Archaeological geology of the Lubbock Lake site, Southern High Plains of Texas

VANCE T. HOLLIDAY  Departments of Geography and Anthropology, Texas A&M University, College Station, Texas 77843

ABSTRACT

The Lubbock Lake site is a well-stratified archaeological locality in Yellowhouse Draw on the Southern High Plains of Texas. It has a cultural record that spans the past 11,000 yr that is contained within a thick sequence of sediments and soils. The sequence at Lubbock Lake is one of the most closely integrated records of late Quaternary human occupation, sedimentation, and soil formation documented in North America. Stratum 1 (11000 yr B.P. and older) was deposited by a meandering stream and contains Clovis-age cultural remains. Stratum 2 is composed of lacustrine sediments (11000 to 10000 yr B.P.) and overlying marsh deposits (10000 to 8500 yr B.P.), with Paleoindian material in both units. The Firstview Soil (8500 to ~6300 yr B.P.) formed in the top of stratum 2. Stratum 3 (~6300 to ~5000 yr B.P.) contains early Archaic material, eolian and marsh deposits suggestive of warm, arid conditions; and the Yellowhouse Soil, indicating a brief period of landscape stability. Stratum 4 (5000 to 4500 yr B.P.) is primarily an eolian unit that marks the second of two periods of severe drought in the middle Holocene. The Lubbock Lake Soil, formed in stratum 4 (beginning 4500 yr B.P.), coincides with the late Archaic and Ceramic periods and documents landscape stability and a return to climatic conditions similar to those of today. Stratum 5 contains late Ceramic, Protohistoric, and Historic archaeological material within eolian and slopewash sediments (and the Apache and Singer Soils), which indicate several shifts toward aridity within the past 1,000 yr.

INTRODUCTION

Geological studies have traditionally accompanied many archaeological investigations on the Southern High Plains of northwestern Texas and eastern New Mexico (for example, Antevs, 1936; Haynes, 1975; Judson, 1953). There are several reasons for this tradition of archaeological geology in the region. Many of the sites are well-stratified, and the necessity for geologic interpretation was obvious. Moreover, much of the focus of archaeology in the region has been on Paleoindian occupations, and the associated deposits have held clues to late Pleistocene environments. In addition, many archaeologists involved in these investigations were students of Pleistocene paleontology and geology. Most of the data available for the archaeological sites is for the Paleoindian period, however, and much of it is qualitative and generalized.

The Lubbock Lake site, best known for its Paleoindian record, is one of several well-stratified sites of the Southern High Plains with a long history of geologic investigations oriented toward archaeological interpretations. Since the early 1970s, the entire 11,000-yr cultural and environmental record of the site has been the subject of geologic investigations focused on the stratigraphy, geochronology, environments of deposition, and pedology. The latter has been particularly significant because the soils provide some understanding of the periods of nondeposition and landscape stability that make up a significant portion of the time represented at the site. Such a well-dated pedologic study is also able to provide information on rates of soil development that can be extrapolated to other nearby sites. This paper reviews the results of the investigations into the archaeological geology of the Lubbock Lake site.

SETTING AND HISTORY OF RESEARCH

The Southern High Plains is a large plateau with a flat, featureless surface interrupted by dune fields, playas, and a few northwest-southeast–trending, ephemeral drainages or draws, tributaries to the Red, Brazos, and Colorado Rivers (Hawley and others, 1976). Lubbock Lake is in an entrenched meander of Yellowhouse Draw, a tributary of the Brazos River, in northern Lubbock County (Fig. 1).

The climate of the region is semi-arid and continental. The average annual precipitation at Lubbock (elevation, 992 m) is 46.8 cm, although there is considerable annual variation (National Oceanic and Atmospheric Administration, 1982).

