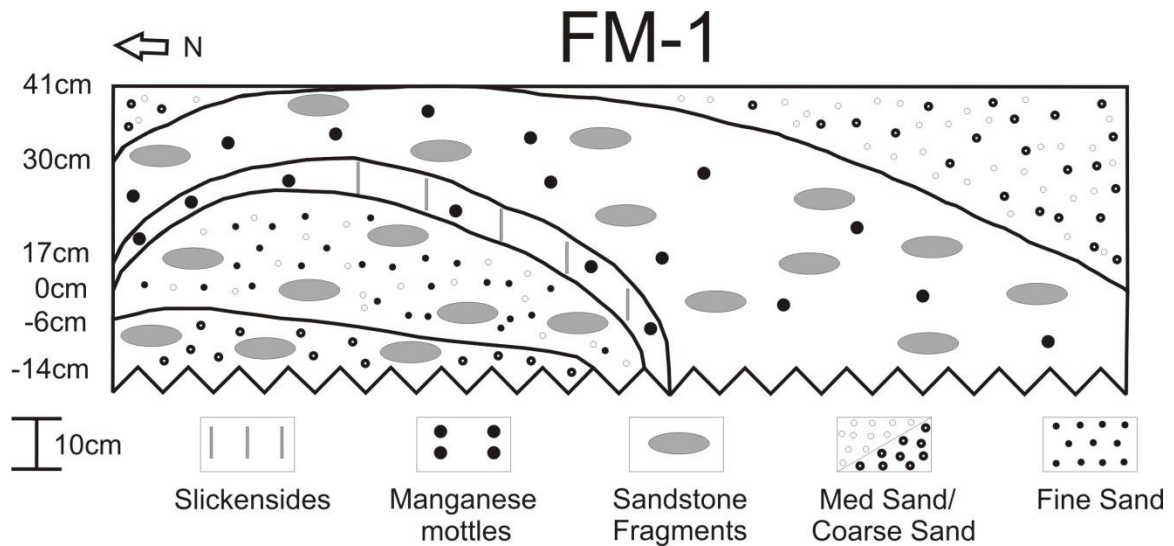


Figure 6.11. FM-1, pedogenic properties.

Profile FM-2 consists of six horizons developed in sediments of six depositional events. The uppermost AC horizon consists of sandy loam with some clay (Appendix E, table 2). The horizon has a medium angular blocky structure. There is a diffused boundary between the AC and the 2C horizon beneath it. The 2C horizon is composed of a medium sub angular blocky loam. The horizon contains some pebbles, calcium carbonates, manganese, and some sandstone. There are also some pores. There is a clear boundary between the 2C and the 3C horizons. The 3C horizon consists of fine angular blocky sand with horizontal laminations, and manganese mottles. There is a clear boundary between the 3C and 4C horizons. The 4C horizon is comprised of fine angular blocky loamy sand, with some lamination, some manganese, few pores, some worm holes, some small pebbles, some sandstone fragments, and some calcium carbonates. There is a diffused boundary between the 4C horizon and the 5C beneath it. The 5C horizon consist of a medium angular blocky sandy loam; with pores, root filaments, some manganese, and some sandstone. There is a diffused boundary between the 5C horizon and the 6C horizon, which was the lowest horizon analyzed. The 6C horizon consists of fine angular blocky loam; few



pores, some manganese, some sandstone fragments, and calcium carbonate (Figure 6.12, 6.13, and 6.14).

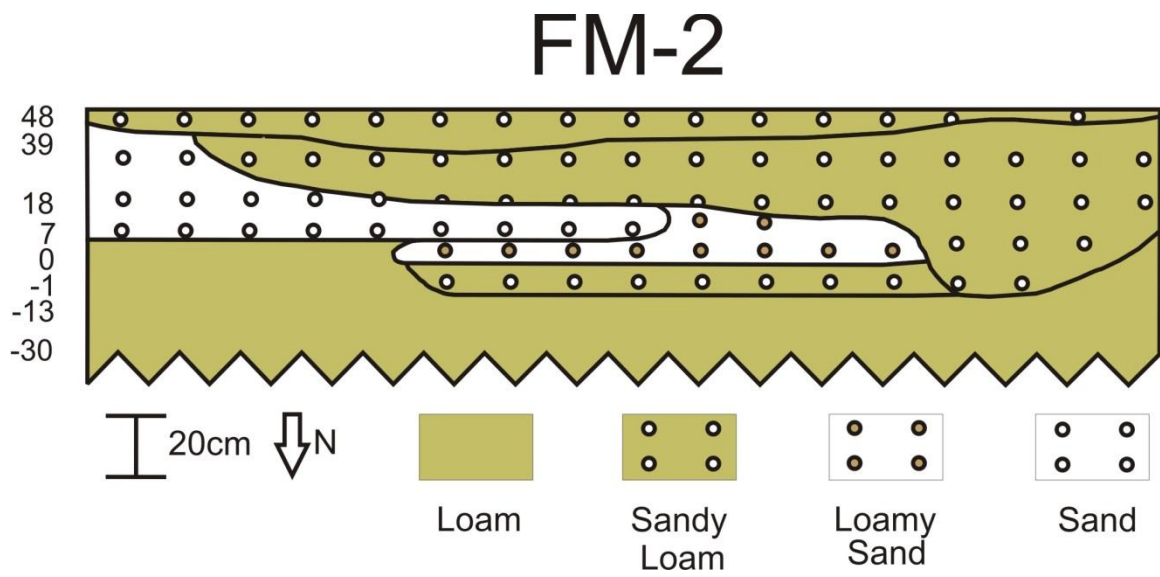


Figure 6.12. FM-2, horizons by texture.

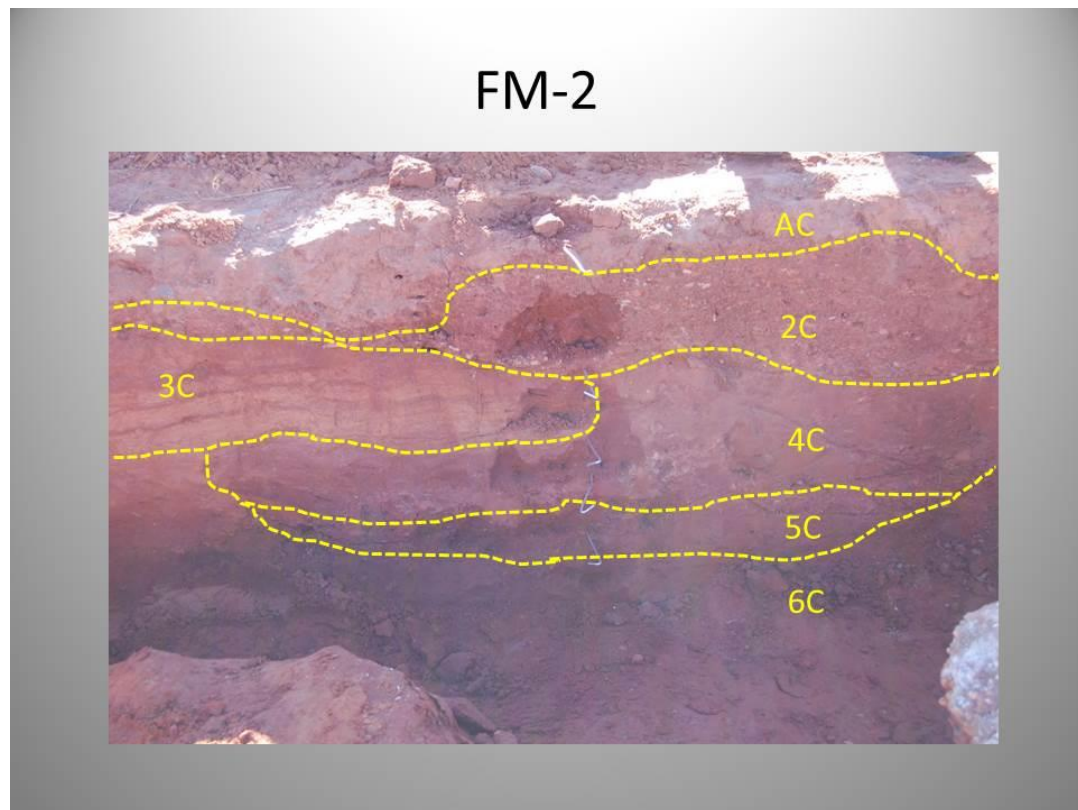


Figure 6.13. FM-2, soil horizons.

