THE SIGNIFICANCE OF THE WACO MAMMOTH SITE TO CENTRAL TEXAS PLEISTOCENE HISTORY

A Thesis Submitted to the
Faculty of Baylor University
in Partial Fulfillment of the
Requirements for the Degree
of
Bachelor of Science
by
George F. Naryshkin

Waco, Texas
December 1981

APPROVED BY THE DEPARTMENT OF GEOLOGY

BAYLOR UNIVERSITY

Chairman of the Department

Signed: [redacted]
Dr. Harold H. Beaver

Approved by Thesis Advisor

Signed: [redacted]
Dr. O. T. Hayward

Thesis Reader

Signed: [redacted]
Dr. R. Bonem

TABLE OF CONTENTS

ILLUSTRATIONS

Figures

I. ABSTRACT

A fossil assemblage consisting of three fragments of the lower jaw of Alligator mississippiensis and of articulated skeletal material of five individual specimens of Mammuthus columbi occurs in point bar deposits of the second terrace of the Brazos River, in Steinbeck Bend, Waco, Texas (Waco West Quadrangle 1/24:000). Correlation of the sequence of gravels, sands and clays with those in the Trinity River indicates Sangamon age or approximately 37,000 years B.P. Reconstruction of the paleoclimatic frost line north of the site, suggests a warmer climate than exists today in the area. Ecologically, the Waco Mammoth Site indicates a homogeneous climate in Central Texas during the Sangamon, that allowed Mammuthus columbi and Alligator mississippiensis to migrate throughout this area.

Examination of the teeth and tusks revealed the sex and age of each individual and from this, the social structure of the community was determined. This showed no similarity to any social structure of the African elephant, suggesting a non-catastrophic cause of death. The high degree of articulation indicated that the mammoths either floated to the point bar shortly after their death, or died in situ. The large percentage of old males at the site suggested that killing by ancient

man (similar to modern poaching practices on the African continent) may have been the cause of death of the mammoths. Kill sites of the Sangamon Age on the Trinity River in Dallas and Denton counties suggest the Waco Mammoth Site could be a product of normal fluvial burial following human kill. No artifacts nor any other signs of ancient man have been at the site, supporting the "floatation to point bar" hypothesis. However, accumulations of mammoth material in this region suggests the widespread practice of mammoth killing by ancient man as early as 37,000 yrs. B.P.

II. BRIEF HISTORY OF THE SITE

In 1978, Paul Barron and Eddie Bufkin of Waco noticed some large bones projecting from the walls of a drainage ditch on the Hejtmancek Farm, McLennan County, Texas. Their discovery was reported to Strecker Museum, at Baylor University, and David Lintz (curator of the museum) identified the bones as mammoth remains.

The property owners granted permission to the museum to remove bones for exhibition. During the next two years of skeletal recovery, volunteers removed skeletal material from the site. The positions of most of the large bones were recorded in photographs and the sediments were carefully searched for artifacts, with negative results. Three mammoth skulls and associated skeletal remains were discovered during this time.

In 1979, I received permission from Strecker Museum to study the site and I discovered two more mammoth skulls. In addition in 1980 David Lintz discovered three fragments of an alligator jaw.

The site is now designated the Waco Mammoth Site and the bones are stored in Strecker Museum.

III. INTRODUCTION

Acknowledgments

Thanks are extended to many people for assistance with this project. Dr. E. L. Lundelius, Jr. of the University of Texas Geology Department contributed his time to identification of fossil material and discussion of this project. Dr. O. T. Hayward of the Baylor University Geology Department contributed suggestions and discussed the project with me, and upon its completion critically read the manuscript. David Lintz of Strecker Museum, Baylor University, aided in construction of the bone map and provided information on the discovery of the alligator and mammoth material. Barbara Dutrow of the Southern Methodist University Geology Department lent her expertise on molar identification and supplied reference material. Dr. D. W. Turner and David Breese of the Baylor Mathematics Department provided information useful in the calculation of tusk volume. Dr. R. Bonem of the Baylor University Geology Department critically read and edited this paper upon its completion.

Purpose

Late Pleistocene history of Central Texas is well represented by terrace and alluvial deposits. However, evidence of precise dates and environmental conditions is limited. Recently vertebrate fossil, skeletal material of mammoths and alligators, has been recovered from terrace deposits of the Brazos River in the vicinity of Waco, McLennan County, Texas. On the basis of this skeletal material, the sedimentary features present at the site, and the relationship of the site to the Brazos River Valley, an environmental interpretation may be possible.

Therefore, it is the purpose of this investigation to 1) describe the skeletal material and sedimentary features of the Waco Mammoth Site, 2) relate this area to the terrace history of the Brazos River, and 3) to interpret the history of the terrace containing the site from the skeletal material and sedimentary history.

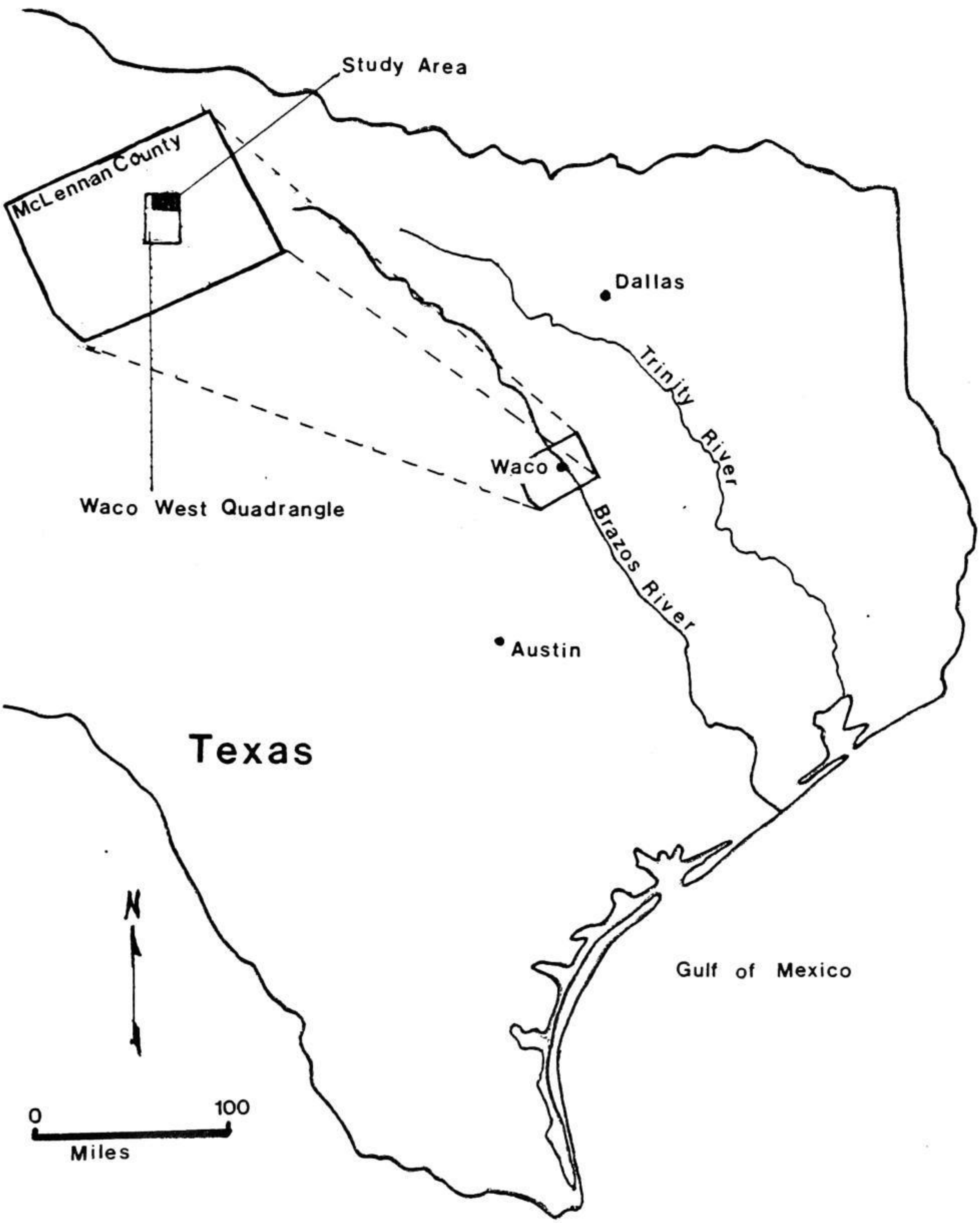
Location

The study area is located in northern Waco, Texas, approximately 70 miles south of Dallas (fig. 1). It lies between the Brazos and Bosque Rivers in a region locally known as Steinbeck Bend (fig. 2.) The site (fig. 3) is situated 420 feet above mean sea level in the Waco West Quadrangle. Although J. M. Burket (1956) mapped the terraces containing the Waco Mammoth Site as first terrace deposits, I have assigned the deposits to the second terrace of the Brazos River as discussed in a later section of this paper.