The regional bedrock consists of Paleozoic and Mesozoic sedimentary rocks overlain by extensive, thick, Miocene and Pliocene alluvial and eolian sediments of the Ogallala Formation. Locally inset into the Ogallala are lacustrine deposits of the Pliocene Blanco Formation. Overlying the Ogallala and Blanco are the extensive Pleistocene eolian sediments of the Blackwater Draw Formation that locally contain lacustrine units (Hawley and others, 1976; Reeves, 1976). At Lubbock Lake, Yellowhouse Draw has cut through the Blackwater Draw Formation and entrenched itself into the Blanco Formation. Maximum downcutting probably occurred in the late Pleistocene and, at that time, the draw attained local relief of ~15 m (Stafford, 1977).

The Lubbock Lake site was discovered in 1936 following excavation of a U-shaped cut to be used as a reservoir along the inside of the meander in the draw (Fig. 2). The excavations completely cut through the late Quaternary valley fill. Subsequent archaeological excavations were conducted in 1939 and 1941 (Wheat, 1974), 1948, 1949, and 1951 (Evans, 1949; Selders, 1952), and in 1959 and 1960 (Green, 1962; Kaczor, 1978). The research leading to this paper began in 1972. Initial geologic investigations of this project were by C. Johnson (1974) and Stafford (1977, 1978, 1981). The author began geologic and pedologic research in 1976 (Holliday, 1982).

The geologic investigations were made possible by the archaeological excavations, exposures along the walls of the reservoir, and excavation of >150 back-hoe trenches along the draw for 2 km north of, and radiating east, south, and west of, the reservoir (Stafford, 1977, 1978; Holliday, 1982). Most of the trenches were described, and samples from many of them.


1483
Figure 1. Topographic map of Yellowhouse Draw in the area of the Lubbock Lake site, showing the location of the reservoir and trenches north of the reservoir. Inset shows the Llano Estacado with Lubbock Lake and major drainages (Yh = Yellowhouse; Bw = Blackwater; RW = Running Water).

were subjected to a variety of laboratory analyses. The descriptions and laboratory results are presented elsewhere (Holliday, 1982, 1983, 1985a, 1985b).

STRATIGRAPHY

The late Quaternary stratigraphic sequence at the Lubbock Lake site consists of a series of fluvial, lacustrine, marsh, eolian, and slopewash deposits derived from the Blackwater Draw Formation and, to a lesser degree, the Blanco Formation. The stratigraphic nomenclature used at the site is a considerable revision of that established by C. Johnson (1974) and modified by Stafford (1977, 1978, 1981) (Table 1). Five primary geologic units (strata), numbered oldest to youngest, have been identified and subdivided into substrata. Vertical subdivisions are identified using uppercase letters (A, B, and so forth), and lateral subdivisions (facies changes), using lowercase abbreviations for the mode of deposition (e = eolian, s = slopewash, l = lacustrine) (Fig. 3; Tables 1 and 2).

Five major soils have formed in the sediments at Lubbock Lake. These soils have been named and classified to the great group level (Soil Survey Staff, 1975; Table 1). Stafford (1981, Fig. 3) classified the soils to the suborder level (Table 1), but the classifications do not reflect the variability of the soils due to differences in their age, landscape position, and postburial alterations. The morphology and genesis of the soils are discussed by Holliday (1982, 1985a, 1985b). The ages of all principal strata, substrata, and soils are well controlled by >100 radiocarbon ages (Holliday and others, 1983, 1985).

Stratum 1

Stratum 1 (Fig. 3) is the oldest deposit containing evidence of human occupation at Lubbock Lake. The unit is predominately alluvial, although Stafford (1978) presents evidence for some localized lacustrine sedimentation. The time at which stratum 1 began to accumulate is unknown, but the end of deposition occurred by 11000 yr B.P., hence the unit is, at least in part, contemporaneous with the Clovis cultural period (11500 to 11000 yr B.P.).