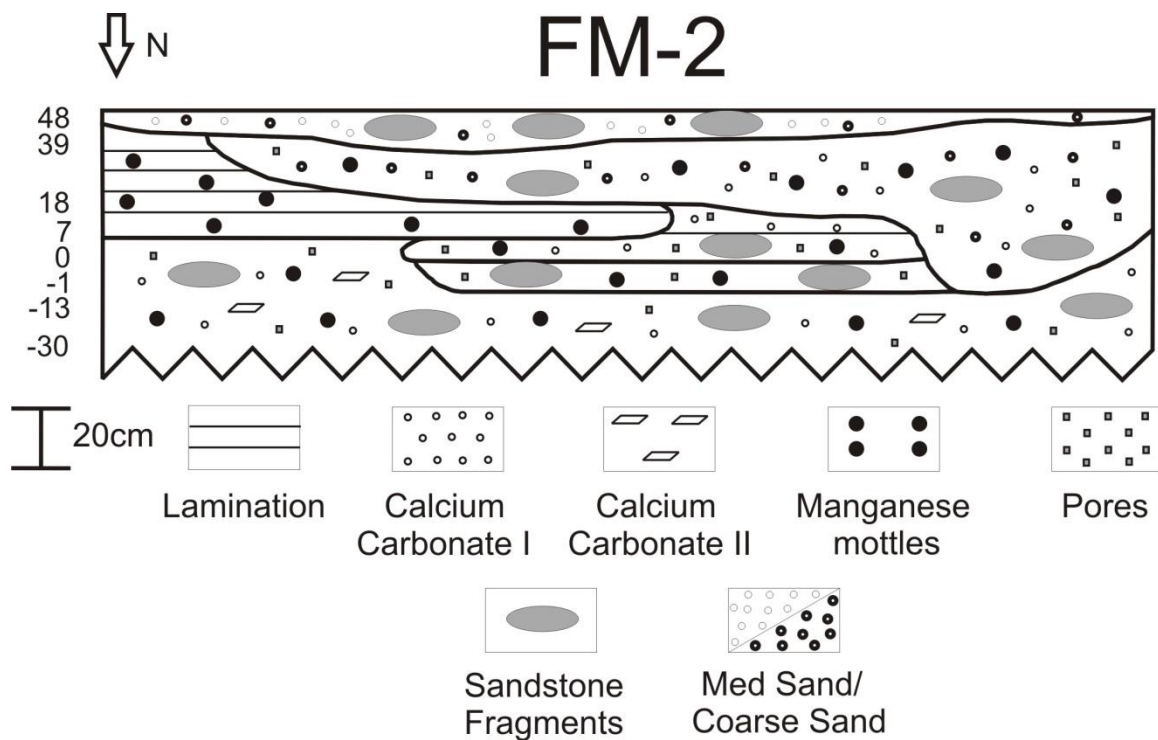


Figure 6.14. FM-2, pedogenic properties.

#### *Discussion*

The Foss Mammoth site is situated within the flood basin of Foss Reservoir. However, this may have been a lower terrace before the reservoir was built. The soils were largely composed of some consistency of sand and loam. Based on the presence of manganese this site is associated with an alluvial environment such as a paleo-channel. While FM-1 contained a horizon consisting of Clay, it is depositional in nature. According to Birkeland (1999), the soils of the Foss Mammoth site are classified as very weakly or weakly developed based on the lack of clay. While there are both stage I and II calcium carbonates, the stage II calcium carbonates are only present in the lower horizon (6C) of FM-2, which could be the remnant of a terrace. The horizons have a hue of 2.5YR based on the Munsell soil color book, which is redder like those of the more developed soils of the Grandfield Mammoth site and terrace 3 of the Helena Mammoth site. However, the color is likely due to the large amounts of sandstone from the adjacent terraces that is present throughout the profiles.

## CHAPTER VII

### FINAL ANALYSIS AND CONCLUSIONS

#### *The Sites*

The original plan for this research was to evaluate known mammoth sites (Domebo, Cooperton, and Grandfield) with regard to other known sites in Southwest Oklahoma. However, as the objectives and goals of this thesis were formulated new mammoth findings became available. Fortunately, these sites were spaced uniquely across western Oklahoma; Helena in the North part of the state, Foss in the center, and Grandfield in the south. This was a unique chance to study new sites in a broader area and in different landscapes within the context of western Oklahoma. This became beneficial when it came to assessing the geomorphology, stratigraphy, and soils, which is what the objectives of this research stated.

#### *Terraces and Soil Development*

The first and second objectives of this research aimed at establishing the relationship between mammoth findings and fluvial terrace relative ages. This refers to the hypothesis put forward by Wyckoff (1992), who stated that older sites were associated with higher terraces, and that younger sites would be associated with lower terraces, and that those in the latter were more likely to have a human connection. However, all of the three studied sites were associated with

the lowest terraces. This could be due to natural processes such as erosional rates of the surrounding bedrock, differences in depositional rates of the stream systems such as capture and stream abandonment, or to human induced change such as damming and direct modification of their natural courses. Oklahoma is home to some of North America's largest meandering rivers; the Arkansas, Cimarron, Canadian, North Canadian, Washita, and Red; all of which are tributaries of the Mississippi River. These rivers have had a major influence on sculpting Oklahoma's landscape, though erosional and depositional forces have modified their morphology and course.

In the case of the Helena mammoth site, the flood plain seems to have built up very close to Terrace 1 (the one with the mammoth finding). However, given the possibility that this is a younger find, definitely younger than 50 ka, this is truly the youngest terrace bearing a relatively young finding. This relatively young age is suggested also by soil development above the OSL date. The lack of a Bt horizon and the poor development of secondary carbonates are indication of a young age.

In the case of the Grandfield site, it is possible that today the finding is on the lowest terrace, because of the rapid and massive accumulation of sediments on the modern floodplain of Deep Red River Creek. Consequently, many more terraces may lie buried below the present floodplain. The soil profiles associated with this site show that the soil is well developed, with a thick Bt horizon suggestive of an old age, probably much older than 50 ka.

Terraces are also modified by human intervention for various reasons. The most notable example is the control of waterways, to reduce flooding while creating reservoirs for human use. This specifically applies to the Foss Mammoth site, Foss Reservoir is human made. This site would not have been uncovered if it had not been for the fact that the water level of the reservoir was low due to several years of drought. Because of the reservoir we cannot get a full picture of what the landscape looks like. Therefore, Foss Mammoth site is considered to be located within the flood basin. As in the case of the Grandfield site, lower terraces lie beneath the recent



alluvium. The second major modification comes in the form of terrace building for agricultural use. Terracing allows farmers to control erosion while providing more usable land. Therefore, placing mammoth finds in any type of context based on the association of terraces is in some instances difficult at best.

#### *Cross-Reference of Study Sites for Comparison*

The third objective of the research was to compare the studied sites in relation to other sites in the region. This is, however, a complex task that will require more geoarchaeological information including dates. At this point, however, the sites can be compared only in general terms.

