STRATIGRAPHY AND GEOCHRONOLOGY OF THE VERNOR MAMMOTH SITE, CLUTE, BRAZORIA COUNTY, TEXAS

A Thesis

by

JUAN CARLOS URISTA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

May 2009

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Michael R. Waters
Committee Members,	Daryl de Ruiter
	Cristine Morgan
Head of Department,	Donny Hamilton

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ABSTRACT

Stratigraphy and Geochronology of the Vernor Mammoth Site, Clute, Brazoria County, Texas. (May 2009)
Juan Carlos Urista, B.A., San Francisco State University
Chair of Advisory Committee: Dr. Michael R. Waters

Remains of a mammoth, other Pleistocene fauna, and a wooden bowl were recovered from the Vernor site located in Clute, Brazoria County on the Texas Gulf Coast. Stratigraphy, sedimentology, and geochronology were used to establish the depositional history of the site. The geologic evidence suggests that these sediments were deposited during a period of fluvial activity by an ancient meander belt of the Brazos River, known today as Oyster Creek, which characterized this region during the Late Pleistocene and Early Holocene. Organics associated with the wooden bowl were radiocarbon dated to 4205 ± 30 yr B.P. (UCIAMS-12039), while sand grains associated with the remains of the mammoth were dated using the luminescence technique to 66,000 ± 7000 yr B.P. (UIC1383). According to these dates and their positions in the stratigraphic record, it was established that the mammoth and other Pleistocene age fauna preceded human occupation, and are not contemporaneous with the wooden bowl.

DEDICATION

Este tesis se lo dedico con todo mi corazón a mis padres – Jesús y Esperanza Urista, quienes sin su apoyo y aliento este proyecto no se hubiera realizado. Muchas gracias por todo.

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I would like to give a special thanks to David Foxe for the monumental task of helping me out in the field, and also for always being there as a great friend. Words cannot begin to describe how much I appreciate all his help and his friendship.

I would also like to give a great, big, special thanks to Cassady Yoder for all the work she has poured into helping me finish this thesis. Her help has been indispensible

during the final stretch where the end seemed so close, yet so far away, and whose encouragement, dedication, and companionship made sure I got there.

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1. INTRODUCTION

In late 2003, a set of mammoth tusks was found in a commercial sand pit in Clute, Brazoria County, Texas. Drs. Robson Bonnichsen and Michael Waters, of the Center for the Study of the First Americans at Texas A&M University, went to Brazoria County to investigate the discovery. Dr. Bonnichsen believed that the arrangement of the tusks and other mammoth bones found might have suggested human butchering. On this premise, Dr. Bonnichsen organized an excavation to begin in January 2004. Along with the remains of the two mammoths, other Ice Age fossils and a wooden bowl were recovered from the sand quarry. The mammoth remains were eventually dated to about 66,000 ± 7000 yr B.P. (UIC1383) using the luminescence dating technique, and the bowl was radiocarbon dated to 4205 ± 30 yr B.P. (UCIAMS-12039), placing it in the Middle Archaic. The mammoth remains thus preceded the human occupation of North America by several tens of thousands of years.

A series of stratigraphic profiles were recorded within the sand pit in order to elucidate the geologic history of the site. This also helped to define the geochronology of the site so that the mammoth remains and the wooden bowl could be understood in their proper stratigraphic and temporal contexts. Because the mammoth remains pre-date human occupation in the Americas, whereas the wooden bowl is evidence of human activity, their temporal association was crucial in defining the geochronology of this site. As Aten (1983: 143-144) states,

> … the late Quaternary geologic history of the upper (Texas) coast… makes clear that many sequential sedimentary deposits and landforms are laterally offset rather than just superimposed. Because of this relationship, the geologic stratigraphy and morphostratigraphy provides both a chronological and spatial organizing framework for the area based on field observations that lead directly to interpretation of ancient geography, climates, habitats, and archaeological data.

This thesis follows the style of Quaternary Research.

Thus, stratigraphic work at the Vernor site will aid not only in the reconstruction of the geologic history, but this will also contribute to the overall understanding of the area during the late Quaternary.

2. LOCATION

The Vernor Mammoth site lies within the Gulf Coast Plain physiographic area (Abbott, 2001) and occurs within the meander belt of an abandoned channel of the Brazos River called Oyster Creek (Bernard et al., 1970; Epps, 1973) at 29°1’49”N, 95°24’58”W (see Figure 2.1). This area of the Texas coast is denoted as the “upper coast” by some researchers (Aten, 1983; Dering and Ayers, 1977) and its boundary stretches from the Brazos River to the Sabine River. During the Quaternary period, the Brazos River constructed a series of large fluvial-dominated deltas across the continental shelf as a result of changes in sea level, sediment supply, and climate, which shifted the position of the coastline (Abdulah et al., 2004). During the time of the mammoth, at about 66,000 yr B.P., the coastline experienced a transgression as sea level rose. Even though this period was marked by a rise in sea level, its magnitude was not as great as the present-day sea level (Abdulah et al., 2004). Later, during the Holocene, the area of the Vernor pit was within the confines of the Oyster Creek meander belt of the Brazos River. This meander belt was active from about 4000 yr B.P. to about 1000 yr B.P. when it was abandoned due to the avulsion that created the present meander belt of the Brazos River (Abbott, 2001; Aten, 1983; Bernard et al., 1970). Although it is about 18 kilometers inland from the coast, today, the Vernor Mammoth site lies about 7.5 meters below sea level and about 3 kilometers east of the Brazos River.

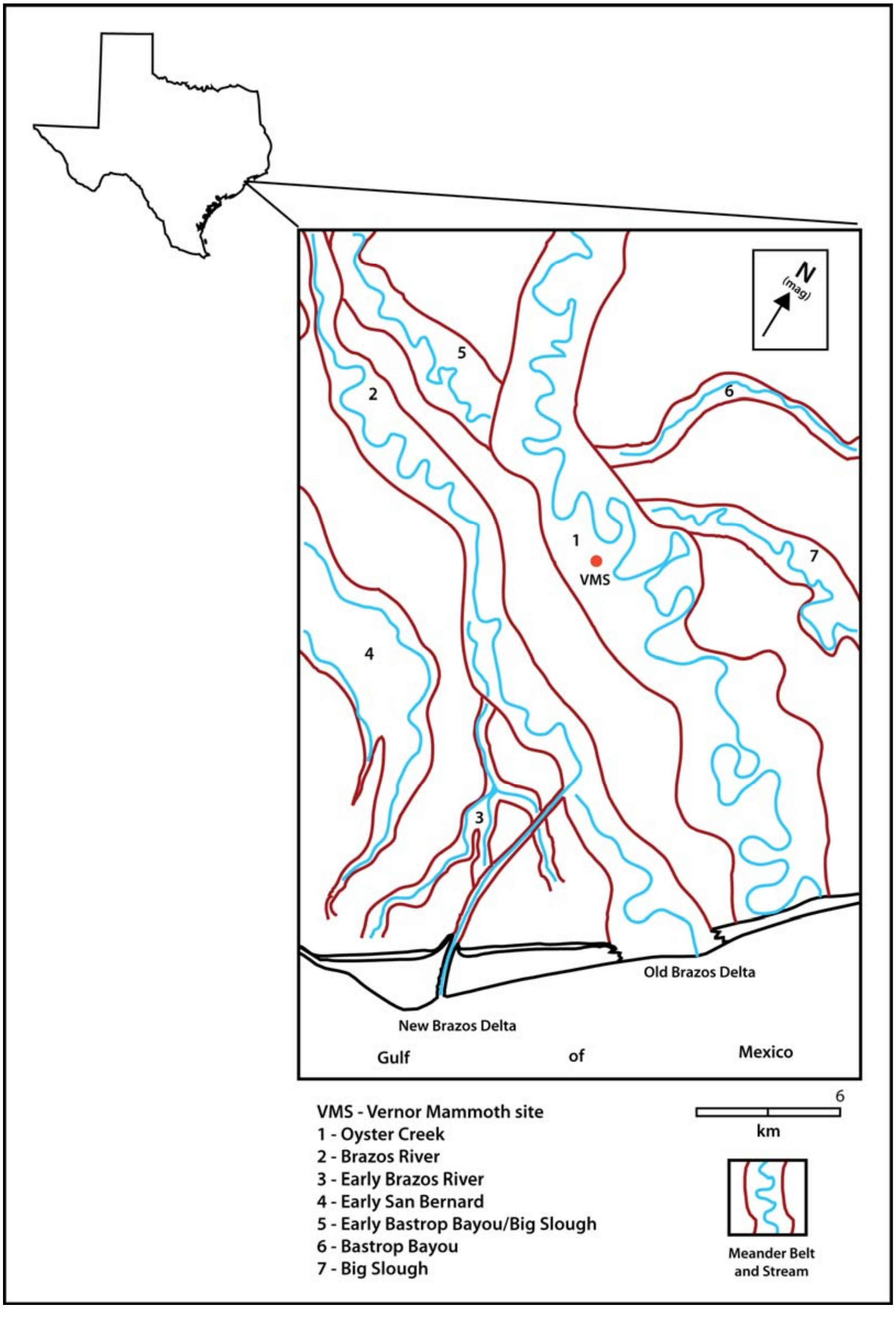


Figure 2.1 – Location of the Vernor Mammoth site and late Quaternary meander belts of the Brazos River (after Aten, 1971: 2).

3. OBJECTIVES

According to Gagliano (1984: 8), a relict system is that which shows “physical evidence of former repetitive movement of energy and materials in a given geographic area, but (whose)… flows no longer occur.” The goal of this thesis is to decipher what type of relict system was in operation throughout the history of the Vernor Mammoth site (Gagliano, 1984). Therefore, in order to shed light on this phenomenon the main objective of this study is to define the stratigraphy and geochronology of the Vernor Mammoth site in order to better understand the type of relic system at work at the site. The stratigraphy and geochronology will help define (1) the depositional history of the site, and (2) the context of the mammoth remains and of the wooden bowl. Stratigaphically, the mammoth remains and the wooden bowl are about 1.5 meters vertically apart from each other. However, they differ in age by about 62,000 years. Therefore, they were deposited at very different stages in the geologic history of the site. Both seem to have been deposited in a fluvial environment, but because this area is characterized by much fluvial activity, the origin and mechanism for each context is unique, especially as it is known that the climate has changed drastically throughout the history of this site. Periods of warm and cold have alternated throughout the Quaternary period, which has induced changes in eustasy and fluvial discharge. Therefore, the stratigraphy and geochronology at this site will shed light on the factors that not only define geology, but also those that have shaped the geology throughout time. Thus, a reconstruction of the climatic changes that are known on the Texas coast will help in understanding the interplay between glaciation and fluctuating sea levels, and this should be reflected in the stratigraphic record. This information is used as a framework in order to tease out a coherent geochronologic record.

The geologic reconstruction of the site was done by creating profiles from trenches dug from within the fenced enclosure in which the mammoth remains were found. These profiles are immediately associated with the mammoth remains (see Figure 3.1). Profiles were also created from around the pit, outside of the fenced enclosure, in order to get a better general understanding of the site's stratigraphy. These profiles were obtained from outcrops found throughout the pit (see Figure 3.2).

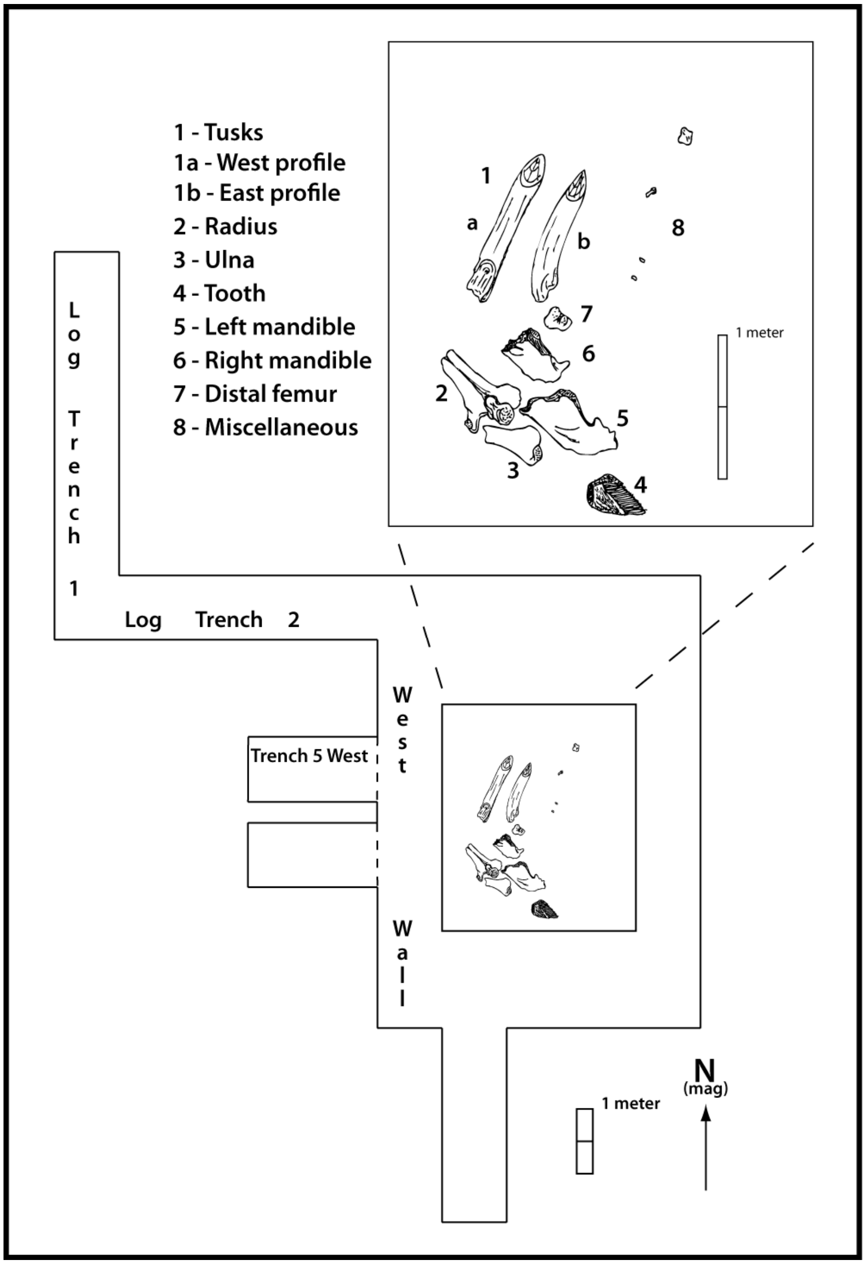


Figure 3.1 – Drawing of mammoth pit within fenced enclosure showing location of profiles.

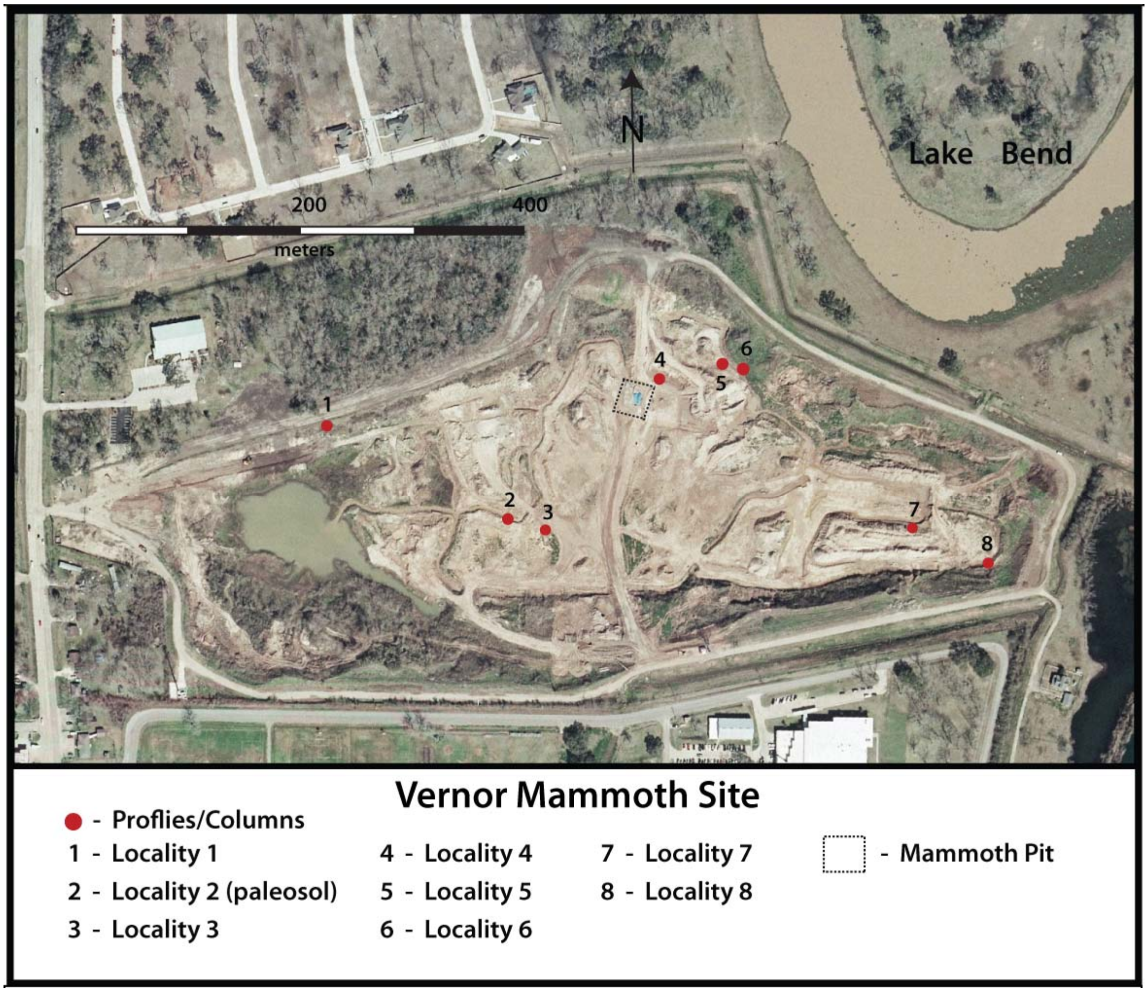


Figure 3.2 – Location of profiles and columns at the Vernor Mammoth site. See Figure 3.1 for a detailed description of profiles located within the fenced enclosure of the mammoth pit.

4. DEPOSITIONAL UNITS OF THE TEXAS GULF COASTAL PLAIN

The literature recognizes two major groups of deposits that make up the Late Quaternary on the Texas coast (Abbott, 2001; Bernard and LeBlanc, 1965; Bernard et al., 1970; Blum, 1990; Blum, 1994; Blum et al., 1995; Blum and Price, 1994; Blum and Price, 1998; Epps, 1973; Van Siclen, 1985; Waters and Nordt, 1995). The older of the two is the Beaumont Formation, and the latter is actually two different sets of deposits known collectively as post-Beaumont deposits. The post-Beaumont deposits include the late Pleistocene Deweyville sediments and younger Holocene sediment package.

Originally, the geology of the Texas Coastal Plain was interpreted according to the four glacial and four interglacial periods that at one point were believed to characterize the climate of the Pleistocene (Fisk, 1944). The glacial periods were characterized by low sea level stands, and the interglacial periods were characterized by high sea level stands. Fisk (1944) developed a model for the Mississippi Valley and the Louisiana coast in which glacial periods with low sea level stands were characterized by valley entrenchment and sediment bypass, whereas interglacial periods were associated with transgression and high sea level stands characterized by the construction of alluvial terraces and deltaic plains (Bernard and LeBlanc, 1965; Blum and Price, 1994; Doering, 1956). According to Fisk's model, the Beaumont Formation was assigned to the "Sangamon" interglacial, the last interglacial of the Pleistocene (Blum and Price, 1994; Fisk, 1944). The importance of this model is evident as it persisted for a long period of time (Aronow, 1971; Bernard and LeBlanc, 1965; Bernard et al., 1970).

However, more recent studies suggest that the geologic history of the Pleistocene is now more complicated than previously thought. To begin with, according to studies done with oxygen isotopes, the partitioning of the Pleistocene into four glacial/interglacial periods has been proven to be inaccurate (Blum, 1990; Blum et al., 1995; Blum and Price, 1994; Williams et al., 1988). According to these studies, it is now known that there were more than four glacial/interglacial periods during the 1.8 million years that make up the Pleistocene. Also, eustasy due to glaciation alone is not responsible for all of the characteristic alluvial deposits. While it is the case that eustasy plays a significant role in the geometry of alluvial deposits near the shoreline, according to several studies done on the Colorado River system (Blum, 1990; Blum, 1994; Blum and Price, 1994), climatic effects in the continental interior determine the amount of discharge and sediment rates delivered to the coastal plain.

Blum and Price (1994) offer a model describing Texas Gulf Coastal alluvial plain deposits according to the interplay between glacio-eustasy and climate. According to this model: (1) Beaumont and post-Beaumont deposits consist of multiple cross-cutting and/or superimposed valley fill complexes; (2) these deposits vary widely in age, possibly representing the last 600 ka; (3) partitioning of valley fill complexes occurs during the initial phase of the low sea level stand; (4) during lowstands, the newly exposed subaerial shelf becomes incised by the channels and so valley axes become fixed in place; (5) soils develop on the remainder of alluvial plain because no deposition occurs; (6) within the extended and incised valley, multiple episodes of lateral migration, aggradation, degredation, and/or floodplain abandonment occur; (7) composite basal valley fill unconformity and minor allostratigraphic units are created within the valley fill complex; (8) transgression and subsequent high sea level stand occur, causing valley complexes to become filled; (9) upstream controls on sediment delivery set the pace at which these alluvial valleys fill; (10) upstream controls on sediment delivery are influenced by climatic factors; (11) near completion of valley fills causes deposition and lateral spread of floodplain sediments; and (12) complete valley filling promotes avulsion.

As mentioned above, stratigraphic architecture in the Texas Gulf Coastal Plain reflects the interaction between glacio-eustasy and climatic factors that affect the rate of discharge and amount of sediment supply (Alford and Holmes, 1985; Blum and Price, 1994; Saucier, 1981). While glacio-eustasy affects the geomorphology and subsequent stratigraphy near the coast, climatic influences in the interior of the continent affect the amount of sediment fed to fluvial process at and near the coast. The valley fill complexes that are formed after incision of the newly exposed continental shelf during periods of low sea stand illustrate this point. Periods of large sediment influx are characterized by the development of meanderbelts, channel aggradation, and floodplain construction. However, periods of low sediment influx are characterized by channel incision and the development of relict terraces as a result of floodplain abandonment, which can also lead to avulsion. Because no deposition occurs on an abandoned floodplain, this in turn causes the formation of soils. Thus, stratigraphy related to periods of low sediment influx is characterized by unconformities. Therefore, allostratigraphic units characterize valley fill complexes. As the sea begins its transgression of the coast during interglacial periods, sediments forming the base of new allostratigraphic units begin to onlap those allostratigraphic units deposited during the lowstand (Blum and Price, 1994).

4.1 Beaumont Formation

Three major units from each set of these Late Quaternary deposits are recognized within the Vernor Mammoth site. The oldest unit (Unit I) excavated is a poorly-drained, bluish, and mottled clay. This is consistent with the description for the Beaumont Formation given by Van Siclen (1985) which consists of fluvial deposits comprised of sandy channels, argillic backswamps, floodplains, and deltaic sediments. These units are more thoroughly described in the *Geologic Atlas of Texas* (Barnes, 1982; Barnes, 1987). Barnes, in the *Geologic Atlas of Texas, Houston Sheet* (1982), mapped three lithostratigraphic units within the Beaumont Formation east of the Vernor Mammoth site. One of the deposits Barnes (1982) describes as “dominantly clay and mud of low permeability, high water holding capacity, high compressibility, high to very high shrink-swell potential, poor drainage, level to depressed relief, low shear strength, and high plasticity.” The geologic units that he associated with this lithstratigraphic unit are interdistributary muds, abandoned channel-fill muds, and overbank fluvial muds. East of the Vernor Mammoth site, Barnes, in the *Geologic Atlas of Texas, Beeville-Bay City Sheet* (1987), describes Beaumont sediments as being “mostly clay, backswamp deposits, and to a lesser extent coastal marsh, mud flat, lagoonal, Recent (Holocene) and older lake, clay dune, and sand dune deposits.”

The Beaumont Formation has been described as a series of alluvial and deltaic deposits found near the coast from the Rio Grande in Texas to the Mississippi River in Louisiana (Aronow, 1971). Blum and Price (1994) describe the Beaumont Formation as a series of multiple cross-cutting and superimposed valley fill complexes according to three major observations they made on a study on the Colorado River. In the first of these observations, they state that Beaumont alluvial plains have a "much greater" areal extent than those constructed by the same rivers of the present interglacial stage; both interglacial stages are similar in duration. Secondly, Beaumont stratigraphic units have a series of paleosols, which denote periods of non-deposition and soil formation, followed by periods of deposition in which these soils become buried. Thirdly, the Beaumont Formation is three to four times as thick at the shelf edge than at the shoreline. They also state that deposition of the Beaumont was not confined to one interglacial period as Fisk (1944) had suggested, but rather spanned several 100-kyr periods in which several glacial and interglacials intervals took place over the Middle to Late Pleistocene.

Several estimates have been given by different authors for the age of the Beaumont Formation. Fisk (1944) and DuBar et al. (1991) correlate the Beaumont Formation with the Sangamon Interglacial (~250 – 125 ka) (DuBar et al., 1991; Kurtén and Anderson, 1980). Alford and Holmes (1985) cite evidence from meander scars in the Sabine River, carbon-14 dates from fill near the Red River, and the absence of more than one loess deposit from the last glacial period to assign a Middle Wisconsin age to the Beaumont. Blum and Price (1994) offer luminescence dates roughly between 102 and 120 ka from the two youngest Beaumont meanderbelts of the Colorado River, that they believe may represent the maximum last interglacial highstand (ca. 129-120 ka) (Chen et al., 1991). However, Blum and Price believe that the Beaumont may extend as far back as 600 ka or more. Therefore, according to all of this data, the age of the Beaumont Formation may be anywhere from 600 to 102 ka, which would put it in the Middle to Late Pleistocene.

4. 2 Post-Beaumont Deposits – Deweyville Alloformation Complex

Although post-Beaumont deposits have not been formally named, researchers note two separate sets of deposits. Those deposits that supersede the Beaumont Formation on the Texas Gulf Coastal Plain, but are older than modern floodplain deposits are known informally as Deweyville. Deweyville deposits are characterized by a series of valley fill complexes which are expressed as terraces (Blum et al., 1995; Blum and Price, 1994; Blum and Price, 1998). These terraces can be seen on the surface as large meander scars with channels that are much bigger than the ones that present rivers occupy, indicating a greater discharge regime during that time (Alford and Holmes, 1985; Aten, 1983; Bernard et al., 1970; Blum et al., 1995). However, these deposits do not find surface expression everywhere. Near the mouth of the Brazos River, they are overlain by Holocene deposits (Bernard et al., 1970; Blum et al., 1995).