The site is in the northwest margin of a drainage ditch which empties to the southeast, into the Bosque River. Vegetation of the site consists of small cedars, prickly pear and pencil cacti, mesquites, live oak, and short grasses.

Fig. 1

Index map of central Texas showing location of study area.



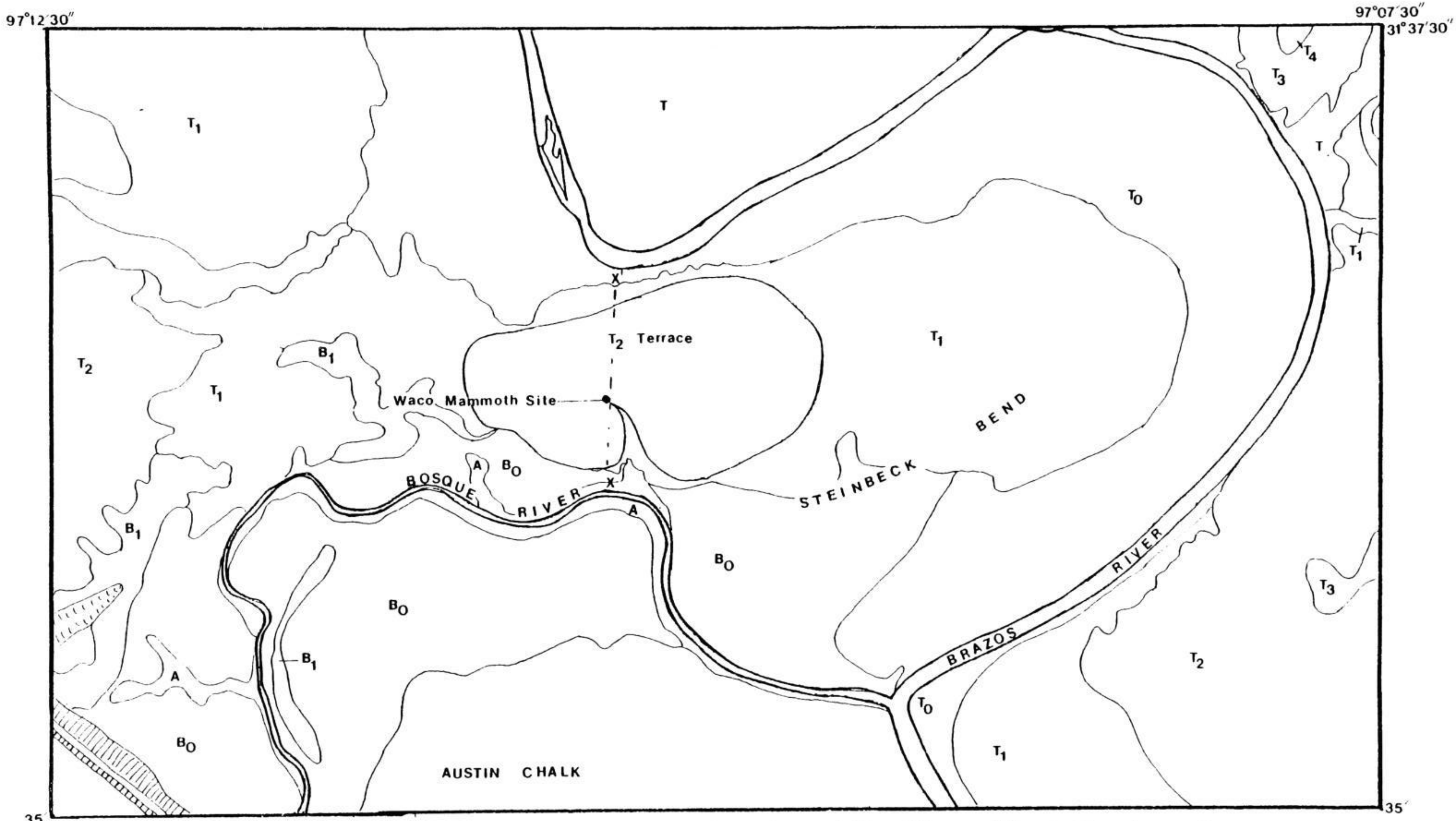


Fig. 2 INDEX MAP of TERRACE DEPOSIT

T = BRAZOS RIVER TERRACE
B = BOSQUE RIVER TERRACE
A = BOSQUE RIVER ALLUVIUM

N-E Section of the Waco West Quadrangle

SCALE 1:24000

TERRACE BOUNDARIES FROM GEOLOGIC MAP BY J.M. BURKET 1963 EXCEPT THAT CONTAINING THE WACO MAMMOTH SITE

Figure 3

Cross section along X-X[1] from figure 2, to show terrace levels.

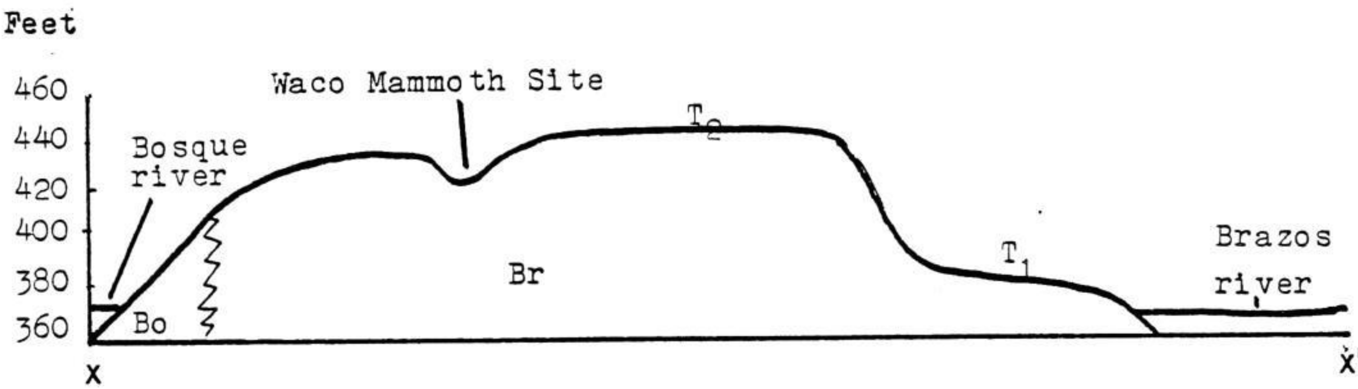
Legend;

T_1.....first terrace

T_2.....second terrace

Bo.....Bosque River deposits

Br.....Brazos River deposits



Horizontal scale= 1:12000

Methods of Investigation

The procedure followed during this investigation included: 1) establishing the environment of deposition and age of the deposit, 2) identifying and describing the skeletal material, 3) determining the social structure of the mammoths, and 4) interpreting a possible cause of death of the mammoths.

Establishing the environment of deposition of the sediments containing the skeletal remains was accomplished by observing the sequence of lithologies at the site, and comparing that sequence to various sedimentary models. Identification of the terrace level required determination of elevation of the site as compared to mean water level of the Brazos River, and observance of the relation of the terrace to other exposed Brazos and Bosque River terraces. Lithology was also considered in determination of terrace level.

David Lintz of Strecker Museum identified the alligator species represented by the skeletal material. The mammoth material was identified by E. L. Lundelius, Jr. with reference to Maglio (1973). Skeletal distribution was described by mapping the relative positions of the bones in the field. Position of bones removed previously was added to the map from photographs taken by museum volunteers. The condition of the skeletal material was determined by simple tests discussed by

Cornwall (1956). These consisted of acid tests to determine calcium content and wet and dry tests to determine the extent of leaching of minerals from the bone material.

Reconstruction of a social structure of the group of mammoths was accomplished in several steps. First, the ages of the individuals were determined by identifying the molars in the lower jaws of the mammoths and assigning the molars to age groups of the African elephant as described by Laws (1966). The molars were identified by E. L. Lundelius, Jr. with reference to R. W. Graham (1979), and by Barbara Dutrow (oral comm., 1980). Next, sex assignment of the individual mammoths was accomplished by plotting volume of one tusk versus age of each individual and comparing the results of this graph to studies by Laws (1966) which used weight of both tusks versus age. Two curves resulted, one representing males and the other representing females which was similar to curves arrived at by Laws (1966) for the African elephant using the weight of both tusks versus age. Finally with the sexes and ages of the mammoths estimated, the individuals at the Waco Mammoth Site were compared and contrasted to social structures of African elephants described by Sykes (1971) and Laws, et al.(1975).