The Domebo Mammoth site, found in 1961, is one of Oklahoma's oldest, and most recognized sites due to its association with Clovis hunting. The site is located in Caddo County in west-central Oklahoma. The geologic features are similar to those associated with the Foss Mammoth site. Unfortunately due to Bureau of Indian Affairs laws, there was only a precursory soil analysis before the site was shut down. The find was located in the bank next to the Domebo branch of the Washita River in alluvial deposits. The bones and artifacts were located in a layer of fine bluish-grey silt. The Domebo site is similar to Foss in that the channel has moved back and forth in major eroding and depositional events. The site itself is under approximately 12.19 meters of alluvium. This alluvium is composed mainly of sand and silt, with some clay. No pedogenic properties were recorded, and color was described subjectively rather than by using the Munsell soil color book. The site and artifacts were radiocarbon dated between 9940 to 12,260 years B.P. (Albritton, 1966).

The Burnham site, discovered in 1986, is located in Woods County in northwestern Oklahoma. This find was originally believed to be a paleontological site only. However, upon further examination, the presence of artifacts brought it to the status of archaeological site. While this

site has been mainly studied for its association to bison, bones from mammoth, horse, and other animals were also found. The funding for this excavation was primarily for geologic dating; therefore, several areas underwent a thorough soil analysis (Wyckoff and Rubenstein, 2003). However, for this research only the Burnham east exposure where the mammoth bones were located is of relevance. The site is composed of alluvial and lacustrine sediments. Stratified sands and gravels lie on the bed rock. Then three alluvial and five lacustrine deposits lie on top. The stratigraphic sequence has six different soil horizons: Ap, Btk, Bgh, BC1b2, BC2b2, and C1b2. The bones of the mammoth were found in lacustrine deposits at the bottom of the profile, between horizons BC1b2 and BC2b2. BC1b2 is composed of loam to fine sandy loam, and BC2b2 is composed of loam. Because of the constant erosion and deposition the soils are not well developed (Carter, 2003). Radiocarbon dating puts the site at between 20,000 to 34,000 years B.P (Wyckoff et al., 2003).

The Hajny Mammoth site is located in Dewey County in west-central Oklahoma. The geology of the area is similar to that of both Domebo and Foss, in that the bedrock is associated with the Cloud Chief Formation, Rush Springs sandstone, and the Marlow Formation of the Whitehorse Group. The site lies on a slope between Terraces one and two. There are a total of ten terraces cut by the South Canadian River which lies below. The site shows evidence of two major depositional events colluvium overlying alluvium. A total of five profiles were analyzed. For this research only the first and fifth profiles are relevant since the deposits run parallel to the slope. Profile one consists of twenty horizons: A1, very fine sandy loam; A2, very fine sandy loam; Bt, loam; Btk, loam; Bk, loam; BCK, loamy sand; 2CBk, sand; 2C1, gravelly sand; 2C2, sand; 2C3, coarse sand; 2C4, gravelly sandy loam; 2C5, gravelly sand; 2C6, very gravelly sand; 2C7, gravelly sand (with bones); 2C8, silt; 2C9, sandy clay loam; 2C10, loamy sand; 2C11, sand; 2C12, gravel; 3R, Permian sandstone. Profile five consist of eight horizons: A1, very fine sandy loam; A2, very fine sandy loam; AB, very fine sandy loam; Bk1, loam; Bk2, loam; 2CBk, gravelly loamy sand; 2C1, gravelly sand; and 2C2, sand. The top six horizons have undergone

pedogenesis and have structure ranging from mildly prismatic to coarse sub-angular blocky structure. The teeth of the two mammoths from this site were tested using the uranium-thorium series method for absolute dates. The west mammoth had a date of 143,000 years old, while the east mammoth had an approximate date of 166,000 years old (Wyckoff et al., 1992).

#### *Issues with Absolute Dating*

As already mentioned, the Foss site is hard to put into any kind of context due to anthropogenic influence in the form of a dam to create a reservoir. The only way to get a complete picture of the site would be if the reservoir was drained. While the bones were radiocarbon dated, its age was inconclusive due to contamination of the bones from being submerged in the lake for so long. An OSL sample was taken, but funds have not yet come available.

The Grandfield mammoth was radiocarbon dated; however, the test came back inconclusive. This was either due to contamination or due to the fact that the age of the mammoth is most likely beyond the reach of radiocarbon dating (ca. 50 ka). By comparing the soil profile of the Grandfield mammoth to that of the sites above, one can surmise that the Grandfield Mammoth is similar to that of the Hajny Mammoth, in that they both had well developed soils. That would place the Grandfield mammoth perhaps close to 144,000 years B.P.

Soils from the Helena Mammoth site were dated at 51,000 years B.P. using optically stimulated luminescence (Appendix C). However the soil that was tested came from below the bone bed. The profiles at the Helena site have not undergone the amount of pedogenesis as the Hajny, or Grandfield site, but are more consistent with those of the Burnham site. Therefore, the Helena Mammoth would fall in an age bracket between 20,000 and 51,000 years B.P. The dating of this site becomes exceedingly more important in the context of when man first came to North America.

## *Conclusions*

This thesis has analyzed three Mammoth localities in western Oklahoma; Helena, Grandfield, and Foss. Each site was analyzed on a geological, geomorphological, hydrological, soil pedogenesis, and archaeological basis. The traits of these sites were then compared to other known sites in Oklahoma (Domebo, Burnham, and Hajny) looking for similarities and differences. Because absolute dates are not yet available at the studied sites, a comparative soil development analysis is at the moment the only indication of a relative date.

With the debate over Clovis and pre-Clovis, and when man first came to North America brewing, no site should simply be dismissed as being too old and therefore unimportant. While there is no direct link to pre-Clovis in the form of tools at the Helena Mammoth site it has yielded enough information to suggest that it may prove more important than previously thought. However, more research is needed. In closing “archaeologists should not walk away from deposits that look older than Clovis” (Wyckoff et al., 2003).

The majority of funding for research is applied to archaeological sites, and in some instances paleontological sites that are considered significant. However, some funding is available through private institutions. Therefore, many sites go unanalyzed and only undergo a summary analysis, causing data which is valuable to our understanding of mammoths, the Late Pleistocene, and impact of human involvement to be lost or ignored. However, soil analysis can be used to cross reference study sites with sites that had been previously analyzed and then verified through absolute dating methods.

The research presented in this thesis is only the beginning of a much larger project, probably a PhD dissertation project, which will focus on several sites in more detail. The use of geoarchaeological methods, dating techniques, and GIS will help better understand the complex situation of Pleistocene megafaunal sites in the southern Great Plains, particularly those sites in association with the first inhabitants of the continent.

## REFERENCES

- Adovasio, J., and J. Page. 2002. *The First Americans: In Pursuit of Archaeology's Greatest Mystery*. New York: Random House LLC.
- Agenbroad, L. 1994a. Geology, hydrology, and excavation of the site. In *The Hot Springs mammoth: A decade of field and laboratory research in paleontology, geology and paleoecology*, ed. L. Agenbroad and L. Mead, 28-67 Rapid City: Fenske Printing Inc.
- Agenbroad, L. 1994b. Taxonomy of North American *Mammuthus* and biometrics of the Hot Springs mammoths. In *The Hot Springs mammoth: A decade of field and laboratory research in paleontology, geology and paleoecology*, ed. L. Agenbroad and L. Mead, 158-207 Rapid City: Fenske Printing Inc.
- Albritton, C. 1966. Stratigraphy of the Domebo site. In *Domebo: A Paleo-Indian Mammoth Kill in the Prairie – Plains*, ed. F. Leonhardy, 11-13 Lawton: Great Plains Historical
- Anderson, A., 1975. The Cooperton Mammoth an early man bone quarry. *Great Plains Journal* 14: 131-73.
- Baker, D. 2010-11. Another Mammoth Legacy in Southwest Oklahoma. *Great Plains Journal* 46: 44-61.
- Baker, D. 2013. Site excel spread sheet. Institute of the Great Plains.
- Barnosky, A., P. Koch, R. Feranec, S. Wing, and A. Shabel. 2004. Assessing the causes of Late Pleistocene extinctions on the continents. *Science* 306: 70-75.
- Barnosky, A., B. Kraatz. 2007. The role of climate change in the evolution of mammals. *Bioscience* 57: 523-32.
- Birkeland, P. 1999. Soils and geomorphology third edition. New York: Oxford University Press.
- Bongino, J. 2007. *Late Quaternary history of the Waco mammoth site: Environmental reconstruction and interpreting the cause of death*. Master's thesis, Department of Geology, Baylor University, Waco.