Blum et al. (1995) suggest putting quotation marks around the name, Deweyville (i.e. “Deweyville”), because they believe there is not one single unit that describes what several authors refer to as Deweyville deposits. Due to regional differences they argue that not everybody is talking about the same thing when referring to deposits that date between the Beaumont Formation and modern floodplain deposits. For example, Saucier and Fleetwood (1970) assign two lacustrine terraces along the Ouchita River of Arkansas and Louisiana as Deweyville. This ambiguity is the main reason researchers have not ascribed it as a formal formation name according to the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). However, all Deweyville deposits have several characteristics in common. The first shared feature is their age, all Deweyville deposits are younger than the Beaumont Formation which they unconformably overlie, but older than Holocene deposits. Thomas (1990) dates these deposits to about 100 ka. Blum (1994) dates a Deweyville terrace of the Colorado River from about 18,000 – 15,000 yr B.P. , and is believed by him to represent the end of the Deweyville range. In Galveston Bay and Sabine Pass, Deweyville deposits are capped by a peat horizon that is about 9000 years old (Aten, 1983; Nelson and Bray, 1970; Rehkemper, 1969). Therefore, these deposits have a range within the Late Pleistocene, from about 100 to 9 ka yr B.P. Second, Deweyville deposits usually consist of a series of fluvial terraces that become smaller over time due to a waning flow regime. Third, these deposits are laid down in a lateral fashion, rather than being vertically stacked. Finally, Deweyville deposits are part of valley fill complexes that form a string of allostratigraphic units.

Blum and others (Blum, 1990; Blum, 1994; Blum et al., 1995; Blum and Price, 1994; Blum and Price, 1998) have identified the above characteristics of the Deweyville deposits and summarize them as valley fill complexes that form a network of allostratigraphic units; each valley fill complex bounded by an unconformity. These allostratigraphic units are expressed on the landscape as terraces; older terraces overlying younger ones. A unique feature of Deweyville deposits is their scarcity of overbank flood deposits. It is believed that this is the main reason that these deposits are laterally rather than vertically stacked. Without bank-stabilizing muds, or oxbow lakes to form resistant clay plugs (Waters, 1992), these mostly sandy deposits accrete laterally, and as result, may be partially responsible for the much larger channels that characterize this time period. Due to this absence of muds, Blum et al. (1995) note that there is a frequent occurrence of sand and gravel quarries on Deweyville surfaces, and as mentioned earlier, the Vernor Mammoth site is located in a sand quarry.

4.3 Post-Beaumont Deposits – Holocene Deposits

Modern deposits from the Texas Gulf Coastal Plain consist of various environments including streams, deltas, barrier islands, wetlands, lagoons, and strandplains among others (Abbott, 2001). Modern fluvial deposits differ form those of the Deweyville period by being vertically stacked rather than laterally accreted. Waters and Nordt (1995) studied fluvial deposits from the Brazos River within a 75 km segment of the floodplain between Hearne and Navasota, Texas. This Holocene deposit consists of an alternating series of channel and floodplain sediments. They identified five units that correspond to avulsion episodes. All of the units have the same general attributes: alternating deposits of channel (thalweg and point bar) and floodplain sediments capped by a soil. However, the oldest unit suggests that the Brazos River at this time (during the terminal Pleistocene) had a much greater flow regime, and thus had greater free-reign as a meandering stream. As a result the deposits during this time were laterally accreted rather than vertically stacked as are all subsequent units. As the flow regime waned after the deposition of the first unit, the river was then confined to a meander belt due to the presence of bank-stabilizing muds which caused it to cut deeper channels, and then deposit its sediments in a vertical fashion.

These deposits have been dated to about 8500 – 250 yr B.P. (A.D. 1700) by Waters and Nordt (1995) and 12,000 – 1000 yr B.P. (A.D. 950) by Blum (1994). It was during the Holocene that the Brazos River occupied the present-day Oyster Creek meander belt. As mentioned above, this meander belt was active from about 4000 BP to about 1000 BP when it was abandoned due to the avulsion that created the present meander belt of the Brazos River (Abbott, 2001; Aten, 1983; Bernard et al., 1970). The point of avulsion is believed to have occurred a few kilometers upstream from Sealy, Texas (Bernard et al., 1970).

5. CLIMATE

Geology and geomorphology are greatly affected by climate. For example, during the Late Pleistocene the Texas coast extended about 100 km out into the continental shelf (Aten, 1983; Gagliano, 1977; Gagliano and Thom, 1967) due to glaciation. Valley entrenchment by the stream throughout the exposed continental shelf during this period had a unique impact on stream morphology, which in turn left a unique impression on the landscape. Thus, changes seen on the geologic and geomorphologic architecture are a reflection of changes in climate. The cooler climate of the Late Pleistocene on the Texas coast was markedly different from that of today which has been classified as subtropical subhumid to subtropical humid (Abbott, 2001; Larkin and Bomar, 1983; Nordt et al., 1994). For a complete summary on the nature of the causes and effects of the last glacial period refer to Williams et al. (1998). On the Gulf of Mexico coastal region it has been suggested that periods of marine regression during cooler climates are associated with valley downcutting, in which streams entrench their channels and the process of erosion predominates. During periods of marine transgression associated with warmer climatic episodes, the shoreline moves further inland and submerges part of the previously exposed continental shelf, and as a result the newly submerged channels are infilled with sediment and aggradation is believed to predominate during this time.

Evidence for climate during the Late Quaternary can be discerned through the use of various agents that serve as proxies (Dincauze, 2000; Williams et al., 1998). These agents include stream channel geometry (Alford and Holmes, 1985; Aten, 1983), soils (Aten, 1983; Mandel and Bettis, 2001), carbon isotopes (Nordt et al., 1994), and pollen (Bryant and Holloway, 1985). The limitations and pitfalls of using proxies to interpret past climates have been discussed elsewhere (Smiley et al., 1991). Although caution must be exercised when using proxies to interpret past climates, nonetheless they are indispensable in that they offer the only insight into discerning past climates. The various studies done on theses agents all show a similar trend: climate during the Late Pleistocene was cooler and dryer than that of the Holocene, which conversely has been warmer and wetter. While pollen and carbon isotope studies have not been conducted on the upper Texas coast, studies dealing with stream geometry and soils have. As mentioned above, these studies show the same trend of cooler/dryer climate during the Late Pleistocene, and warmer/wetter climate during the Holocene, i.e. cooler/dryer climate during glacial periods, and warmer/wetter climate during interglacial periods.

Meander scars that date to the Deweyville period have been identified on the Texas coast (Bernard and LeBlanc, 1965; Bernard et al., 1970) The unique characteristic of these meander scars are that they represent relict channels of the Brazos River, and are much bigger than the present Brazos River channel (Epps, 1973). This has been shown to be the case from measurements taken from meander wavelength and meander radii, two meander dimensions taken from relict channels that can be used to assess paleodischarge (Alford and Holmes, 1985; Carlston, 1965). These measures indicates that stream channel geometry during deposition of the Deweyville alloformation was much greater than that occupied by the Brazos River today, suggesting that the present-day Brazos River is an underfit stream (Aten, 1983; Epps, 1973; Waters and Nordt, 1995). Large relict channels in the period from 14,000 – 9,000 yr B.P. have also been identified elsewhere (Dury, 1977; Knighton, 1998).

The dynamic nature of the stream channel geometry as illustrated between the Late Pleistocene and the Holocene seems to be a consequence of changes in climate that had an effect upon stream discharge. The period between 14,000 and 9,000 yr B.P. coincides with a warming trend after the late glacial maximum at 18,000 yr B.P., with a slight interruption due to the Younger Dryas at about 11,000 yr B.P. It is worth noting that during this transitional period from the Late Pleistocene to early Holocene, heavy precipitation characterized lower latitudes. This period is characterized by the formation of pluvial lakes, such as Lake Bonneville in Utah and Lake Lahontan in Nevada. Although these massive interior lakes seemed to be formed by the enormous precipitation during this period, other factors such as diminished evaporation, greater cloud cover, or change in vegetation that may have induced runoff may have contributed, or been largely responsible for their formation (Williams et al., 1998).

Either heavy rainfall or any of the reasons given above, possibly in conjunction with rainfall, seem to be the reason(s) why the Brazos River may have had a discharge many times greater, and hence greater channel dimensions than those of today. Another reason may be an absence of bank-stabilizing muds as Blum et al. (1995) have suggested.

While a larger Brazos River is associated with the colder Late Pleistocene, and a smaller Brazos River with the warmer Holocene, this would imply that greater stream discharges occur during periods of cooler climate versus lesser stream discharges occurring during warmer periods. It is tempting to explain this simply as increased discharge due to a wetter climate resulting from decreased evapotranspiration and increased precipitation as a result of cooler weather (Alford and Holmes, 1985); however, this is not the case. According to studies done along the Gulf Coast (Alford and Holmes, 1985; Coleman, 1980; Delcourt, 1980; Moran, 1975; Otvos, 1975; Wright, 1981), during the Late Pleistocene, at the time of deposition of the Deweyville alloformation complex, climate in this region was dryer. So an increase in precipitation due to glaciation seems unlikely.

Alford and Holmes (1985) suggest that during the Late Pleistocene the climate in the Gulf coast region was probably even warmer than today. They suggest that this increase in temperature may have led to a higher frequency of tropical storms in the Gulf of Mexico which may have resulted an increase in precipitation. Several studies (Coleman, 1980; Moran, 1975; Wendland, 1977) have shown a strong correlation "between increased surface water temperatures and incidence of tropical storms" (Alford and Holmes, 1985: 400). Therefore, increased precipitation from Gulf storms during this warmer period could have contributed to the large meander scars found in the southeastern United States. The magnitude of such an impact would require, according to Alford and Holmes (1985), twice the amount of precipitation, if evapotranspiration were to remain constant or slightly increased. These large meander scars can be seen from Texas to North Carolina, but none, with the exception of some found in Illinois (Bolduc, 1982), have been located further north (Gagliano and Thom, 1967). This gives further credence to the idea that warmer waters from the Gulf of Mexico and Atlantic

Ocean may have had a significant impact on stream channel geometry. Large meander scars found in Illinois are the result of channels acting as sluice conduits for glacial meltwater (Alford and Holmes, 1985; Bolduc, 1982), something that would be impossible for the smaller rivers of the Gulf coast, such as the Brazos River, that are too far south to be directly impacted by glacial meltwater.

This suggests that streams active during periods associated with a warmer climatic regime will have a greater stream channel geometry than streams active during periods associated with a cooler climatic regime. On the other hand, several studies suggest that sea surface temperatures in the tropics during the last glacial maximum (~18,000 yr B. P.) may have been cooler than today by about 5° C (Colinvaux et al., 1996; Guilderson et al., 1994; Stute et al., 1995; Thompson et al., 1995; Williams et al., 1998). This is more in line with conventional thinking that climate was cooler during the Late Pleistocene. This, however, is an overgeneralization. It may be that this particular region of the Gulf coast of Texas was warmer in the Late Pleistocene than today.

It seems that periods with the greatest amount of discharge happen in the transitional period between glacial and interglacial periods. It is during this period of climatic warming that glaciers begin to ablate and release more water into streams, and into the atmosphere as water vapor, thereby increasing their discharge. The greatest amount of discharge by the Brazos River during the Late Quaternary occurred during the deposition of the Deweyville alloformation complex in the period between 30,000 and 9,000 B.P. The last glacial maximum occurred about 18,000 years ago (Williams et al., 1998). From that time to about 11,000 yr. B.P., a warming trend occurred punctuated by an episode of major ice loss occurring between 14,000 – 12,000 yr B.P. (Jansen and Veum, 1990; Mix, 1987; Williams et al., 1998)   This warming trend ended with the Younger Dryas stadial at about 11,000 yr. B.P., a period that saw the climate return to cold conditions reminiscent of the last glacial maximum (Williams et al., 1998). The end of the Younger Dryas stadial marks the boundary between the Pleistocene and the Holocene at about 10,500 yr. B.P. The Holocene has been punctuated by two more episodes of rapid ice loss from about 10,000 – 9,000 yr. B.P. and another one from 8,000 – 6,000 yr. B.P. (Jansen and Veum, 1990; Mix, 1987; Williams et al., 1998), but there was less discharge during this time due smaller ice sheets. Thus, the Brazos River at the time of Deweyville deposition experienced a major warming trend that may have lead to increased precipitation, and thus was wholly or partly responsible for the extreme channels characteristic of that time. As we move closer to the present the meander scars show a propensity towards smaller channels due to a waning flow regime. As described above, when glaciers released more water due to a warming trend, and this water found its way into the Brazos River through increased precipitation, the channels swelled in proportion. However, as the glaciers that fed this precipitation became smaller and eventually disappeared, a threshold was reached in which discharge could no longer accommodate the increased channel geometry. The Brazos River responded to this change in regime by entrenching its channel to form a narrower one that could better accommodate a decreased discharge (Waters and Nordt, 1995).

According to the above data, a general picture of climate during the site's history can be deduced. The general trend is that cooler/drier periods prevailed during deposition of the Beaumont Formation, while warmer/wetter periods have characterized Post-Beaumont deposits with transitional periods from glacial to interglacial being the wettest. Thus, during deposition of the Deweyville Alloformation complex, the climate was much wetter, even more so than today. This likely lead to increased precipitation, which in turn maintained a Brazos River with a much bigger stream channel geometry. As precipitation decreased, the Brazos River became an underfit stream as its reduced discharge could not accommodate its former channel dimensions. This drier climate caused the river to entrench itself and occupy a much smaller channel.

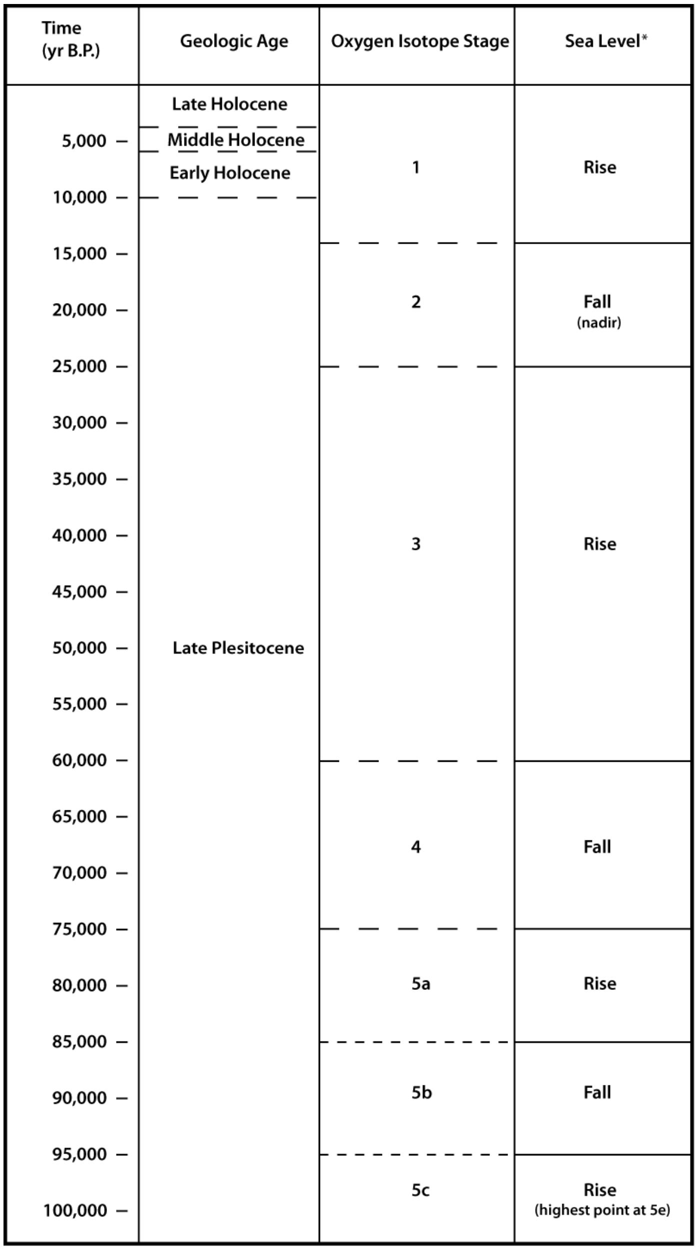
6. SEA LEVEL

The fluctuating sea level that has characterized the Quaternary period has been responsible, as described above, for changes in the channel form of the Brazos River. In particular, these fluctuations in sea level have been most expressed in baselevel adjustments that the river has responded to. As previously mentioned, the Brazos River constructed a series of large fluvial-dominated deltas across the continental shelf as a result of changes in sea level, sediment supply, and climate which shifted the position of the coastline (Abdulah et al., 2004).

Sea level curves have been created to measure the amount of sea water available during a certain period of time in relation to present sea level (Abdulah et al., 2004; Bloom, 1983; Chen et al., 1991; Williams et al., 1988). Eustatic sea level changes are not uniform throughout the world due to the nature of the geoid – the three-dimensional, uneven form of the ocean basin characterized by topographic highs (ridges) and lows (valleys) (Williams et al., 1998). Therefore, sea level curves represent the average sea level for a given period, since, “no single history of sea-level necessarily applies to in exact detail to any other place” (Williams et al., 1998: 120). During the last glacial maximum, worldwide sea level was anywhere from 120-150 meters below present conditions (Williams et al., 1998).

On the Gulf coast, formation of the Vernor Mammoth site occurred during Oxygen Isotope Stage 5e – at about 125,000 yr B.P. (Abdulah et al., 2004; Williams et al., 1998). The Gulf coast began to reach its present level at about 20,000 yr B.P. during Oxygen Isotope Stage 2. The period between 20,000 and 9,500 yr B.P. was characterized by a rapid rise in sea level, interrupted temporarily by the Younger Dryas from about 11,000 and 10,500 yr B.P. This period of coastal transgression is characterized by wetter conditions as peat deposits from this period suggest (Gagliano, 1984). Coastal transgression seemed to halt from about 9,500 to 8,000 yr B.P. and finally reached its present sea level in the upper Texas coast at about 3,000 yr B.P. (Blum et al., 2002; Gagliano, 1984). During this time, the mean sea level was about 50 meters below present sea level. Refer to Table 6.1 for a synthesis of sea level, geologic ages, Oxygen Isotope stages, and climate.

Table 6.1 – Chronology linking geologic age, climate, oxygen isotope stages, and sea level (Abdulah et al., 2004).



Time (yr B.P.)	Geologic Age	Oxygen Isotope Stage	Sea Level*
	Late Holocene	1	Rise
5,000	Middle Holocene		
	Early Holocene		
10,000	Late Plesitocene		
15,000		2	Fall (nadir)
20,000			
25,000		3	Rise
30,000			
35,000			
40,000			
45,000			
50,000			
55,000			
60,000		4	Fall
65,000			
70,000			
75,000		5a	Rise
80,000			
85,000		5b	Fall
90,000			
95,000		5c	Rise (highest point at 5e)
100,000			

* Sea level maximum during Stage 5e followed by a general falling trend that reached its nadir during Stage 2. Falling trend punctuated by some rises. After Stage 2 nadir, sea level rises to its present height, although not quite as high as Stage 5e.

7. DESCRIPTION OF UNITS

There are three allostratigraphic units identified at this site that correspond to the major depositional units of the Texas Gulf Coast Plain. Figure 7.1 shows a generalized geologic column composed of these units and Figure 7.2 shows the profiles and columns that were used to construct this generalized profile. Table 7.1 gives a summary of the sedimentary features that characterize each unit. For a full sedimentary description of each locality see Appendix IV. Unit I represents an eustarine deposit of the Beaumont Formation which dates from the Middle to Late Pleistocene. The unit itself is a bed of mud, thickness undetermined, that shows evidence of redoximorphic features that resulted from repeated cycles of wetting and drying. A bed of in situ oysters (*Crassostrea virginica*) is found within this unit. This type of oyster flourishes in brackish waters (Andrews, 1977; Paine, 1993). This evidence coupled with the fact that the unit shows anywhere between 30 and 40 percent of redoximorphic features suggests that it was subjected to repeated cycles of saturation followed by limited aeration, and thus this unit was deposited in an estuary. A paleosol is also found within the top of the unit in one of the exposures. A photograph and illustration of the paleosol horizons is illustrated in Figures 7.3 and 7.4. The level of soil horizon development suggests that the paleosol in Unit I experienced an episode of prolonged stability for soil formation as the sea level retreated. This soil must have at one point capped most of Unit I. As the river meandered, the soil was eroded away in some parts of Unit I.

The paleosol found at the Vernor site is located in an outcrop in the southern portion of the pit (see Figure 3.2). Table 7.2 shows a field description and laboratory analysis of the paleosol horizons. For a complete list of features, refer to Table 1 in the Appendix IV. Five soil horizons were identified at this outcrop, with a total solum thickness of 90 cm (see Figure 7.3 and 7.4). Most of the colors are brown to yellowish brown with the exception of horizon Ck, the deepest horizon, being yellowish red. All horizons are high in clay content (> 36% clay). The surface and subsoil horizons, A_1, A_2, and Ck are clays, while the illuviated horizons, Bw and Bk are clay loams. All horizons reacted violently with 10% HCl, indicating that they are all calcareous. The bottom two horizons had soft secondary concretions of calcium carbonate. The textural changes in

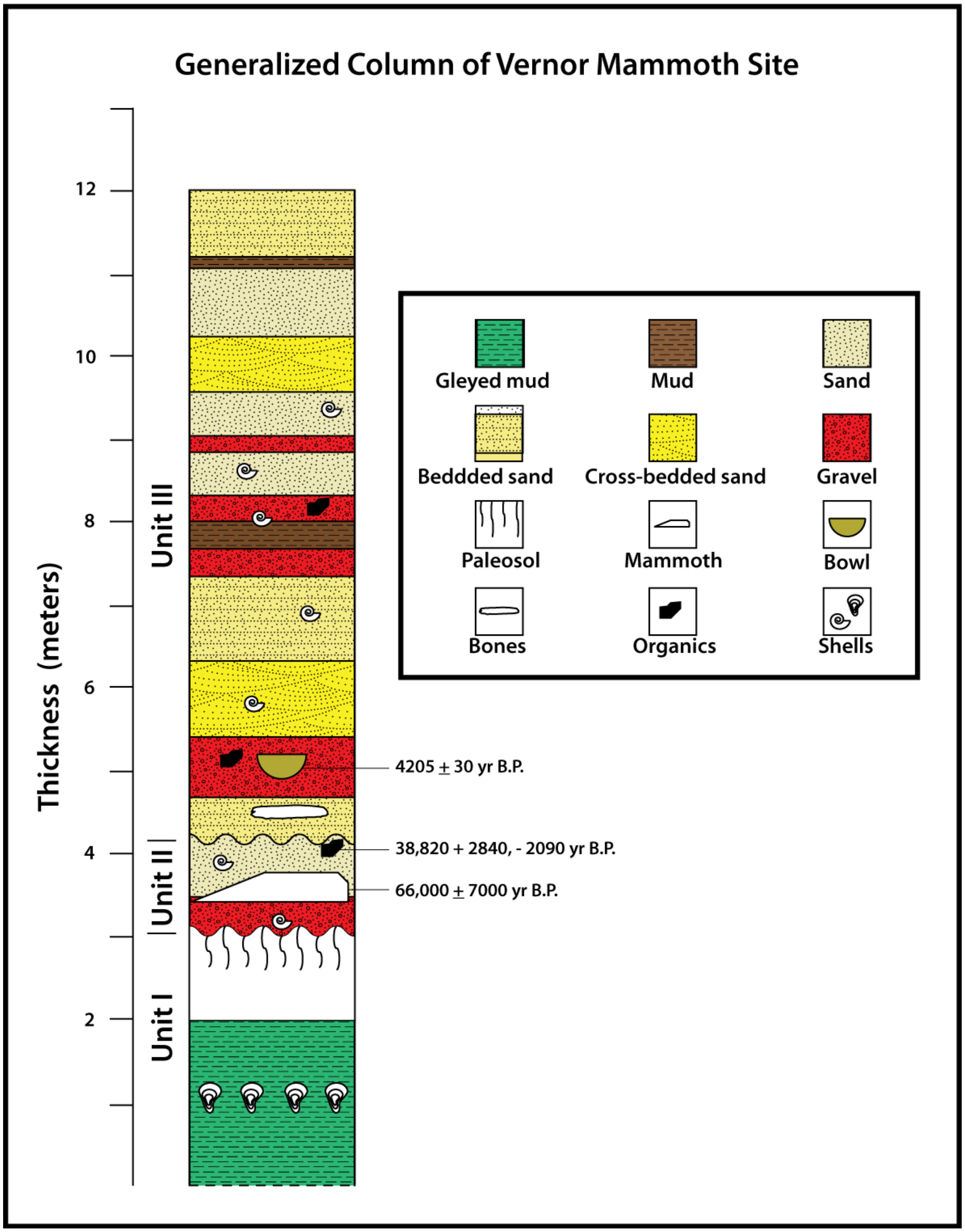


Figure 7.1 – Generalized stratigraphic column of the Vernor Mammoth site.

the horizons and the presence of secondary calcium carbonate indicate that the texture differences between horizons is depositional, not pedogenic. In other words, the soil was not weathered to the extent that clay was translocating in the profile. The organic carbon content is very high in the A horizons, > 10g kg $^{-1}$, indicating a large

Table 7.1 – Selected sedimentary features of units.