The probable cause of death of the mammoths was determined using a method described by Western (1980), who found that if the percentages of ages and sexes of individuals in the social structure present in the death assemblage is similar to the percentages of ages and sexes of individuals in a living social structure of a similar species, the cause of death was one which killed the entire group at one time, and was probably catastrophic. Other possible causes of death included an *in situ* death assemblage and a transported death assemblage.

Literature Review

Previous works which were found to be useful in this study can be divided into five separate categories.

The first category concerns descriptions and age determination of terrace deposits of the Brazos River. Deussen (1924) recognized that the Brazos River contained paired terraces and he described six terrace levels ranging from 30 to 310 feet above the present river level. Hendricks (1935) described Brazos River terraces in Parker County, and Plummer and Hornberger (1935) noted three terrace levels in Palo Pinto County. The high terrace was assigned Early Pleistocene or Pliocene age, and the middle terrace was dated as Late Pleistocene by mammoth remains. Bronaugh (1950) noted a lower terrace 20 to 50 feet above the present Brazos River level and an upper terrace from 70 to 200 feet above mean low water. He assigned an age of Early to Early-Middle Pleistocene to the high terraces. Slaughter, et al. (1962) attributed formation of the second terrace of the upper Trinity River to an interglacial or interstadial preceding the Wisconsin Glaciation and suggested that the terrace deposits were of Sangamon Age. Crook and Harris (1957) correlated the second terraces of the Brazos and Trinity Rivers based on fossil evidence.

Burket (1965) mapped the terraces of the Brazos River in the Waco area. However, he based his data on elevations alone, and, in the immediate area of the mammoth site in Steinbeck Bend, mapped the terrace as the first terrace levels. Epps (1973) described all levels of the Brazos River terraces in detail. He assigned terraces with elevation of 40 to 60 feet above the present flood plain to the second terrace, and attributed the terrace formations to glacial cycles.

The second category of previous investigations pertains to depositional models of river systems. Allen (1969, 1970) developed a classical point bar model for meandering streams which could be used to determine environment of deposition. Epps (1973) described modern point bar deposits of the modern Brazos River, noting the occurrence of gravel, clay, and sand sequences and describing sediment size.

The third category of references deals with the faunal material found at the site and their suggested environments. In 1933, Ditmars described the environment of modern _Alligator mississippiensis_ (Daudin) to be warm swamps along rivers. Slaughter, _et al_. (1962) described the paleoenvironment of _Alligator mississippiensis_ (Daudin) to be a timberland in moist climates. In 1956, deAnda described the environment of _Mammuthus columbi_ (Falconer) as a timberland in contrast to the environment of _Mammuthus imperator_ (Leidy), which he described as an open grassland. In 1973, Maglio explained the taxonmic problem of the North American mammoths and placed them in the genus Mammuthus, rather than Elephas. Lundelius (1972) considered the presence of Mammuthus columbi (Falconer) to indicate only an environment of non-frost.

The fourth category of previous works concerns environmental studies of the terraces. Lundelius (1971) noted that the second terrace of the Brazos River changed environmentally from the Gulf Coastal Plain to the Great Plains and suggested an age of Sangamon to the terrace based on the fossil assemblages found there.

The fifth category of previous investigations deals with: 1) the age and sex determination of modern elephants; 2) social structures of modern elephants; and 3) expected paleo social structures based on living assemblages of vertebrates. In 1966, R. M. Laws developed a method of age determination for the African elephant using molar measurements. In 1971, K. S. Sykes defined social structures of the African elephant based on observations of elephants in the wild. Western (1980) stated that a catastrophic death event in the fossil record will result in a distribution of fossil taxa similar to the living assemblage. Voorhies (1981) determined the sexes of extinct mammals in an ash-covered water hole by finding pregnant females and comparing the skeletal features to members of a similar species. Social structures of the species were determined by estimating ages of the members and knowing the sexes, comparing the data to that for the social structures of the closest living species.

IV. DESCRIPTIONS

Lithologic Description

The Waco Mammoth Site was exposed by the excavation of a drainage ditch that cuts through a sequence of Brazos River terrace deposits. The lowest level of erosion of the drainage ditch reveals large gravels (10 cm in length) composed of angular limestone blocks, rounded pebbles of quartz and chert (5 cm in diameter), Cretaceous mollusks and minor amounts of pebble-sized rose quartz. Within this bed are lenses of pea gravels of similar composition.

Above this layer is a sequence of fine sandy silt and smaller gravels. The sand seams are approximately 10 cm in thickness and, when wet, are grey in color with yellow streaks. The silt is overlain by a layer of large gravels (10 cm in length) of the same composition as the lowermost gravel layer. Above this is another 10 cm thick sandy silt, greyish-white in color, which is overlain by 10 to 30 cm of pea gravels and caliche.

The gravel and caliche layer is in turn covered by a yellow-stained silt layer 30-100 cm thick containing clay and sand. The remains of *Alligator mississippiensis* (Daudin) were found at the base of this layer, in the top of the gravels, and remains of *Mammuthus columbi* (Falconer) were found just above in this same layer. The layer is grey and clay-like in consistency when wet and very resistant when dry. This fossil-bearing layer grades upward into a 1-2 meter thickness of reddish-brown soil containing caliche and limonite nodules at its base. X-ray analysis of a sample of the silt layer, taken above the bone layer, showed the major constituent to be calcite.

The soil profile at this locality is that of an Axtell Series (U.S. Dept. Agriculture, 1958, p. 38).

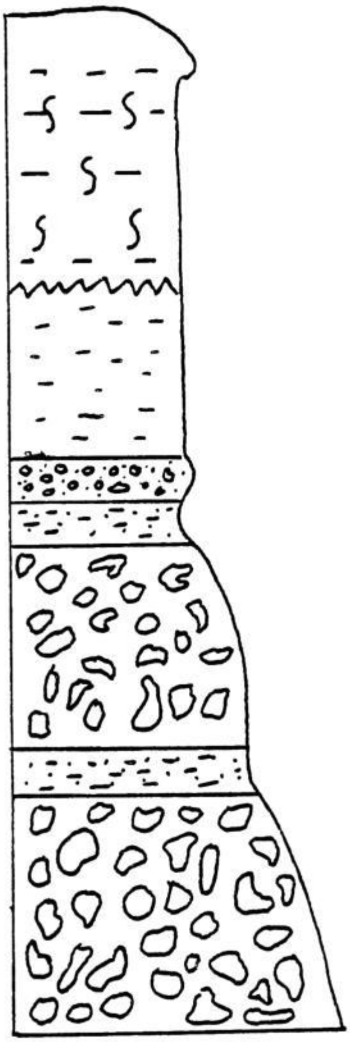
> A horizon-Varies from 4-12 inches thick; light brown fine sandy loam (65% sand, 25% silt, 10% clay) friable when wet, hard when dry, ph6; abrupt undulatory boundary boundary with B horizon.
>
> B horizon-Interval from 12 inches below surface to 45 inches; reddish-brown to yellowish-red clay; sticky when wet, very hard when dry; mottled pale brown and reddish-brown spots; ph increases downward from 5-8; often contains calcium carbonate concretions near base.
>
> C horizon-Interval from 45 inches below surface to 66 inches; pale brown to yellowish-red calcareous clay.

This overall sequence (fig. 4, 5) is equivalent to the Pemberton Hill sequence of the second terrace of the Trinity River (Slaughter, *et al*. 1962).

The Pemberton-Hill Sequence is described by Slaughter, *et al*. (1962) for the second terrace sediments of the Trinity River. The Hill and Lower Shuler Members are considered to have formed in more moist climatic conditions than the Upper Shuler and Richards Members of the sequence.

Fig. 4

Measured section of the Waco Mammoth Site and its relation to the Pemberton-Hill sequence of the second terrace of the Trinity River in Dallas and Denton counties.



Waco Mammoth Site	Pemberton-Hill Sequence
Red Alluvium	Richards Member
Yellow Sandy Clay	Upper Shuler Member
Small Gravels	
Laminated Sands and Silts	Lower Shuler Member
Large Gravels	Hill Member
Laminated Sands and Silts	
Large Gravels	

Vertical height of section = 6 ft.

Fig. 5

View to the east of the Waco Mammoth Site showing the lithology of the site and the position of the mammoth bones in the point bar deposits. The shoulder blade marked "c" is the shoulder blade adjacent to mammoth #1 in fig. 9.

