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RADIOCARBON AGES FROM THE LUBBOCK LAKE SITE: 1981-1984

by

Vance T. Holliday, Eileen Johnson, Herbert Haas, and Robert Stuckenrath

ABSTRACT

Forty-eight additional radiocarbon ages became available for Lubbock Lake (Southern High Plains of Texas) during the period 1981-1984. A new but unreliable radiocarbon age is available from Stratum 1 (deposition ending about 11,000 years B.P.; Clovis-age occupation). Thirty-three new radiocarbon ages are available from Stratum 2 and suggest the following refinements to the previously established radiocarbon chronology for the deposit: (1) the initial phase of lacustrine (diatomite) deposition lasted from 11,000 to about 10,500 years B.P. (early Folsom occupation); (2) the first cycle of marsh (organic-rich clay) sedimentation occurred between about 10,500 and 10,200 years B.P. (late Folsom occupation); (3) the substrata 2A-2B contact is not time-transgressive and dates to 10,000 years B.P. or a little less (Plainview occupation); (4) near-shore deposits (substratum 2s) are facies of all or portions of substrata 2A and 2B; (5) eolian sediments (substratum 2e) began to accumulate by 9000 years B.P. (early Firstview occupation); and (6) the Firstview Soil developed in upper substratum 2B beginning about 8500 years B.P. (Firstview occupation) and ended as late as 6300 to 6200 years B.P. (early Archaic occupation), which also would be the age for the beginning of Stratum 3 deposition. Both new and previously reported radiocarbon ages from upper Stratum 3 and lower Stratum 4 suggest that the Yellowhouse Soil formed in Stratum 3 along the valley margins during the period 5500-5000 years B.P. (middle Archaic occupation). At this time along the valley axis, Stratum 3 was eroded and then substratum 4A was deposited as a result of increased spring activity. New radiocarbon ages from charcoal further document human activity at Lubbock Lake during the Protohistoric (Garza) period. The additional radiocarbon ages from Lubbock Lake strengthen the position of the site as one of the best-dated sites in North America.

INTRODUCTION

Lubbock Lake (41LU1), on the Southern High Plains of Texas, is one of the best-dated archaeological sites in North America, yielding 69 radiocarbon ages as of 1980 (Holliday et al. 1983). Since 1980, an additional 48 radiocarbon determinations were secured on a variety of materials from all principal cultural periods (Paleo-Indian through Historic). The following is a discussion of those additional 48 ages. Holliday et al. (1983) discuss in some detail the site setting and stratigraphy, materials dated, and calibrations. Additional information on the stratigraphy and soils at Lubbock Lake is provided by Holliday (1983, 1985a, 1985b). A brief summary is presented as a review and in order to deal with matters specifically related to the new radiocarbon ages.

Lubbock Lake, now a State and National Historic Landmark, is on the north side of the city of Lubbock, Lubbock County, Texas, on the Southern High Plains. The site covers about 120 ha and is located in an entrenched meander of Yellowhouse Draw, which is a tributary of the Brazos River (Fig. 1). The site was discovered in 1936 during the excavation of a U-shaped cut along the inside of the meander (Figs. 1, 2). Lubbock Lake contains deposits 3 m to 5 m thick that record cultural activity, sedimentation, and soil formation, and floral and faunal changes that span the past 11,500 radiocarbon years.

The radiocarbon ages from Lubbock Lake were determined by the radiocarbon laboratories of Southern Methodist University (SMU) and the Smithsonian Institution (SI). A variety of materials from the site were dated, including wood, charcoal, shell, bone, and two fractions from organic-rich sediments. Most of the new ages were determined on the NaOH-soluble (humic acid; SMU) and NaOH-insoluble (humin; SI) fractions from organic-rich lacustrine deposits and the A horizons of buried soils. All radiocarbon ages from Lubbock Lake are based on a radiocarbon half-life of 5568 years and are expressed in radiocarbon years before present (years B.P.) with one standard deviation. Corrections for C-13/C-12 fractionation were made for many samples and are informally indicated in the text by the letter "f" after the laboratory number. The standard procedures of respective laboratories are outlined elsewhere (Haas and Haynes 1975; Haynes and Haas 1974; Stuckenrath and Mielke 1973).