Unit	**Color**	**Texture**	**Shells**	**Environment**
Unit I	**Due to presence of redoximorphic features:** **5YR 3/4 - 5YR 4/6 (yellowish red)** **and** **5BG 6/1 - 5Y 7/1 (greenish gray - light gray)**	**Clay**	***Crassostrea virginia* in situ.**	**Estuary, low-energy environment; flood plain; paleosol.**
Unit II	**For massive loamy sand:** **10YR 4/4 - 10YR 6/3** **(dark yellowish brown - pale brown)**	**Various but massive sandy loam usually present.**	**Various including *Rangia flexuosa*.**	**Mostly fluvial channel deposits.**
Unit III	**For crosbedded loamy sand:** **10YR 5/3 - 10YR 5/4** **(brown - yellowish brown)**	**Various but crossbedded sandy loam usually present.**	**Various**	**Mostly point-bar deposits.**

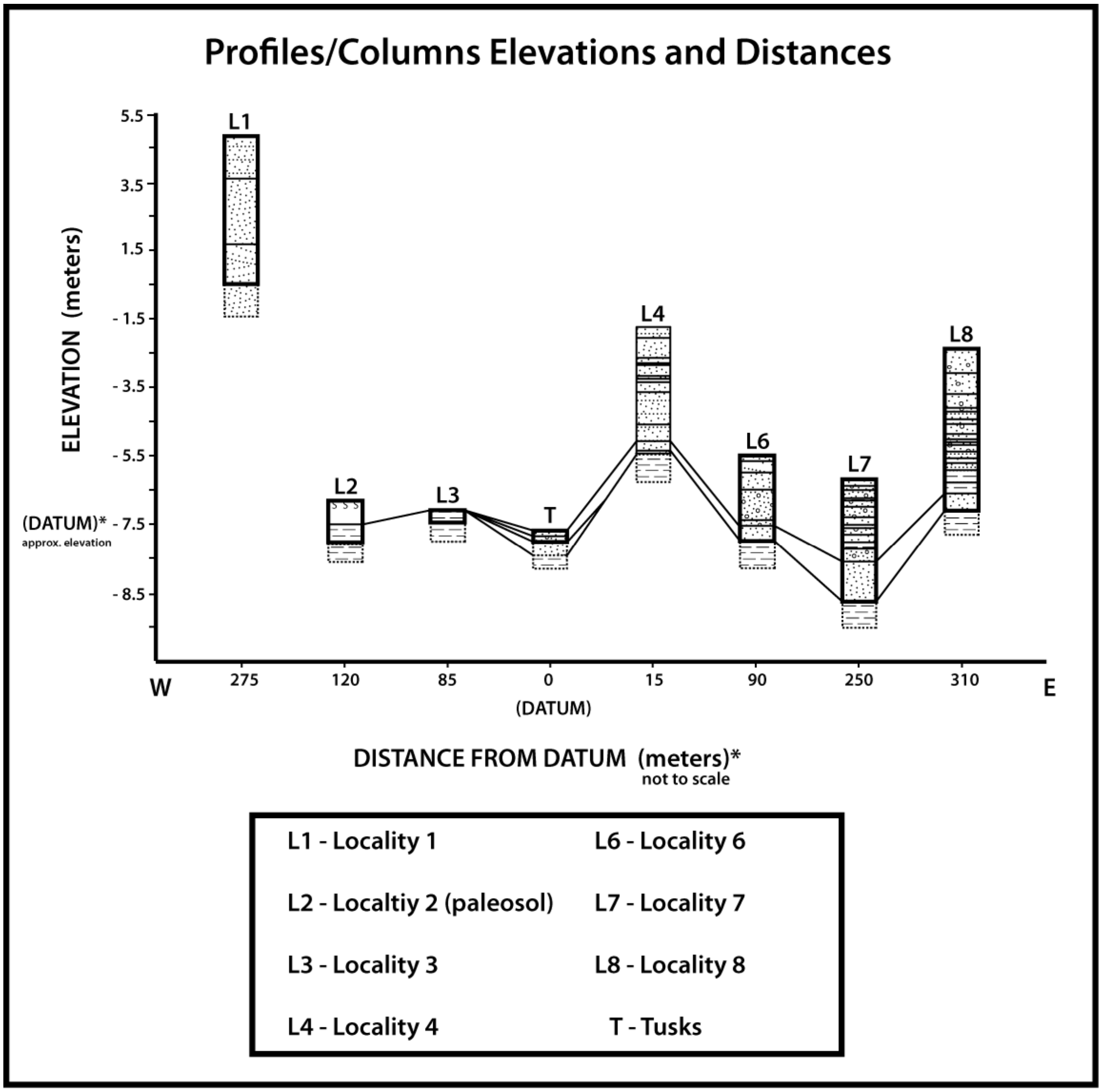


Figure 7.2 - Elevations and distances for profiles and columns.

accumulation of organic matter, most probably because of the wetness of the soil, estuary environment. Many redoximorphic features present in the two deepest horizons further indicate soil formation under very wet soil conditions. Additionally, horizon Bk contains several remains of the eastern oyster, *Crassostrea virginica*.

The paleosol found at the Vernor Mammoth site is identified as an Inceptisol, which is characteristic of estuaries, with a Calcic horizon and Ochric epipedon, which is

Table 7.2. – Selected horizon characteristics of the paleosol. See Table 1 in the Appendix III for a complete of list of features.

Horizons	Depth (cm)	Color	Texture Class	Total Clay (g/kg)	Organic Content (g/kg)	Inorganic Carbon (g/kg)	Redox Features	Shells	HCl Rcn.
A1	0-34	10YR 4/3 (brown/dark brown)	Clay	535	12.7	21	No	No	Violently
A2	34-54	10YR 4/4 (drk. yellowish brown)	Clay	494	11.3	16.4	No	No	Violently
Bw	54-63	10YR 5/6 (yellowish brown)	Clay Loam	369	4.3	14.2	No	No	Violently
Bk	63-90	10YR 5/6 (yellowish brown)	Clay Loam	391	1.5	19.4	5Y 7/1 (light gray)	Yes	Violently
Ck	90-119 +	5YR 4/6 (yellowish red)	Clay	523	2.1	31.4	5Y 7/1 (light gray)	No	Violently

characteristic of estuaries. It is worth noting that the surface horizons meet all the criteria of a Mollic epipedon, except for color. Owing to the subjective nature of using a Munsell book to determine color, this soil may well contain a Mollic epipedon. If so, it would be classified as a Mollisol.

Some evidence exists that the B horizons for this soil were deposited at different times. Multiple depositions are common in alluvial environments. Soil properties including multiple textures, and oyster shells in the fourth horizon (Bk) provide evidence of multiple depositions. There may be four depositional episodes. The first is represented by the clay Ck horizon, the second by clay Bk horizon with oyster shells, the third by the clay loam without oyster shells, and the fourth by the clay A horizons. Though deposition occurred at different times, the organic and organic soil profiles show the main pedogenesis of the soil occurring over all five horizons. This evidence includes organic carbon accumulating primarily in the A horizon and inorganic carbon increasing with depth as inorganic carbon is leached through the profile. The slightly higher inorganic carbon in the surface could be from later translocations from material deposited above the paleosol, or from subsequent events.

The soil's parent material was initially deposited in an estuary, characterized as a wet, low-energy environment, during the Pleistocene. The parent material appears to be

Figure 7.3- Photograph of the paleosol found at the Vernor Mammoth site with horizon designations. It is 6.92 meters below sea level.

estuarine muds of the Prairie Coast which contain in-situ remains of the eastern oyster (*Crassostrea virginica)*. Thus, the paleosol initially formed in a subhumid environment as sea level rose creating an estuary. Pedogenesis occurred as this area occupied a floodplain and sea level continued to drop. Later, this soil was buried under channel deposits. All of the surrounding material at higher elevations than the paleosol are all channel deposits, either fluvial sands or gravel.

Figure 7.4 – Photograph of Locality 2 – the paleosol facing south.

According to Bernard and LeBlanc (1965), Pleistocene and Holocene sediments are separated by a conspicuous unconformity. They describe the sediments immediately below the unconformity as containing less water than the Holocene deposits and as being stiffer, mottled, oxidized and/or leached and containing nodules, caliche, and concretions in most cases. This description fits the paleosol capping Unit I and the area below where the paleosol was eroded. While the paleosol is oxidized and contains many gastropods and nodules, the area below the paleosol is composed mostly of a greenish-gray clay that contains yellowish-red mottles with some nodules. This type of color scheme is characteristic of gleying in which the soil was formed in a reduced environment (Waters, 1992).

Unit II represents a series of fluvial deposits, most likely a point bar sequence that represents the Deweyville Alloformation Complex. Muds are rare in this unit as expected in Deweyville deposits. Although several different deposits have been identified in this unit, two deposits are worth noting. The first deposit is a massive loamy sand whose color ranges from grayish brown to pale brown. This deposit appears in every profile and column recorded. Clay rip-ups from Unit I are found in this deposit, thus it appears that this unit represents a sandy channel. The other deposit worth noting is a gravel deposit that contains gleyed rip-ups from Unit I. Although this deposit does not appear in every profile or column that was recorded, it is important for its association with the mammoth remains.

The mammoth remains and remains of other extinct Pleistocene fauna were recovered from Unit II. Exactly which deposit the mammoth remains rest on is a bit nebulous. One of the tusks seems to be resting within the sandy deposit, while the other one seems to be resting on the gravel (see Figures 7.5 through 7.8). It could be that both tusks originally were deposited with the sand, and at a later time, the gravel undercut the sand where the tusks were resting on. The sand associated with the mammoth tusks were luminescence dated to 66,000 ± 7000 yr B.P (UIC-1383). This luminescence age conforms to Oxygen Isotope Stage 4 (~75 – 58 ka B.P.) in which sea level was dropping, although it did not drop as low as during the Late Glacial Maximum at about

18,000 yr B.P., which conforms to Oxygen Isotope Stage 2 (~25 – 12 ka B.P.) (Abdulah et al., 2004). A radiocarbon age was also taken from woody debris found in another sandy deposit that is higher in elevation than those associated with the mammoth remains (see Figures 7.9 and 7.10). This woody debris was radiocarbon dated to 38,820 + 2,840 - 2090 yr B.P. (GX-30701), and most likely represents an infinite age, and as such represents the minimum age of the basal portion of Unit II.

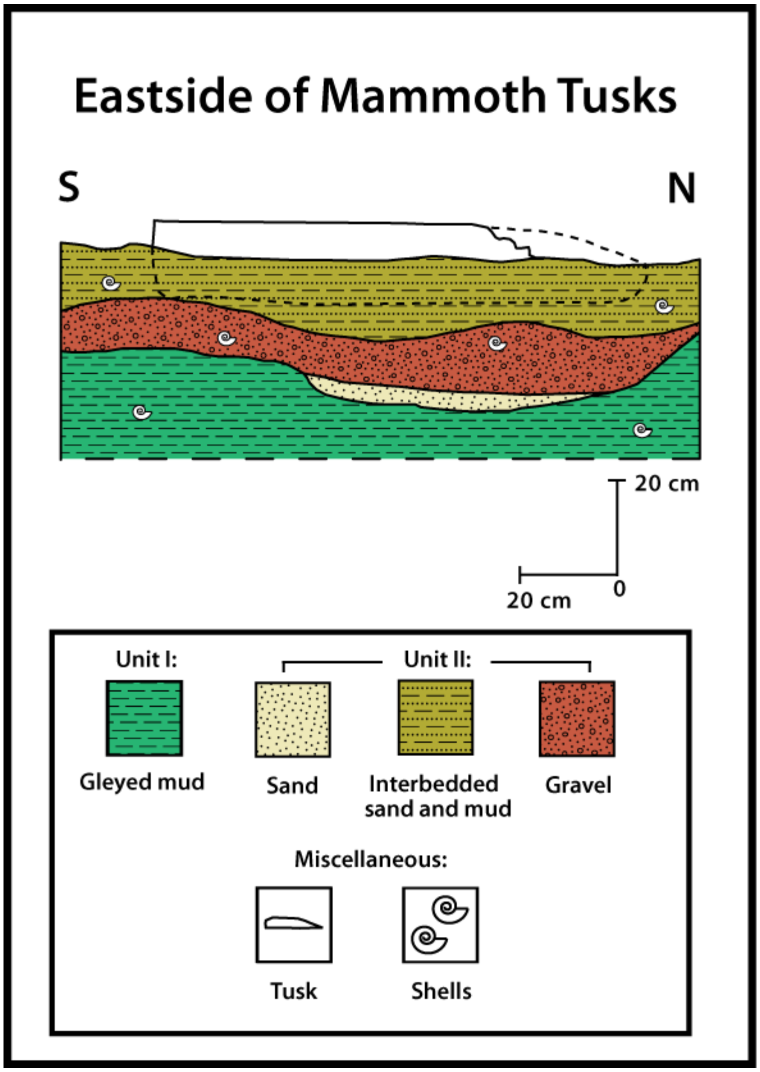


Figure 7.5 – Profile of eastside of mammoth tusks.

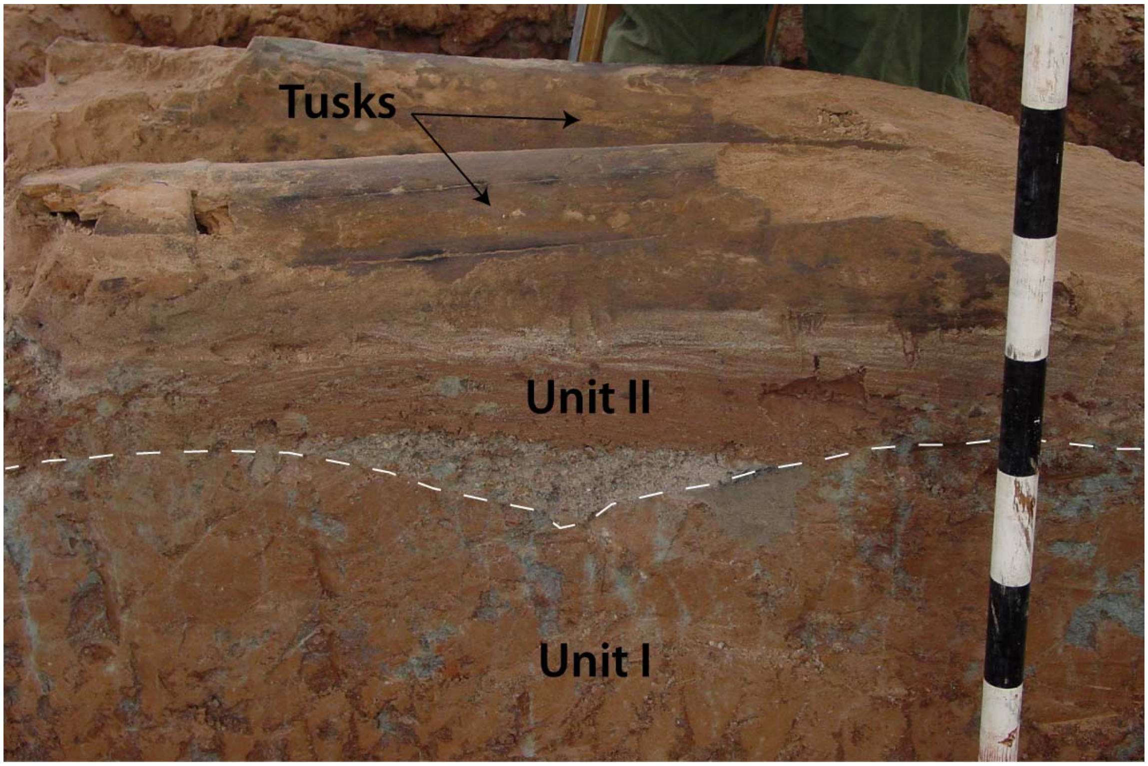


Figure 7.6 – Photograph of eastside of mammoth tusks showing stratigraphy and units.

Walther's Law states that what we see in the vertical stratigraphic record does not reflect the synchronous nature of lateral deposits (Boggs, 2001; Middleton, 1973), and Unit II represents this idea in its extremity as it lacks bank-stabilizing muds. In Unit II, the overall arrangement of deposits from this unit clearly suggests lateral rather than vertical accretion. This conforms to the characteristic that Deweyville deposits display which Blum and others (Blum, 1990; Blum, 1994; Blum et al., 1995; Blum and Price, 1994; Blum and Price, 1998) have identified. As mentioned above, the lack of clay in this unit suggests an absence of bank stabilizing muds that would cause the deposits to accrete vertically. Instead these deposits seem to accrete laterally. For other profiles and columns featuring Unit II refer to Appendices I and II.

Unit III corresponds to Holocene-age deposits and is represented by a series of fining-upward fluvial deposits which vary according to their location in the pit, and are usually represented by a point bar sequence. This point bar sequence is illustrated in

Figures 7.11 – 7.15, which represent Locality 4,and show a series of units with the following general sequence: massive sand that grades into weakly laminated sand, which in turn grades into laminated sand and mud, followed by an erosional contact in which channel sands and rip-ups are deposited, then a layer of laminated mud, followed by a series of sands bounded by gravels, then sand with weak lamination, and finally more strongly laminated sand and mud capped by flame structure. Thus this sequence suggests deposition of a point bar, in particular the top part of a point bar. The erosional contact that occurs between the laminations and channel sands represents a chute channel rather than a disconformity. The laminated mud represents overbank deposits.

Other columns and profiles from Unit III (refer to Appendices I and II) show this general sequence of fluvial deposits as well, although there is a distinction between deposits at the bottom versus those at the top of Unit III. Deposits at the bottom tend to show less vertical stacking and more lateral accretion, whereas those at the top show the opposite. It is important to point out that even those deposits at the bottom tend to show more lateral accretion, they still contain overbank muds, which differentiates them from the laterally accreted deposits of Unit II. Unit II and Unit III are also differentiated by a disconformity which separates them. This erosional contact is illustrated in places such as Locality 4 (see Figures 7.11 and 7.13), Locality 5 (see Figures 9.2 and 9.3), and Locality 6 (see Figures 8.3 and 8.4). This erosional contact is usually demarcated by gravel lag deposits that represent a channel cutting into the older massive, loamy sand deposits.

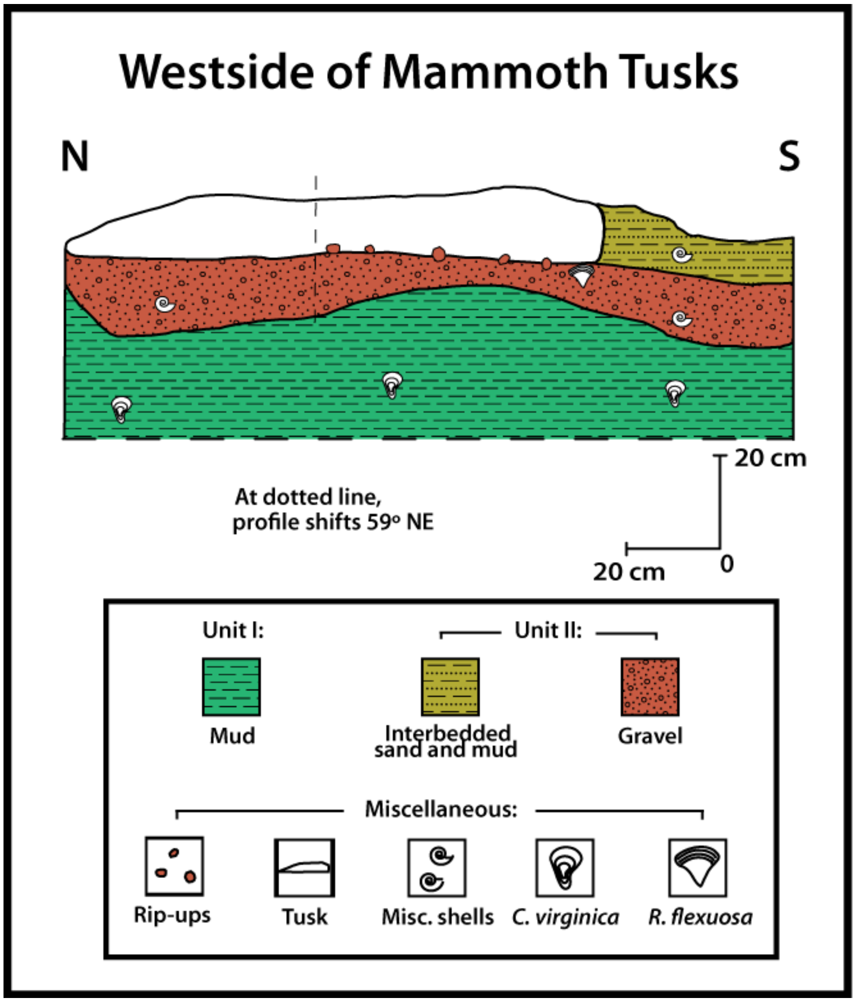


Figure 7.7 – Profile of westside of mammoth tusks.

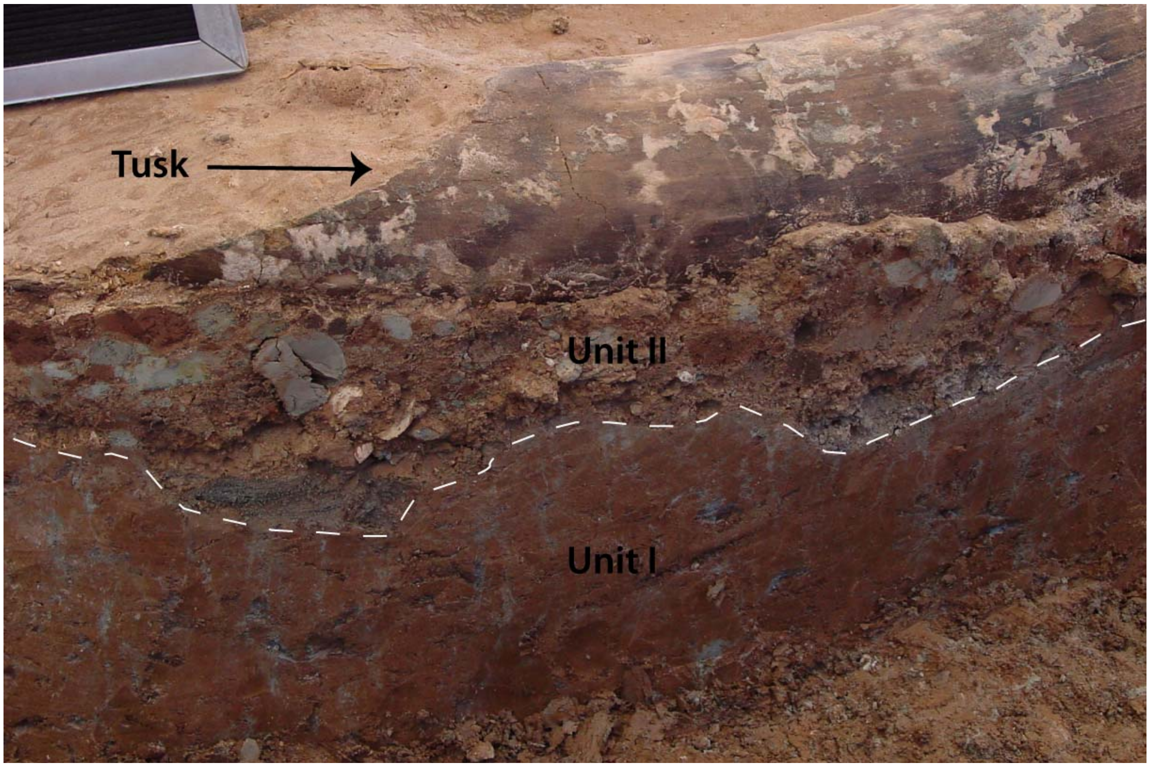


Figure 7.8 – Photograph of westside of mammoth tusks showing stratigraphy and units.

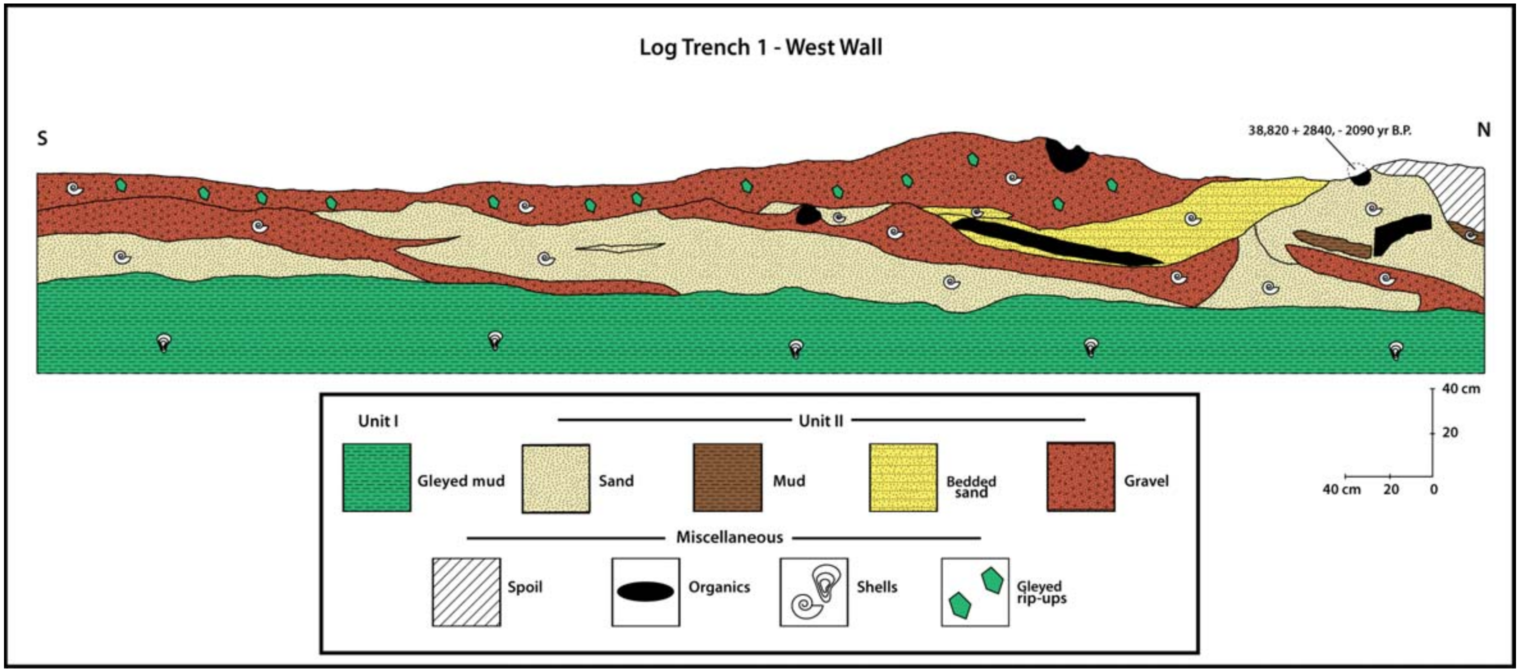


Figure 7.9 – Profile of Log Trench 1 – West Wall showing location of where infinite age was sampled from.