- Carlson, K. T. Cox, and L. Bement. 2014. Foss Mammoth skull excavation Custer County, Oklahoma. In *Archaeological Resource Technical Report No. 3*. Norman: The University of Oklahoma, Oklahoma Archaeological Survey
- Carter, B. 2003. The environment of deposition, authigenic features, and the age of the Burnham site: A post-1991 perspective. In *The Burnham Site in Northwestern Oklahoma*, ed. D. Wyckoff, J. Theler, and B. Carter 93-127 Norman: Sam Noble Oklahoma Museum of Natural History.
- Cordova, C., W. Johnson, R. Mandel, and M. Palmer. 2011. Opal phytoliths, carbon stable isotopes, and other microfossils from soils and paleosols of the south-central Great Plains. *USA. Catena* 85: 87-108.
- Dalquest, W., and G. Schultz. 1992. *Ice age mammals of Northwestern Texas*. Wichita Falls: Midwestern State University Press.
- Faith, J., and T. Surovell. 2007. Synchronous extinction of North America's Pleistocene mammals. *Proceedings of the National Academy of Sciences* 106 (49): 20641-45.
- Fiedel, S. 2005. Man's best friend mammoths worst enemy? A speculative essay on the role of dogs in Paleoindian colonization and megafaunal extinction. *World Archaeology* 37 (1): 11-25.
- Firestone, R., A. West, J. Kennett, L. Becker, T. Bunch, Z. Revay, P. Schultz, T. Belgia, D. Kennett, J. Erlandson, O. Dickenson, A. Goodyear, R. Harris, G. Howard, J. Kloosterman, P. Lechler, P. Mayewski, J. Montgomery, R. Poreda, T. darrah, S. Hee, A. Smith, A. Stich, W. Topping, J. Wittke, and W. Wolbach. 2007. Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling. *Proceedings of the National Academy of Sciences of the United States of America* 104 (41): 16016-21.
- Fox, J., C. Smith, and D. Lints. 1992. Herd bunching a the Waco mammoth site: Preliminary investigations, 1978-1987. In *Proboscidean and paleoindian interactions*, ed. J. Fox, C. Smith, and K. Wilkins, 51-73. Waco: Markham Press Fund
- Goble, R. 2014. OSL analysis and sample preparation. *Department of Geosciences, University of Nebraska Lincoln*.
- Goebel, T., M. Waters, and D. O'Rourke. 2008. The Late Pleistocene dispersal of modern humans in the Americas. *Science* 319: 1497-1502.
- Goldberg, P. and R. Macphail. 2006. *Practical and theoretical geoarchaeology*. Malden: Blackwell Publishing.
- Grayson D., and D. Meltzer. 2002. Clovis hunting and large mammal extinctions: A critical review of the evidence. *Journal of World Prehistory* 69(4): 313-59.
- Haynes, C. 1966. Elephant hunting in North America. *Scientific America* 214: 104-12.

- Haynes, C., and J. Warnica. 2012. Geology, archaeology and climate change in Blackwater Draw, New Mexico: F. Earl Green and the geoarchaeology of the Clovis site. In *Eastern New Mexico University Contributions in Anthropology Vol. 15*, ed J. Kilby, Portales: Eastern New Mexico University.
- Haynes, G. 2002. The catastrophic extinction of North American mammoths and mastodonts. *World Archaeology* 33 (3): 391-416.
- Haynes, G. 2009. Introduction to the volume. In *American Megafaunal Extinctions at the End of the Pleistocene*, ed. G. Haynes, 1-20 Netherlands: Springer.
- Holen, S., and K. Holen. 2012. Evidence for a human occupation of the North American Great Plains during the Last Glacial Maximum. In *IV Simposio Internacianal: El Hombre Temprano En America*, ed. J. Lopez, C. Sanchez, A. Gonzalez, and F. Arellano, 85-105 Mexico City: Instituto Nacional de Anthropolgia and Historia.
- Holen, S., and K. Holen. 2013. The mammoth steppe hypothesis: the Middle Wisconsin (Oxygen Isotope Stage 3) peopling of North America. In *Paleoamerican Odyssey*, ed. G. Ketron and M. Waters, 429-44 Ft. Collins: Center for the Study of the First Americans.
- Holiday, V. 1987. Cultural chronology. In *Lubbock Lake*, ed. E. Johnson, 22-25. College Station: Texas A&M University Press.
- Holiday, V., and B. Allen. 1987. Geology and soils. In *Lubbock Lake*, ed. E. Johnson, 14-21. College Station: Texas A&M University Press.
- Huntley, D., and M. Lamothe. 2001. Ubiquity of anomalous fading in K-feldspars and the measurement and correction for in optical dating. *Can. J. Earth Sci.* 38: 1093-1106.
- Johnson, E., and V. Holiday. 1987a. Introduction. In *Lubbock Lake*, ed. E. Johnson, 3-13. College Station: Texas A&M University Press.
- Johnson, E., and V. Holiday. 1987b. Summary. In *Lubbock Lake*, ed. E. Johnson, 159-62. College Station: Texas A&M University Press.
- Koch, P., and A. Barnosky. 2006. Late Quaternary extinctions: state of the debate. *Annual Review of ecology, Evolution, and Systematics* 37: 215-50.
- Laury, R. 1994. The paleoenvironment of the Hot Springs mammoth site. In *The Hot Springs mammoth: A decade of field and laboratory research in paleontology, geology and paleoecology*, ed. L. Agenbroad and L. Mead, 28-67 Rapid City: Fenske Printing Inc.

- Mandel, R. 2000. Introduction. In *Geoarchaeology in the Great Plains*, ed. R. Mandel, 4 Norman: University of Oklahoma Press.
- Martin S. 1973. The discovery of America. *Science* 179 (4077): 969-74.
- McAndrews, J., and L. Jackson. 1988. Age and environment of Late Pleistocene mastodont and mammoth in southern Ontario. In *The Buffalo Society of Natural Sciences volume 33*, ed. R. Laub, N. Miller, and D. Steadman, 161-71. Toronto: University of Toronto.
- Meltzer, D. 2009. *First Peoples in a New World: Colonizing Ice Age America*. Berkeley: University of California Press.
- Meltzer, D., and J. Mead. 1983. The timing of Late Pleistocene mammalian extinctions in North America. *Quaternary Research* 19: 130-35.
- Munsell. 2012. *Soil Color book*. Grand Rapids: Munsell Color.
- Northcutt, J. 2007. Prehistoric discoveries in the Wichita Mountains. *Great Plains Journal* 43: 3-45.
- OGS. 2014. Geologic map of Oklahoma. Oklahoma Geological Survey.  
[http://www.ogs.ou.edu/geolmapping/Geo\\_mapOk19](http://www.ogs.ou.edu/geolmapping/Geo_mapOk19). (accessed 7 March 2014).
- Retallick, H. 1966. Geomorphology of the Domebo site. In *Domebo: A Paleo-Indian mammoth kill in the prairie – plains*, ed. F. Leonhardy, 3-10 Lawton: Great Plains Historical Association.
- Smith, K., and R. Cifelli. 2000. *A synopsis of the Pleistocene vertebrates of Oklahoma* Norman: University of Oklahoma.
- USDA. 2013. Guide to texture by feel. *Web Soil Survey*. Washington: U.S. Department of Agriculture, Natural Resource Conservation Service.  
<http://websoilsurvey.nrcs.usda.gov> (accessed 12 November 2013).
- USDA. 2014. Web soil survey. *Web Soil Survey*. Washington: U.S. Department of Agriculture, Natural Resource Conservation Service.  
<http://websoilsurvey.nrcs.usda.gov> (accessed 25 May 2014).
- USGS. 2014. Map locator and downloader. United States Geologic Survey Store.  
[http://store.usgs.gov/b2c\\_usgs/usgs/maplocator/](http://store.usgs.gov/b2c_usgs/usgs/maplocator/) (accessed 3 April 2014).
- Wallinga, J. 2002. Optically stimulated luminescence dating of fluvial deposits: a review. *BOREAS* 31: 303-22.
- Ward, P., and B. Carter. 1999. Rates of stream incision in the middle part of the Arkansas River basin based on late Tertiary to mid-Pleistocene volcanic ash. *Geomorphology* 27: 205-28.