Stratum 1 is in a buried terrace and at the base of the valley fill. The sediments that form the buried terrace appear as isolated deposits averaging 2 m thick and composed of carbonate gravel and sand. This deposit was referred to as substratum 03 by Stafford (1981, Fig. 5), and it was suggested that the deposit was related to the Tahoka Formation (~25000 to 12000 yr B.P.; Hawley and others, 1976). The deposit contains Rancholabrean fauna with evidence of butcher-
The stratum 1 basal valley fill has been most intensively and extensively studied in area 2 (Fig. 2), where the unit contains the butchered and broken remains of late Pleistocene (Rancholabrean) megafauna (E. Johnson, 1983; Johnson and Holliday, 1985a). This feature (feature 1 in area 2; FA2-1) dates to ~11100 yr B.P. (Holliday and others, 1983). Three subunits of stratum 1 have been identified in area 2. A gravel deposit (substratum 1A) extending across the floor of the valley represents a point bar complex and is up to 1 m thick. FA2-1 rests on a gravel bar within the point bar complex. Apparently, Paleoindians butchered animals and processed the bone for marrow extraction and tool manufacture on this bar (E. Johnson, 1983; Johnson and Holliday, 1985a). Substrata 1A and FA2-1 are buried by an overbank loamy sand deposit (substratum 1B) that fines upward into clay (substratum 1C). Substrata 1B and 1C together are up to 1 m thick, and they thin toward the western valley margin.

The presence of FA2-1 within stream sediments raises the possibility that the bone is not in situ. There are areas at the site where bone in substratum 1B is not in place. Some small bone fragments have been found within 1B in area 2, indicating that they were picked up during the overbank flood event. Undoubtedly, there was some disturbance of the feature; however, sev-
eral lines of evidence show that FA2-1 is essentially in place. Almost all of the bone rests directly on the gravel. Significant disturbance should produce bone wedged into the gravel or supported by the 1B sand. The maximum particle size of 1B which buries the bone in area 2 is fine sand and, contrary to Stafford (1983, p. 156), cut-and-fill sequences have not been identified within 1B in the excavation area, although coarser, bed-load material and numerous disconformities are common in 1B in other areas of the site. The particle size of 1B and availability of coarser material suggest that the water had insufficient energy to carry large bone or bone fragments. The presence of climbing ripples (Stafford, 1977) also suggests that 1B was a low-energy deposit undergoing aggradation (Harms and others, 1975). Finally, the broken remains of an infant mammoth skull, although mostly unattached, were found, essentially, in anatomical position. Water flowing with sufficient energy to disturb FA2-1 would be expected to scatter the skull parts, given their relatively flat and porous nature.

**Stratum 2**

Stratum 2, composed of five subunits (Tables 1 and 2), is primarily a lacustrine and marsh deposit that contains most of the Paleindian record at Lubbock Lake. Substratum 2A, found along the valley axis, conformably overlies stratum 1 and contains beds of pure diatomite deposited by standing water. Interbedded with the diatomite are lenses of sapropelic silt and clay with few diatoms but abundant phytoliths, interpreted as being marsh sediments accreted when water was just below the surface. Major beds, or groups of beds, of diatomite and clay are designated “Local Beds” (LB) in excavation areas (Fig. 4). Stafford (1981, 1983) considered the maximum water depth producing 2A to have been 80 cm. Holliday and Johnson (1983) proposed that water may have been deeper, but the geologic evidence was simply not preserved. Deposition of substratum 2A began at −11000 yr B.P. and terminated at 10000 yr B.P., or slightly later.

Figure 3. Generalized cross section of the late Quaternary stratigraphy of the Lubbock Lake site (location of section shown in Fig. 2).
Stafford (1981) documented a wedge of calcium carbonate which interfingers with 2A. It is considered to be a spring deposit. The wedge is highly calcareous, but the 2A deposits < 2 m away are noncalcareous and contain abundant siliceous material. An alternate hypothesis is that the carbonate wedge was in place prior to stratum 2 deposition. The lenses of carbonate that interfinger with 2A are composed of clasts of carbonate, suggesting that material was eroded off of the wedge as 2A was being deposited. In area 5 (Fig. 2), however, stratum 2s is highly convoluted, suggestive of spring activity (C. Vance Haynes, 1983, personal commun.).