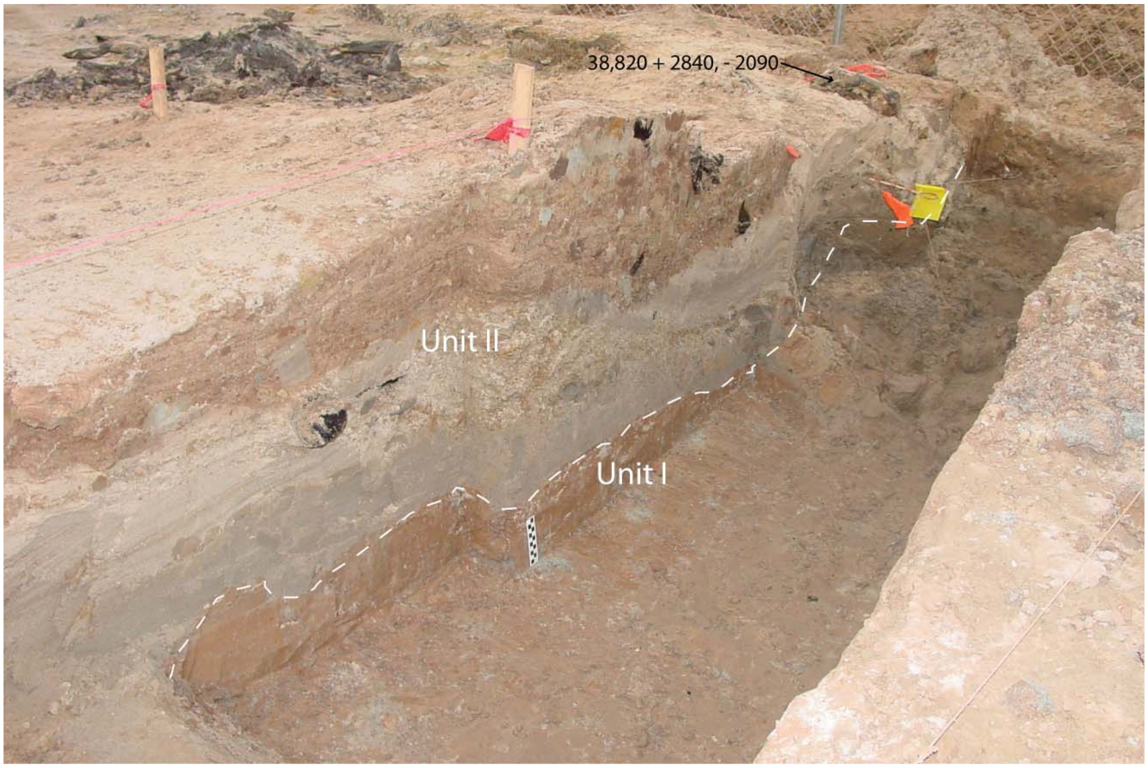


Figure 7.10 – Photograph of Log Trench 1 – West Wall showing unit designations and showing location of where infinite age was sampled from.

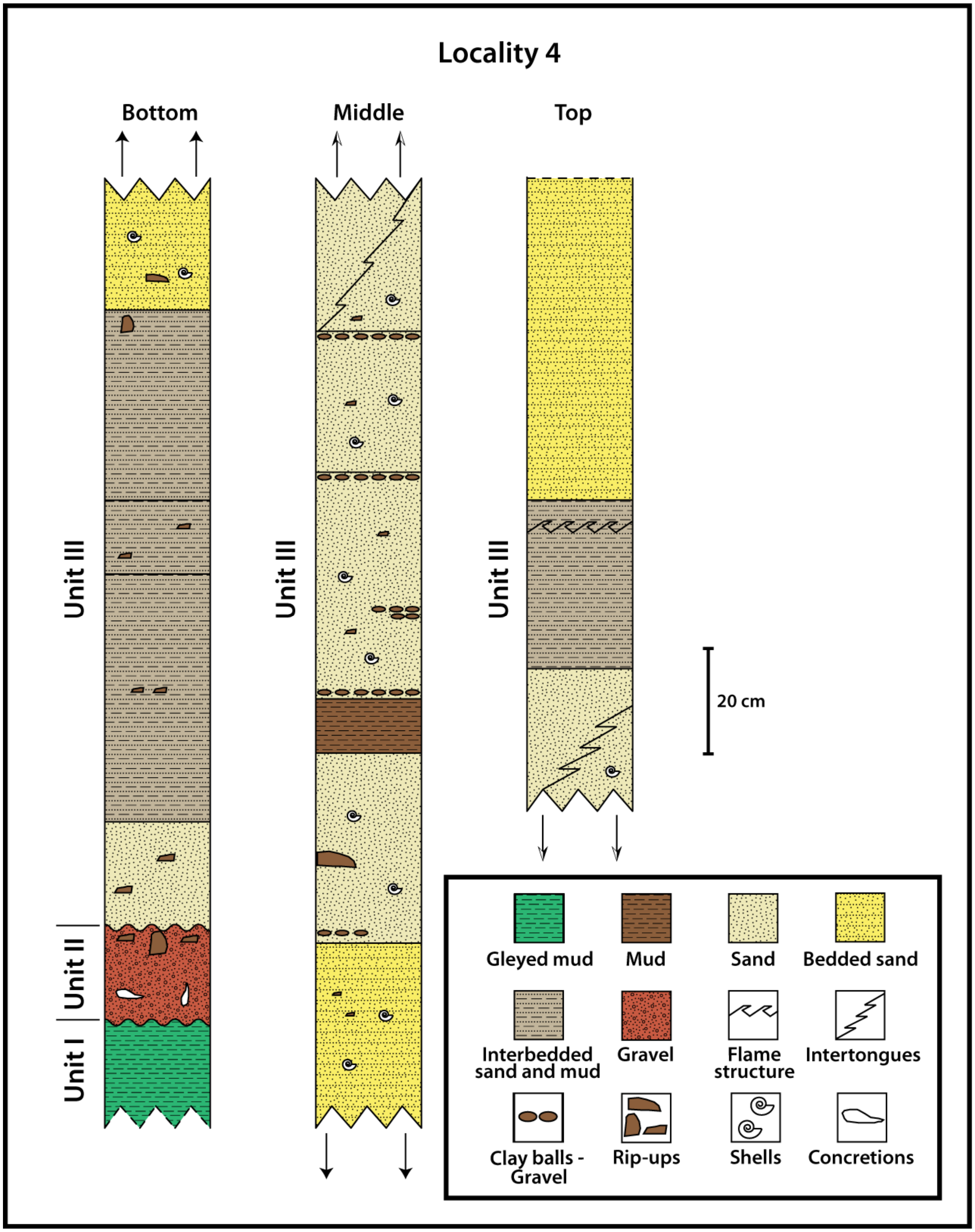


Figure 7.11 – Stratigraphic column of Locality 4 showing the typical stratigraphic sequence of Unit III. It is 1.76 meters below sea level.

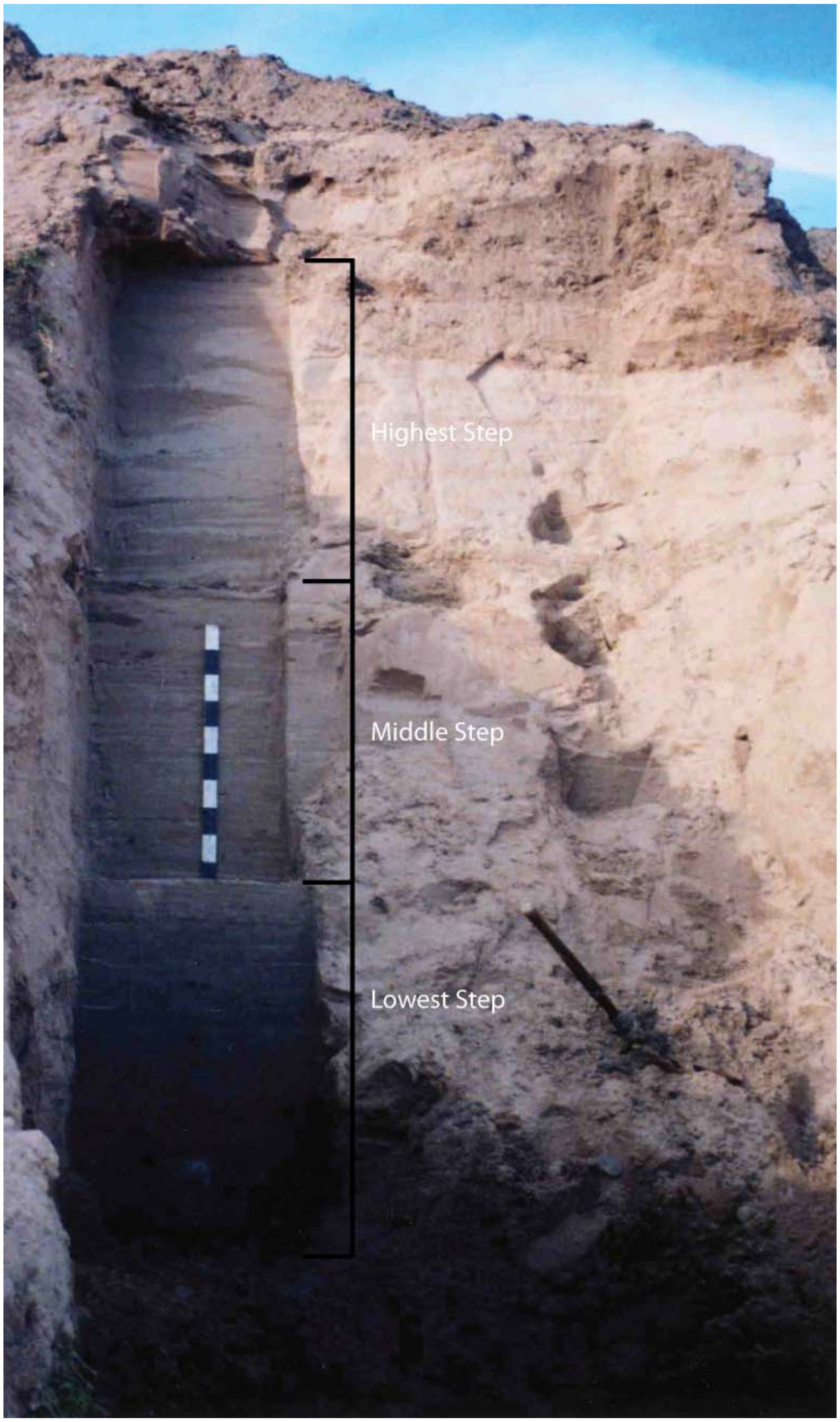


Figure 7.12 – Photograph of Locality 4 facing north showing all three steps.

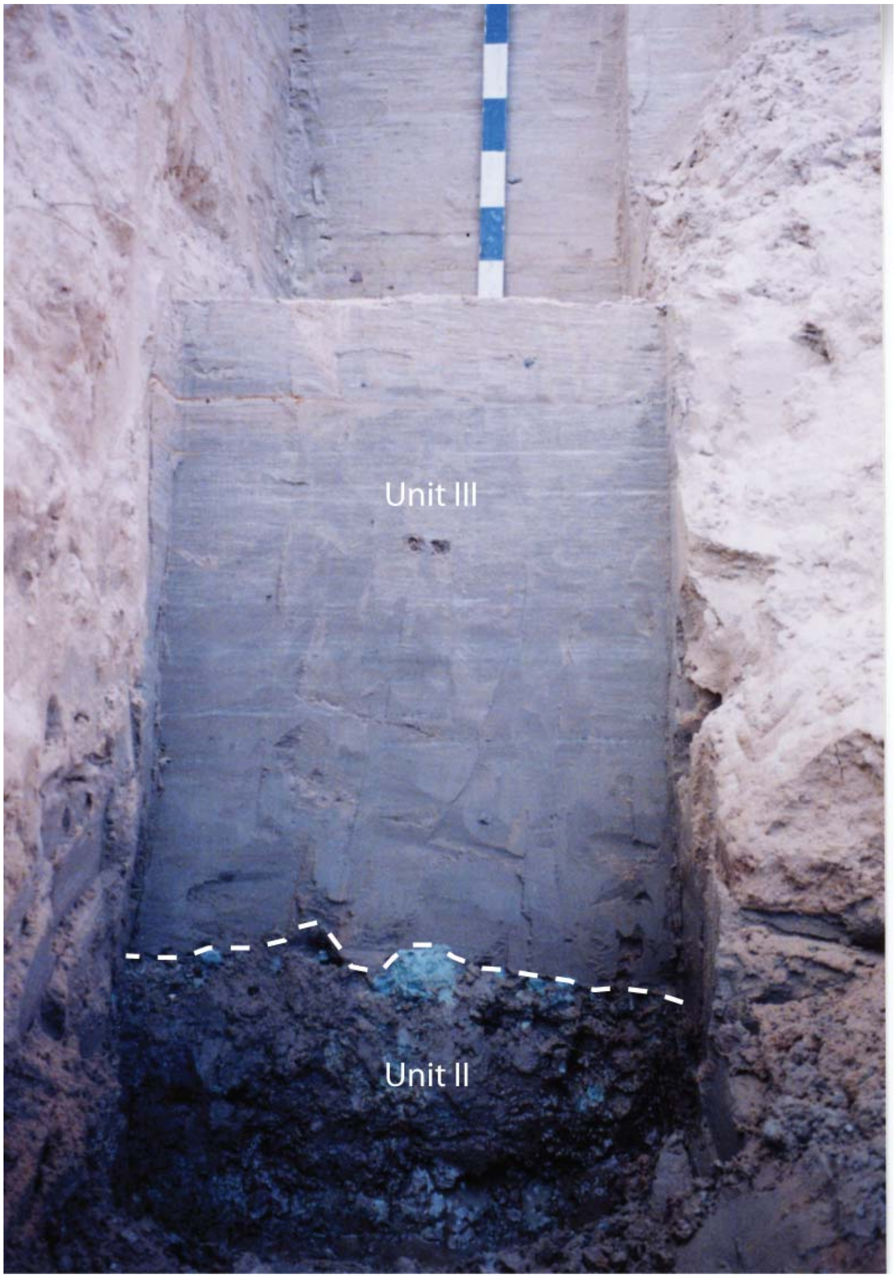


Figure 7.13 – Photograph of Locality 4 facing north showing stratigraphy of lowest step. Unit I is missing.

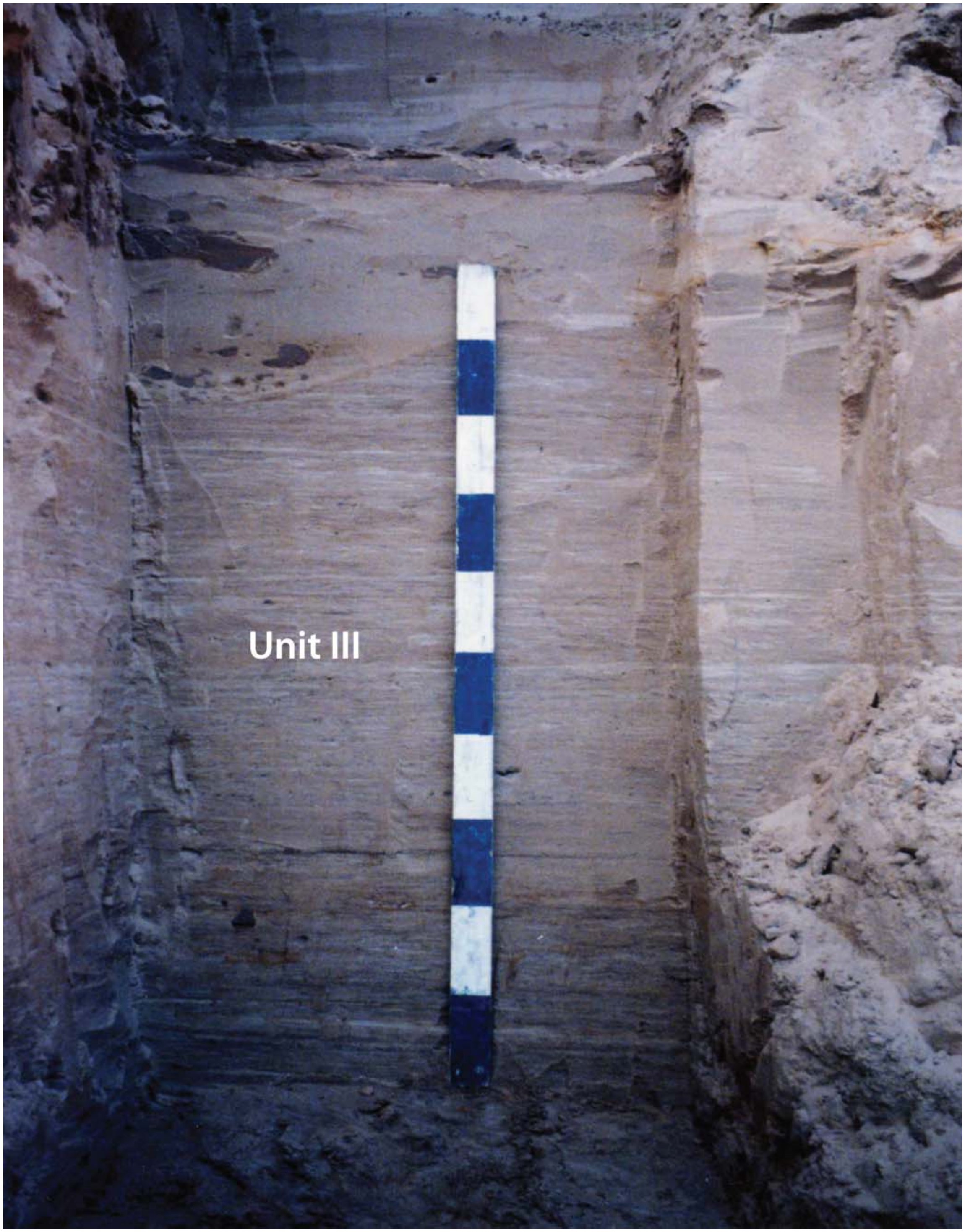


Figure 7.14 – Photograph of Locality 4 facing north showing stratigraphy of middle step.

Figure 7.15 – Photograph of Locality 4 facing north showing stratigraphy of highest step.

8. FAUNAL REMAINS

Remains of Pleistocene fauna, including Columbian mammoths have been found throughout Texas (Lundelius, 1972; Steele and Carlson, 1989; Suhm, 1980). The mammoth remains discussed here were deposited in the sands, and possibly also, the gravels of Unit II. Although two individual mammoths (*Mammuthus columbi*) were found, the one excavated within the fenced enclosure, which comprises the main excavation pit, was better preserved and was more complete (see Figures 8.1 and 8.2).

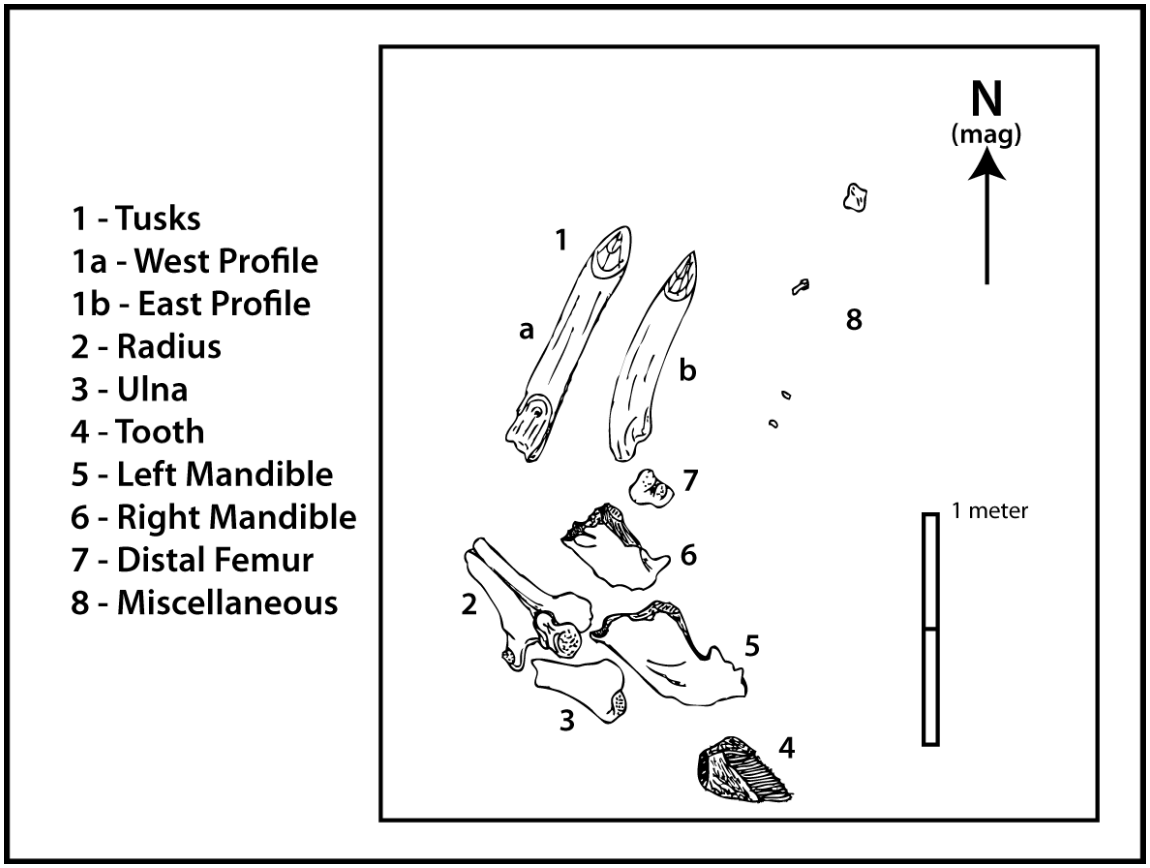


Figure 8.1- Drawing of mammoth remains with each part labeled.

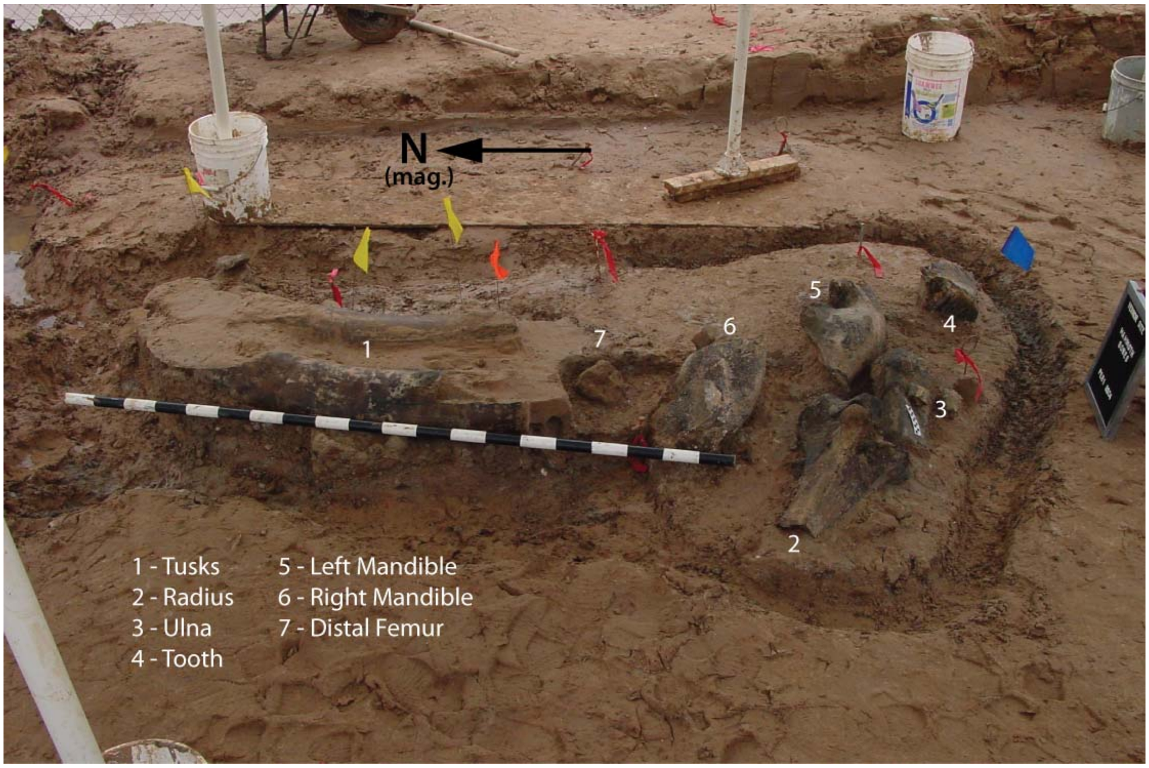


Figure 8.2 – Photograph of mammoth remains facing west with each part labeled.

The remains recovered from the excavation pit include both tusks, mandible, ulna, radius, distal femur, teeth and other smaller bones. Because Unit II comprises a fluvial channel, these remains are oriented toward direction of flow, which is south-west for the tusks and south-east for the other remains. It is likely that the animal died and its carcass floated downstream. This could also account for much of the skeletal material being missing. In this scenario the heaviest remains sank, and possibly remained close to where the carcass came to rest, while the other bones, especially the smaller ones were transported downstream. Another scenario could be that the mammoth died near the banks of the ancient Brazos River the remains were then scavenged by carnivores, and thus the bones became dispersed. As the hydrology of the river changed, part of the remains were swept by the current, and transported downstream to the location where they were ultimately found.

As mentioned previously, the sand in which these remains were found in has been dated to 66,000 ± 7000 yr B.P. (UIC1383) using luminescence dating, thus predating the human occupation in the Americas by several tens of thousands of years (Dillehay, 2000; Fiedel, 1999; Fiedel, 2000; Waters and Stafford, 2007). However, this age is significant because it suggests that these are some of the oldest mammoth remains in Texas (see (Lundelius, 1972). Remains of other Pleistocene fauna were also recovered throughout the pit including camelids, bovids, and equids. For a complete list of the fauna, refer to Table 8.1. Most of these other faunal remains were surface finds. Apart from the mammoth remains, bones of two other animals were found in their stratigraphic context. One bone was found within the main excavation unit in Profile Trench 5 West, and the other was found in Locality 6 (see Figures 8.3 – 8.5). Both of these bones are most likely bovid remains and are associated with channel deposits. However, the bone found in Profile Trench 5 West is associated with Deweyville deposits, while the one found in Locality 6 is associated with Holocene deposits.

All remains recovered from the site are typical of fauna found on the Texas coast during the late Quaternary. Two species were identified – *Mammuthus columbi* and *Procyon lotor* (common name: raccoon), and the ecological niche that each occupied has been documented. The stomach contents of Columbian mammoths, as well as studies on their tooth enamel, and pollen found in association with them suggest that they were occupying grasslands (Hoppe, 2004; Mead et al., 1994; Owen-Smith, 1987), but some research also suggests that they may have been occupying forested, or more woody areas (Gillette and Madsen, 1993; Van Devender et al., 1987). The raccoon (*Procyon lotor*) today is known to inhabit woody areas, although it is extremely adaptable to other environments (Kurtén and Anderson, 1980; Mugaas et al., 1993), and that it probably occupied this ecological niche in the past as well (Martinez-Meyer et al., 2004). While this may suggest that the environment may have been a mix of a grassland with some wooded areas, however, these faunal remains were found in a fluvial environment, which suggests that they may have come from a different environment further upstream.