- Waters, M., and T. Stafford. 2007. Redefining the age of Clovis: implications for the peopling of the Americas. *Science* 315: 1122-26.
- Wintle, A., and A. Murray. 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Science Direct* 41: 369-91.
- Whitley, D., R. Dorn. 1993. New perspectives on the Clovis vs. Pre-Clovis controversy. *Society for American Archaeology* 58: 626-47.
- Wyckoff, D., B. Carter, P. Flynn, L. Martin, B. Branson, and J. Theler. 1992. *Interdisciplinary studies of the Hajny mammoth site, Dewey County, Oklahoma*. Norman: Oklahoma Archeological Survey.
- Wyckoff, D., B. Carter, and J. Theler. 2003. Looking back on an odyssey: Summarizing the findings at the Burnham site. In *The Burnham Site in Northwestern Oklahoma*, ed. D. Wyckoff, J. Theler, and B. Carter 263-304 Norman: Sam Noble Oklahoma Museum of Natural History.
- Wyckoff, D., and P. Rubenstein. 2003. History of the Burnham site research. In *The Burnham Site in Northwestern Oklahoma*, ed. D. Wyckoff, J. Theler, and B. Carter 13-42 Norman: Sam Noble Oklahoma Museum of Natural History.

## APPENDIX A

### OKLAHOMA MAMMOTH SITE DATA BASE

## DATA BASE MAIN

database - Microsoft Excel													
V1 DEP_ENV													
1	ID#	DATE ENTERED	SOURCE	SOURCE_ID	SITE_ID	SITE_NAME	DATE_FOUND	LATITUDE	LONGITUDE	COUNTY	STATE	NEAR_INT	PRIV/STATE/OTHER
2	MM0001	2/9/2014	OAS/OSU	P34AL1		HELENA MAMMOTH	JUL-2013			ALFALFA	OK		PRIVATE
3	MM0002	2/9/2014	OAS			FOSS MAMMOTH	OCT-2013			CUSTER	OK		BOR
4	MM0003	2/9/2014	MGP			GRANDFIELD MAMMOTH				TILLMAN	OK		PRIVATE/PUBLIC
5	MM0004	2/9/2014	OAS	34K126		COOPERTON MAMMOTH	JUL-1964			KIOWA	OK		PRIVATE
6	MM0005	2/9/2014	OAS			APACHE MAMMOTH	JAN-1984			CADDO	OK		PUBLIC
7	MM0006	2/9/2014	MGP	66.147.1		HUFFERR	JUL-1966			COMMANCHE	OK		PRIVATE
8	MM0007	2/9/2014	MGP	3/6/1900			APR-1966			COMMANCHE	OK		
9	MM0008	2/9/2014	OAS	CD-50		DOMERO MAMMOTH	JAN-1962			CADDO	OK		BIA
10	MM0009	2/10/2014	MGP	85.9.1			FEB-1984			CADDO	OK		PRIVATE
11	MM0010	2/10/2014	MGP	80.1			JAN-1980			KIOWA	OK		PRIVATE
12	MM0011	2/10/2014	MGP	82.59.4		CHICKASHA MAMMOTH	DEC-1982			GRADY	OK		PRIVATE
13	MM0012	2/10/2014	MGP	89.20.1			APR-1989			COTTON	OK		PRIVATE
14	MM0013	2/10/2014	MGP	68.42			FEB-1984			COMANCHE	OK		PRIVATE
15	MM0014	2/10/2014	MGP	63.72		STEPHENS MAMMOTH	JAN-1961			COMANCHE	OK		PRIVATE
16	MM0015	2/10/2014	MGP	63.45			MAR-1963			COMANCHE	OK		PUBLIC
17	MM0016	2/10/2014	MGP	63.46			JAN-1984			COMANCHE	OK		PUBLIC
18	MM0017	2/10/2014	MGP	84.1.1			JAN-1984			CADDO	OK		PRIVATE
19	MM0018	2/10/2014	OAS	34CT97			SEP-1992			COTTON	OK		PRIVATE
20	MM0019	2/10/2014	OAS	34CM364			JUL-1985			COMMANCHE	OK		PRIVATE
21	MM0020	2/16/2014	NORTHCUTT			ERICK	?			BECKHAM	OK		PRIVATE
22	MM0021	2/16/2014	NORTHCUTT			JESTER	1974?			GREER	OK		PRIVATE
23	MM0022	2/16/2014	NORTHCUTT			SHUMATE	AUG-1964			GREER	OK		PRIVATE
24	MM0023	2/16/2014	NORTHCUTT			MANGUM	JUN-1981			GREER	OK		PRIVATE
25	MM0024	2/16/2014	NORTHCUTT			HOLLIS	1923?			HARMON	OK		PRIVATE

Appendices A, table 1.

**DATABASE KEY (MAIN):**

- ID# - Sequential number given to known site.
- DATE – Date data was entered.
- SOURCE – Source of data or information.
- SOURCE\_ID – Identification number given to site by individual agencies if different than Oklahoma Archaeological Survey
- SITE\_ID – Site identification number assigned by Oklahoma Archaeological Survey or other government agency.
- SITE\_NAME – Site name.
- DATE\_FOUND – Date site was originally found.
- LATITUDE – Latitude of site.
- LONGITUDE – Longitude of site.
- COUNTY – County in which site is located.
- STATE – State in which site is located.
- NEAR\_INT – Nearest intersection.
- PRIVATE/STATE/OTHER – Ownership
- SPECIES\_TYPE – Species (mammoth/mastodon/Etc.).
- TIME\_GEOL – Geologic time in which fauna lived.
- NUM\_ASSEM – Number of mammals at site.
- BONES – Bones found at site.
- PHOTO\_BONES – Where photos taken of bones.
- DATE\_TYPE – Type of dating method used.
- ABSOLUTE\_DATE – Absolute date uncorrected.
- M&M\_VALUE – Meltzer and Mead validity score if assigned.
- DEP\_ENV – Depositional environment (fluvial, colluvium, aeolian).
- SOIL\_SURVEY – Soil survey identification.
- SOIL\_ANALYSIS – YES/NO
- CULTURE – Clovis/Pre-Clovis/Other/None.
- ARTIFACTS – YES/NO.
- PHOTOS\_ARTIFACTS – Where photos taken of artifacts.
- COMMENTS – Any additional identification or information of site or artifacts.