Substratum 2B overlies 2A, conformably in some areas, disconformably in others (Fig. 4). The unit is a generally homogeneous deposit of sapropelic silt and clay with abundant phytoliths and few diatoms, similar to the silt and clay interbeds in 2A. A few lenses of silicified plant remains occur locally in 2B. Substratum 2B is considered to represent a slowly aggrading bog with little, or no, standing water, possibly indicating a lowering water table. Deposition of the unit occurred from 10000 to ~8500 yr B.P.

Substrata 2s and 2e are facies of both 2A and 2B (Tables 1 and 2). Substratum 2s is a nearshore deposit consisting of sandy slopewash interbedded with lenses of lacustrine sediment from transgressions of 2A and 2B. Substratum 2e is an eolian facies common on the west side of the valley and interfinger with 2s. This eolian facies increases in areal extent through stratum 2 time. Lenses of sediment representing transgressions of 2B are common within 2e. The eolian sediments began to accumulate as early as 9000 yr B.P.

Substratum 2F consists of localized deposits of quartz and carbonate sand up to 50 cm thick that overlies 2B. Stafford (1981, 1983) considered 2F to be spring-laid, although direct evidence for this origin is lacking (Holliday and Johnson, 1983). Holliday (1985a) suggested that the material is slopewash; however, uniform particle size and absence of bedding or grading suggests that 2F may be eolian, simply a transgression of 2E across the 2B marsh. Substratum 2F was deposited episodically between ~8500 and ~6300 yr B.P.

The Firstview Soil formed in the top of stratum 2 from 8500 to 6300 yr B.P. This represents a significant period of landscape stability in the early Holocene and a hiatus in marsh (2B) and eolian (2e) sedimentation. The soil is weakly developed (Table 1). Where the soil has formed in 2B, it has a relatively high organic-matter content, often abundant silicified root remains, and commonly exhibits a gleys horizon immediately below the A horizon, indicating a marsh environment with the water table at, or just below, the surface (Fig. 6). Toward the west valley margin, where the soil formed in 2e, it was considerably better drained.

Paleoindian archaeological features are common in stratum 2. Folsom-age (10500 to 10200 yr B.P.) bison kill/butchering locales are found in the sapropelic interbeds of substratum 2A (Sellards, 1952; E. Johnson, 1983). Plainview-age (-10200 to < 10000 yr B.P.) bison kill/butchering locales are found at the 2A-2B contact and in substratum 2s (Johnson and Holliday, 1980; Holliday and Johnson, 1984). Firstview and other late Paleoindian period (< 10000 to ~ 8000 yr B.P.) bison kill/butchering locales and a camp are found in upper 2B and 2s (Johnson and Holliday, 1981; Holliday and Johnson, 1984). Apparently, hunters killed and butchered animals along the floor of the draw when the water table was low and only isolated pools of water existed. When standing water was available or when the 2B marsh was aggrading, kills took place near, or along, the shore. The kills are of only a few individuals, and there are no apparent geomorphic means (for example, in arroyos or dunes) of trapping larger groups of animals. There is also little evidence that animals were bogged down; diatomite beds immediately below the bone beds in 2A show no deformation. The limited information also indicates that Paleoindian camps were located along the valley margins.

The time for formation of the Firstview Soil spans the Paleoindian-Archaic transition (~8000 yr B.P.) and includes most of the early Archaic (8000 to 6000 yr B.P.); however, no Archaic cultural material has been found in association with the surface of the soil (Johnson and Holliday, 1985b).

**Stratum 3**

Stratum 3 rests conformably on stratum 2 and is subdivided into substrata 3e and 3f (Table 1 and 2). Substratum 3e is fine grained, of relatively uniform particle size (sandy loam), and thickens toward the valley margin. These characteristics mean that 3e probably is eolian, although there are some slopewash additions near the valley margin. Substratum 3f, found only along the valley axis, is highly calcareous and friable. The two substrata interfinger (Fig. 3), and the physical properties of 3f suggest that it is a lowland lacustrine facies of 3e.