Table 8.1- Vernor Mammoth site faunal list.

Vernor Mammoth Site Faunal List

Identified to Species

Mammuthus columbi
Procyon lotor

Identified to Genus

Bison sp.
Equus sp.
Chelonia sp.

Identified to Family

Felidae
Canidae
Bovidae
Cervidae
Camelidae

Identified to Order

Artidactyla

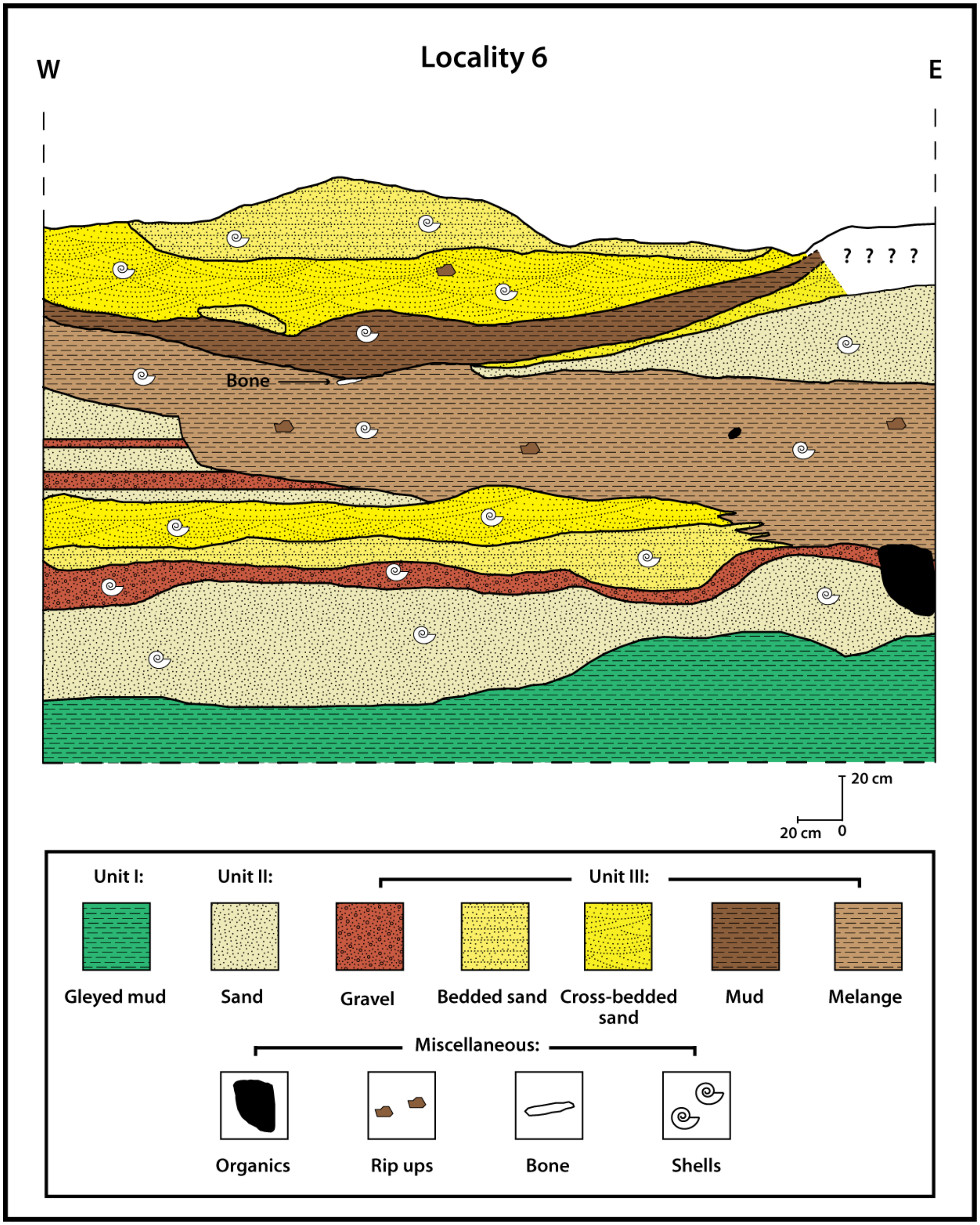


Figure 8.3 – Profile of Locality 6 showing location of bone. It is 13.95 meters below the top of the pit.

Figure 8.4 – Photograph of Locality 6 facing north and showing unit designations with trowel used for scale. Bone is not visible here.

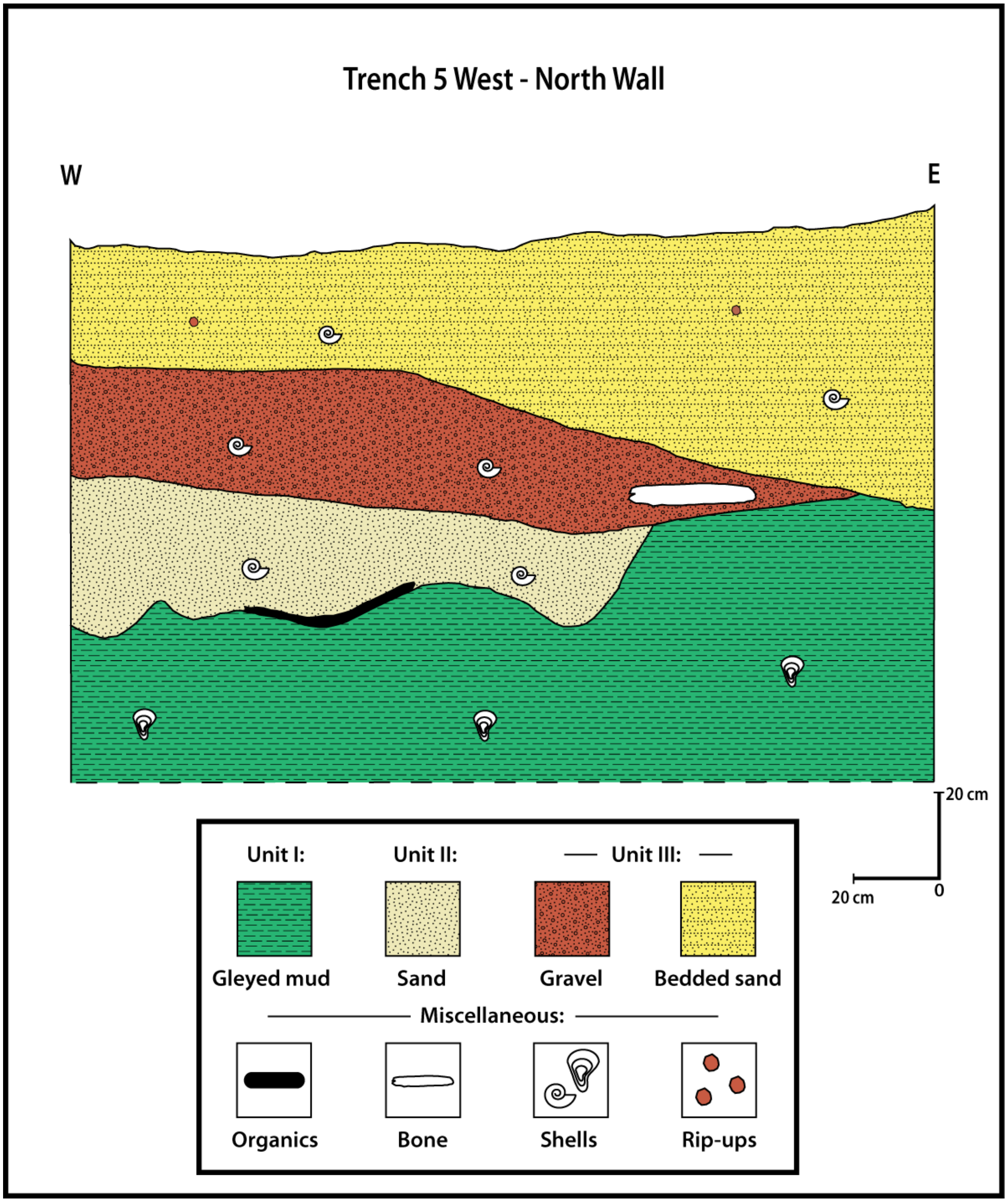


Figure 8.5 – Profile of Trench 5 West – North Wall showing location of bone.

Different types of invertebrates were recovered from this site. However, only *Crassostrea virginica* – the eastern oyster, was found in situ (see Figures 8.6 and 8.7).

C. virginica lives in estuaries and can tolerate a wide range in temperature and salinity. Normally, it lives in areas where the annual temperature range is between -2° C and 36°C, and the salinity is between 5 and 40 ppt (Shumway, 1996). Although *C. virginica* is neither a good proxy for climate or salinity due to its sizable range for each of those attributes, it is, however, still useful as an environmental indicator. Since it thrives in estuaries, it occupies a specific niche, the confluence of fresh and salt water. This species was found in the gleyed muds of the Beaumont Formation in situ as mentioned above. Therefore, this is compelling evidence that this unit was deposited in an

Figure 8.6 – Photograph of Locality 3 facing west showing location of *Crassostrea virginica* in situ. It is 7.0 meters below sea level. Trowel used for scale.

Figure 8.7 – *Crassostrea virginica* in situ facing west. Trowel used for scale.

estuarine environment, and based on this can be correlated to Oxygen Isotope Stage 5e (~125,000 yr B.P.), which represents the maximum flooding surface (Abdulah et al., 2004). During this time, sea level was at its highest and formed a delta inland from today's coast in the vicinity of the Vernor Mammoth site. Here an estuary formed in which the eastern oyster thrived.

Also recovered was *Rangia flexuosa* (common name – brown rangia) (see Figure 8.8). This species was recovered from the gravel of Unit II on which at least one of the mammoth tusks was resting on. This species is important to the study because it occurrence is uncommon and it was found closely associated with the mammoth tusks. This type of species is found in river-influenced areas (Andrews, 1977), and thus gives further credence that the deposits associated with the mammoth are fluvial in nature.

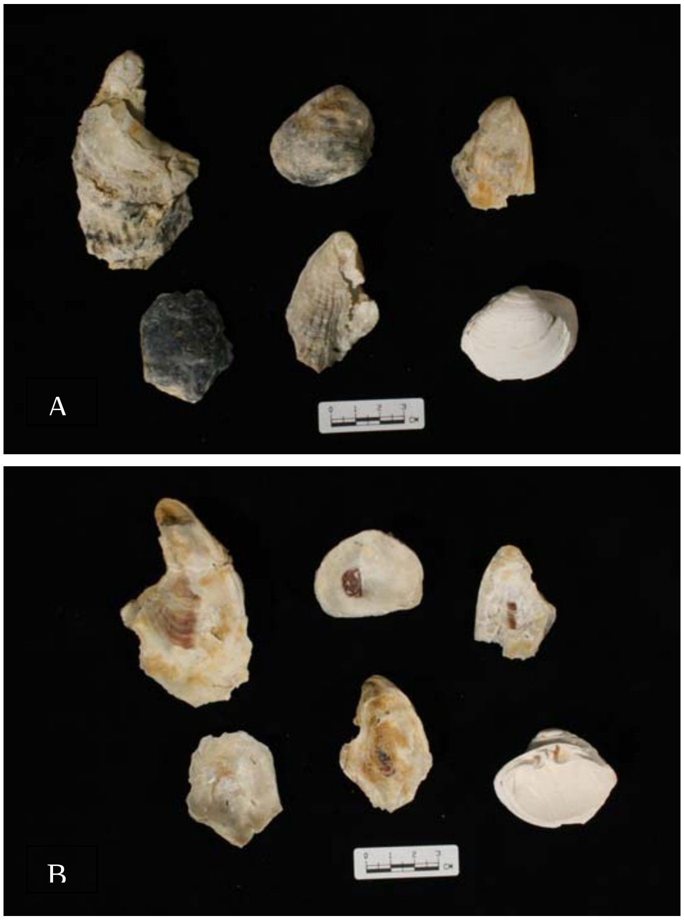


Figure 8.8 – Photographs of *Crassostrea virginica* and *Rangia flexuosa* (shown lower right) specimens. 8.6A- Dorsal side, 8.6B- Ventral side.

9. WOODEN BOWL

The wooden bowl was recovered from a sandy deposit, overlain by mud, which contained a high concentration of wooden debris in Unit III. The bowl measures 20.0 x 17.5 cm length-to-width and is about 6 cm deep (see Figure 9.1). Due to the site being located in a commercial sand pit, the original context of the bowl was destroyed by a backhoe. However using approximate estimates, a profile (Locality 5), near the original context was dug, cleaned, and recorded (see Figures 9.2 and 9.3). From pictures taken of the original context, a similar deposit was identified in Locality 5. This deposit contains a large amount of wooden debris and is associated with sandy deposits overlain by mud.

Figure 9.1- Photographs of the wooden bowl.

There are several reasons why the wooden bowl is significant. First, it is evidence of human activity at, or somewhere upstream from the site. Second, two radiocarbon dates, one from the wooden bowl, and another associated with the bowl were radiocarbon dated to 4205 ± 30 yr B.P (UCIAMS-12039), and 3760 ± 60 (GX-30849) respectively . These dates place the bowl somewhere in the Middle Holocene, far much younger than the Pleistocene date for the sands associated with the mammoth remains, or even the youngest deposits from within the main excavation unit, in which wood was radiocarbon dated to about 40,000 yr B.P. Vertically, the deposits are only about 1.5 meters apart, a very small amount considering the great time difference. This implies that there is a geological unconformity somewhere between the deposits found in the main excavation unit and those associated with the bowl. Lastly, the fact that it preserved so well is important given that wood is rarely preserved at sites in subtropical subhumid to humid environments. Preservation in this case occurred because the artifact was water logged, and it was water logged because, a) it was deposited in a fluvial environment, and b) the site rests below sea level.

As mentioned above, the wooden bowl was discovered in a sandy deposit, overlain by mud, which contained a high concentration of wooden debris. This context suggests that the bowl floated downstream from the location where it was recovered, and eventually it was buried by mud either from a floodplain or an oxbow lake. Although the exact distance it traveled is unknown, the fact that it was found intact and with no highly discernable damage may suggest that it did not travel very far, although this remains uncertain. According to the radiocarbon age, the cultural context of this bowl falls within the Middle Archaic (Aten, 1983; Hester, 1977; Jelks, 1978; Story, 1980), although the exact cultural group is unknown. This is due to the rather sparse amount of cultural evidence found in the upper Texas coast. Aten (1983: 155) believes that this scant amount of evidence is due to “unrecognizable diagnostic artifacts for the period.” He believes that these groups must have occupied floodplains and estuaries, features for which archaeological evidence is not readily observable.

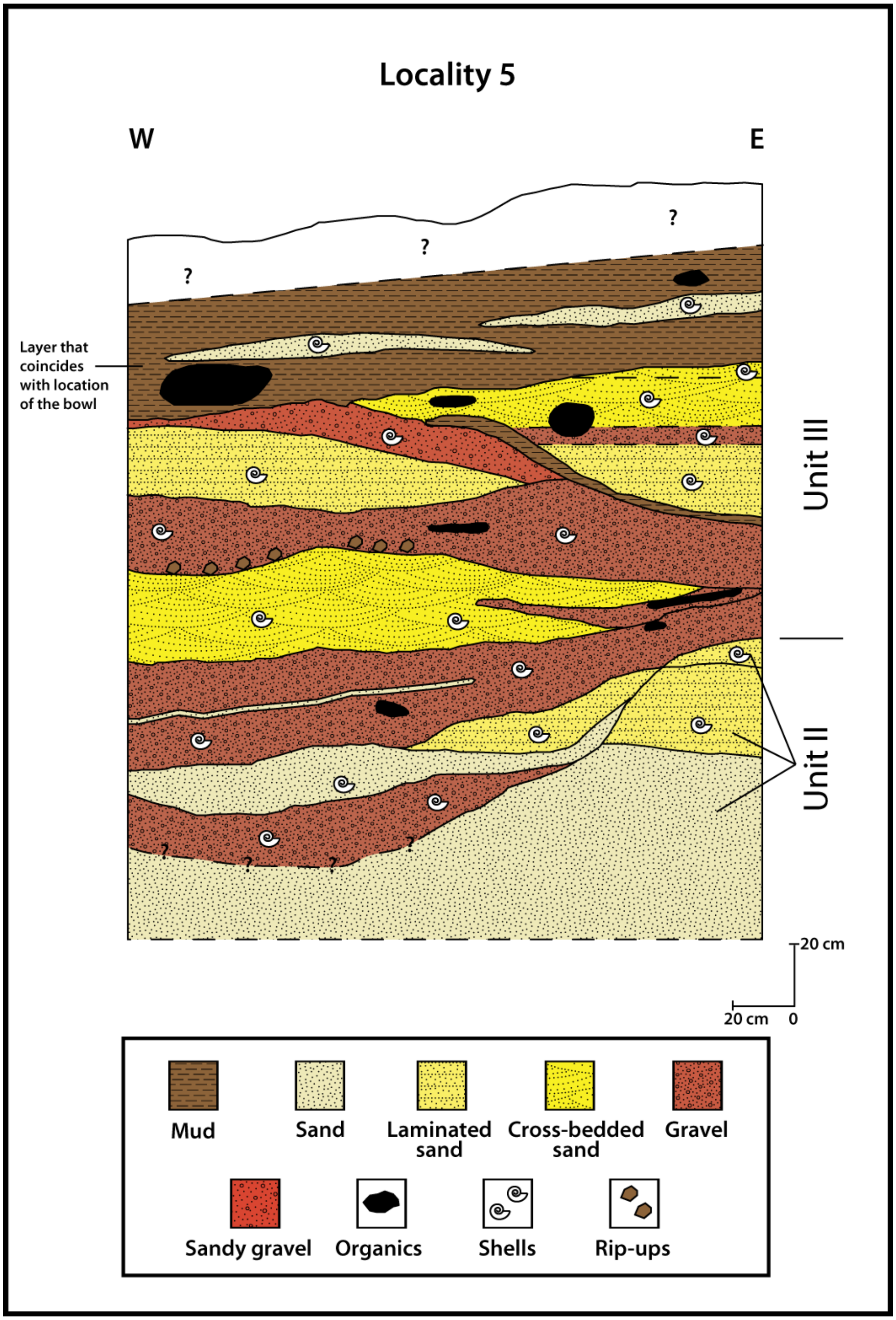


Figure 9.2 - Profile of Locality 5 showing layer associated with the location of the wooden bowl. It is 7.64 meters below sea level – approximately 16 meters below the top of the pit.

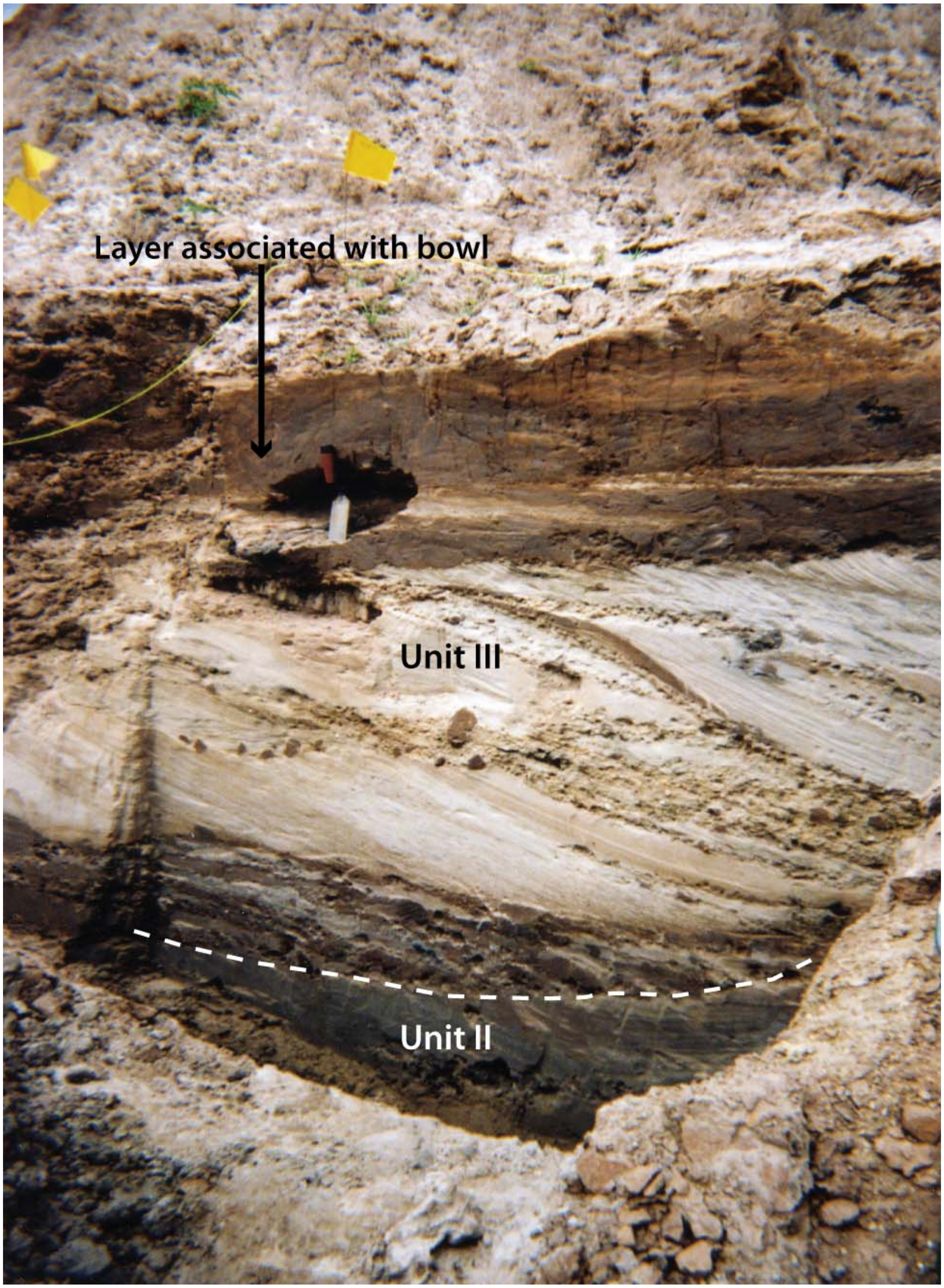


Figure 9.3 – Photograph of Locality 5 showing unit designations and layer associated with the location of wooden bowl.

10. GEOCHRONOLOGY

According to the faunal and artifact materials recovered and the avulsion event that caused the Brazos River to abandon the Oyster Creek meander belt, the geologic age for the Vernor Mammoth site ranges from about 125,000 to 1,000 yr B.P. This time period spans the Quaternary. Deposition at this site began during Oxygen Isotope Stage 5 (~125,000 yr B.P.), the period of maximum flooding stage when the sea level was highest in this area. An estuary was formed in which the eastern oyster, *Crassostrea virginica*, thrived, and deposition of the Beaumont Formation was occurring at this time. Also during this time the paleosol was formed.

At about 100,000 yr B.P., the sea level had dropped and culminated in Oxygen Isotope Stage 5c. This coastal regression created a fluvial/deltaic system seaward from the earlier delta, and caused what Nordt et al. (2004) have referred to as a dewatering effect. With further regression the river began to migrate seaward and began to erode the paleosol. Floodplain deposits characterize this period.

At about 70,000 yr B.P., during oxygen isotope Stage 4 (~75 – 58 ka B.P.), deposition of the Deweyville sediments began; this is the time period associated with the Vernor mammoth, and other Pleistocene megafauna. Sea level continued to fall during Stage 4, with a slight transgression leading up to Stage 3. Throughout Stage 3 (~58 – 25 ka B.P.), after a slight sea level rise, the trend was a general fall in sea level, which culminated in the Stage 2 lowstand. Therefore, deposition of the Deweyville alloformation complex lasted until oxygen isotope Stage 2. During this period (~25 – 12 ka B.P.) sea level was characterized by a lowstand that reached its nadir during the Late Glacial Maximum at about 18,000 yr B.P. These oxygen isotope periods are dominated by fluvial sediments cutting into the pre-existing Beaumont floodplain as the paleosol capping these deposits became eroded in some places yet buried in others. This began the construction of the Deweyville alloformation during the Late Pleistocene and continued until the end of the Pleistocene at about 10,000 yr B.P. (Farrand, 1990). Point bar deposits make up the majority of sediments at this site during deposition of the Deweyville.

After 10,000 yr B.P. , during Oxygen Isotope Stage 1 (~12 ka B.P. to present), as the Pleistocene comes to an end, the climate begins to warm and sea level begins to rise, culminating in the present-day sea level at about 3,500 yr B.P. (Aten, 1983). It is during the Holocene that the Oyster Creek meander belt of the Brazos River is active from about 4,000 to 1,000 yr B.P. It is also during this period that the wooden bowl comes to rest in the fluvial sediments of the Oyster Creek meander belt by some unknown Middle Archaic group somewhere upstream from its final resting place at about 4,000 yr B.P., during the initial phase of the Brazos River/Oyster Creek meander belt. Continued use of the meander belt by the river caused rapid burial of the wooden bowl, which contributed to its remarkable preservation. At about 1000 yr B.P., the Brazos River avulsed, thus abandoning the Oyster Creek meander belt and occupying the meander belt in which it is presently found.

11. CONCLUSION

The Vernor Mammoth site offers a glimpse into conditions that prevailed during the Late Pleistocene and throughout the Holocene. The stratigraphy shows a sequence of fluvial deposits throughout the history of the site that illustrates the conditions that once operated and make up the relict system found at the site. These sediments were deposited by an ancient Brazos River that once occupied the Oyster Creek meander belt. Luminescence and radiocarbon ages were used to demonstrate that there is no contemporaneous association between the mammoth remains and the wooden bowl – the mammoth remains date to the Late Pleistocene, to a time before humans had arrived in the Americas, while the bowl dates to the Middle Archaic by some unknown group. These dates in turn helped organize the Pleistocene faunal remains, paleosol, and a wooden bowl to act as reference points that help in ordering the stratigraphy into a geochronology that helps in understanding major episodes in the site's formation.