All radiocarbon ages from Lubbock Lake are calibrated for variations in the production of atmospheric C-14 if possible (Table 1). The high-precision calibration curves of Stuiver (1982) are used for the period 1950 to 0 radiocarbon years B.P. Some radiocarbon ages within this period have several possible calendar corrections and all are listed (Table 1). Calibrated age ranges (at the 95% confidence level) are presented for radiocarbon ages between 7240 and 1950 radiocarbon years (Table 1) following Klein et al. (1982). Radiocarbon ages older than 7240 years B.P. cannot be corrected and should be considered minimum calendar dates.

RADIOCARBON AGES

The radiocarbon ages are discussed by stratigraphic unit or, where applicable, by subunit with reference to excavation areas or trenches from which they were secured (Figs. 1, 2). The five principal strata at Lubbock Lake are numbered oldest to youngest (Fig. 3). The five major soils that formed in these deposits have been named. Vertical subdivisions of strata (substrata) are identified by uppercase letters in alphabetical order, oldest to youngest. Facies within strata are identified by lowercase letters following the numbers (e = eolian, *l* = lacustrine, s = slopewash).

Stratum 1

Stratum 1 contains the earliest evidence for human occupation at Lubbock Lake (Johnson 1983; Johnson and Holliday 1985) and is the oldest wide-spread valley fill in Yellowhouse Draw in the area. The unit is an alluvial deposit from a meandering stream that was decreasing in competency up to about 11,000 years B.P. when sedimentation ceased. The maximum age for Stratum 1 is unknown. Stratum 1 contains a processing station with late Pleistocene megafauna that dates to about 11,100 years B.P. (Clovis age).

One new radiocarbon age available from Stratum 1 is from Area 2 (Fig. 2), which produced several of the other ages for Stratum 1. The sample is from organic-rich sediments that fill a channel cut into overbank sand and clay (substrata 1B and 1C, respectively) which represent the last phases of Stratum 1 alluviation. The channel is a sloughlike feature that represents the final stage of flowing water in Yellowhouse Draw and is choked with the butchered remains of *Bison antiquus* (feature 2