The Yellowhouse Soil, formed at the top of stratum 3, is weakly developed (Table 1). The soil represents a brief interval of landscape sta-
bility and an interruption of eolian deposition and aggradation of the alkaline lake sediments. Where the soil formed in 3f (along the valley axis), it has a relatively organic-rich A horizon, and there is minimal leaching of CaCO$_3$ in the highly calcareous parent material. These characteristics indicate that the water table was high, perhaps just below the surface, along the floor of the draw as the soil formed. Along the valley margins, where the soil formed in 3e, the soil is oxidized and considerably lower in carbonate content, pointing to considerably better drainage.

Deposition of stratum 3 began ~6300 yr B.P. The end of deposition and the beginning of formation of the Yellowhouse Soil is unknown. Burial of stratum 3 and the Yellowhouse Soil was time-transgressive. Along the valley axis, substratum 3f was eroded and buried by stratum 4, beginning ~5500 yr B.P. Along the valley margins, stratum 3 and its soil were not buried until as late as 5000 yr B.P.

Stratum 3 time coincides with parts of the early and middle Archaic cultural periods. Considerable archaeological material has been recovered from stratum 3, contrary to Stafford (1981, p. 557). Most of the material is from 3e; little has been found in 3f, probably because it represents an alkaline marsh and would, therefore, not be inviting to occupants (Holliday and Johnson, 1983; Johnson and Holliday, 1985b).

**Stratum 4**

Stratum 4 consists of several types of deposits and a soil. Substratum 4A disconformably overlies stratum 3 and is found only along the valley axis (Fig. 3). The unit contains low-energy alluvial sediment (cross-bedded sand) deposited by an intermittent stream, interbedded with transgressive backwater/lowland marsh deposits (clay) (Table 2). Substratum 4A is common at, and downstream from, Lubbock Lake but is not seen upstream from the reservoir. For this reason, it is considered to be the result of spring discharge. The olive hues in substratum 4A (Table 2), with oxidized mottles at both the top and bottom of the unit, indicate that some post-depositional reduction took place.

Substratum 4B is primarily an eolian deposit up to 3 m thick (Fig. 5; Table 2). This is shown by the fine-grained and relatively uniform particle size of the unit (sandy clay to sand clay loam) and the fact that it thickens toward the west (upwind). Clay mineralogy is very similar to that of the Blackwater Draw Formation of the High Plains surface (mainly illite, smectite, and mixed-layer illite-smectite) (Allen and others, 1972), rather than that of the Blanco Formation (dominated by palygorskite and sepiolite).

---

**Figure 5.** Strata 4 and 5 in trench 95 (Fig. 2), with excellent examples of the morphology of the Singer Soil, buried Apache Soil, and buried Lubbock Lake Soil (with multiple calcic horizons).

**Figure 6.** Plot of sedimentation rates at Lubbock Lake over the past 11,000 yr, illustrating the episodic nature of the depositional events and the relatively long intervals of landscape stability and soil formation. Numbers are strata, and abbreviations are respective soils (Fv = Firstview; Yh = Yellowhouse; LL = Lubbock Lake; Ap = Apache; Sg = Singer).
(Bigham and others, 1980) exposed along the valley walls and expected in an alluvial deposit in the draw.

In the lowermost portions of the valley, an organic-rich marsh facies of 4B is apparent (stratum 4I). This marsh deposit is identical to, but smaller in areal extent than, the marsh sediments in 4A. Apparently, a marsh of varying size existed along the valley bottom throughout stratum 4 deposition.

The Lubbock Lake Soil has formed in the top of stratum 4B (Fig. 5). This soil is the best developed (Table 1) and most widespread one at the site. The A horizon is so distinctive that it was given geologic stratum designation and used as a marker bed from the time of the first excavations (for example, Table 1). Zones of CaCO₃ accumulation are also quite prominent. Lenses of stratum 4I are apparent in the A horizon of the soil in a few exposures, indicating that the lowland marsh existed during the time of Lubbock Lake Soil formation, periodically transgressing across the stable landscape.