The recognition of unconformities was paramount to this study. The mammoth remains, paleosol, and wooden bowl aided in the recognition of periods where stability and non-deposition prevailed. This allowed for the site to be broken into three periods that coincide with known depositional units – Beaumont Formation, Deweyville allostratigraphic complex, and Holocene deposits. The Beaumont Formation dates to the Late Pleistocene and is composed of estuarine and floodplain deposits. The Deweyville allostratigraphic complex dates for the Late Pleistocene to the beginning of the Holocene. This set of deposits is characterized by a series of channel and point bar sediments that are laterally accreted rather than vertically stacked. This period of time is characterized by large meander scars that reflect a period of much greater discharge. The Holocene deposits are composed of channel, mostly point bar deposits that differ from Deweyville deposits in that they are vertically stacked.

This thesis has contributed to our understanding of the upper Texas Gulf Coast Plain during the Late Quaternary. In addition, the geochronology presented here provides important contexts for two rare finds: the mammoth and the wooden bowl. The mammoth is one of the earliest mammoth remains found in Texas, and the wooden bowl helps shed light on the cultures of the Middle Archaic, a group that is underrepresented in the archaeological record. Future studies involving more radiocarbon dates from organic materials from various layers of Units II and III will help further refine the geochronology presented here.

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APPENDIX A

The following figures represent columns of localities shown in Figure 3.2 that were not mentioned in the main body of the text. They were included to offer a clearer picture of stratigraphy of the site.

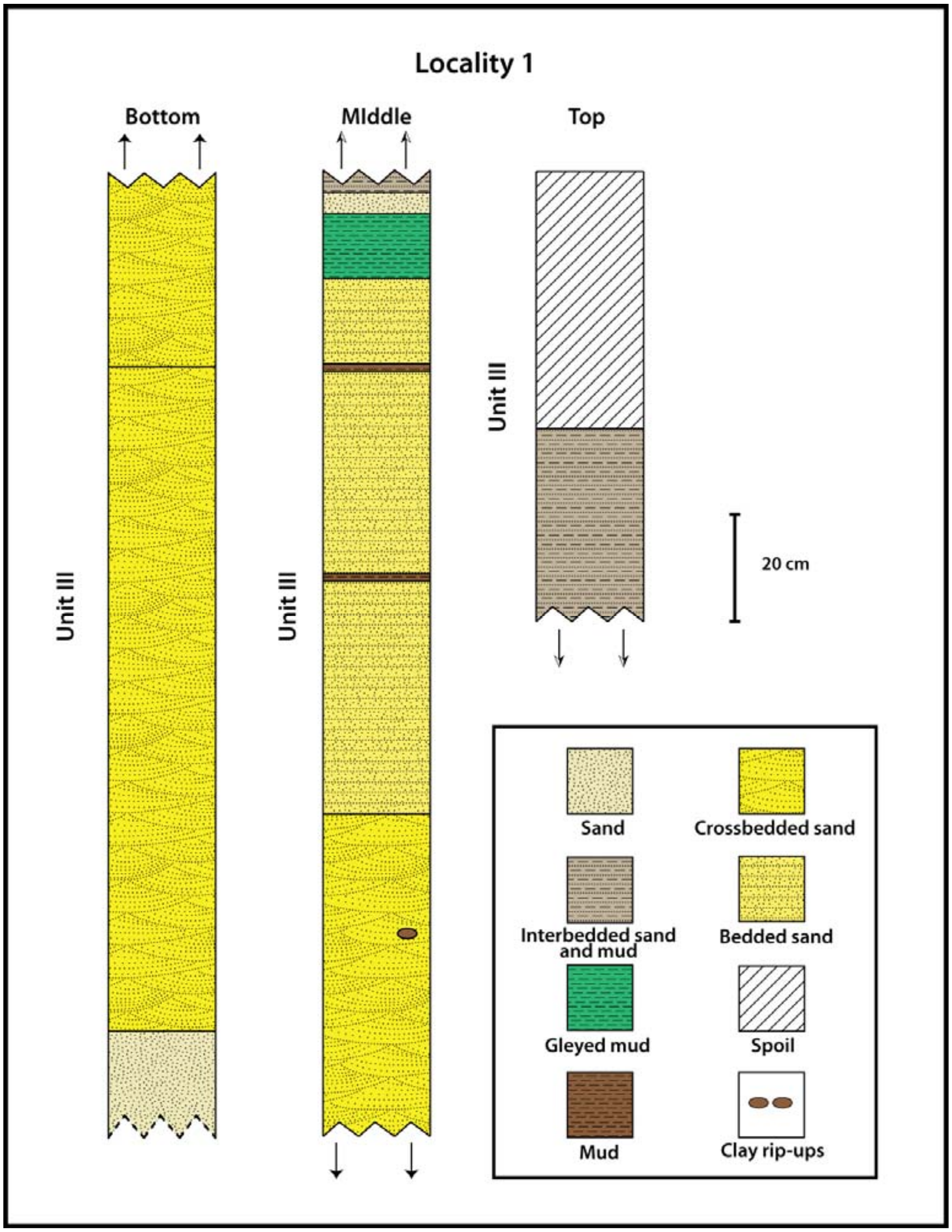


Figure A.1 – Stratigraphic column of Locality 1. It is 4.59 meters above sea level.

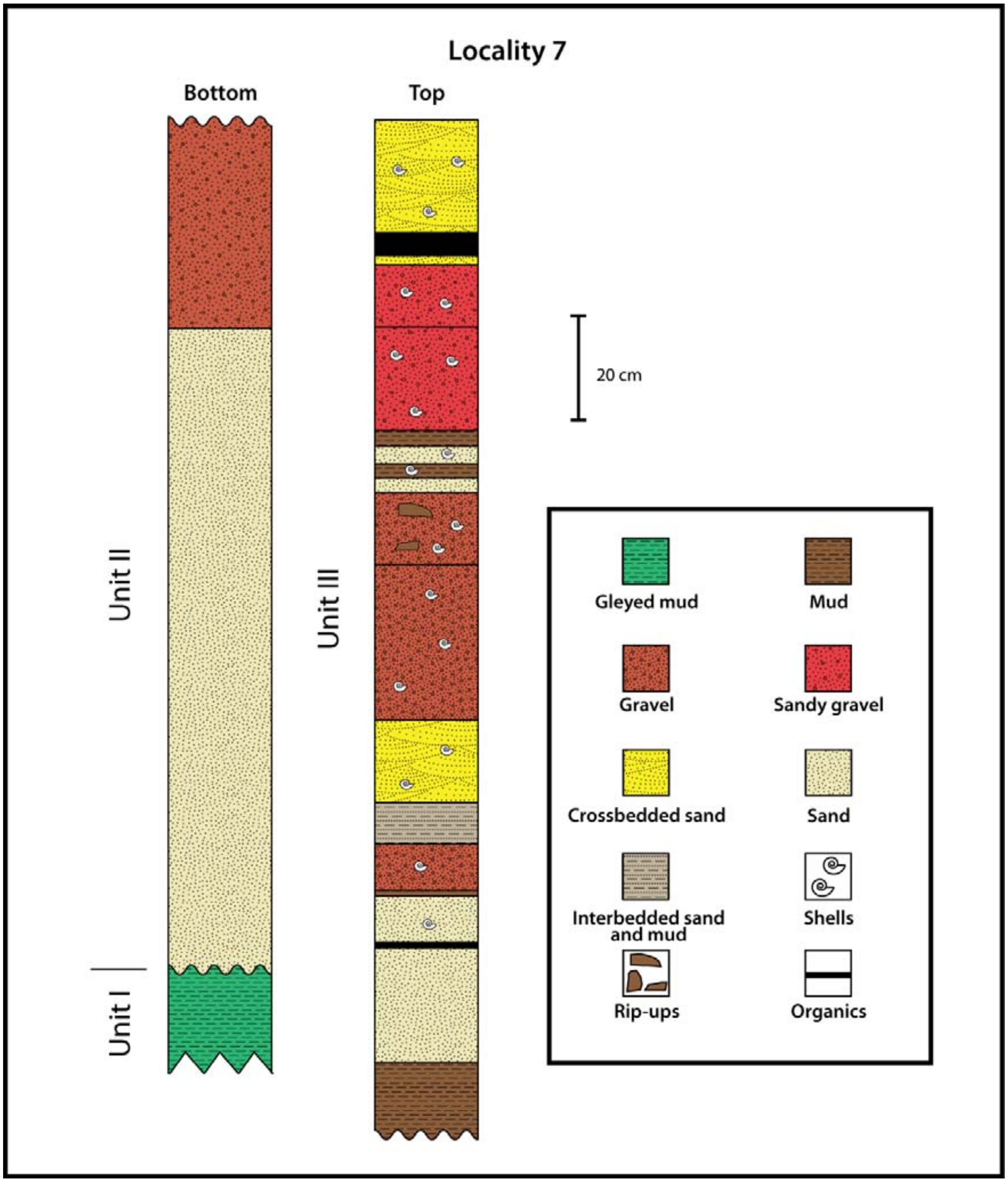


Figure A.2 – Stratigraphic column of Locality 7. It is 6.16 meters below sea level.

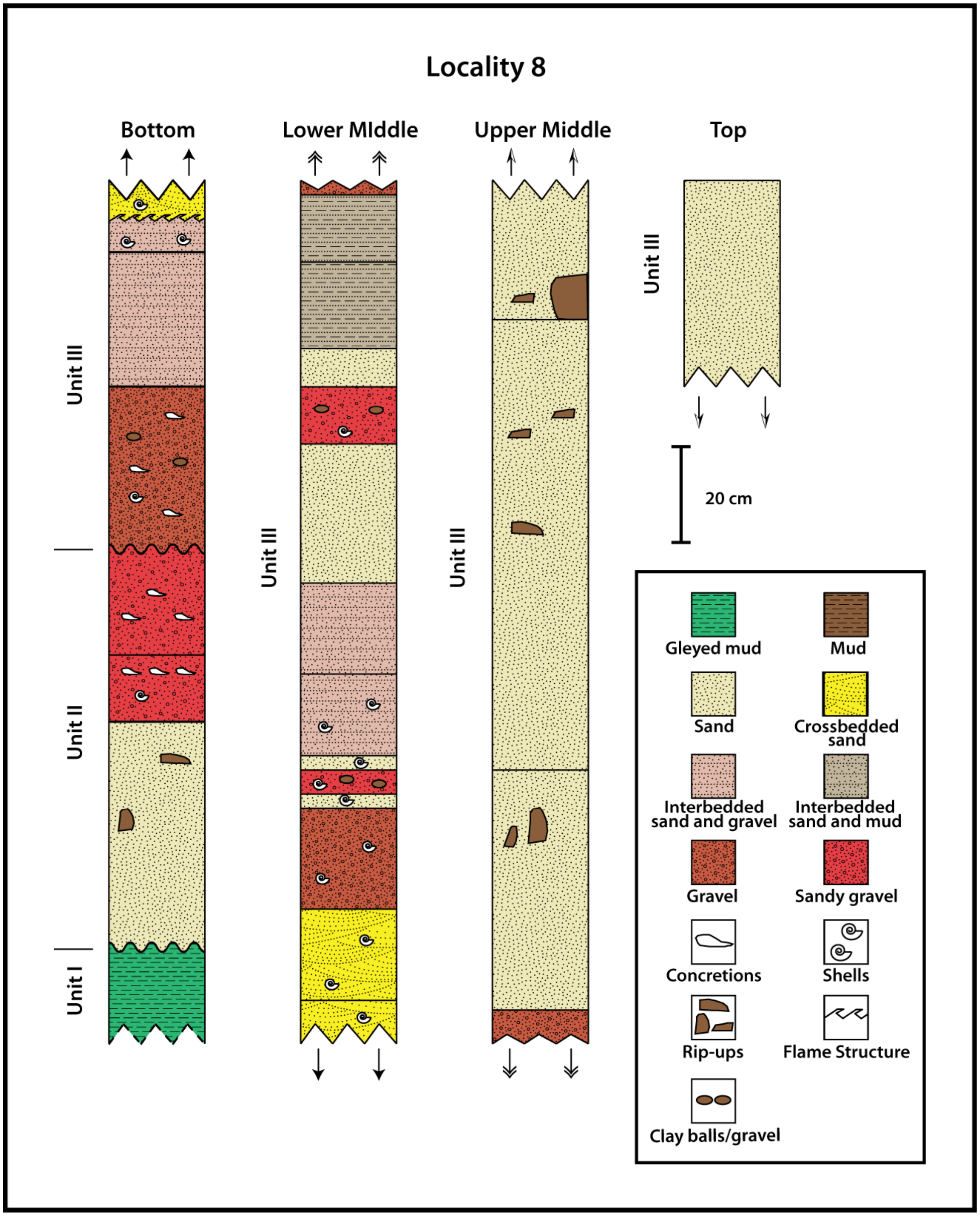


Figure A.3 – Stratigraphic profile of Locality 8. It is 2.4 meters below sea level.

APPENDIX B

The following figures represent profiles from within the main excavation unit which appears as “Mammoth Pit” in Figure 3.2, and whose location within the main excavation unit is shown in Figure 3.1, but were not mentioned in the main body of the text. These figures were included to offer a clearer picture of stratigraphy immediately associated with the mammoth remains.

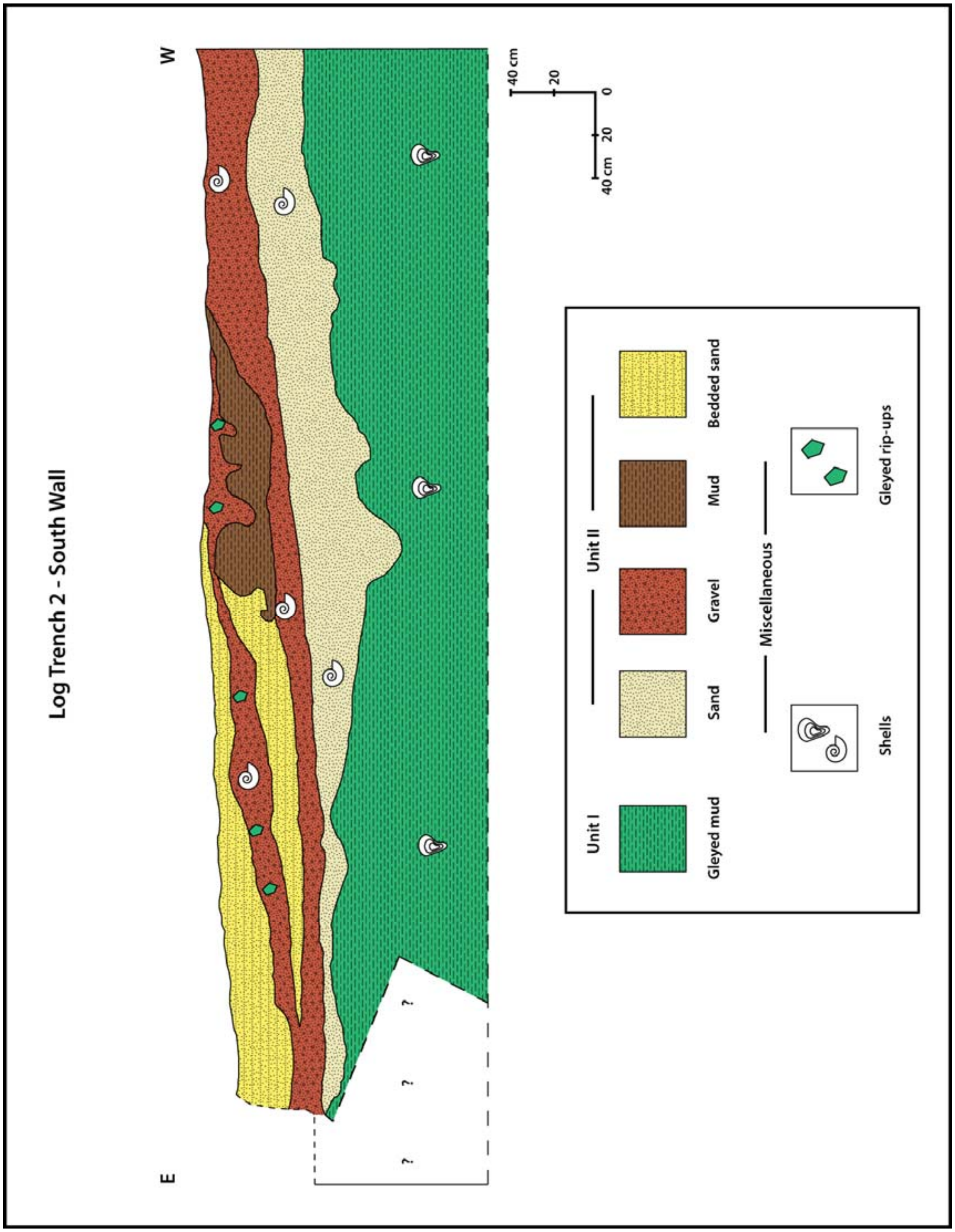


Figure B.1 – Profile of Log Trench 2 – South Wall located within main excavation unit.

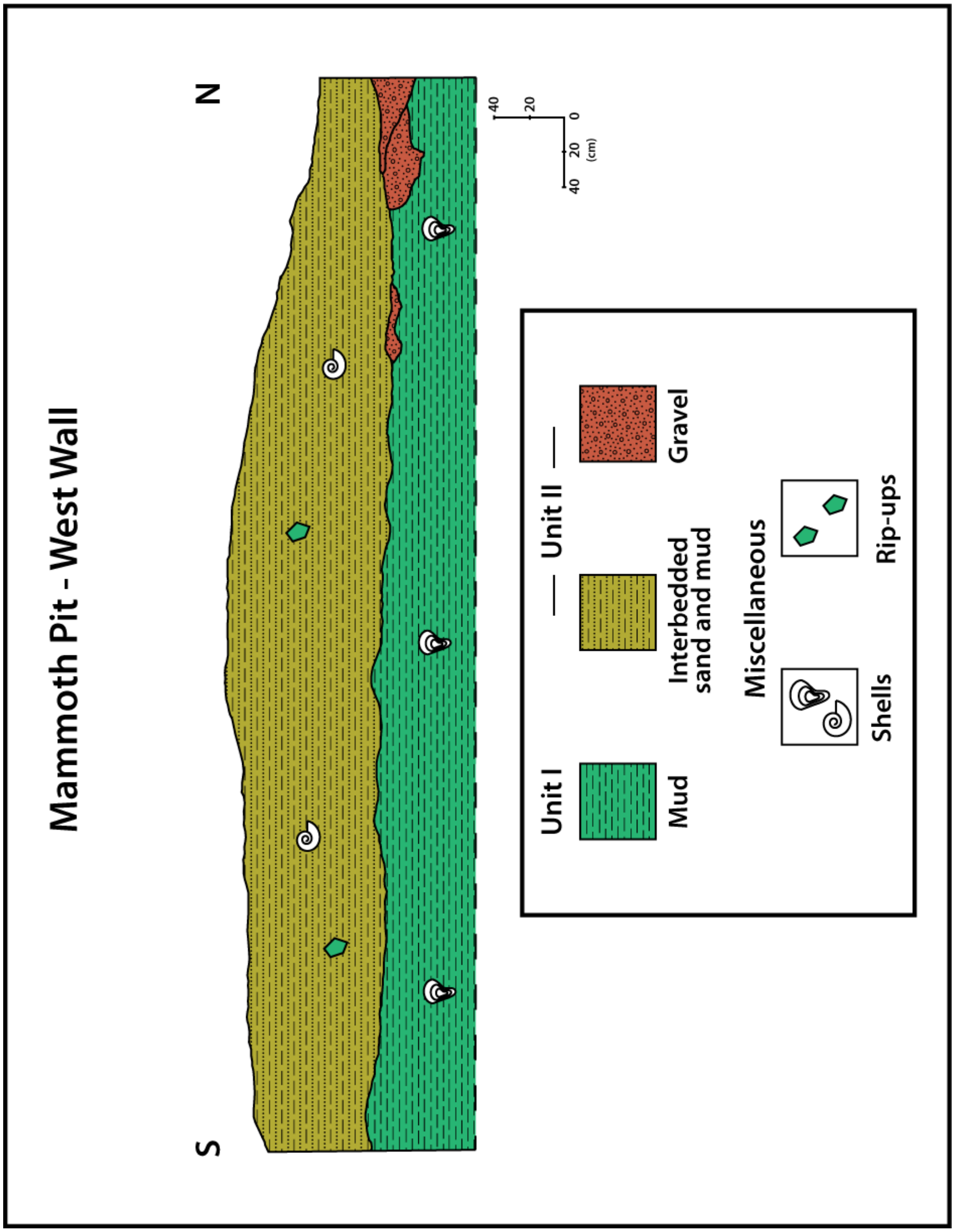
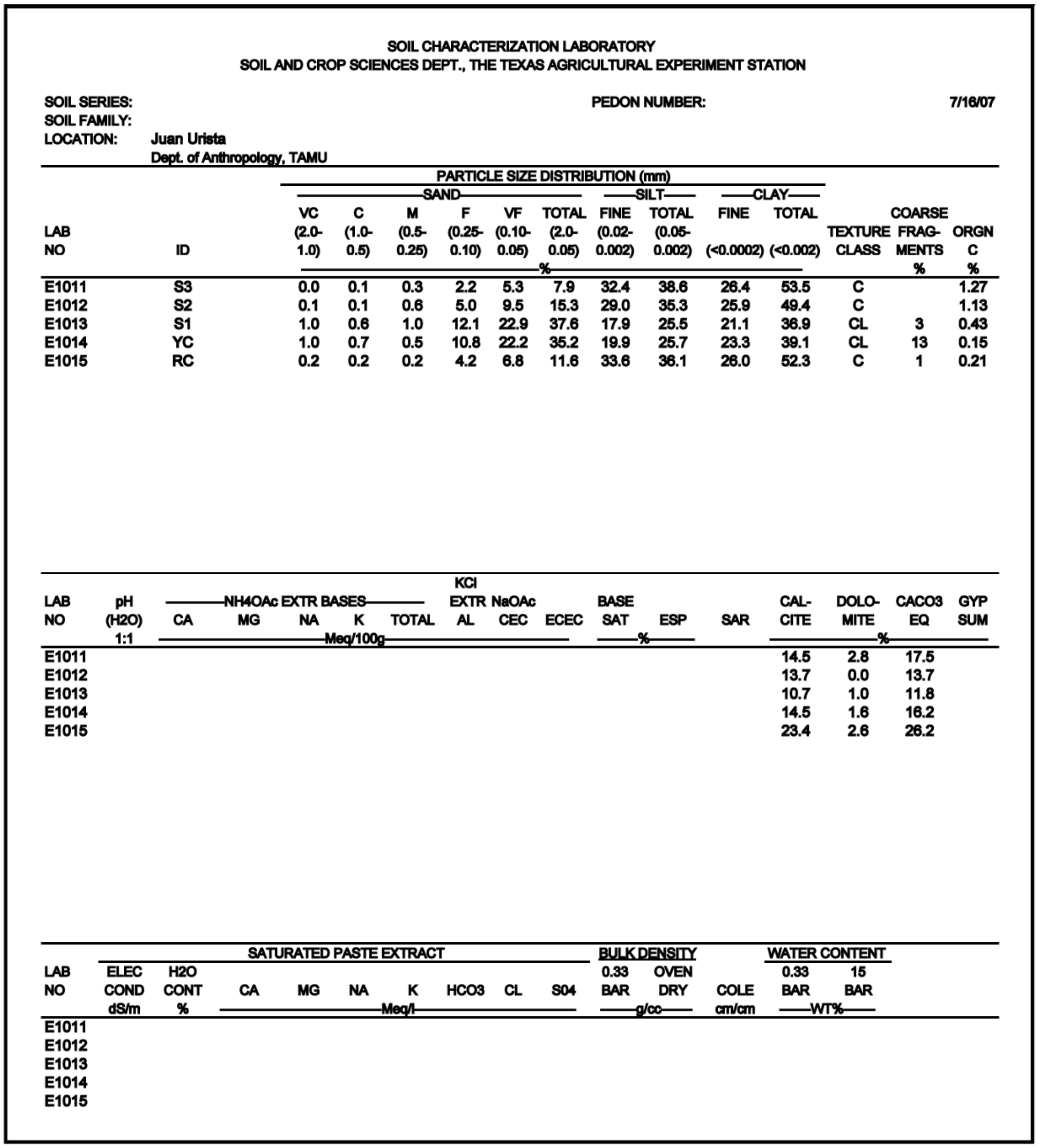


Figure B.2 – Profile of Mammoth Pit – West Wall located within main excavation unit.

APPENDIX C

Presented here are the soil characterization lab results of various attributes of the paleosol which were summarized in Table 7.1.



SOIL CHARACTERIZATION LABORATORY
SOIL AND CROP SCIENCES DEPT., THE TEXAS AGRICULTURAL EXPERIMENT STATION

SOIL SERIES: PEDON NUMBER: 7/16/07
SOIL FAMILY:
LOCATION: Juan Urista
Dept. of Anthropology, TAMU

		PARTICLE SIZE DISTRIBUTION (mm)												
		SAND						SILT		CLAY				
LAB NO	ID	VC (2.0-1.0)	C (1.0-0.5)	M (0.5-0.25)	F (0.25-0.10)	VF (0.10-0.05)	TOTAL (2.0-0.05)	FINE (0.02-0.002)	TOTAL (0.05-0.002)	FINE (<0.0002)	TOTAL (<0.002)	TEXTURE CLASS	COARSE FRAG-MENTS	ORGN C
		%											%	%
E1011	S3	0.0	0.1	0.3	2.2	5.3	7.9	32.4	38.6	26.4	53.5	C		1.27
E1012	S2	0.1	0.1	0.6	5.0	9.5	15.3	29.0	35.3	25.9	49.4	C		1.13
E1013	S1	1.0	0.6	1.0	12.1	22.9	37.6	17.9	25.5	21.1	36.9	CL	3	0.43
E1014	YC	1.0	0.7	0.5	10.8	22.2	35.2	19.9	25.7	23.3	39.1	CL	13	0.15
E1015	RC	0.2	0.2	0.2	4.2	6.8	11.6	33.6	36.1	26.0	52.3	C	1	0.21

		NH4OAc EXTR BASES														
LAB NO	pH (H2O) 1:1	CA	MG	NA	K	TOTAL	KCl EXTR AL	NaOAc CEC	ECEC	BASE SAT	ESP	SAR	CAL-CITE	DOLO-MITE	CACO3 EQ	GYP SUM
		Meq/100g								%			%			
E1011													14.5	2.8	17.5	
E1012													13.7	0.0	13.7	
E1013													10.7	1.0	11.8	
E1014													14.5	1.6	16.2	
E1015													23.4	2.6	26.2	

	SATURATED PASTE EXTRACT									BULK DENSITY			WATER CONTENT	
LAB NO	ELEC COND	H2O CONT	CA	MG	NA	K	HCO3	CL	S04	0.33 BAR	OVEN DRY	COLE	0.33 BAR	15 BAR
	dS/m	%	Meq/l							g/cc		cm/cm	WT%	
E1011														
E1012														
E1013														
E1014														
E1015														

Table C.1 – Table showing soil characterization of “Vernor” paleosol.