## DATA BASE SITE

Apache Mammoth 90.002 - Microsoft Excel

MGP Arch. Collection Data Sheet for Apache Mammoth 90.002									
Accession Number	Catalog Number	Current Location	Discipline	State Site Number	Site Name	Field Site Number	UTM Coordinates	Township/Range/Section	USGS Topo
3 90.002	90.002.001	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
4 90.002	90.002.002	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
5 90.002	90.002.003	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
6 90.002	90.002.004	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
7 90.002	90.002.005	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
8 90.002	90.002.006	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
9 90.002	90.002.007	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
10 90.002	90.002.008	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
11 90.002	90.002.009	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK
12 90.002	90.002.010	Arch; R10, Box 2, Bag 1	Archaeological		Apache Mammoth			SE¼, NW¼, NW¼, Sec.21, T.5N, R.11W	Apache, OK

Appendices A, table 2. Source: Baker, 2013

## **DATABASE KEY (SITE):**

- Accession Number – Is a unique sequential number or number letter combination assigned to the object or group of objects within a single transaction. The number is used in both the accession record and catalog record and is used as a cross reference key in information searches. Typically, accession numbers are composed of the year the accession (object) was received and sequential number denoting the order in which the accessions were received in that year. For example, 2007.1 indicates the first object or group of objects received in 2007.
- Catalog Number – Is the sequential number of an object based on the accession number within the accession. It is a unique number assigned to a particular object or artifact. For example, 2007.1.25 indicates it is the 25<sup>th</sup> object within that particular collection. Recording the catalog numbers of the accessioned material in the accession system provides an important cross reference between the accession and catalog record.
- Current Location – This indicates the location in which the object is going to be stored. For example, RA-CA-S5-B3-Bag4, Row A, Cabinet A if applicable, Shelf 5, Box3, Bag 4.
- Discipline – Type of find Archaeological/Paleontological.
- State Site Number – Control number given by state agency.
- Site Name – Name of site.
- Field Site Number – Preliminary number given to site upon discovery (this may change during the excavation of the site, especially if it is later deemed archaeological).
- UTM Coordinates – Location coordinates.
- Township/Range/Section – Location identification.
- USGS top – Name of Topographic map associated with site.
- County – County in which site is located.
- State – State in which site is located.
- Country – Country in which site is located.
- Provenience – Record the location where an object was found originally collected as documented by the original collector.
- Within Site Provenience – Additional location information on specimen.
- Item Count Individual – Number of specimens associated with location.
- Item Count Lot – Number of items associated with specific item (number of pieces).
- Item Count Bulk – Number of overall items.
- Archaeological Type – Age association.
- Material Type – Mineral/Vegetable/Animal/Human Remains/Unidentifiable.
- Specific Material Type – Bone/Plant/Stone.
- Object Name. – Type of object.
- Description – Description of animals.
- Condition –
  - Complete-Excellent: 100% of the object is present and there is no sign of damage.

- Complete-Good: 100% of the object is present but minor damage is visible and or active deterioration is present.
- Complete-Fair: 100% of the object is present but some damage is visible and or active deterioration is present.
- Complete-Poor: 100% of the object is present but significant damage is visible and or active deterioration is present.
- Incomplete-Excellent: More than 50%, but less than 100% of the object is present and there is no sign of damage or deterioration.
- Incomplete-Good: More than 50%, but less than 100% of the object is present but minor damage is visible and or active deterioration is present.
- Incomplete-Fair: More than less than 100% of the object is present but some damage is visible and or active deterioration is present.
- Incomplete-Poor: More than 50%, but less than 100% of the object is present but significant damage is visible and or active deterioration is present.
- Fragment-Excellent: Less than 50% of the object is present and there is no sign of damage or deterioration.
- Fragment-Good: Less than 50% of the object is present but minor damage is visible and or active deterioration is present.
- Fragment-Fair: Less than 50% of the object is present but some damage is visible and or active deterioration is present.
- Fragment-Poor: Less than 50% of the object is present but significant damage is visible and or active deterioration is present.
- Condition Notes – Additional comments on condition.
- Height – Height of specimen.
- Width – Width of specimen.
- Depth – Depth of specimen.
- Diameter – Diameter of specimen.
- Weight – Weight of specimen.
- Measurement Notes – Type of measurements.
- Date Cataloged – Date specimen was cataloged.
- Notes – Additional notes on specimen.

[illegible]



**DATABASE KEY (SOIL):**

- Horizon – Horizon designation (i.e. A, O, B, C, etc.).
- Depth (cm) – Depth of Horizon in centimeters (measured from specific point).
- Color (Moist) – Color according to Munsell Soil Color Book while wet.
- Color (Dry) – Color according to Munsell Soil Color Book while dry.
- Structure – Structure of soil according to Birkeland (1999).
- Texture – Texture according to the USDA (2013) Guide to texture by feel.
- Consistence – (i.e. firm/friable).
- Boundary – Between horizons (i.e. diffuse, clear, wavy).
- PH – pH of soil (i.e. base/acidic).
- Effervesce – Reaction to calcium carbonate using HCL.
- Descriptives – Additional descriptive information on soil horizon.

## APPENDIX B

### HELENA MAMMOTH SITE SOIL SHEETS

# HM-1, SOIL SHEET

Helena_Mammoth - Microsoft Excel															
Profile Sheet for: Helena Mammoth (HM-1); 10-24-2013; N24/E18															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
1	Horizon	Depth (cm)	Color (Moist)	Color (Dry)	Structure	Texture	Consistence	Bounded	PH	Effer	Descriptives				
2		169	2.5YR 4/8	2.5YR 3/3	None	Loam	very firm	Diffuse	6	Mild	Roots, Some Calcium Carbonates, moderate Pores				
3	1 Ap	150	2.5YR 4/6	2.5YR 3/3	Med Sub Ang Blocky	Loam	very firm	Clear Horizontal	6	Mild	abundant Pores, Calcium Carbonate filaments (I), few roots				
4	2 Bk	93	2.5YR 4/6	2.5YR 3/3	Coarse Blocky	Sandy Clay Loam	very firm	Clear Horizontal	6	Moderate	abundant Pores, Calcium Carbonate (from lower layer)				
5	3 2ACb	86	2.5YR 4/8	2.5YR 3/3	Sub Ang Blocky	Sandy Clay Loam	very firm	Diffuse	6	Moderate	moderate Pores, Calcium Carbonate (I/II), roots				
6	4 2Bk1	55	2.5YR 4/8	2.5YR 3/3	Sub Ang Blocky	Sandy Clay Loam	very firm	Diffuse	6	Moderate	few Pores, Calcium Carbonate (I/II), Manganese Mottles				
7	5 2Bk2	0	2.5YR 4/8	2.5YR 3/3	Sub Ang Blocky	Loam	moderately firm	Diffuse	6	Moderate	Manganese Layers and Mottles (at various locations and depths)				
8	6 2C	-22	2.5YR 4/8	2.5YR 3/3	Sub Ang Blocky	Loam	firm		6	Mild					
9	7														

Appendices B, table 1.

## HM-2, SOIL SHEET

Helena Mammoth - Microsoft Excel																							
Profile Sheet for: Helena Mammoth (HM-2); 10-24-2013; N18/E20																							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Horizon	Depth (cm)	Color (Moist)	Color (Dry)	Texture	Structure	Consistence	Boundedness	PH	Effervescence	Remarks	Notes												
1 Ap	80	5YR 4/6	5YR 3/3	None	Silt Loam	firm	Diffuse	6	None	few roots, abundant pores													
2 Bk	69	5YR 5/6	4/4	Med	Blocky	moderately firm	Diffuse	6	Mild	moderate pores, calcium carbonate, few roots													
3 2Bk	16	5YR 5/8	4/6	Coarse	Sub Ang	Silt Loam	Diffuse	6	Mild	moderate pores, root filaments (l), lamination													
4 2Cu	-22.5	5YR 4/6	3/4	None	Loam	moderately firm	Clear	Horiz	Moderate	Colluvial													
5 3Cu	-42	5YR 5/6	4/4	None	Loam	moderately firm	Clear	Horiz	Very Mild	Lamination													
6																							
7																							

Appendices B, table 1.