A....Clay and silt
B....Pea sized gravels
C....Shoulder blade(approximately .5 meters in length)

Description of Skeletal Material

The skeletal material consists of bones, teeth, and tusks of five mammoths either in whole or fragments, and three jaw fragments of an alligator. The alligator jaw framents were located at the top of the small gravel layer, below the yellow sandy clay, or Upper Shuler Member (fig. 4). The mammoth material was found in the Upper Shuler Member, above the alligator bones.

Condition of the Skeletal Material

The skeletal material does not contain detectable calcium carbonate (as tested with dilute HCl). Cavities in the bone resemble fresh bone and extend to the periphery of the bone. When wet, the bone is almost spongy, and a fingernail is easily pressed into it. When dry, the bone is brittle and crumbles easily. This is characteristic of decalcified bone material and is a result of the leaching of calcium from the bone (Cornwall, 1956).

The tusk ivory splintered easily upon movement. The molars contained fractures between lamella and showed evidence of degeneration of the cement.

The alligator material appeared to be harder than the mammoth material and did contain calcium carbonate.

Skeletal Positioning

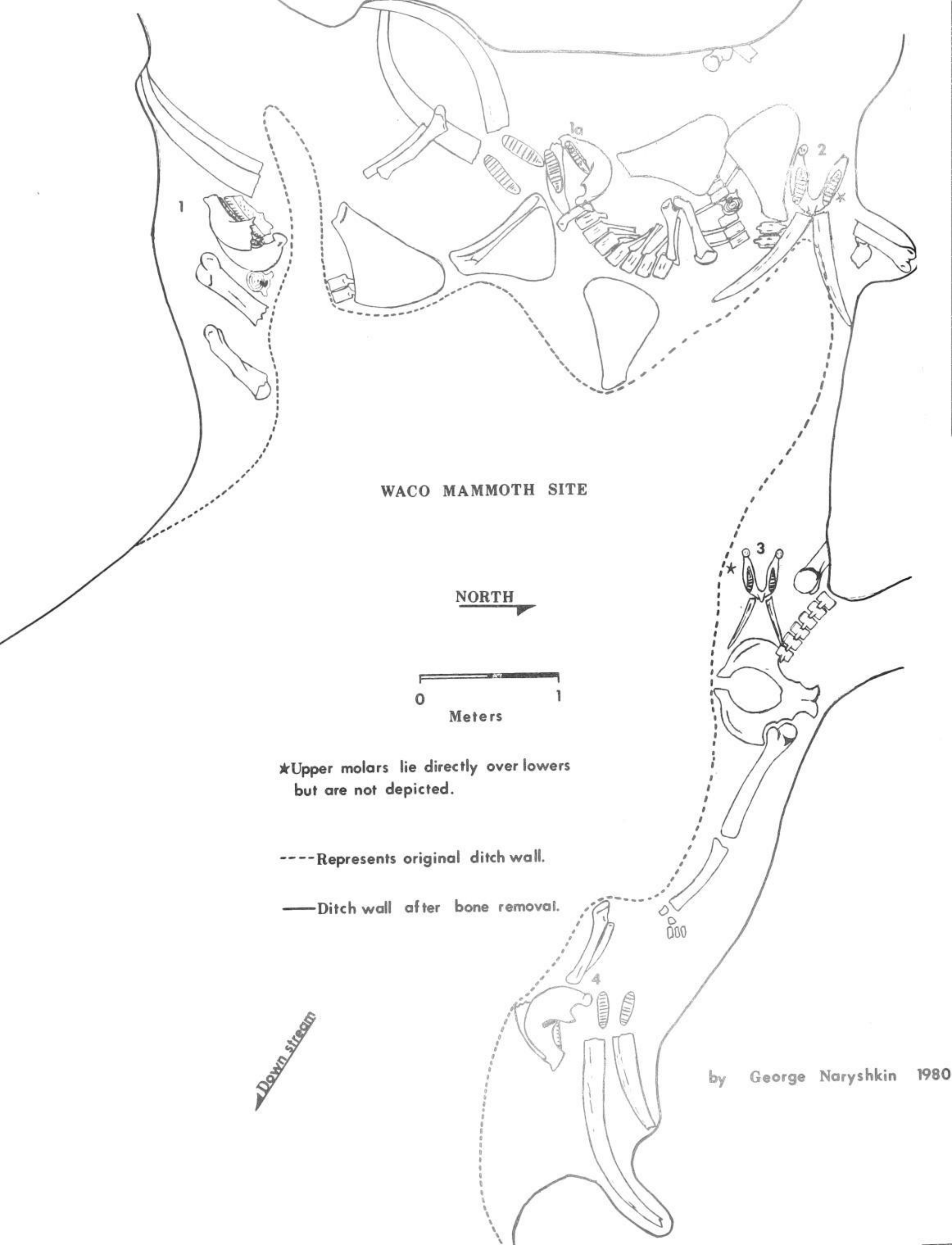
Figures 6 is a map of the bones of the site. It was not possible to determine the position of any material collected prior to this investigation. However, this diagram accurately represents the gross features of the site. The bone lay along the periphery of the ditch, projecting from the wall of the ditch and extending into the wall. Hundreds of pounds of bone fragments have been recovered downstream and these are no doubt from the center of the site which is now cut by the ditch.

The bones were not totally articulated, although relatively high degrees of articulation were apparent throughout the site. Therefore, it was not always obvious which bones belonged together, and individuals were assigned identification numbers by skulls (see fig. 6) which were the most numerous skeletal items.

A total of five individuals were identified. All contained either full articulation or close association of upper and lower jaws and tusks. All crania were crushed, possibly due to overlying sediments.

Long bones, such as humerous, radius and ulna, and femur and tibia were often found articulated. Ribs (not shown in figure 6) were well articulated along articulated vertebrae sections, but even when found free of vertebrae were articulated.

Fig. 6



WACO MAMMOTH SITE
NORTH
0
1
Meters
★Upper molars lie directly over lowers but are not depicted.
----Represents original ditch wall.
——Ditch wall after bone removal.
Down stream
1
1a
2
3
4
by George Naryshkin 1980

Faunal Descriptions

Order CROCODILLIA

Alligator mississippiensis (Daudin)

Alligator mississippiensis (Daudin)

Referred specimen: lower right jaw, 3 fragments. Not catalogued, in Strecker Museum.

Discussion of species: the skeletal material cannot be distinguished from a recent specimen of the same species. See fig. 7 and fig. 8.

Environment: Recent specimen live in warm, swampy areas, often near rivers (Ditman, 1933). Slaughter (1962) suggested the presence of *Alligator mississippiensis* in the paleo record to indicate timber regions during times of moist climates.

Order PROBOSCIDIA

Mammuthus columbi (Falconer)

Mammuthus columbi (Falconer)

Referred specimen: third molar of lower right jaw, of mammoth number 4. See figure 9.

Discussion of species: a 10cm line, drawn anterior to posterior along the grinding surface bisects 7 enamel

Fig. 7

Alligator mississippiensis(Daudin)

3 fragments of lower right jaw.

Lateral view.

Scale: each block = 5cm.

Fig. 8

Alligator mississippiensis(Daudin)

Dorsal view

Scale: each block=5cm.

Fig. 9

Mammuthus columbi (Falconer)

Lower left and right M_3

Length A-B=10cm.

ridges. Cement is 2 mm thick. The molar contains a total of 15 enamel ridges. This suggests the species is Mammuthus columbi (Falconer) rather than Mammuthus imperator (Leidy), the other southern species (Maglio, 1973).

Environment: The mammoth's closest living relative, Loxodonta africana, inhabits the continent of Africa in grasslands of non-frost regions. It migrates hundreds of miles per year through many environmental nitches. Mammuthus columbi (Falconer) is considered by deAnda (1956) to have inhabited regions of timberland. Lundelius (1974) suggested the presence of Mammuthus columbi (Falconer) did not represent any particular habitat, other than restriction to the southern North American continent below the frost line.

Age and Tusk Volume Calculations

In order to interpret the taphonomy of the site age and tusk volume of the mammoths has been calculated.

All five mammoths were used in this study. Most of the molars were identified by E. L. Lundelius, Jr. The infant molars were identified by referring to R. W. Graham (1979) and Barbara Dutrow (1980, oral comm.) also provided measurements used in identifying the molars. The identification and placement of the molars in the lower jaws were then compared to the age groups for the African elephant (Laws, 1966), and this information is shown in figure 10.

Tusk measurements were made in situ on tusks prior to excavation. The tusks that had been removed were measured in casts. Measurements included the radius of the base of the tusk and the arc length measured along the outer arc of the tusk (fig. 11). Volume of the tusks was then calculated as suggested by D. W. Turner and D. Breese (1980, oral comm.). D. Breese (ibid) calculated the volume of a straight cone and entered an error of approximately 5% for a curved cone, such as a tusk. This was considered to be sufficiently accurate for use in this study (fig. 12).