APPENDIX D

Presented here are the various attributes of the stratigraphic layers and their sediments. Information gathered from the field includes length, thickness, structure, presence, size, and shape of gravels, presence and size of concretions, presence of shells, presence of organics, and presence and size of rip-ups. Information gathered in the lab includes texture, plasticity, stickiness, color, sorting, sphericity, angularity, size, and reaction to HCl. Texture, plasticity, and stickiness were done by hand. Color was identified using a Munsell Color book, using moist samples, and although done in the lab, always next to window under natural light. Sorting, sphericity, angularity, and size were done using a 10x hand lens; size was determined according to the Wentworth scale (Wentworth, 1922). 10 M HCl was used to test for presence of calcium carbonate. Also included are comments, notes, and observations mainly from the field, but otherwise stated if any of these comments were made in the lab. Locality 3 is not included here because no information on the attributes of the sediments were collected – only its location, distance, depth, the fact that it correlates to Unit I, and that it contains many remains of *Crassostrea virginica* were noted as previously mentioned in the main body of the text.

Table D.1 – Table showing length, thickness, texture, and plasticity of layers and sediments.

Profile/Column	**Layer**	**Length (m)**	**Thickness (cm)**	**Texture**	**Plasticity**
Log Trench 1 - West Wall N-S		6.51			
	1			Clay	Plastic
	2			Sandy loam	Nonplastic
	3			Clay loam (maybe silty clay loam)	Plastic
	4			Sandy clay loam	Nonplastic
	5			Sandy clay loam	Nonplastic
	6			Sandy loam	Nonplastic
	7			Sandy loam	Nonplastic
	8			Sandy clay loam	Nonplastic
	9			Sandy clay loam	Nonplastic
	10			Sandy clay loam	Nonplastic

Profile/Column	**Layer**	**Length (m)**	**Thickness (cm)**	**Texture**	**Plasticity**
Log Trench 1 - West Wall N-S Contd.	11			Sandy loam	Nonplastic
	12			Sandy loam	Nonplastic
	13			Sandy clay loam	Nonplastic
Log Trench 2 - South Wall		4.8			
	1			Clay	Plastic
	2			Sandy loam	Nonplastic
	3			Sandy clay loam	Nonplastic
	4			Clay	Plastic
	5			Sandy clay loam	Nonplastic
	6			Silty clay loam	Plastic
	7			Sandy loam	Nonplastic
Mammoth Pit - West Wall		6			
	1			matrix - Sandy clay loam	Nonplastic
	2			Sandy clay loam	Nonplastic
	3			Sandy loam	Nonplastic
Trench 5 West		2			
	1			Clay	Plastic
	2			Sandy loam	Nonplastic
	3			Sandy clay loam	Nonplastic
	4			Sandy loam	Nonplastic
Eastside of Mammoth Tusks		1.2			
	1			Sandy loam	Nonplastic
	2			Sandy clay loam	Plastic ???
	3			Loamy sand	Nonplastic
Westside of Mammoth Tusks		1.5			
	1			Clay	Plastic
	2			Sandy clay loam	Plastic ???
	3			Loamy sand	Nonplastic
Locality 1			> 428		
	1		???	Sandy loam	Nonplastic
	2			Sandy clay loam	Nonplastic
	3		100	Sandy loam (scl?)	Nonplastic
	4		100		
	Lighter			Sandy loam	Nonplastic
	Darker			Sandy loam	Nonplastic
	5		12	Clay or clay loam	Plastic
	6		4	Sandy clay loam	Nonplastic
	7		40	Sandy loam	Nonplastic
	8		48		
Locality 2 - Paleosol			119		
	A1		34		

Profile/Column	Layer	Length (m)	Thickness (cm)	Texture	Plasticity
Locality 2 – Paleosol Contd.	A2		20		
	Bw		9		
	Bk		27		
	Ck		29		
Locality 4		0.655			
	Step 1A		???		
	Step 1B		18	scl or cl	Plastic
	Step 1C		20	Sandy loam	Nonplastic
	Step 1D		47	??? No texture	???
	Step 1E		14	Sandy loam	Nonplastic
	Step 2A1		36	Sandy loam	Nonplastic
	Step 2A2		60	Sandy clay loam	Nonplastic
	Step 2B1		31	Sandy clay loam	Nonplastic
	Step 2B2		10	Sandy clay loam	Nonplastic
	Step 3A				
	Step 3B1		40	Sandy loam	Nonplastic
	Step 3B2		27	Sandy clay loam	Nonplastic
	Step 3B/C		16	Sandy loam	Nonplastic
	Step 3C1		36	Sandy loam	Nonplastic
	Step 3C2		43	Sandy clay loam	Nonplastic
	Step 3C3		32	???	Nonplastic
Locality 5		2			
	1			Sandy loam	Plastic ???
	2			Sandy clay loam	Plastic ???
	3			Sandy clay loam	Plastic ???
	4			Loamy sand	Nonplastic
	5			Sandy clay loam	Plastic ???
	6			Sandy clay loam	Plastic
	7			Sand - scl; mud - clay	Plastic/plastic
	8			Sandy clay loam	Plastic
	9			Sandy clay loam	Plastic
	10			Unable to texture	
	11			Sandy loam	Nonplastic
	12			Sandy loam	Nonplastic
	13			Sandy clay	Plastic
	14a			Sandy loam	Nonplastic
	14b			Sandy loam	Nonplastic
	14c			Sandy loam	Nonplastic
	14d			Sandy loam	Nonplastic
	15			Mud, unable to adeg. texture	Plastic
	16			Sandy clay loam	Plastic

Profile/Column	**Layer**	**Length (m)**	**Thickness (cm)**	**Texture**	**Plasticity**
Locality 5 Contd.	17			Sandy loam	Plastic
	18			Silty clay loam or silty loam	Plastic
Locality 6		4			
	1			Mud, unable to adeq. texture	Plastic
	2			Sandy loam	Nonplastic
	3			sl or scl	Plastic
	4			Sandy loam	Nomplastic
	5			Sandy loam	Nonplastic
	6			Sandy loam	Nonplastic
	7			Sandy loam	Plastic ???
	8			Sandy loam	Nonplastic
	9			???	???
	10			Clay	Plastic
	11			Sandy loam	Nonplastic
	12			???	
	13			Sandy loam	Nonplastic
Locality 7		0.9			
	1		???		
	2		124	Sandy loam	Nonplastic
	3		44	??? Sand/loam combo	
	4		14	Clay	Plastic
	5		22	Sandy loam, maybe loamy sand	Nonplastic
	6		10	Sandy loam, maybe loamy sand	Nonplastic
	7		10	Maybe sandy loam	Nonplastic
	8		8	Sandy loam	Nonplastic
	9		16	Sandy loam; maybe loamy sand	Nonplastic
	10		30	Difficult to texture	???
	11		18	Some type of loam	
	12		12	Sandy loam - higher clay content	Nonplastic
	13		20	Difficult to texture	???
	14		12	Difficult to texture	???
	15		20	Sandy clay loam	Nonplastic
Locality 8		0.645			
	Lower Step A		47	Sandy clay loam	Nonplastic
	Lower Step B		35 (entire Unit B)	Sandy loam	Nonplastic

Profile/Column	**Layer**	**Length (m)**	**Thickness (cm)**	**Texture**	**Plasticity**
Locality 8 Contd.	Lower Step B		see above	Sandy clay	Plastic
	Lower Step C		34	Sandy clay loam	Plastic ???
	Lower Step D		28	Sandy loam or loamy sand	Nonplastic
	Lower Step E		7	Sandy loam	Nonplastic
	Lower Step F1		17	Sandy clay loam	Nonplastic
	Lower Step F2		19	Sandy clay loam	Nonplastic
	Lower Step G		21	scl and clay	np and p
	Lower Step H		3	Clay loam	Nonplastic
	Lower Step I		5	Sandy loam	Nonplastic
	Lower Step J		3	Sandy loam	Nonplastic
	Lower Step K		17	Sandy clay loam	Nonplastic
	Higher Step A		19	Sandy loam	Nonplastic
	Higher Step B		29	Sandy loam	Nonplastic
	Higher Step C		12 and 7	Sandy loam	Nonplastic
	Higher Step D		19	Sandy loam	Nonplastic
	Higher Step E		14	Sandy loam	Nonplastic
	Higher Step F		10	Sandy clay loam	Nonplastic
	Higher Step G		50	Sandy loam	Nonplastic
	Higher Step H		94	Sandy loam	Nonplastic
	Higher Step I		72	Sandy loam	Nonplastic

Table D.2 – Table showing stickiness, color, and sorting of the sediments.

Profile/Column	**Layer**	**Stickiness**	**Color**	**Sorting**
Log Trench 1 - West Wall N-S	1	Very sticky	5BG 6/1 (Greenish Gray) - 70%; 5YR 3/4 (Yellowish Red) - 30%	
	2	Slightly sticky	10YR 5/3 (Brown)	Moderately sorted
	3	Moderately sticky	7.5YR 3/4 (Dark brown)	Moderately sorted
	4	Slightly sticky	Between 10YR 4/2 (dark grayish brown) and 10YR 4/3 (brown/dark brown)	Poorly sorted
	5	slightly sticky	10YR 5/3 (brown); clay rip-ups? - 5YR 4/4 (reddish brown)	Moderately sorted
	6	Slightly sticky	10YR 6/3 (pale brown)	well sorted
	7	Slightly sticky	10YR 5/3 (brown)	Very poorly sorted
	8	Slightly sticky	10YR 5/2 (grayish brown)	Well sorted
	9	Slightly sticky	matrix - 10YR 4/3 (brown/dark brown); gley - 2.5Y 6/2 (light brownish gray); mud rip-ups - 7.5YR 4/4 (brown/dark brown)	???
	10	Slightly sticky	10YR 4/3 (brown/dark brown)	Poorly sorted
	11	Nonsticky	10YR 6/3 (pale brown)	Well sorted
	12	Slightly sticky	10YR 5/2 (grayish brown)	Very well sorted
	13	Slightly sticky	matrix - 10YR 4/3 (brown/dark brown); clay - 7.5YR 5/4 (brown)	Very poorly sorted
Log Trench 2 - South Wall	1	Very sticky	5BG 6/1 (greenish gray) - 70%; 5YR 3/4 (yellowish red) - 30%	
	2	Slightly sticky	10YR 5/2 (grayish brown)	Very well sorted
	3	Slightly sticky	matrix - 10YR 4/3 (brown/dark brown); gley - 2.5Y 6/2 (light brownish gray); mud rip-ups - 7.5YR 4/4 (brown/dark brown)	???
	4	Very sticky	Between 10YR 4/3 (brown/dark brown) and 10YR 3/3 (dark brown)	
	5	Slightly sticky	~10YR 5/3 (brown)	Very well sorted
	6	Moderately sticky	7.5YR 3/4 (dark brown); gleyed balls - 5Y 6/1 (gray)	???

Profile/Column	**Layer**	**Stickiness**	**Color**	**Sorting**
Log Trench 2 - South Wall Contd.	7	Nonsticky	Between10YR 5/3 (brown) and 10YR 4/3 (brown/dark brown); gleyed balls - 5Y 5/1 (gray)	Well sorted
Mammoth Pit - West Wall	1	Slightly sticky	10YR 4/3 (brown/dark brown)	
	2	Slightly sticky	10YR 4/3 (brown/dark brown)	Poorly sorted
	3	Slightly sticky	Between 10YR 5/3 (brown) and 10YR 4/3 (brown/dark brown)	Well sorted
Trench 5 West	1	Very sticky	5BG 6/1 (greenish gray) - 70%; 5YR 3/4 (yellowish red)	
	2	Slightly sticky	10YR 5/3 (brown)	Moderately sorted
	3	Slightly sticky	10YR 4/3 (brown/dark brown)	Poorly sorted
	4	Slightly sticky	Between 10YR 5/3 (brown) and 10YR 4/3 (brown/dark brown)	Well sorted
Eastside of Mammoth Tusks	1	Slightly sticky	10YR 5/2 (grayish brown)	Very well sorted
	2	Slightly sticky	matrix - 10YR 4/3 (brown/dark brown); clay balls - 2.5Y 6/2 (light brownish gray)	???
	3	Slightly sticky	10YR 4/3 (brown/dark brown)	Well sorted
Westside of Mammoth Tusks	1	Very sticky	5BG 6/1 (greenish gray) - 70%; 5YR 3/4 (yellowish red) - 30%	
	2	Slightly sticky	matrix - 10YR 4/3 (brown/dark brown); clay balls - 2.5Y 6/2 (light brownish gray)	???
	3	Slightly sticky	10YR 4/3 (brown/dark brown)	Well sorted
Locality 1	1	Slightly sticky	2.5Y 6/2 (light brownish gray)	Very well sorted
	2	Slightly sticky	10YR 5/4 (yellowish brown)	Very well sorted
	3	Slightly sticky	~2.5Y 6/2 (light brownish gray)	Well sorted
	4			
	Lighter	Slightly sticky	2.5Y 6/2 (light brownish gray)	Very well sorted
	Darker	Slightly sticky	2.5Y 6/4 (light yellowish brown)	Very well sorted
	Lighter	Slightly sticky	2.5Y 6/2 (light brownish gray)	
	5	Very sticky?	7.5YR 5/4 (brown); mottles - 10YR 7/1 (light gray)	
	6	Slightly sticky	10YR 5/8 (yellowish brown)	Well sorted
	7	Nonsticky	10YR 5/4 (yellowish brown)	Well sorted ???
	8			

Profile/Column	**Layer**	**Stickiness**	**Color**	**Sorting**
Locality 2 - Paleosol	A1		10YR 4/3 (brown/dark brown)	
	A2		10YR 4/4 (dark yellowish brown)	
	Bw		10YR 5/6 (yellowish brown)	
	Bk		10YR 5/6 (yellowish brown); mottles - 5Y 7/1 (light gray)	
	Ck		5YR 4/6 (yellowish red) or 4/4 (reddish brown); mottles - 5Y 7/1 (light gray)	
Locality 4	Step 1A			
	Step 1B	Moderately sticky	5YR 4/3 (reddish brown)	
	Step 1C	Slightly sticky	10YR 4/4 (dark yellowish brown)	Very well sorted
	Step 1D	???	10YR 4/4 (dark yellowish brown)	Very well sorted
	Step 1E	Slightly sticky	10YR 5/4 (yellowish brown) (closer to) or 10YR 4/4 (dark yellowish brown); lighter than previous layer	Very well sorted
	Step 2A1	Slightly sticky	10YR 4/4 (dark yellowish brown)	Very well sorted
	Step 2A2	Slightly sticky	Either 10YR 5/4 (yellowish brown) or 10YR 4/4 (dark yellowish brown)	Very well sorted
	Step 2B1	Slightly sticky	7.5YR 5/4 (brown); rip-ups - 7.5YR 4/4 (brown/dark brown)	Mod. Sorted ???
	Step 2B2	Slightly sticky	7.5YR 4/4 (brown/dark brown)	Very well sorted
	Step 3A			
	Step 3B1	Slightly sticky	10YR 5/4 (yellowish brown)	Very well sorted
	Step 3B2	ss to ms	10YR 5/4 (yellowish brown)	grv. Lenses - ps
	Step 3B/C	ss to ms	10YR 5/4 (yellowish brown)	Moderately sorted
	Step 3C1	Slightly sticky	Between 10YR 6/4 (light yellowish brown) and 10YR 5/4 (yellowish brown)	Very well sorted
	Step 3C2	Moderately sticky	10YR 5/4 (yellowish brown)	Very well sorted
	Step 3C3	ss to ms	10YR 4/4 (dark yellowish brown)	Very well sorted
Locality 5	1	Slightly sticky	10YR 6/3 (pale brown)	Well sorted ???
	2	Moderately sticky	10YR 5/3 (brown)	Well sorted

Profile/Column	Layer	Stickiness	Color	Sorting
Locality 5 Contd.	3	Moderately sticky	10YR 5/3 (brown)	Mod. well sorted
	4	Slightly sticky	10YR 6/3 (pale brown)	Poorly sorted
	5	Slightly sticky	10YR 5/4 (yellowish brown)	Well sorted
	6	Slightly sticky	10YR 5/4 (yellowish brown)	Well sorted
	7	ss/vs	10YR 5/3 (brown); 10YR 4/3 (brown/dark brown)	Moderately sorted
	8	Moderately sticky	10YR 5/3 (brown)	Well sorted
	9	Slightly sticky	10YR 5/3 (brown)	Poorly sorted
	10	???	All - 10YR 5/4 (yellowish brown); clay balls - 5YR 4/4 (reddish brown)	Poorly sorted
	11	Slightly sticky	10YR 5/3 (brown)	Well sorted
	12	Slightly sticky	10YR 5/3 (brown)	Poorly sorted
	13	Moderately sticky	5YR 4/3 (reddish brown)	
	14a	Slightly sticky	10YR 6/3 (pale brown)	Very well sorted
	14b	Slightly sticky	10YR 4/3 (dark brown)	Very poorly sorted
	14c	Slightly sticky	10YR 5/3 (brown)	Well sorted
	14d	Slightly sticky	10YR 5/3 (brown)	Well sorted
	15	Moderately sticky	7.5YR 4/2 (brown/dark brown)	
	16	Slightly sticky	10YR 5/4 (yellowish brown)	Moderately sorted
	17	Slightly sticky	7.5YR 4/4 (brown/dark brown)	Moderately sorted
	18	ss to ms	7.5YR 4/4 (brown/dark brown)	
Locality 6	1	ms to vs	5YR 4/3 (reddish brown); mottles - 5Y 7/1 (light gray)	
	2	Slightly sticky	2.5Y 5/2 (grayish brown)	Well sorted ???
	3	Slightly sticky	All - 10YR 4/3 (brown/dark brown)	Poorly sorted
	4	Slightly sticky	10YR 6/2 (light brownish gray)	Well sorted
	5	Slightly sticky	10YR 5/3 (brown)	Moderately sorted
	6	Slightly sticky	Sand - 10YR 6/2; clay - 7.5YR 4/4 (brown/dark brown)	Moderately sorted
	7	Slightly sticky	Sand - 10YR 4/4 (dark yellowish brown); clay - 7.5YR 5/4 (brown)	Poorly sorted
	8	Slightly sticky	10YR 5/3 (brown)	Very well sorted

Profile/Column	**Layer**	**Stickiness**	**Color**	**Sorting**
Locality 6 Contd.	9	???	Gravel - 10YR 5/4 (yellowish brown); mud - 5YR 3/4 (dark reddish brown)	Very poorly sorted
	10	Moderately sticky	5YR 4/3 (reddish brown)	
	11	Slightly sticky	10YR 5/3 (brown); clay balls - 7.5YR 4/2 (brown/dark brown)	Poorly sorted
	12		10YR 5/4 (yellowish brown)	Very poorly sorted
	13	Slightly sticky	10YR 5/3 (brown)	Poorly sorted
Locality 7	1			
	2	Slightly sticky	Bet. 10YR 6/2 (light brownish gray) and 10YR 6/3 (pale brown); mud - 7.5YR 3/4 (dark brown)	
	3		10YR 4/3 (brown/dark brown)	Very poorly sorted
	4	Very sticky	10YR 4/3 (brown/dark brown)	
	5	Slightly sticky	10YR 5/3 (brown)	Well sorted
	6	Slightly sticky	10YR 4/3 (brown/dark brown)	Moderately sorted
	7	Slightly sticky	10YR 5/4 (yellowish brown)	Very poorly sorted
	8	Slightly sticky	10YR 5/3 (brown); Mud balls - 10YR 4/3 (brown/dark brown)	Well sorted
	9	Slightly sticky	~10YR 6/3 (pale brown)	Well sorted
	10	???	7.5YR 3/2 (dark brown)	Very poorly sorted
	11		10YR 4/3 (brown/dark brown); mud - 7.5YR 3/4 (dark brown)	
	12	Slightly sticky	10YR 4/3 (brown/dark brown)	Moderately sorted
	13	???	7.5YR 3/4 (dark brown)	Very poorly sorted
	14	???	10YR 5/3 (brown)	Very poorly sorted
	15	Slightly sticky	~10YR 4/3 (brown/dark brown) (bit lighter than this)	Moderately sorted

Profile/Column	**Layer**	**Stickiness**	**Color**	**Sorting**
Locality 8	Lower Step A	Slightly sticky	10YR 5/3 (brown); clay balls - 7.5YR 4/4 (dark brown/brown)	Moderately sorted
	Lower Step B	Slightly sticky	10YR 5/4 (yellowish brown)	Well sorted
	Lower Step B	Very sticky	7.5YR 4/4 (brown/dark brown)	
	Lower Step C	Slightly sticky	10YR 4/4 (dark yellowish brown)	Poorly sorted
	Lower Step D	Nonsticky	10YR 5/3 (brown); mud - 10YR 4/4 (dark yellowish brown)	Well sorted
	Lower Step E	Nonsticky	10YR 5/4 (yellowish brown)	Very well sorted
	Lower Step F1	Slightly sticky	10YR 5/3 (brown)	Well sorted
	Lower Step F2	Slightly sticky	10YR 5/3 (brown)	Well sorted
	Lower Step G	sl and ???	sand - 10YR 5/4 (yellowish brown); clay - 10YR 4/4 (dark yellowish brown)	Well sorted
	Lower Step H	Moderately sticky	10YR 4/3 (brown/dark brown)	Very well sorted
	Lower Step I	Slightly sticky	10YR 4/4 (dark yellowish brown)	Poorly sorted
	Lower Step J	Slightly sticky	10YR 4/4 (dark yellowish brown); fleck - 10YR 3/2 (very dark grayish brown)	Moderately sorted
	Lower Step K	Slightly sticky	10YR 4/3 (brown/dark brown)	Poorly sorted
	Higher Step A	Slightly sticky	Between 10YR 5/4 (yellowish brown) and 10YR 4/4 (dark yellowish brown)	Well sorted
	Higher Step B	Slightly sticky	~10YR 4/4 (dark yellowish brown)	Well sorted
	Higher Step C	Slightly sticky	10YR 4/3 (brown/dark brown)	???
	Higher Step D	Slightly sticky	10YR 4/4 (dark yellowish brown)	Very well sorted
	Higher Step E	Moderately sticky	10YR 5/4 (yellowish brown)	Very well sorted
	Higher Step F	Slightly sticky	Sand - 10YR 4/4 (dark yellowish brown); clay - 7.5YR 4/4 (brown/dark brown)	Well sorted
	Higher Step G	Slightly sticky	Sand - 10YR 4/3 (brown/dark brown)	

Profile/Column	**Layer**	**Stickiness**	**Color**	**Sorting**
Locality 8 Contd.	Higher Step H	Slightly sticky	Sand - 10YR 4/4 (dark yellowish brown); mud - 10YR 2/1 (black); other mud - 7.5YR 3/4 (dark brown)	
	Higher Step I	Slightly sticky	Sand - bet. 10YR 5/4 (yellowish brown) and 10YR 4/4 (dark yellowish brown); mud - 10YR 4/3 (brown/dark brown)	

Table D.3 – Table showing sorting (matrix), sphericity, angularity and size of sediments.