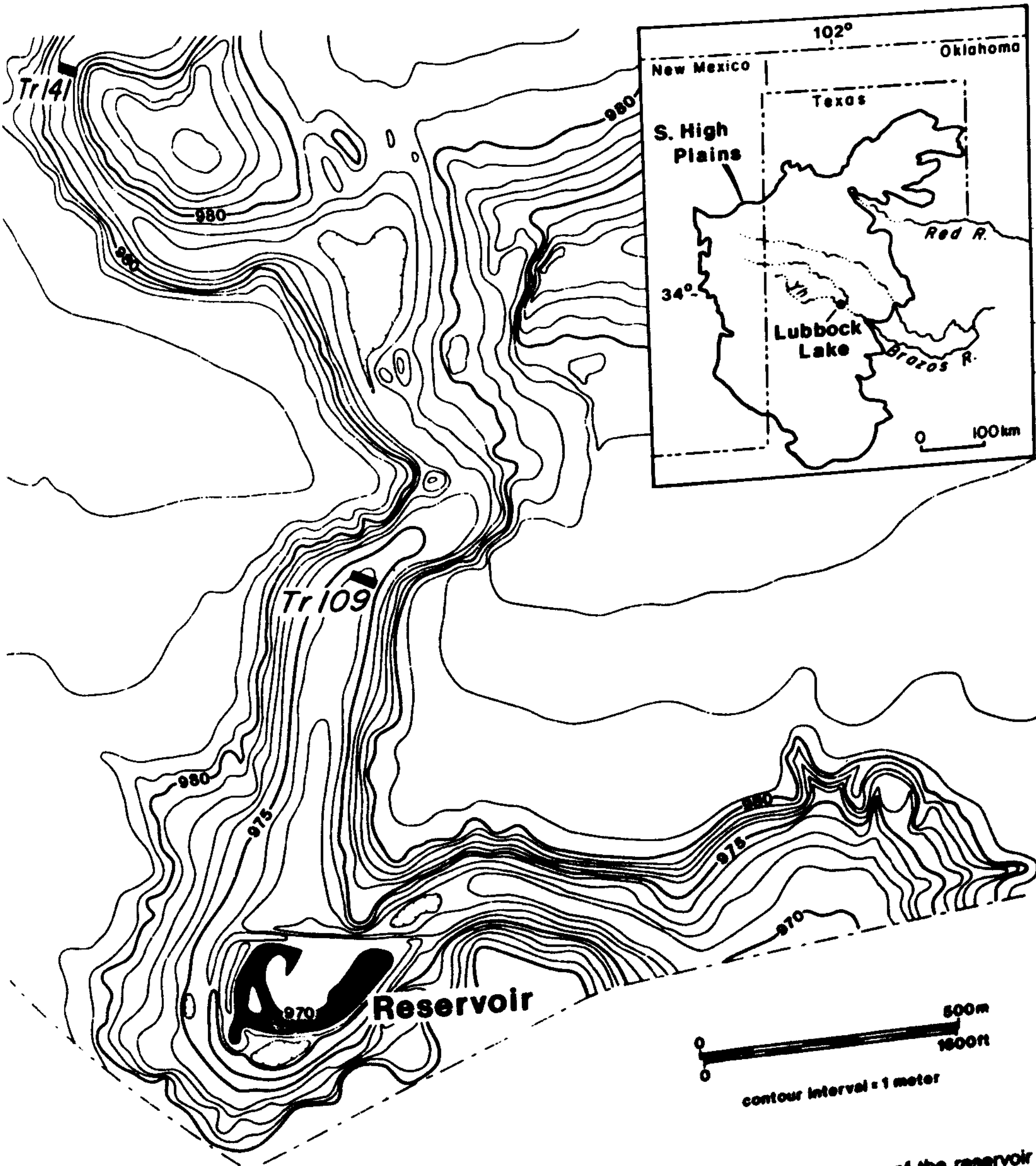

Fig. 1. Topographic map of Yellowhouse Draw in the area of Lubbock Lake with the locations of the reservoir cut and trenches 109 and 141. Inset shows the location of Lubbock Lake and Yellowhouse Draw (Yh) on the Southern High Plains.

in Area 2: FA2-2). The sample yielded a radiocarbon age of 9660 ± 100 years B.P. (SMU-1109). Based on previously reported dates on wood from Stratum 1 and numerous radiocarbon ages from the immediately overlying unit (substratum 2A), this radiocarbon assay is considered to be too young. For several years the feature was exposed low in the wall of the reservoir cut and may have been subject to contamination by groundwater or water in the reservoir.

Stratum 2

Over half of the new radiocarbon ages from Lubbock Lake are from Stratum 2. This situation primarily reflects the continuing emphasis of excavation on the Paleo-