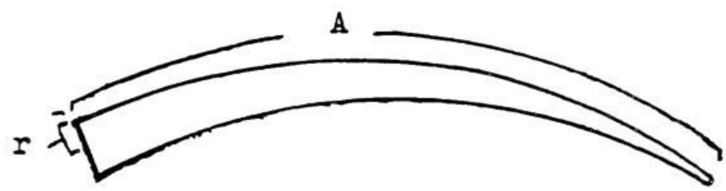
Fig. 10

Age at death of individuals based on Laws' age group frequencies for the African elephant (Laws, 1966, p. 3-13)

Skull #	Age Group (Laws, 1966)	Age (ibid.)
1	XXI	36+2 yrs
1a	XXIII	43+2 yrs
2	XXII	39±2 yrs
3	VII	6±2 yrs
4	XXVI	49±2 yrs

Fig. 11

Tusk measurements and their locations.



A= arc length in cm.
r = radius in cm.

Fig. 12

Volume of one tusk of each individual using the formula;

$$\text{volume} = 1/3 \ \pi r^2 h$$

$\pi = 3.14$

r = largest radius

h = arc length measured along outer edge of tusk

Skull #	h(cm)	r(cm)	Volume(cc)
1	164	4.87	4081.5
1a	176	6.87	8711.4
2	98	4.25	1853.7
3	27	2	113.1
4	200	5.75	6925.5

The volume of one tusk versus age of each mammoth is shown as a plot in figure 13. Figure 14 is a graph of tusk weight versus age of a community of African elephants sampled by Laws (1966) which is very similar to figure 13. Figure 15 lists the results of the tusk and tooth study for the Waco Mammoth Site.

Fig. 13

Tusk volume of one tusk versus age of each mammoth of the Waco Mammoth Site. Resulting curves represent rates of tusk growth for male and female members of the site. Numbers represent identification of individual mammoths (fig. 9). Circles with arrows represent individuals considered to be males. Circles with cross represent individuals considered to be females. Open circle represents youngster for which sex was indeterminate because of youth.

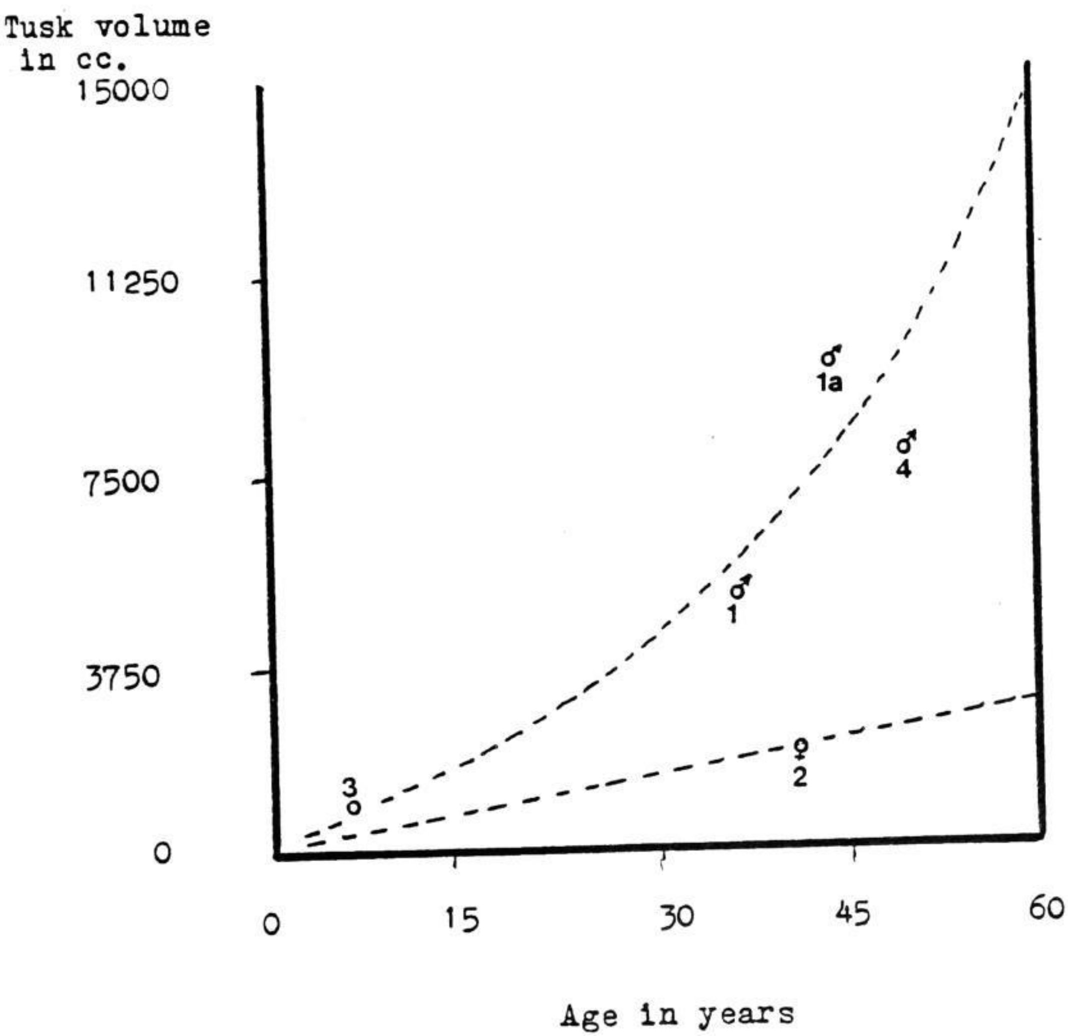


Fig. 14

Male and female tusk growth rates of African elephants from Murchinson Falls and Queen Elizabeth Parks(Laws,1966,fig.15). Circle with arrow represents male tusk-growth curve. Circle with cross represents female tusk-growth curve.

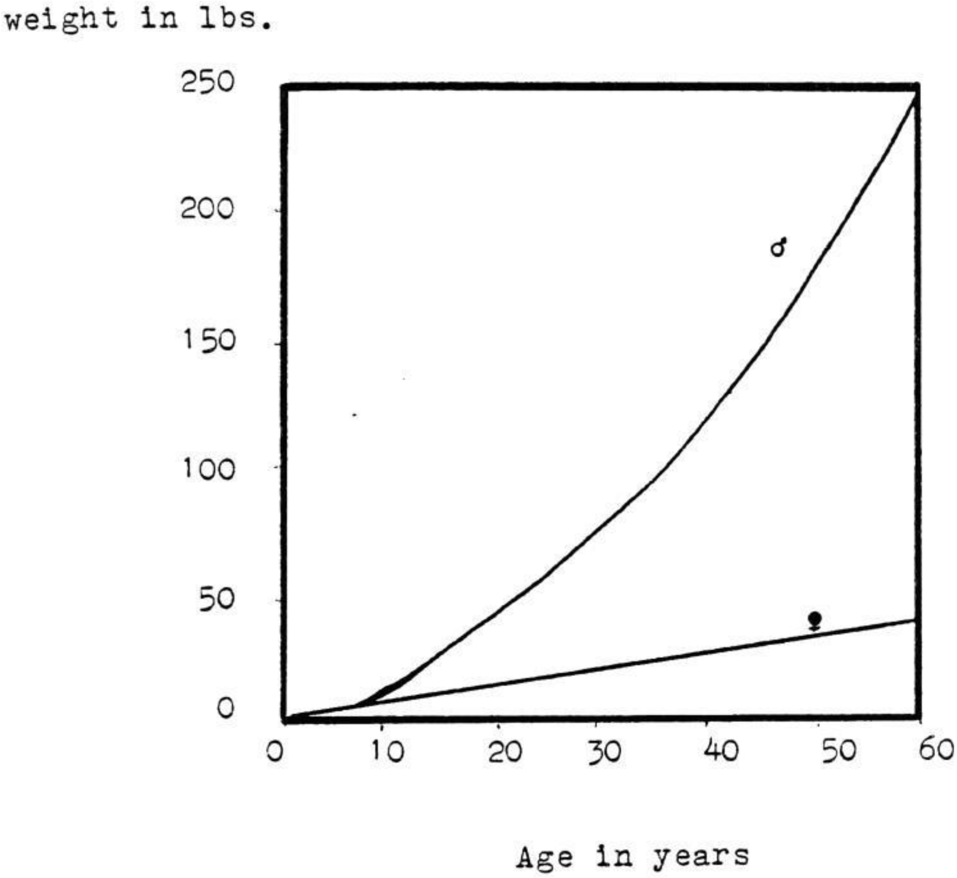


Fig.15

Individual sexes and ages of mammoths at the Waco Mammoth Site, from figure 12.