# HM-3, SOIL SHEET

Helena Mammoth - Microsoft Excel																						
Profile Sheet for: Helena Mammoth (HM-3); 10-24-2013																						
Horizon	Depth (cm)	Color (Moist)	Color (Dry)	Texture	Consistence	Boundedary	PH	Effer	Descriptives													
1	Bk	35	2.5YR 5YR 3/4	Sub Ang Silt Loam	moderate firm	Clear Horiz	6	Very Mild	moderate pores, few roots													
2	Cu	14	5YR 5YR 4/6	Blocky	moderate firm	Clear Horiz	6	Mild	moderate pores, few roots, Reworked Calcium Carbonate (in cracks), some lamination													
3	2Cu	-25	5YR 5YR 4/4	None	moderate firm		6	Mild	Lamination (horizontal and cross-bedding)													
4		-42	5YR 5YR 4/4	None	moderate firm		6	Mild														
5																						
6																						
7																						

Appendices B, table 1.

## APPENDIX C

### HELENA MAMMOTH OSL RESULTS

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UNL #	Field #	Burial Depth (m)	H <sub>2</sub> O (%) <sup>a</sup>	K <sub>2</sub> O (%)	U (ppm)	±	Th (ppm)	±	Cosmic (Gy)	Dose Rate (Gy/ka)
UNL3769	Mammoth	1.2	9.6	2.13	0.07	2.11	0.14	8.94	0.43	2.81±0.11 Quartz 3.47±0.13 Feldspar
D <sub>e</sub> (Gy)	No. of Aliquots	Uncorrected Age (ka)				Corrected Age (ka)				
		g <sub>2days</sub> (%/decade)								
136.3±3.1	27	>48.4±2.2					-			>48.4±2.2 Minimum Quartz Age, based on 2D <sub>o</sub>
125.6±1.5	54	36.2±1.4					4.14±0.44			51.0±4.6 50°C Feldspar, IRSL
136.2±4.0	51	39.2±1.8					3.59±0.52			52.5±5.4 225°C Feldspar, post-IR IRSL
UNL #	Skew/2σ <sub>e</sub> <sup>b</sup> Kurt/2σ <sub>k</sub> <sup>b</sup> c/c <sub>crit</sub> <sup>b</sup>			k/k <sub>crit</sub> <sup>b</sup>	Overdisp (%) <sup>c</sup>	CAMMed <sup>d</sup>	CAMPDF Fit <sup>e</sup>	CAMMode <sup>f</sup>	CAMMean <sup>g</sup>	
UNL3769	Quartz, 2D <sub>o</sub>	0.10	-0.44	0.01	-0.41	12	1.01	1.00	0.92	0.99
	50C Feldspar	0.72	-0.15	0.07	-0.10	14	1.02	1.03	1.06	0.99
	225C Feldspar	-0.58	0.50	-0.06	0.34	7	1.01	1.00	1.05	1.01
<sup>a</sup> In-situ Moisture Content										
<sup>b</sup> Bailey & Arnold (2006)										
<sup>c</sup> Galbraith (2005)										
<sup>d</sup> Central Age Mode/Median										
<sup>e</sup> Central Age Mode/Probability Density Function Fit										
<sup>f</sup> Central Age Mode/Mode										
<sup>g</sup> Central Age Mode/Unweighted Mean										
Error on De is 1 standard error										
Error on age includes random and systematic errors calculated in quadrature										
Feldspar composition/dose-rate calculated for pure KAlSi <sub>3</sub> O <sub>8</sub>										

<sup>a</sup> In-situ Moisture Content

<sup>b</sup> Bailey & Arnold (2006)

<sup>c</sup> Galbraith (2005)

<sup>d</sup> Central Age Model/Median

<sup>e</sup> Central Age Model/Probability Density Function Fit

<sup>f</sup> Central Age Model/Mode

<sup>g</sup> Central Age Model/Unweighted Mean

Error on De is 1 standard error

Error on age includes random and systematic errors calculated in quadrature

Feldspar composition/dose-rate calculated for pure KAISi<sub>3</sub>O<sub>8</sub>





References:

- Adamiec, G. & Aitken, M. (1998): Dose-rate conversion factors: update. *Ancient TL*, **16**, 37-50.
- Aitken, M. J. (1998). *Introduction to Optical Dating*. Oxford, Oxford University Press.
- Auclair, M., Lamothe, M. & Huot, S. (2003): Measurement of anomalous fading for feldspar IRSL using SAR. *Radiation Measurements* **37**, 487-492.
- Bailey, R.M. & Arnold, L.J. (2006): Statistical modeling of single grain quartz D<sub>e</sub> distributions and an assessment of procedures for estimating burial dose. *Quaternary Science Reviews*, **25**, 2475-2502.
- Ballarini, M., Wallinga, J., Wintle, A.G. & Bos, A.J.J. (2007): A modified SAR protocol for optical dating of individual grains from young quartz samples. *Radiation Measurements*, **42**, 360-369.
- Buylaert, J.P., Murray, A.S., Thomsen, K.J. and Jain, M. (2009): Testing the potential of an elevated temperature IRSL signal from K-feldspar. *Radiation Measurements* **44**, 560-565.
- Cunningham, A.C. and Wallinga, J. (2010): Selection of integration time intervals for quartz OSL decay curves. *Quaternary Geochronology*, **5**, 657-666.
- Durcan, J.A. and Duller, G.A.T. (2011): The fast ratio: A rapid measure for testing the dominance of the fast component in the initial OSL signal from quartz. *Radiation Measurements*, **46**, 1065-1072.
- Galbraith, R.F., Roberts, R.G., Laslett, G.M., Yoshida, H. and Olley, J.M. (1999): Optical dating of single and multiple grains of quartz from Jinnium Rock Shelter, Northern Australia: Part I, experimental design and statistical models. *Archaeometry* **41**, 339-364.
- Huntley, D.J. and Lamothe, M. (2001): Ubiquity of anomalous fading in K-feldspars and the measurement and correction for it in optical dating. *Can. J. Earth Sci.* **38**, 1093-1106.
- Murray, A.S. & Wintle, A.G. (2000): Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements*, **32**, 57-73.
- Murray, A.S. & Wintle, A.G. (2003): The single aliquot regenerative dose protocol: potential for improvements in reliability. *Radiation Measurements*, **37**, 377-381.
- Prescott, J.R. & Hutton, J.T. (1994): Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements*, **23**, 497-500.
- Rodnight, H. (2008): How many equivalent dose values are needed to obtain a reproducible distribution? *Ancient TL*, **26**, 3-9.
- Wintle, A.G. and Murray, A.S. (2006): A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Radiation Measurements* **41**, 369-391.

March 17, 2014

### OSL Analysis and Sample Preparation

#### Sample Preparation/Dose-Rate Determination:

Sample preparation was carried out under amber-light conditions. Samples were wet sieved to extract the 90 – 150  $\mu\text{m}$  fraction, and then treated with HCl to remove carbonates and with hydrogen peroxide to remove organics. Quartz and feldspar grains were extracted by flotation using a 2.7  $\text{gm cm}^{-3}$  sodium polytungstate solution, then treated for 75 minutes in 48% HF, followed by 30 minutes in 47% HCl. The sample was then resieved and the <90  $\mu\text{m}$  fraction discarded to remove residual feldspar grains. The etched quartz grains were mounted on the innermost 5mm of 1 cm aluminum disks using Silkospray. Feldspar grains were extracted by flotation using a 2.58  $\text{gm cm}^{-3}$  sodium polytungstate solution, then treated for 40 minutes in 10% HF to etch and remove the outer alpha-irradiated layer from the rims, followed by 30 minutes in 47% HCl.

Chemical analyses were carried out using a high-resolution gamma spectrometer. Dose-rates were calculated using the method of Aitken (1998) and Adamiec and Aitken (1998). The cosmic contribution to the dose-rate was determined using the techniques of Prescott and Hutton (1994).