Stratum 4A deposition occurred between ~5500 and 5000 yr B.P. Deposition of 4B began before 5000 yr B.P. and ended at ~4500 yr B.P. A long period of landscape stability followed, during which time the Lubbock Lake Soil formed. Formation of the soil ceased <1000 yr B.P. in areas of stratum 5A deposition. On the east side of the site, stratum 4 was never buried, and pedogenesis has continued to the present.

Stratum 4 contains some middle Archaic (6000 to 4000 yr B.P.), late Archaic (4000 to 2000 yr B.P.), and Ceramic (2000 to 500 yr B.P.) cultural remains. Johnson and Holliday (1985b) documented a considerable inventory of archaeological material from throughout the unit that was not concentrated in upper stratum 4 as stated by Stafford (1981, p. 557). Considering, however, that the A horizon was at the surface for 3,500 to 4,500 yr, the amount of material from that zone is not suggestive of intense occupation.

Stratum 5

Stratum 5 is the youngest deposit at Lubbock Lake and is divided into two substrata, 5A and 5B, each of which consists of two facies (Fig. 3). The up-slope, valley-margin facies of both substrata (designated simply 5A and 5B and found only along the west and south sides of the site) are composed of layers of slopewash sand and gravel and eolian sand (Table 2),burying stratum 4 (Figs. 3 and 5). Substratum 5B is thinner than is 5A (Table 2) and separated from it by a soil formed in 5A. The lowland, valley-axis, lacustrine facies (5A1 and 5B1) are composed of relatively organic-rich clay. These lacustrine sediments represent a continuation of the lowland marsh deposition of stratum 4, although of considerably wider areal extent. Substratum 5B1 is probably related to the standing water known to have existed at the site in the late 19th and early 20th centuries (Holden, 1962).

Several soils have formed in stratum 5: the Apache Soil in 5A and the Singer Soil in 5B (Fig. 5). These soils represent returns to landscape stability, which was interrupted by the episodic deposition of 5A and 5B. Both soils are well drained, as evidenced by oxidized colors and CaCO₃ translocation. They differ in degree of development, stratigraphic position, and periods of development. The Apache Soil is weakly to moderately developed (Table 1), although the A horizon is locally prominent and sometimes serves as a stratigraphic marker. Zones of CaCO₃ accumulation are also locally prominent. Where only 5A was deposited over stratum 4, the Apache Soil is the present surface soil. The Singer Soil is very weakly developed (Table 1) and is the surface soil where 5B was deposited.

Radiocarbon ages indicate that deposition of 5A began ~750 to 600 yr B.P. Deposition ceased, and the Apache Soil began forming ~450 yr B.P. Between 300 and 250 yr B.P., substratum 5A was buried by 5B in some areas. Historic European materials in 5B mean that deposition of the unit ended, and the Singer Soil began developing ~100 yr B.P.

Cultural remains from the late Ceramic (circa 1300 A.D. to 1450 A.D.), Protohistoric (1450 A.D. to 1650 A.D.), and Historic (1650 A.D. to present) periods are abundant in stratum 5 (Johnson and others, 1977). The valley-margin deposits include camping sites, and both facies of stratum 5 contain bone beds representing areas where the bones of game animals were broken for marrow extraction and tool manufacture. The presence of upright, articulated limbs in the bone bed from one Historic bison kill suggests that the lacustrine sediments were used to bog the animal down. The absence of deformation in deposits underlying the stratum 5 lacustrine sediments where the bone beds have been found indicate that these deposits below the marsh provided firm footing beneath the water for executing these activities.

SUMMARY AND CONCLUSIONS

The stratigraphic sequence at Lubbock Lake provides an excellent record of Late Quaternary deposition and soil formation. Documentation of episodes of deposition, investigation of microstratigraphy in excavation areas, and the recognition of soils and determination of their lengths of development provide data of considerable significance to the interpretation of associated archaeological remains. Perhaps most important, almost half of the time represented by the stratigraphic record at Lubbock Lake is composed of periods of landscape stability and soil formation (Fig. 6). This stability results in problematic situations whereby long periods of occupation can be compressed stratigraphically into a few centimetres at the surface of each soil. For example, the surface of the Firstview Soil was exposed from ~8500 to <6500 yr B.P., spanning the important cultural transition from the latest Paleoindian to early Archaic, and the surface of the buried Lubbock Lake Soil (4500 to <1000 yr B.P.) spans the late middle Archaic, late Archaic, and most of the Ceramic cultural periods.