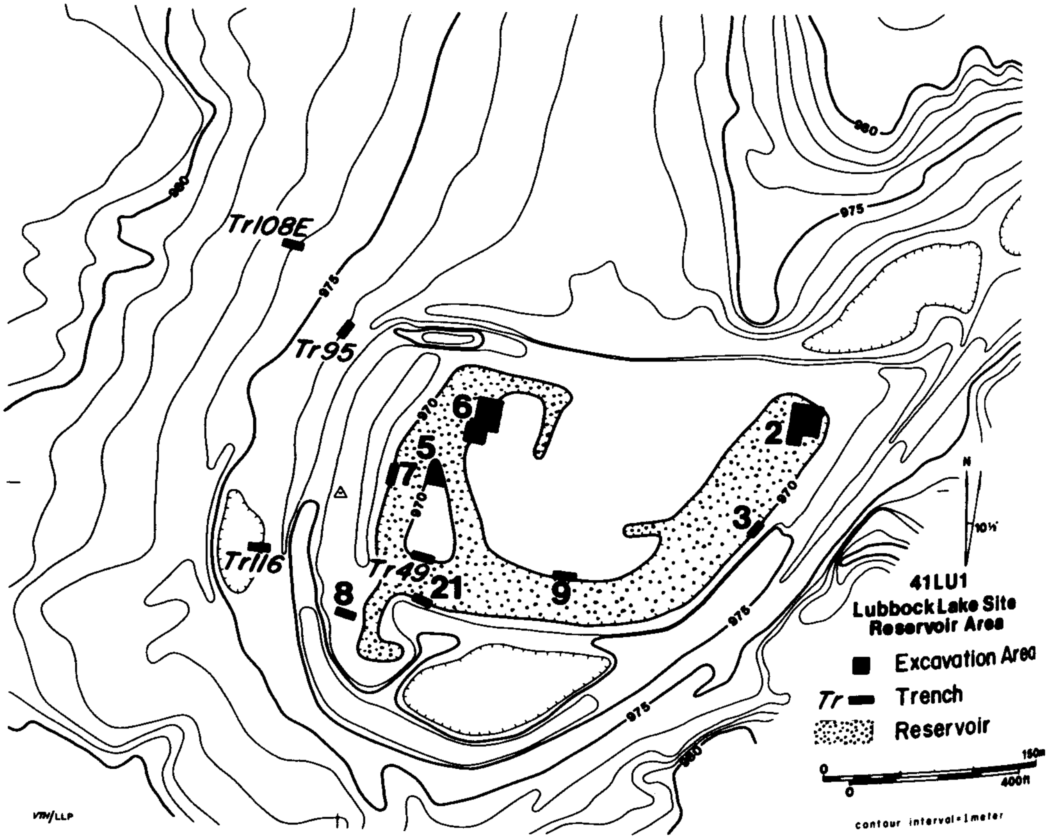

Fig. 2. Topographic map of the area around the reservoir cut at Lubbock Lake showing the location of 1981-1984 sampling areas for radiocarbon ages (contours within the reservoir cut are not shown).

Indian occupations at the site, which are concentrated in Stratum 2 (e.g., Johnson and Holliday 1980, 1981). In addition, problems apparently related to contamination of some of the samples from Stratum 2 led to field resampling and determination of a number of re-runs.

Stratum 2 consists of lacustrine and marsh deposits with a superimposed soil. Generally, the lower half of the unit consists of beds of laminated diatomite with intercalated beds of organic-rich clay. In some excavation areas, sets of diatomite laminae and clay interbeds have been identified as local beds (LB). Substratum 2A dates from 11,000 to about 10,000 years B.P. and contains Folsom cultural material. Substratum 2B generally comprises the upper half of Stratum 2; consists of homogeneous, organic-rich silt and clay; and dates from about 10,000 to 8500 years B.P. A soil (Firstview Soil) developed in upper substratum 2B from 8500 to about 6500 years B.P. Folsom occupation debris is found within substratum 2A, Plainview material comes from the 2A-2B contact, and cultural remains from the Firstview occupation occur in upper substratum 2B (Johnson 1983).

In recent excavation seasons, work focused on a shore facies of Stratum 2 (substratum 2s). The unit is of minor areal exent but of considerable archaeological significance. Substratum 2s consists of lenses of slopewash composed of sand- and gravel-sized particles of quartz and carbonate interbedded with organic-rich lenses of lacustrine sediment. These interbeds range from a few to a few tens of centimeters thick. Substratum 2s comprises the entire Stratum 2 sequence in some areas but in other areas is overlain by substratum 2B. Therefore, the 2B-2s contact is time-

Table 1. Radiocarbon Ages from the Lubbock Lake Site (1981-1984), in Stratigraphic Order (based on a half-life of 5568 years).

	Lab. No.	Area	Age (years B.P.)	Calibration (years B.P.)	Calibration (B.C./A.D.)	Remarks
Stratum 5						
5A	SI-5350	Tr95	modern[u]			buried A horizon, humin
	SMU-968	7	440 ± 40	510 ± 40*	A.D.1440	charcoal, upper GA7-5
	SMU-970	7	380 ± 50	475 ± 50*	A.D. 1475	charcoal, middle GA7-5
	SMU-893	7	450 ± 50	510 ± 50*	A.D. 1440	charcoal, (f), lower GA7-5, same sample as I-208
Stratum 4						
4B	SMU-1090	7	1270 ± 40	1185 ± 40* 1200 ± 40* 1235 ± 40* 1255 ± 40*	A.D. 765 A.D. 750 A.D. 715 A.D. 695	top of buried A horizon, humic acid (f)
	SMU-1177	Tr108E	1550 ± 50	1415 ± 50* 1465 ± 50*	A.D. 535 A.D. 485	top of buried A horizon, humic acid (f)
	SMU-1191	Tr108E	2070 ± 130	2355 ± 1730**	405 B.C.-A.D. 200	middle of buried A horizon, humic acid (f)
	SI-4589	8	655 ± 60[u]	655 ± 60*	A.D. 1295	base of buried A horizon, humin
	SI-5351	Tr95	1505 ± 50[u]	1395 ± 50*	A.D. 555	charcoal
4*l*	SI-4971	Tr109	1910 ± 75	1880 ± 70	A.D. 70	marsh sediment, humin
	SI-4972	Tr141	2500 ± 165	2830-2335**	880-385 B.C.	marsh sediment, humin
	SI-4970	Tr109	5010 ± 95	6025-5595**	4075-3645 B.C.	marsh sediment, humin
4A	SMU-1092	Tr95	1740 ± 50[u]	1630 ± 50* 1650 ± 50* 1655 ± 50* 1695 ± 50*	A.D. 320 A.D. 300 A.D. 285 A.D. 255	organic-rich sediment, humic acid (f)
	SMU-1200	Tr116	5270 ± 150	6370-5730**	4420-3780 B.C.	organic-rich sediment, humic acid (f)
Stratum 3						
3*l*	SMU-1093	Tr49	5220 ± 50	6275-5755**	4325-3805 B.C.	top of buried A horizon, humic acid (f)
Stratum 2						
2e	SMU-1192	Tr108E	8730 ± 240		6780 B.C.	marsh sediment, humic acid (f), same as SMU-648
2sLBc	SMU-699	5	9780 ± 100		7830 B.C.	marsh sediment, humic acid
2sLBb	SMU-1261	5	9950 ± 120		8000 B.C.	marsh sediment, humic acid (f)
2s	SI-4590	9	7365 ± 150[u]		5415 B.C.	marsh sediment, humin
	SMU-849	9	9480 ± 70		7530 B.C.	bone, acid hydrolization, first fraction
	SMU-851	9	10,040 ± 150		8090 B.C.	bone, acid hydrolization, second fraction