Profile/Column	**Layer**	**Sorting (matrix)**	**Sphericity**	**Angularity**	**Size**
Log Trench 1 - West Wall N-S	1				
	2	Very well sorted	High	Subangular to subrounded	medium (lower) to medium (upper)
	3				
	4	Very well sorted	High	Subangular to subrounded	fine (upper) to medium (lower)
	5	Moderately sorted	High	subangular to subrounded	fine (lower) to medium (upper)
	6		High	Subrounded	fine (upper) to medium (upper)
	7	Poorly sorted	High	Subangular to subrounded	fine (lower) to very coarse (upper)
	8		High	Subangular to subrounded	fine (lower) to medium (upper)
	9	well sorted	High	angular to subrounded	fine (lower) (most) to medium (lower) (rare)
	10	Moderately sorted	High	subangular to subrounded	fine (lower) to medium (upper) (rare)
	11		High	subangular to subrounded	fine (lower) to medium (upper) (rare)
	12		High	Subangular	medium (lower) to medium (upper)
	13	Well sorted	High	subangular to subrounded	fine (lower) to fine (upper)
Log Trench 2 - South Wall	1				
	2		High	Subangular	medium (lower) to medium (upper)
	3	Well sorted	High	angular to subrounded	fine (lower) (most) to medium (lower) (rare)
	4				
	5		High	Mostly subrounded	very fine (upper) to fine (lower)
	6	Well sorted	mostly low	subangular to subrounded	very fine (upper) to medium (upper)
	7		High	mostly subrounded	very fine (upper) to fine (upper)
Mammoth Pit - West Wall	1	Well sorted	mostly high	Subangular to subrounded	fine (lower) to medium (lower)

Profile/Column	**Layer**	**Sorting (matrix)**	**Sphericity**	**Angularity**	**Size**
Mammoth Pit - West Wall Contd.	2	Well sorted	in between	Mostly subangular	fine (lower) to medium (upper)
	3	Well sorted	High	Subangular to subrounded	fine (lower) to medium (lower)
Trench 5 West	1				
	2	Very well sorted	High	Subangular to subrounded	Medium (lower) to medium (upper)
	3	Well sorted	in between	Mostly subangular	
	4		High	Subangular to subrounded	fine (lower) to medium (lower)
Eastside of Mammoth Tusks	1		High	Subangular	medium (lower) to medium (upper)
	2	Well sorted	High	subrounded to subangular	fine (upper) to medium (upper)
	3		Low to high	subangular to rounded	fine (lower) to medium (lower)
Westside of Mammoth Tusks	1				
	2	Well sorted	High	Subrounded to subangular	fine (upper) to medium (upper)
	3		Low to high	Subangular to rounded	fine (lower) to medium (lower)
Locality 1	1		High	Subangular to subrounded	fine (lower)
	2		High	Undetermined	fine (lower) to fine (upper)
	3		High	Subangular to subrounded	fine (lower) to medium (lower); coarser than Unit 7
	4				
	Lighter		High	Subangular to subrounded	fine (upper) to medium (lower)
	Darker		High	Subangular to subrounded	fine (upper) to medium (lower)
	5				
	6		High	Subangular to subrounded	fine (lower) to fine (upper)
	7		High	Subangular to subrounded	fine (lower) to fine (upper)
	8				
Locality 2 - Paleosol	A1				
	A2				
	Bw				
	Bk				
	Ck				

Profile/Column	**Layer**	**Sorting (matrix)**	**Sphericity**	**Angularity**	**Size**
Locality 4	Step 1A				
	Step 1B				
	Step 1C		High	Subangular to subrounded	fine (lower)
	Step 1D		High	angular to subronded	very fine (upper) to fine (lower)
	Step 1E		High	Subangular to subrounded	fine (upper) to medium (lower)
	Step 2A1		High	Subangular to subrounded	fine (lower) to fine (upper)
	Step 2A2		High	Angular to subrounded	fine (lower) to fine (upper)
	Step 2B1	Very well sorted?	High	Angular to subrounded	fine (lower) to medium (lower)
	Step 2B2		High	Angular to subangular	very fine (upper) to fine (lower)
	Step 3A				
	Step 3B1		High	Angular to subangular	fine (lower) to medium (lower)
	Step 3B2	Very well sorted	High	Angular to subrounded	fine (lower) to medium (lower)
	Step 3B/C		High	Angular to subangular	fine (lower) to medium (lower) (mostly)
	Step 3C1		High	Angular to subrounded	fine (lower) to medium (lower)
	Step 3C2		High	Subangular to subrounded	fine (upper) to medium (lower)
	Step 3C3		High	Subangular to subrounded	fine (upper) to medium (lower)
Locality 5	1		High	Subrounded to rounded	fine (lower) to fine (upper)
	2		High	angular to subrounded	very fine (upper) to fine (upper)
	3		High	subangular to subrounded	fine (upper) to medium (upper)
	4	Well sorted	High	subangular to subrounded	very fine (upper) to medium (lower) - mostly fine (lower)
	5		High	subangular to subrounded	very fine (upper) to fine (lower)
	6		High	subangular to subrounded	very fine (upper) to fine (upper)

Profile/Column	**Layer**	**Sorting (matrix)**	**Sphericity**	**Angularity**	**Size**
Locality 5 Contd.	7		High	subangular to subrounded	very fine (upper) (mostly) to medium (lower) w/ few vc (u) grains
	8		Low	subrounded to rounded	fine (lower) to medium (lower)
	9	???	Hard to say	subangular to subrounded	Matrix - fine (lower) to medium (lower)
	10	???	Hard to say	subangular to subrounded	Matrix - fine (upper) to coarse (lower)
	11		Mostly high	subangular to subrounded	fine (upper) to medium (lower)
	12	???	High	subangular to subrounded	fine (upper) to medium (lower)
	13				
	14a		Mostly low	Angular to subangular	fine (upper) to medium (lower)
	14b	Very well sorted	Hard to say	Subangular to subrounded	fine (upper) to medium (lower)
	14c		Mostly high	subrounded to rounded	fine (upper) to medium (lower)
	14d		Mostly high	subrounded to rounded	medium (lower) to medium (upper)
	15				
	16		High	subangular to subrounded	fine (low) to medium (low)
	17		High	subangular to angular	Medium (low) ???
	18				
Locality 6	1				
	2		Mostly high	angular to subrounded	fine (upper)
	3		High - low	Angular to subrounded	fine (lower) to ~2.51 cm
	4		High	Subangular to subrounded	medium (lower) to medium (upper)
	5		High	Subangular to subrounded	medium (lower) to medium (upper)
	6		High	Subangular to subrounded	fine (lower) to very coarse (clay balls)
	7		Low	Angular to subrounded	medium (lower) to very coarse
	8		high - low	Subangular to subrounded	fine (lower) to fine (upper)

Profile/Column	Layer	Sorting (matrix)	Sphericity	Angularity	Size
Locality 6 Contd.	9		???	Rounded to angular	fine (lower) to 4.64
	10	sand - md. sorted	Mostly high	subangular to subrounded	Medium
	11		High	Subangular to subrounded	fine (upper) to very coarse - upt to 3.12 cm
	12				fine (lower) to 3.46 cm
	13	Well sorted	Mostly low	Angular to subangular	fine (upper) to medium (lower)
Locality 7	1				
	2	Very well sorted	High	Subangular to subrounded	fine (upper) to medium (lower)
	3		High	Angular to subangular	fine (upper) to very coarse (lower)
	4				
	5		High	Subangular to subrounded	fine (upper) to medium (upper)
	6		High	Angular to subrounded	fine (lower) to medium (lower)
	7	Moderately sorted	High	Angular to subangular	fine (lower) to very coarse (???)
	8		High	Subangular to subrounded	fine (lower) to medium (upper)
	9		High	Angular to subrounded	fine (lower) to medium (lower)
	10		High	Angular to subangular	fine (lower) to very coarse (???)
	11	Well sorted	High	Subangular to subrounded	fine (lower) to medium (lower)
	12		High	Angular to subangular	very fine (upper) to coarse (low)
	13	Moderately sorted	High	Angular to subangular	medium (lower) tp coarse (upper)
	14	Well sorted	High	Angular to subangular	very fine (upper) to medium (upper)
	15		High	Angular to subangular	fine (lower) to coarse (lower)
Locality 8	Lower Step A	Very well sorted	High	Subangular to subrounded	fine (lower) to fine (upper)
	Lower Step B		High	angular to subangular	fine (upper) to medium (upper)
	Lower Step B				

Profile/Column	**Layer**	**Sorting (matrix)**	**Sphericity**	**Angularity**	**Size**
Locality 8 Contd.	Lower Step C		High	Angular to subangular	medium (lower) to medium (upper)
	Lower Step D		Mostly high	subangular to subrounded	fine (upper) to medium (lower)
	Lower Step E		High	Subangular to subrounded	fine (lower) to fine (upper)
	Lower Step F1		High	Subangular to subrounded	fine (upper) to medium (lower)
	Lower Step F2		High	angular to subangular	fine (lower) to medium (lower)
	Lower Step G		High	angular to subangular	fine (lower) to medium (upper)
	Lower Step H		High	Subangular to subrounded	fine (upper)
	Lower Step I	Well sorted	High	Subangular to subrounded	fine (lower) to fine (upper)
	Lower Step J		Mostly high	angular to subangular	fine (lower) to coarse (upper) - mostly bet fn (lwr) & med (lwr)
	Lower Step K	Well sorted	High	subangular to subrounded	fine (lower) to medium (lower)
	Higher Step A		High	subangular to subrounded	fine (lower) (mostly) to medium (lower)
	Higher Step B		High	Subangular to subrounded	fine (lower) to medium (upper) - mostly fn (lwr) to fn (upr)
	Higher Step C	Very well sorted	High	Subangular to subrounded	fine (lower) to fine (upper)
	Higher Step D		High	Subangular to subrounded	fine (lower) to fine (upper)
	Higher Step E		High	Angular to subrounded	fine (upper) to fine (lower)
	Higher Step F		High	Subangular to subrounded	
	Higher Step G	Well sorted	High	Subangular to subrounded	fine (lower) to medium (lower)
	Higher Step H	Well sorted	High	Angular to subrounded	very fine (upper) to fine (upper)
	Higher Step I	Well sorted	High	Angular to subrounded	fine (lower) to medium (upper)

Table D.4 – Table showing structure, gravel size, gravel shape, and concretions of the sediments.

Profile/Column	**Layer**	**Structure**	**Gravel size (cm)**	**Gravel shape**	**Concretions (cm)**
Log Trench 1 - West Wall N-S	1	Massive			
	2	Massive	Clay balls - 1.54		
	3			Equant	
	4	Massive	Clay balls - ~1.07	Equant	
	5		Clay balls - gravel size	Bladed?	~0.82
	6	Massive			
	7		clay balls up to 5.36		
	8	Laminations			
	9		~4.0		
	10	Laminations	clay balls - ~0.5 cm	Equant?	
	11	Massive			
	12				
	13	Massive	average - 2.43		Up to 5.9
Log Trench 2 - South Wall	1	Massive			
	2				
	3		~4.0		
	4	Massive			
	5	Laminated			
	6		gleyed ball - ~2.15	Prolate	
	7	Laminated	gleyed balls - ???		
Mammoth Pit - West Wall	1		up to 2.87	Eqnt./Blded.	
	2		clay balls up to 5.3 cm	sl. prol. to eq.	
	3	Laminated	Only two - ~3.5 & ~5.0		
Trench 5 West	1	Massive			
	2	Massive	clay balls - ~1.54		
	3		clay balls - up to 5.3	sl. pro. to eq.	
	4	Laminated			
Eastside of Mammoth Tusks	1				
	2		0.6 to 3.5		
	3	Laminated			
Westside of Mammoth Tusks	1	Massive			
	2		0.6 - 3.5		
	3	Laminated			
Locality 1	1				
	2	Cross-bedded			

Profile/Column	**Layer**	**Structure**	**Gravel size (cm)**	**Gravel shape**	**Concretions (cm)**
Locality 1 Contd.	3	Cross-bedded			
	4				
	Lighter	???			
	Darker	???			
	5				
	6		mottled mud - ~0.40	???	
	7				
	8				
Locality 2 - Paleosol	A1				
	A2				
	Bw				
	Bk				
	Ck				
Locality 4	Step 1A				
	Step 1B				Yes
	Step 1C				
	Step 1D	???	???		
	Step 1E	Laminated	clay balls - ~1.0	Equant	
	Step 2A1	Laminated			
	Step 2A2	Laminated			
	Step 2B1				
	Step 2B2				
	Step 3A				
	Step 3B1				
	Step 3B2		coarse to 1.89		
	Step 3B/C				
	Step 3C1				
	Step 3C2				
	Step 3C3	Laminated			
Locality 5	1				
	2	Laminated			
	3	Laminated			
	4		1.21	Bladed	5.85
	5	Laminated			
	6	Laminated			
	7	Laminated?	Clay balls - 4.7		
	8	Cross-bedded			
	9				
	10		~2.0; clay bs. ~5.0	gr. - bl. to eq.	
	11	Laminated			
	12		1.5	???	

Profile/Column	**Layer**	**Structure**	**Gravel size (cm)**	**Gravel shape**	**Concretions (cm)**
Locality 5 Contd.	13				
	14a	Laminated			
	14b		up to 2.6	???	
	14c	Cross-bedded			
	14d	Cross-bedded			
	15				
	16				
	17				
	18				
Locality 6	1				
	2	Massive			
	3		up to 2.51	bld. To eq.	
	4	Laminated			
	5	Flaser?	clay balls - ~0.71	Equant	
	6		clay balls - ~2.6	Equant	
	7	Melange???	???	Eq. to blded.	
	8	Massive			
	9	???	up to 4.64	Eq. to prol.	
	10	Massive			
	11	Laminated	up to 3.12	Eq. to angular	
	12	Cross-bedded	cb - ~3.46; gr. ~0.78	Angular	
	13	Laminated	clay - up to 2.66	Bladed	
Locality 7	1				
	2				
	3		2.09	Eq., pr., bl	~6.56 h, 6.44 w
	4				
	5				
	6		~1.60	???	~3.36
	7		3.22 or 3.55	Various	
	8	Laminated	mud balls - ~1.95	???	
	9	Cross-bedded			
	10		~0.54	???	
	11		avg. - ~1.13	Eq., ob, pr.	
	12	Laminated			
	13		avg. ~0.51 and up to 1.88	Eq., ob, pr.	
	14		Up to 1.71	Eq., ob., bl.	
	15	Cross-bedded			

Profile/Column	**Layer**	**Structure**	**Gravel size (cm)**	**Gravel shape**	**Concretions (cm)**
Locality 8	Lower Step A		clay balls - ~2.95	???	
	Lower Step B				
	Lower Step B		???	Equant	~3.04
	Lower Step C		5.53	bladed	Yes
	Lower Step D	Laminated			
	Lower Step E	Laminated			
	Lower Step F1	Cross-bedded			
	Lower Step F2	Cross-bedded			
	Lower Step G		clay balls - up to 3.85	???	
	Lower Step H				
	Lower Step I		0.88	blded & oblt	
	Lower Step J				
	Lower Step K	Laminated	~0.68	blded & eq	
	Higher Step A	Laminated			
	Higher Step B	Massive			
	Higher Step C		clay balls - ~1.80	???	
	Higher Step D	Laminated			
	Higher Step E	Laminated			
	Higher Step F		clay balls - ~1.42	???	
	Higher Step G		clay balls - ~ 12.0	???	
	Higher Step H		clay balls - ~1.84	???	
	Higher Step I		clay balls - ~ 4.0	???	

Table D.5 – Table showing presence of shells, reaction to HCl, organics, and rip-ups.

Profile/Column	**Layer**	**Shells**	**Reaction to HCl**	**Organics**	**Rip-ups (cm)**
Log Trench 1 - West Wall N-S	1	Yes	Violently		
	2	Yes/Coll.	Violently		
	3	Yes	Violently		
	4	Yes/Coll.	Violently		
	5	Yes	Violently		~4.0
	6	Yes	Strongly		
	7	Yes/Coll.	Violently		
	8	Yes	Strongly		
	9	Yes	Violently		~9.0
	10	Yes	Strongly		
	11	Yes	Very slightly		
	12	Yes	Slightly		
	13	Yes/Coll.	Slightly		
Log Trench 2 - South Wall	1	Yes	Violently		
	2	Yes	Slightly		
	3	Yes	Violently		~9.0
	4	Not visible	Violently		
	5	Not visible	Very slightly		
	6	Not visible	Slightly		
	7	Yes	Very slightly		
Mammoth Pit - West Wall	1	Yes/Coll.	Violently		
	2	???	???		
	3	Yes	Violently		
Trench 5 West	1	Yes	Violently		
	2	Yes/Coll.	Violently		
	3		???	???	
	4	Yes	Violently		
Eastside of Mammoth Tusks	1	Yes	Slightly		
	2	Yes/Coll.	Violently		
	3	Yes	Strongly		
Westside of Mammoth Tusks	1	Yes	Violently		
	2	Yes/Coll.	Violently		
	3	Yes	Strongly		
Locality 1	1	Not visible	None		
	2	Not visible	None		
	3	Not visible	None		
	4				
	Lighter	Not visible	None		
	Darker	Not visible	None		
	5	Not visible	None		
	6	Not visible	None		

Profile/Column	**Layer**	**Shells**	**Reaction to HCl**	**Organics**	**Rip-ups (cm)**
Locality 1 Contd.	7	Not visible None			
	8				
Locality 2 - Paleosol	A1		Violently		
	A2		Violently		
	Bw		Violently		
	Bk	Yes/Coll.	Violently		
	Ck	Not visible	Violently		
Locality 4	Step 1A				
	Step 1B	Not visible	V		
	Step 1C	Not visible	None		Yes
	Step 1D	Not visible	V		???
	Step 1E	Not visible	V		
	Step 2A1	Not visible	V		
	Step 2A2	Yes	V		
	Step 2B1	Yes	V		Up to ~22.0
	Step 2B2	Not visible	V		
	Step 3A				
	Step 3B1	Yes	V		
	Step 3B2	Yes	V		
	Step 3B/C	Yes	V		
	Step 3C1	Yes	St		
	Step 3C2	Not visible	V		
	Step 3C3	Not visible	V		
Locality 5	1	No	???		
	2	Yes	V		
	3	Yes	V		
	4	Yes	V		
	5	Yes	V		
	6	Yes	V		
	7	Yes	V	Yes	
	8	Yes	V		
	9				
	10	Yes	V	Yes	
	11	Yes	V		
	12	Yes	???		
	13		V		
	14a	Yes	V		
	14b	Yes	V		
	14c	Yes	V		
	14d	Yes	V		
	15	Not visible	V	Yes	
	16	Yes	V		
	17	Yes	V		
	18	Not visible	V	Yes	

Profile/Column	**Layer**	**Shells**	**Reaction to HCl**	**Organics**	**Rip-ups (cm)**
Locality 6	1	Not visible	???		
	2	Yes	V		
	3	Yes	V		
	4	Yes	V		
	5	Yes	V		
	6	???	???		
	7	Yes	V	Yes	1.0 - 25.0
	8	Yes	V		
	9	Yes	V		
	10	Yes	V		
	11	Yes	V		
	12	Yes	V		
	13	Yes	V		
Locality 7	1				
	2	not visible	Slightly		~2.27
	3	Not visible	Strongly		
	4	Not visible	Violently		
	5	Not visible	Strongly		
	6	Yes/Coll.	???	Yes/Coll.	
	7	Yes	Violently		
	8	Not visible	Strongly		
	9	Yes	Strongly		
	10	Yes/Coll.	???		
	11	Yes	Strongly		
	12	Yes	Strongly		
	13	Yes/Coll.	Violently		
	14	Yes/Coll.	Strongly		
	15	Yes	Strongly		
Locality 8	Lower Step A	Yes	V		
	Lower Step B	Yes	V		
	Lower Step B	Not visible	V		
	Lower Step C	Yes			
	Lower Step D	Not visible	V		
	Lower Step E	Yes	V		
	Lower Step F1	Yes	V		
	Lower Step F2	Yes	V		

Profile/Column	**Layer**	**Shells**	**Reaction to HCl**	**Organics**	**Rip-ups (cm)**
	Lower Step G	Yes	???		
	Lower Step H	Yes	???		
	Lower Step I	Yes	V		
	Lower Step J	Yes	V		
	Lower Step K	Yes	V		
	Higher Step A	Not visible	V		
	Higher Step B	Not visible	Strongly		
	Higher Step C	Yes	Violently		
	Higher Step D	Not visible	Strongly		
	Higher Step E	Not visible	Violently		
	Higher Step F	Yes	Violently		
	Higher Step G	Not visible	More Viol.		
	Higher Step H	Not visible	More still		
	Higher Step I	Not visible	Violently		Possibly

Table D.6 – Table showing field observations, notes, and comments of the layers and their sediments.

Profile/Column	**Layer**	**Field Observations/Notes/Comments**
Log Trench 1 - West Wall N-S	1	Slickensides; redox features
	2	
	3	Clay balls; coarse (upper) bits of shell
	4	
	5	Can't find gray clay balls from field observation; coarse (upper) bits of shell; accurate size for rip-up cannot be determined
	6	Coarse (many scales of coarse) bits of shell
	7	Angular fragments about 0.3 cm; iron staining the matrix; - Shell bits up to 0.99 cm
	8	Coarse (lower) bits of shell
	9	Medium (upper) bits of shell; size of clay balls and rip-ups difficult to determine in lab - thus will use field observation
	10	Could be the same as the "clay ball" layer, but larger clay balls, plus its mainly composed of sand; - medium (lower) bits of shell; actual size and and shape of clay inclusions difficult to determine
	11	Very little iron staining - medium (upper) bits of shell
	12	Medium (upper) bits of shell
	13	Used 16x hand lens for sphericity, angularity and size
Log Trench 2 - South Wall	1	Slickensides; redox features
	2	Medium (upper) bits of shell
	3	Medium (upper) bits of shell; size of clay balls and rip-ups difficult to determine in lab - thus will use field observation
	4	Load structures or bioturbation?
	5	
	6	
	7	Did not see gleyed observed in field in the lab sample; very coarse shell bits
Mammoth Pit - West Wall	1	Gravel - composed of clay balls and possibly sandstone; - very coarse bits of shell also present.
	2	Clay balls brown to gleyed
	3	The only two clay balls found could be rip-ups; - very coarse to smaller bits of shell
Trench 5 West	1	Slickensides; redox features
	2	
	3	Bone found; Clay balls brown to gleyed
	4	Two clay balls were found in West Wall Unit 3; - very coarse to smaller bits of shell
Eastside of Mammoth Tusks .	1	Medium (upper) bits of shell
	2	
	3	Up to very coarse (upper) bits of shell

Profile/Column	**Layer**	**Field Observations/Notes/Comments**
Westside of Mammoth Tusks	1	Slickensides; redox features
	2	
	3	Up to very coarse (upper) bits of shell
Locality 1	1	
	2	Cross-bedded sand; white at top to yellowish down further… then returns to white
	3	Flaser?
	4	Two samples.
	Lighter	
	Darker	
	5	Redox features
	6	
	7	
	8	Spoil - not collected.
Locality 2 - Paleosol	A1	
	A2	
	Bw	
	Bk	Redox features; shells
	Ck	Redox features
Locality 4	Step 1A	
	Step 1B	No shells found in lab, instead could be concretions; concretions and sediments fizz
	Step 1C	Few clay ball rip-ups
	Step 1D	Few laminations; color same as darker brown laminations from above and sand from below; few clay ball rip-ups
	Step 1E	Laminations about 1mm in width; some oxidation present very few clay balls
	Step 2A1	Permanent dark brown laminations ~2 mm in width
	Step 2A2	Laminations less than A1, same as last unit (continuation); bits of shell
	Step 2B1	Light brown like the one from the laminations; brown clay rip-ups are laminated; very few bits of shell
	Step 2B2	Brown clay band w/ some sand, possibly from same unit as below; sand not same from previous layer
	Step 3A	Highest; same as previous layer, not collected.
	Step 3B1	Light brown sand w/ gravelly lenses; very few darker intertongues; didn't see gravel in sample collected; coarse bits of shell
	Step 3B2	Light brown sand w/ gravelly lenses; fewer bits of coarse shell;
	Step 3B/C	Gradual boundary; few bits of shell present; very few coarse to very coarse grains
	Step 3C1	Light brown sand w/ darker intertongues; very few bits of shell
	Step 3C2	Darker brown intertongues grade into the laminations in layer above (not previous layer)
	Step 3C3	Darker brown laminations with flame or load structures

Profile/Column	Layer	Field Observations/Notes/Comments
Locality 5	1	
	2	Medium bits of shell
	3	Medium bits of shell
	4	Concretions and nodules present; Small ??? Pieces of broken shell; gravel not very rounded
	5	Medium bits of shell
	6	Very few medium bits of shell
	7	Seven alternating layers of sand and mud - seems to start and end with mud; layers are about 9.0 cm thick; very few medium to coarse bits of shell
	8	Cross-bedded structure - ripples?; coarse flecks of shell
	9	
	10	Texture hard to determine due to high volume of gravel; greater abundance of gravel than previous layer, but could be same layer, also larger; clay balls make up base; only matrix description is size
	11	Medium bits of shell
	12	Shell size not determined
	13	
	14a	Very few specks of shell
	14b	Medium to coarse bits of shell
	14c	Medium to very coarse bits of shell
	14d	Medium bits of shell
	15	
	16	Fine (low) to medium (low) bits of shell (very few)
	17	Coarse bits of shell (few)
	18	Unable to get enough material to properly texture
Locality 6	1	Hard to texture, most likely clay; mottles - iron reduction
	2	Fine (upper) bits of shell
	3	Up to 1.87 cm bits of shell
	4	Most likely sand lams. are pure sand and clay lams. some type of loam; very few bits of shell, but field obs. Noted some shell, so possibly. bigger, but more detected in sample
	5	Lots of small shells
	6	Interbeds of sand and clay resemble laminations, but are bigger; sand contains some clay balls
	7	Bone at top, possibly cervid; melange??? - marble clay rip-ups mixed w/ gravels and sand; no appreciable structure - there's no order
	8	Oxidized banding; medium bits of shell
	9	Bone found?????; there seems to be some kind of structure
	10	Clay w/ some sandy clay, but mostly clay; few bits of shell
	11	Mostly sand; bits of shell; gravel comes in many shapes from somewhat rounded (equant) to highly angular
	12	ratio of sand to gravel seems to be ~50%/50%; bits of shell
	13	Bits of shell

Profile/Column	**Layer**	**Field Observations/Notes/Comments**
Locality 7	1	Not collected.
	2	Some mud rip-ups present
	3	Mostly gravel; difficult to texture
	4	
	5	
	6	Some mud balls, concretions, shells; thin lens between Units 10 and 9
	7	Bits of shell present; difficult to texture
	8	Much finer than Units 10 and 11
	9	Medium to coarse bits of shell
	10	Mostly gravel; difficult to texture;; mud balls present; very little sands
	11	Coarse gravel; difficult to texture; greater amount of sand versus gravel than Unit 6; bits of shell; gravel; rip-up - 9.0 x 5.0 cm
	12	Laminations of sand and mud w a thick band of mud; seems no mud was collected
	13	
	14	More sand than gravel
	15	Medium bits of shell
Locality 8	Lower Step A	Water table; 2.20 m below is gleyed, marble clay; few very fine bits of shell; clay balls not noticed in field; mud also fizzes
	Lower Step B	Alternating gray sand and mud; bits of shell
	Lower Step B	alternating gray sand and mud; gravelly; shells observed in field are actually concretions
	Lower Step C	Gravelly; gravel composed of clay balls (largest), concretions and other minerals/rocks; field observation noted lots of shells, but are concretions instead, but also small bits of shell
	Lower Step D	Fine laminations of light brown sand and dark brown sand; planar laminations; darker laminations are mud
	Lower Step E	Laminations w/ load or flame structure?, structure at top of unit; fine bits of shell (few)
	Lower Step F1	Cross-bedding of light brown sand and dark brown sand; coarse bits of shell
	Lower Step F2	Cross-bedding of light brown sand and dark brown sand; coarse bits of shell
	Lower Step G	Clay ball layer mostly in dark brown sand; clay ball up to 3.85 cm; bits of shell smaller, but more abundant
	Lower Step H	Band of dark brown sand; coarse bits of shell (very few)
	Lower Step I	Light brown sands with gravels and clay balls; coarse bits of shell
	Lower Step J	Massive light brown sand; coarse dark flecks; bits of shell
	Lower Step K	Fine laminations of sand and gravel ~1 cm in width; light brown sand; darker brown gravels; lots of coarse- and gravel-sized flecks - no organics; possible seed found; coarse bits of shell

Profile/Column	**Layer**	**Field Observations/Notes/Comments**
Locality 8 Contd.	Higher Step A	Laminations, possibly continued from unit below;
	Higher Step B	Mid brown sand; no structure - massive
	Higher Step C	Lighter color with lots of gravel-sized clay balls; medium bits of shell (very few)
	Higher Step D	Tightly packed laminations of light and dark brown that doesn't resemble any others
	Higher Step E	Light band (whitish) with laminations; oxidation on top
	Higher Step F	Lots of tightly packed small clay balls (~2 cm); oxidation?; scl with clay balls, sl w/o; very few bits of shell present
	Higher Step G	Light brown sand with ots of large clay balls; clay balls ~12 cm high; mud - clay, plastic, very sticky
	Higher Step H	Dark brown sand with lots of clay balls - Mn stained
	Higher Step I	Light brown sand with clay balls; rip-ups?

VITA

Biographical Information

Name: Juan Carlos Urista

Address: Department of Sociology and Anthropology, Radford University,
Radford VA 24142-3948

Email Address: jurist@radford.edu

Education: M.A., Anthropology, Texas A&M University, May 2009

B.A., double major in Anthropology and Geology, San Francisco State University, May 2003

Teaching Experience

2007-2009 Adjunct Professor, Department of Sociology and Anthropology, Radford University

Professional Conference Presentations

May, 2008 "The Vernor Mammoth Site: A Geoarchaeological Investigation on the Texas Coast", conference presentation at the 10th Annual Uplands Archaeology in the East Conference, Radford University, Radford, Virginia