Skull #	Sex	Age
1	Male	36± 2 yrs
1A	Male	43± 2 yrs
2	Female	39± 2 yrs
3	unknowm	6± 2 yrs
4	Male	49± 2 yrs

number of males; 3

number of females; 1

ave. age of males; 42± 2 yrs

mean age of males; 43± 2 yrs

% of males to females; 75%

V. INTERPRETATIONS

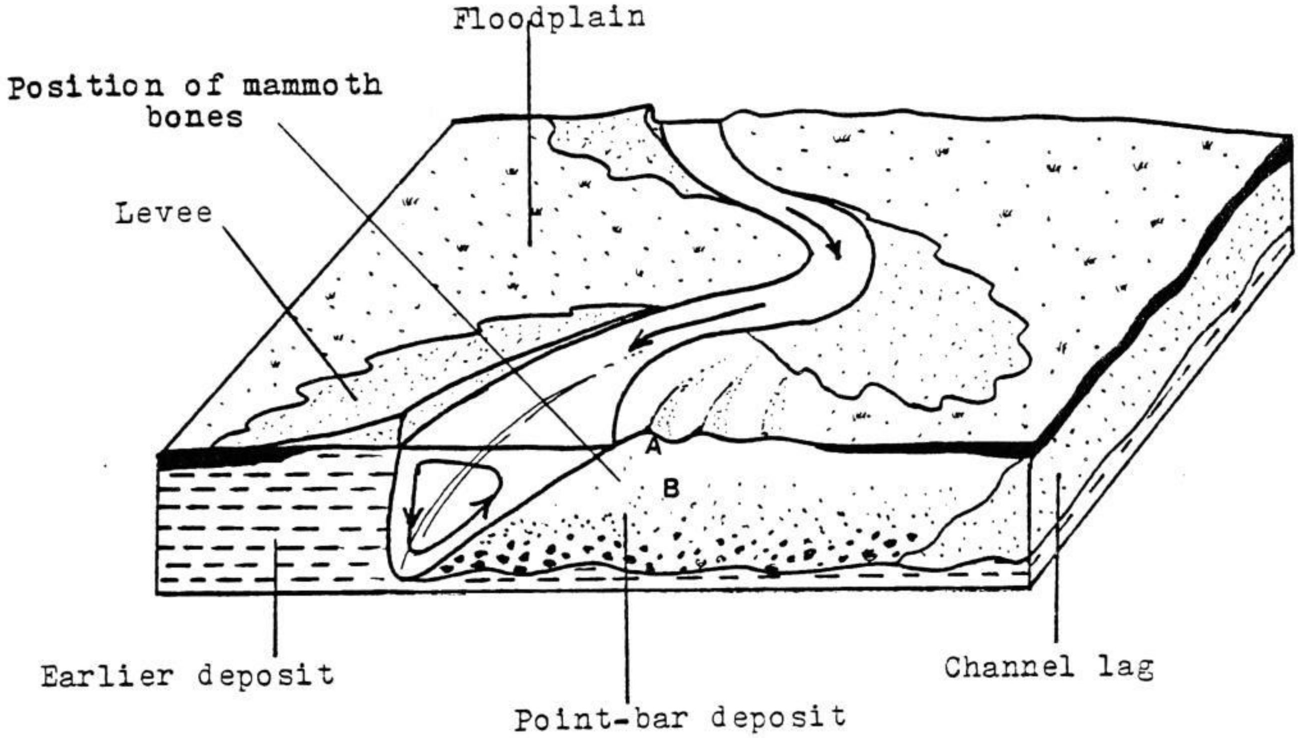
Depositional Model

The sequence of sands and gravels, which grades upward at the site is representative of point bar deposition by comparison with Epps (1973) and Allen (1964) as illustrated on figure 16. Point bars are deposited on the inside of bends of meandering streams. As the stream erodes the outside bank, it deposits on the inside of the bend where flow is slower. As the water flows around the bend, it creates a helicoidal flow that migrates up the inside bank and results in finer grading of the sediments grading upwards.

The alligator bones were deposited with gravels of the same size as the alligator jaw fragments, and the mammoth bones were deposited in an overlying silt layer which was deposited by waters too quiet to carry heavy mammoth bones which indicates flotation of the bones and carcas to the point bar, or placement of the skeletal material there by man. There are no large gravels present with the mammoth bones, which indicates that the bones were not moved along the bottom with gravels of similar size or weight.

Fig. 16

Model of point bar deposition illustrating the position of the mammoth bones in the point bar sequence of the Waco Mammoth Site (adopted from Allen, 1964).



A and B represent positions of A and B in fig. 5.

Paleoclimatic Interpretation

Interpretation of the paleoclimatic environment of the mammoth site is based upon both sedimentalogic and biotic studies.

The lithology of the sediments of the site is equivalent to the Pemberton-Hill sequence of the T_2 terrace from the upper Trinity River in Dallas and Denton counties. The upper members of this sequence (fig. 4) are considered to represent dryer conditions than the underlying sediments, (Slaughter, et al., 1962). This trend is also apparent in the Waco Mammoth Site where the silt layer contains more caliche nodules than the underlying sediments.

Studies by Slaughter and Ritchie (1963) and Slaughter and McLure (1965) describe Sangamon age deposits containing *Mammuthus columbi* (Falconer) and *Alligator mississippiensis* (Daudin) in the Central Texas region. Comparison of the Waco Mammoth Site with these suggests that the paleoclimate environment of the Waco Mammoth Site was similar to that described for Texas, west and south of Dallas. This area contains extinct species that cannot tolerate frost and are found in Sangamon terrace deposits of the Trinity River. However, because the fauna of the Waco Mammoth Site consist of large vertebrates, it does not provide local climatic information. Based on the species present, the site was south of the frost line, and sediments indicate that the site was along a river margin, possibly in a swampy area.

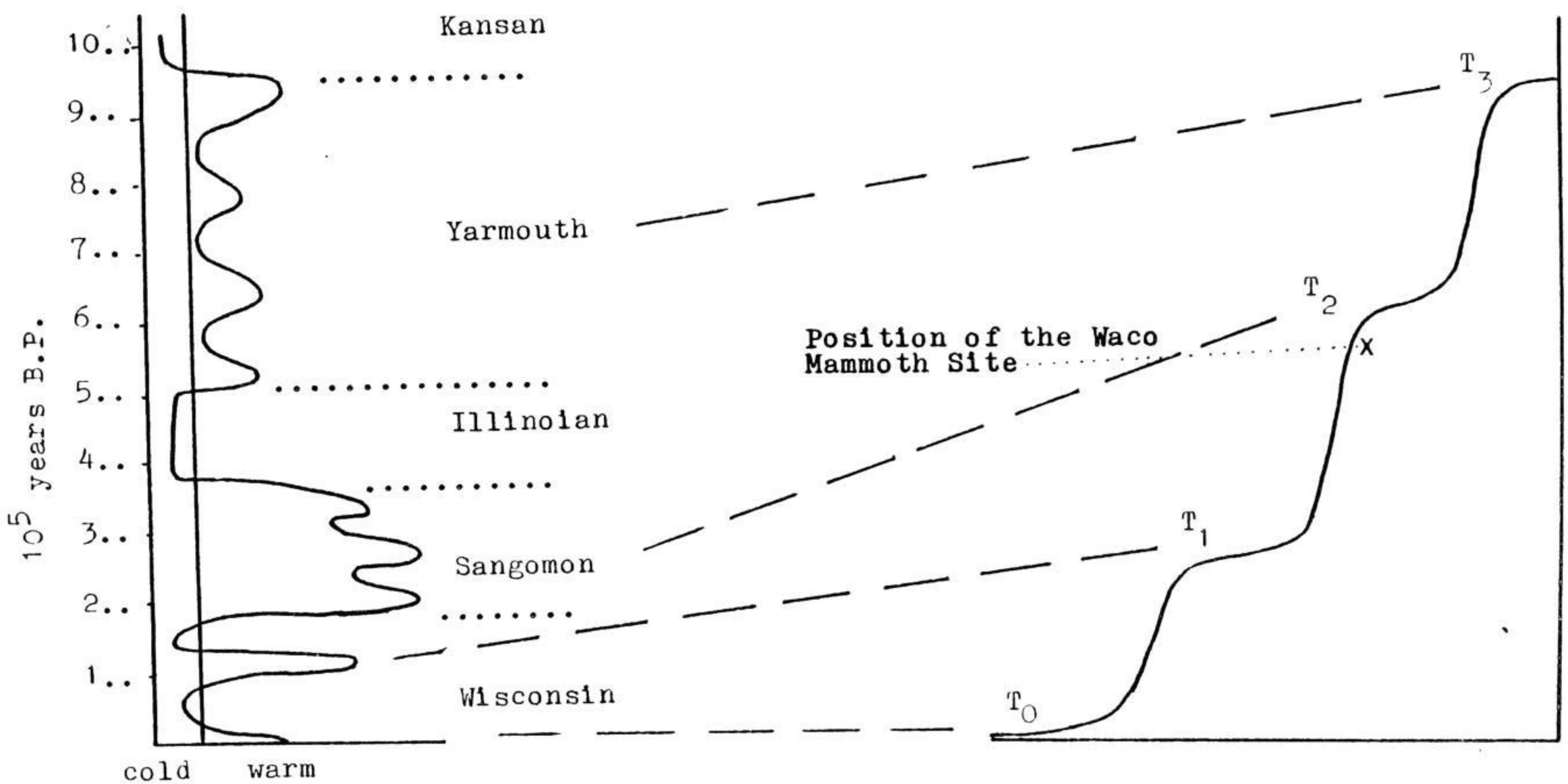
Age of Deposition

Determination of time of deposition was based in part on the supposition that during times of nonglaciation, or high sea level, alluviation occurs, and during times of glaciation or low sea level, down-cutting of alluvial plains forms terraces. Thus, a sequence of glaciations and nonglaciations forms a pattern of "steps" or terraces of river deposits (fig. 17).