The deposits at Lubbock Lake provide evidence for local paleoenvironments and suggest general, regional climatic trends (Fig. 7). The stratum 1 deposits demonstrate that a perennial stream flowed through the site. The buried stratum 1 terrace also indicates that there was at least one late Pleistocene cycle of alluviation and downcutting, followed by the last cycle of alluvial activity. Discharge was probably maintained by runoff and spring activity. Microfaunal evidence suggests that the environment at Lubbock Lake during the Clovis period was considerably cooler, with higher effective precipitation than today (E. Johnson, 1976). Cultural debris is common in the fluvial deposits, and caution must be exercised in interpreting their provenience. A fluvial environment does not, however, preclude finding artifacts in situ.

The abrupt hydrologic change from flowing water (stratum 1) to standing water (stratum 2) was probably due to a decrease in discharge, although it is not known whether this was a decrease in runoff or in spring discharge. This change was probably the result of climate change, but a mechanism for impounding the water is still required. Stafford (1983) proposed that discrete ponds existed in natural pool and riffle topography at the top of stratum 1. The long exposures of strata 1 and 2 show no evidence for this. Where paleotopographic lows at the top of stratum 1 are present, the diatomite drapes over both lows and highs. Discrete accumulations of diatomite are not apparent in any of the low areas.

The origin of the disconformity locally apparent between 2A and 2B is uncertain. Eolian sedimentation is documented in stratum 2, and the disconformity is found only on the western (upwind) side of the site. This suggests that the disconformity may represent local wind deflation. Stafford (1981, 1983) considered the disconformity to be significantly time-transgressive and
that 2B represented 2A deposits that had been churned due to bioturbation. Data now suggest that whatever time is represented by the 2A–2B disconformity is not within the resolving power of the radiocarbon method (Holliday and others, 1983, 1985). Bedding, furthermore, is locally apparent in 2B, but few diatoms occur, which is not what would be expected in churned 2A. Finally, it does not seem likely that biological activity would consistently mix only the upper half of the deposit.

Individual ponds producing the 2A and 2 B sediments were probably larger than the reservoir area, and evidence for a dam has been found ~1 km upstream from the reservoir (trench 118; Figs. 1 and 8). A thin, organic-rich lens of clay overlies a thick deposit of sand with interbedded gravel (considered to be strata 2 and 21 equivalents, respectively, on the basis of stratigraphic position and lithology). Elevations of the top of stratum 2, upstream and downstream from trench 118, suggest that stratum 2 occurs in stair-step fashion down Yellowstone Draw (Fig. 8) and that individual ponds were, perhaps, hundreds of metres long. Some were probably longer. This situation would be expected for lacustrine deposits in a valley, rather...
than a continuous deposit of uniform thickness dipping downvalley, as suggested by Stafford (1981, Fig. 13).

The exact nature of the dam is unknown. Beavers were probably not involved because beaver remains have not been found at Lubbock Lake or in the region (E. Johnson, 1976, 1983). It is possible that eolian sand reworked from stratum 1 could have blocked the channel because trench 118 is located where the draw becomes considerably constricted.

Lacustrine deposition at Lubbock Lake took place from 11,000 to 10,000 yr B.P., followed by marsh deposition until 8500 yr B.P., then landscape stability and soil formation occurred until ~6300 yr B.P. Eolian deposition becomes increasingly important beginning as early as 9000 yr B.P. This gradual change in the depositional environment is, again, probably related to a decrease in runoff and spring discharge, but their respective importance cannot be determined from the stratigraphic record.