#### Optical Measurements:

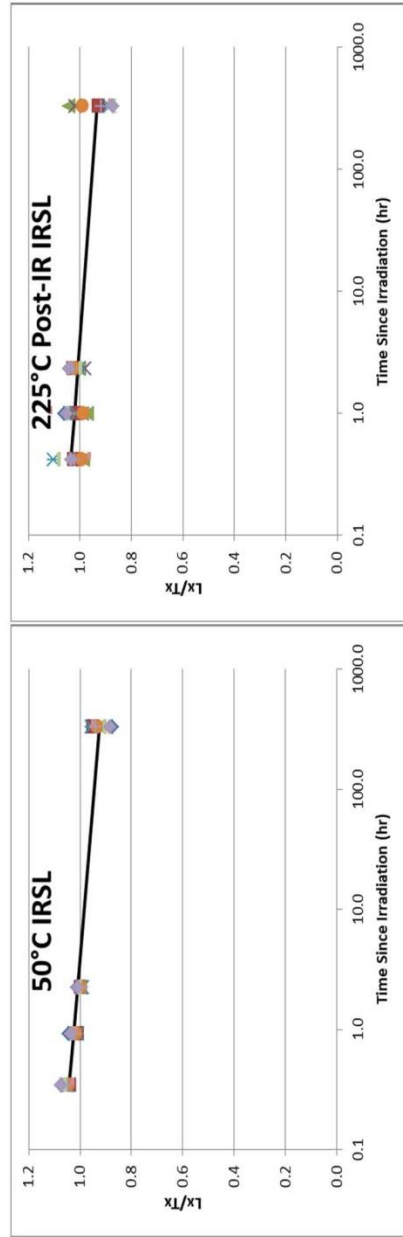
Optically stimulated luminescence analyses were carried out on Riso Automated OSL Dating System Models TL/OSL-DA-15B/C and TL/OSL-DA-20, equipped with blue and infrared diodes, using the Single Aliquot Regenerative Dose (SAR) technique for quartz (Murray and Wintle 2000). Early background subtraction (Ballarini et al., 2007; Cunningham and Wallinga, 2010) was used. Preheat and cutheat temperatures of 240°C/10s and 220°C/0s were used. Growth curves showed that the sample was above saturation ( $D/D_0 > 2$ ; Wintle and Murray, 2006); a minimum age of  $48.4 \pm 2.2$  ka was calculated based upon the average value of  $2D_0$ . Optical ages are based upon a minimum of 50 aliquots (Rodnight, 2008). Calculation of sample  $D_e$  values was carried out using the Central Age Model (Galbraith et al. 1999).

50°C IRSL and 225°C post-IR IRSL measurements were carried out using the dating protocol outlined by Buylaert et al. (2009). Uncorrected ages are  $36.2 \pm 1.4$  ka (50°C IRSL) and  $39.2 \pm 1.8$  ka (225°C post-IR IRSL). Fading corrections were determined and applied using the methods outlined by Huntley and Lamothe (2001) and Auclair et al. (2003). Fading corrected ages are  $51.0 \pm 4.6$  ka (50°C IRSL) and  $52.5 \pm 5.4$  ka (225°C post-IR IRSL). Residual doses were less than 1 Gy for both the 50°C and 225°C data.



Ronald J. Goble  
Professor & Director, Luminescence Geochronology Laboratory

**Fading tests:**



## APPENDIX D

### GRANDFIELD MAMMOTH SITE SOIL SHEETS

# GM-1, SOIL SHEET

Grandfield, Mammoth - Microsoft Excel																
Profile Sheet for: Grandfield Mammoth (GM-1); 01-09-2014; South Side																
Horizon	Depth (cm)	Color (Moist)	Color (Dry)	Structure	Texture	Consistence	Bounded	PH	Effervescence	Descriptives						
1	Ap	2.5YR 2.5/4	3/4	None	Loam	firm	Diffuse	6	Moderate	few roots, Calcium Carbonate (I), Plowing has penetrated into Btk Horizon						
2	Btk	2.5YR 2.5/4	3/4	Med	Clay	firm	Clear	6	Moderate	Clay, Calcium Carbonate Granules (II), Very Hard, Roots, few Pores, Manganoses mottles, Slickensides						
3	Btk2	2.5YR 2.5/4	3/4	Sub Ang	Clay	firm	Clear	7	Moderate	Abundant Pores, Manganese, Root Marks, Calcium Carbonate (I/II)						
4	C	2.5YR 2.5/4	3/4	Sub Ang	Sandy Loam	firm	Clear	7	Moderate	Laminations, Very Few Small Pores, Massive (no Structure), Very Little Manganese, Calcium Carbonate (I/II)						
5	2C	2.5YR 2.5/4	3/4	Ang	Sandy Loam	firm		7	Moderate	very few small Pores, Gravel Lens, Worm Holes, Calcium Carbonate (I/II)						
6																
7																

Appendices D, table 1.

## APPENDIX E

### FOSS MAMMOTH SITE SOIL SHEETS

## FM-1, SOIL SHEET

Foss Mammoth - Microsoft Excel																
Profile Sheet for: Foss Mammoth (FM-1); 12-16-2013; East Side																
	Horizon	Depth (cm)	Color (Moist)	Color (Dry)	Stuc- ture	Tex- ture	Consis- tence	Boun- dary	PH	Effer	Descriptives					
1	AC		2.5YR 4/6	5YR 3/4	Ang Blocky	Sandy Loam	very firm	Diffuse	6	None	medium and very coarse sand.					
2	2C		2.5YR 3/6	3/6	Ang Blocky	Sandy Loam	moderately firm	Diffuse	6	None	some pebbles, Some sandstone, few Manganese mottles.					
3	3C		2.5YR 3/4	4/6	Ang Blocky	clay	moderately firm	Diffuse	7	None	Slickensides, Manganese					
4	4C		2.5YR 4/8	3/6	None	Sand	moderately firm/ friable	Diffuse	7	None	Some sandstone, fine to medium sands,					
5	5C		2.5YR 4/8	3/6	Ang Blocky	Sand	moderately firm/ friable		7	Mild	very coarse sand, small pebbles, Some sandstone					
6																
7																

Appendices E, table 1.

# FM-2, SOIL SHEET

Foss Mammoth - Microsoft Excel																						
Foss Mammoth (FM-2): 12-16-2013; South Side																						
Profile Sheet for: Foss Mammoth (FM-2): 12-16-2013; South Side																						
Horizon	Depth (cm)	Color (Moist)	Color (Dry)	Structure	Texture	Consistence	Boundedness	PH	Effervescence	Descriptives												
1	AC	48	2.5YR 2.5YR 3/6	Med Angular	Sandy Loam	firm	Diffuse	6	None	Some sandstone, medium to very coarse sand.												
2	2C	39	2.5YR 2.5YR 3/6	Med Sub Blocky						few Pores, Some sandstone, Manganese mottles, Some pebbles, Some Calcium Carbonate (stage I)												
3	3C	18	2.5YR 2.5YR 3/6	Ang Blocky	Sandy Loam	firm	Clear	6	Mild	Lamination, manganese mottles												
4	4C	7	2.5YR 2.5YR 4/6	Fine Ang Blocky	Sand	moderately firm/friable	clear	6	None	Some Lamination, Some sandstone, Manganese mottles, few pores, few Wormholes, Some Calcium Carbonate (stage I), very few pebbles												
5	5C	-1	2.5YR 2.5YR 3/6	Ang Blocky	Loamy Sand	firm	Diffuse	6	Mild	few Pores, Some Root Filaments, Some sandstone, Manganese mottles, few pebbles												
6	6C	-13	2.5YR 2.5YR 3/6	Med Ang Blocky	Sand Loam	moderately firm	Diffuse	6	Very Mild													
7		-30	2.5YR 2.5YR 3/6	Fine Ang Blocky	Loam	moderately firm/friable		6	Moderate	few Pores, Manganese mottles, Some sandstone, Calcium Carbonates (stage I/II)												

Appendices E, table 2.



# VITA

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