The present flood plain is assigned the symbol T_0 for the first alluvial surface. This is undergoing deposition during the interglacial (fig. 17). The most recent terrace would have been formed during an interglacial and a following down cutting phase of the Wisconsin glaciation. This is the T_1 terrace. According to studies by Wollin, et al. (1971), only one warm period occurred during the Sangamon interglacial which might have formed the T_2 flood plain that later became a terrace (fig. 17). Wollin, et al. (1971) suggests a date of 20,000 to 40,000 years B.P. for the Sangamon interglacial period, and Slaughter, et al. (1966) reported radiocarbon dates in the vicinity of 37,000 years B.P. for the T_2 terrace of the upper Trinity River in Dallas and Denton Counties, Texas. The T_2 terraces of the Brazos and Trinity rivers have been correlated by Crook and Harris (1957). E. L. Lundelius, Jr. (1971) reported an age of Sangamon for various fossil collections along

Fig. 17

Generalized climatic curve based on Foraminifera in cores from the Atlantic Ocean on left(Wollin et al., 1971, fig.7). Correlation to river terrace development is shown on right. T_2 is the second terrace.



the T_2 terrace of the Brazos River. There is, therefore, strong evidence that the T_2 terrace of the Brazos River in the vicinity of the Waco Mammoth Site was deposited during the Sangamon interglacial.

Factors Responsible for Bone Condition

The alligator material appears more resistant than the mammoth material and indicates a faster burial and less exposure to the elements. This higher resistance is not believed to be a result of the higher bone density of cold-blooded animals. The alligator material occurs in a layer containing gravels similar in size to the jaw fragments and therefore it is believed that the jaw fragments were transported as part of a bed load deposit in the point bar sequence. The mammoth material is more weathered and occurs in silt layers. The mammoth bones could have been gradually covered by the silt and exposed during water level fluctuations and were gradually covered by the silt. Later, the cutting of the drainage ditch exposed and weathered the material in the walls of the ditch. Fractured bones result from compaction by overlying sediments from expansion and contraction of soils and alternate wetting and drying of the smectite-rich clays which resulted in soil expansion and contraction.

Factors Responsible for Skeletal Positioning

The position of skeletal material at the Waco Mammoth Site shows a high degree of articulation of large sections of the mammoths. The Lehner Mammoth Site in southeastern Arizona (Haurey, et al., 1959) is similar to the Waco site in containing six lower jaws of mammoths and other skeletal material in a single excavation area. However, the Lehner site differs from the Waco site in having scattered bones with little articulation and having associated artifacts so that the death of the mammoths could be attributed to man. Slaughter, et al. (1962) reported a mammoth kill site on the second terrace of the Trinity River in Dallas and Denton Counties, which contained an inverted skull with the rest of the skeleton lying on its side. Scattering and burning of the bones indicated that this mammoth's death was also due to man. However, no evidence has been found at the Waco site that would permit me to attribute death at this site to the activity of man.

The size of the articulated body sections of the Waco Mammoth Site indicates that the mammoths were not transported in parts by man, but either died in place, or were killed or died upstream along the banks of the ancient Brazos River and floated to their final resting place during times of flood waters.

Taphonomy of the Site

The sexes and ages calculated for individual mammoths are shown in figure 15. Although no information of this kind has been documented for mammoths, Laws (1966) plotted similar information for the African elephant (fig. 14) using weight of both tusks, rather than the volume of one tusk. The two plots in figures 14 and 15 are similar and suggest that the age groups of Laws (1966) are applicable to *Mammuthus columbi* (Falconer), assuming that tusk growth is greater for male mammoths, as indicated by the African elephant (fig. 14).

Using these data, the Waco Mammoth Site appears to contain 75% males to 25% females. This is in marked contrast to the social structures of African elephants observed in the wild by Laws (1966), and Sykes (1971) as shown in figures 18 and 19. These both have a low ratio of males to females in all mixed social structures.

It was therefore assumed that the mammoths at the Waco Mammoth Site did not represent an entire living social group. This in turn suggests a non-catastrophic cause of death (D. Western, 1980) and suggests that the mammoths died individually.

Fig. 18

African Elephant Social Structures (Sykes, 1971, p.263)

Sub-clan or family unit

one cow
teenage offspring
juveniles
calves(both sexes)

Clan

senior cow
teenage offspring
juveniles
calves
one or more sub-clans
elderly cows

Herd

clan
sire bull
one or more mature bulls

Congregation or gathering

several herds
senior bull
senior cows

Bull herds

senior bull
other sexually mature bulls
max. size 12-15

Loners

senile bulls

Fig. 19

African Elephant Social Structures(Laws et al,1975,p.132-161)

Bull herd

entirely males

ave. size 2.39

mean size 3.08

range of size 1-11

mean age 30.6 yrs. range of age 20-49

Solitary Females

ave. age 55 yrs.

range of age 52-59 yrs

Family units

mean size 11.6, range of size 2-29

members;

- adult females
- immature females
- immature males
- some sexually mature males

ave. number of mature males 2.15

mean % of mature males to females 8.9 ± 1.38 *

mean age of adult males 24.4 yrs.

* % from only one sample , although other samples were not significantly different.

The large percentage of old males at the site might indicate kills by man in a manner similar to modern poaching practices in which the poachers wait for the trailing bull of the herd and kill him without interference from the rest of the herd (Sykes, 1971). However, from the evidence available, it is not possible to attribute this accumulation of skeletal material of several individuals in a single point bar deposit to a single origin.

Ecology of the Site

The ecology of a specific geographic area is the product of the interactions of geology, climate and biology.

The Waco Mammoth Site is located on an ancient point bar of the Brazos River (see depositional model, this paper). The sediment sequence is indicative of a meandering river, which flooded intermittantly forming flood plains (Allen, 1964, 1970).

The climate of the site affected both the sediments and fauna of the area. The upper members of the T_2 terrace, on which the site is located, contain caliche horizons which indicate a period of dryer climate. The alligator material was found below the caliche horizon and the environment of *Alligator mississippiensis* (Daudin) is believed to have been that of a warm, swampland (Ditmars, 1933). *Mammuthus columbi* (Falconer) is indicative of a non-frost environment (Ludelius, 1972), and deAnda (1965) considered *Mammuthus columbi* (Falconer) as indicative of a timberland environment.

The mammoths of the Waco Mammoth Site were probably brought to the site by flood waters, but the herds to which these individuals belonged probably grazed the Brazos River bottoms and much of the Central Texas area.

The alligator, however, was restricted to the immediate vicinity of the river and its tributaries, but could move up or down stream for great distances.

Significance of the Waco Mammoth Site to Central Texas Pleistocene History

Investigations of second terrace deposits in Central Texas indicate the widespread occurrence of *Mammuthus columbi* (Falconer) and provide information about the extent and character of ecologic niches which were inhabited by the mammoths at various times. The Clear Creek Local fauna of the second terrace of the Upper Trinity River contains *Mammuthus columbi* (Falconer) (Slaughter and Ritchie, 1963). The extant species of the Clear Creek Local Fauna now exist in an area which receives less rainfall, and has warmer winters than the immediate area of the Clear Creek Local Fauna.

Another site on the second terrace of the Trinity River in Denton and Dallas Counties contained both *Mammuthus columbi* (Falconer) and *Alligator mississippiensis* (Daudin)(Slaughter, *et al*., 1962).