The mode of deposition at Lubbock Lake continued to be one of eolian and marsh sedimentation after ~6300 yr B.P., but eolian sediments dominate the stratigraphic record in the middle Holocene, and the marsh deposits become highly calcareous. The increasing amount of eolian deposits through stratum 2 and in stratum 3 suggests a gradual reduction in the regional vegetation cover which, in turn, points to a trend toward regional aridity and possible warming. This warming trend is also suggested by limited paleobotanical and paleontological data (Johnson and Holliday, 1985b). The change in lacustrine sedimentation from stratum 2 to stratum 3 is abrupt, although it probably does not signal an abrupt climate change. More likely, a geochemical threshold was crossed (as the marsh waters warmed), and an environment favoring silica precipitation changed to one favoring carbonate precipitation (Holliday, 1985a). In addition, there may have been a concomitant decrease in spring discharge, resulting in a change from fresh to brackish water and a concentration of calcium carbonate.

The time from ~5500 to 5000 yr B.P. is principally one of nondeposition, with formation of the Yellowhouse Soil in stratum 3. Given that the modern environment is one of nondeposition, this short period probably was one in which a climate similar to the modern climate prevailed, following a period of drought. There is some localized erosion and deposition (substratum 4A) along the valley axis, most likely the result of a short period of reactivation of springs due to a rise in the water table following the first drought.

The eolian sediments of substratum 4B are believed to be the manifestation of a severe drought that lasted from ~5000 to 4500 yr B.P. Landscape stability and formation of the Lubbock Lake Soil, considered to represent climatic conditions essentially like those of today, followed the drought and continued throughout most of the rest of the Holocene epoch. Deposition of the marsh sediments of substratum 4f demonstrates that even at the aridity maximum and throughout much of the past 4,500 yr, some water was available along the floor of the draw.

Stratum 5, with localized slopewash and eolian sediments, indicates that there were also several climatic departures toward aridity within the past 1,000 yr. During this time, however, a marsh continued to exist and, apparently, expanded.

In summary, the sediments and soils at Lubbock Lake document a climatic shift from somewhat cooler and more moist conditions at the end of the Pleistocene to two periods of drought in the middle Holocene. The past 4,500 yr have been a period of essentially the modern climate, there being several brief periods of aridity within the past 1,000 yr. Human occupation of the site appears to have been more or less continuous for over the past 11,000 yr, although the data are not sufficient to precisely document population movements in response to climatic changes.

The stratigraphic sequence preserved at Lubbock Lake is, generally, remarkably similar to that documented at localities along Yellowhouse Draw below Lubbock Lake (Stafford, 1981) and along Blackwater Draw and Running Water Draw, the next two ephemeral drainages north of Yellowhouse (Holliday, 1983, 1985c).
ACKNOWLEDGMENTS

I would like to express my thanks and appreciation to a number of individuals for reviewing drafts of this paper and providing helpful comments and suggestions: E. Arthur Bettis III, John Costa, C. Reid Ferring, John W. Hawley, Eileen Johnson, James C. Knox, and David L. Weide. This research is part of the continuing research of the Lubbock Lake Project (The Museum, Texas Tech University; Eileen Johnson, Director), supported by the National Science Foundation (S07C-14857; BNS7612006; BNS7612006-A01; BNS78-11155); National Geographic Society; Texas Historical Commission; Sigma Xi; City and County of Lubbock; the Center for Field Research (EARTHWATCH); The University of Colorado—Boulder; The University of Wisconsin—Madison; Texas Tech University; and The Museum, Texas Tech University.

REFERENCES CITED


Holliday, V. T., 1985a, Guidebook to the Central Llano Estacado (Friends of the Pleistocene South-Central Cell Field Trip): Lubbock, Texas, ICASALS and The Museum, Texas Tech University, 165 p.


Reaves, C. C., Jr., 1976, Quaternary stratigraphy and geologic history of the Southern High Plains, Texas and New Mexico, in Mahaney, W. C., ed., Quaternary stratigraphy of North America: Stroudsburg, Pennsylvania, Dowden, Hutchinson, and Ross, p. 213-234.


Sellers, H. H., 1952, Early man in America: Austin, Texas, University of Texas Press.