Mammuthus sp. also occurred in Stonewall and Haskell Counties in the Osage Plains, and in Brazos County. Both locations, though assigned an age of Sangamon, differ in environmental conditions as indicated by other fauna. The nature of this environmental difference was not discussed by Lundelius (1971).

The Ingleside fauna in San Patricio County, Texas contained both <u>Mammuthus columbi</u> (Falconer) and <u>Alligator mississippiensis</u> (Daudin). The paleo climate was interpreted as being south of the frost line, and warmer than exists in that area today (Lundelius, 1972).

These studies and the Waco Mammoth Site suggest a wide geographic range for <u>Mammuthus columbi</u> (Falconer) and <u>Alligator mississippiensis</u> (Daudin) in Central Texas, and indicates their climatic range to be south of the frost line. The fossil assemblages were deposited in fluvial environments but these environments reflect only the environments of burial since the range of the mammoths extended far from the streams. The fossil assemblages also suggest the possibility of man's presence in the Central Texas region as early as 37,000 yrs. B.P. (Slaughter, <u>et al</u>., 1962).

VI. CONCLUSIONS

1.) The Waco Mammoth Site is located in sequences of gravels, sands and silts, which fine upwards. This lithologic sequence is indicative of a point bar deposition.

2.) The sequence of sediments of the Waco Mammoth Site is similar to that of the Pemberton-Hill sequence of the Upper Trinity River and indicates that the younger terrace deposits of the Waco Mammoth Site were deposited during dryer conditions than the older terrace deposits. The fauna of the Waco Mammoth Site indicates that the paleo climate of the site was one of warmer winters than exists in the area today, and that frost did not reach as far south as the site.

3.) Elevation of the terrace containing the Waco Mammoth Site and relationships to other terraces of the Brazos River suggest that it is a second terrace. Reported ages of second terrace deposits of the Trinity River and correlation of that terrace to the second terrace of the Brazos River suggest that the second terrace deposit containing the Waco Mammoth Site in Sangamon in age (about 37,000 years B.P.).

4.) The location of alligator and mammoth material in the stratigraphic sequence, and the conditions of the skeletal material indicates that the alligator material was transported after disarticulation as part of the bed load, but that the mammoth material was transported in large articulated segments by flood waters, then gradually covered by silt during flood stages.

5.) The high degree of articulation of large body sections of the mammoths indicates that they were not transported in parts by man, but that they either died in place, or died upstream along the banks of the Brazos River and then floated onto the point bar.

6.) Determination of sex and age of the individual mammoths was based on African elephant data. From this a taphonomic study found that the group of mammoths did not represent a typical social structure and, therefore, their deaths were probably not the result of a catastrophic event. The large percentage of old males in the group suggests that poaching may have been a factor in their deaths.

7.) The ecology of the mammoth site suggests that it was a warm, swampland environment surrounded by timberland in which mammoths roamed and alligators were restricted to the river or tributaries. Man may also have inhabited the area and hunted the mammoth as early as 37,000 years B.P.

8.) The widespread occurrence of *Mammuthus columbi* (Falconer) on second terrace deposits of Central Texas indicate that mammoths roamed the Central Texas region during the Sangamon.

VII. SUGGESTIONS FOR FURTHER RESEARCH

The purpose of this paper was to describe the Waco Mammoth Site and to explain its significance to the geologic history of Central Texas. In the progress of this study a number of other problems were encountered that could not be undertaken in the current study. These include the following:

1.) A full archaeological excavation of the site might uncover remaining skeletal material and perhaps more individual mammoths and other species, and might disclose human artifacts. This would be important in explaining the death assemblage of the mammoths.

2.) A more detailed search for micro-biota in the sediments of the site, if successful, might yield information which would enable a more accurate local climatic statement to be made.

3.) A more detailed study of tooth and tusk growth rates of *Mammuthus columbi* (Falconer) involving a large sampling of individuals is needed for comparison to similar data for the African elephant. This study would result in a new tool backed by more data, which would be useful in mammoth site interpretations.

VIII. REFERENCES

Allen, J. R. L. (1964) Studies in fluvial sedimentation; Six cyclothems from the Lower Old Red Sandstone, Anglo-Welsh Basin. Journ. Sedimentalogy, v. 3, p. 163-198.

Bronaugh, R. L. (1950) Geology of the Brazos River terraces in McLennan County, Texas. Unpublished masters thesis, Univ. of Texas, 41 pp.

Burket, J. M. (1965) Geologic map of the Waco West Quadrangle, Texas. Scale 1:2400.

Cornwall, I. W. (1956) <u>Bones for the Archaeologist</u>, The Macmillan Co. 255 pp.

Crook, W. W., Jr. and Harris, R. K. (1957) Hearths and artifacts of early man, Lewisville, Texas, and associated faunal material; Bull. Texas Arch. Pal. Co., v. 28.

deAnda, L. A. A. (1956) The second mammoth and associated artifacts at Santa isabel Iztapau, Mexico; Am. Antiquity, v. 22, pp. 12-28.

Deussen, A. (1924) Geology of the Coastal Plain of Texas west of Brazos River; U. S. Geol. Survey Prof. Paper 126, p. 114-115.

Ditmars, R. L. (1933) <u>The Reptile Book</u>, Doubleday, Doram and Co., Inc.

Epps, L. (1973) A geologic history of the Brazos River. Baylor Geol. Studies, Bull. 24, 43 pp.

Flawn, P. T. and Burket, J. M. (1965) Urban geol. of greater Waco, part I. Baylor Geol. Stud. Bull. 8, 45 pp.

Graham, R. W. (1979) Pleistacene and Holocene Mammals, Taphonomy, Paleoecology of Friesenhahu Cave, Local Fauna, Bexar County, Texas. Austin, University of Texas. Unpublished Ph.D. Dissertation.

Goudie, A. S. (1977) Environmental Change, Clarendon Press, Oxford.

Haury, E. W., Sayles, E. B., and Wasley, W. W. (1959) The Lehner Mammoth Site, Southeastern Arizona; Am. Antiquity, v. 25. pp. 2-30.

Hendricks, C. L. (1935) Geology of Parker County: Univ. Texas Bur. Econ. Geology Bull. 5724 p. 49.

Laws, R. M. (1966) Age Criteria for the African Elephant, (Loxodonta-a, africana); E. African Wildlife journ. 4.

__________, Parker, I. S. C. and Johnstone, R. C. B. (1975) Elephants and Their Habitats; Clarendon Press, Oxford.

Lundelius, E. L., Jr. (1971) Late Pleistocene Vertebrates from the Brazos River Terraces, Texas. The Geol. Soc. of America, v. 3, no. 3, Abstracts with programs.

Lundelius, E. L., Jr. (1972) Fossil vertebrates from the Late Pleistocene Ingleside fauna, San Patricio County, Texas. Bureau of econ. geol. The U. of Texas at Austin, report of investigations, n. 77, 74 pp.

Maglio, V. J. (1973) Origin and evolution of the Elephantidae. The Am. Phil. Soc., Ind. Square, Phil., v. 63, part 3.

Plummer, F. B. and Hornberger, J., Jr. (1935) Geology of Palo Pinto County, Texas: Univ. Texas Bull. 3534, pp. 214-218.

Slaughter, B. H., Crook, W. W., Jr., Harris, R. K., Allen, D. C., and Seifert, M. (1962) The Hill-Shuller local faunas of the Upper Trinity River, Dallas and Denton Counties, Texas; U. of Texas Bur. of econ. geol., report of invest. n. 48, 75 pp.

____________, and McClure, W. L. (1965) The Sims Bayou local fauna; Pleistocene of Houston, Texas. Texas journal science, v. 17, p. 404-417.

____________, and Ritchie, R. (1963) Pleistocene mammals of the Clear Creek local fauna, Denton County, Texas. Journ. of the grad. research center, v. VXXXI, n. 3, pp. 117-131.

Sykes, S. K. (1971) <u>The Natural History of the African Elephant</u>, Am. Elsevier pub. co., inc., N. Y. pp. 397.

U. S. Dept. Agriculture (1958) Soil survey, Brazos County, Texas; U. S. soil conservation service, series 1951, n. 1, 65 pp.

Voohies, M. R. (1981) Dwarfing the St. Helens eruption, ancient ashfall creates a Pompeii of prehistoric animals. Nat. Geographic, v. 159, n. 1. pp. 66-75.

Western, D. (1980) Linking the ecology of the past and present mammal communities. <u>Fossils in the Making</u>, "Vertebrate Taphonomy and Paleoecology." Edited by A. K. Behrensmeyer and A. P. Hill. The U. of Chicago Press.

Wollin, G., Ericson, D. B., and Ryan, W. B. F. (1971) Variations in magnetic intensity and climatic changes; Nature, v. 232, pp. 549-551.