Table 1 (continued).

	Lab. No.	Area	Age (years B.P.)	Calibration (years B.P.)	(B.C./A.D.)	Remarks
	SMU-847	9	7220 ± 60[u]		5270 B.C.	bone, thermal release, 520° C
	SMU-848	9	9660 ± 80		7710 B.C.	bone, thermal release, 710° C
	SMU-850	9	10,250 ± 580		8300 B.C.	bone, thermal release 780° C
2B, upper	SMU-1094	5	6240 ± 40	7315-6925*	5365-4975 B.C.	top of buried A horizon, humic acid (f)
2B, middle	SMU-1089	5 (Sta.M)	8130 ± 80		6180 B.C.	marsh sediment, humic acid (f), same as C-558 & SI-5499
	SI-5499	5 (Sta.M)	8585 ± 145		6635 B.C.	marsh sediment, humin, same as C-558 & SMU-1089
2B, lower	SMU-1116	2	9550 ± 90		7600 B.C.	marsh sediment, humic acid (f)
	SMU-1118	2	9550 ± 100		7600 B.C.	marsh sediment, humic acid (f)
2B, base	SMU-972	3	8430 ± 60?		6480 B.C.	marsh sediment, humic acid (f)
	SMU-1111	21	9310 ± 90?		7360 B.C.	marsh sediment, humic acid (f)
	SI-4179	5	9075 ± 100		7125 B.C.	marsh sediment, humin, same as SMU-829
	SMU-829	5	9170 ± 80		7220 B.C.	marsh sediment, humic acid (f), same as SI-4179
	SMU-828	6	9870 ± 140		7920 B.C.	marsh sediment, humic acid, same as SMU-759
	SI-4591	6	7245 ± 90[u]		5295 B.C.	marsh sediment, humin, same as SI-4974 & 3198
	SI-4974	6	9605 ± 195?		7655 B.C.	marsh sediment, humin, same as SI-4591 & 3198
	SI-3198	6	11,770 ± 140[u]		9820 B.C.	marsh sediment, humin, same as SI-4591 & 4974
2ALB4	SI-4593	6	8335 ± 80[u]		6385 B.C.	marsh sediment, humin, same as SI-3199 & 4975
	SI-3199	6	9115 ± 70[u]		7165 B.C.	marsh sediment, humin, same as SI-4593 & 4975
	SI-4975	6	9905 ± 140		7955 B.C.	marsh sediment, humin, same as SI-4593 & 3199
	SMU-1115	21	10,070 ± 100?		8120 B.C.	marsh sediment, humic acid (f)
ALB2	SMU-975	3	9720 ± 80?		7770 B.C.	marsh sediment, humic acid (f), same as SMU-846

Table 1 (continued).

	Lab. No.	Area	Age (years B.P.)	Calibration (years B.P.)	(B.C./A.D.)	Remarks
	SMU-846	3	$10{,}160 \pm 80^{?}$		8210 B.C.	marsh sediment, humic acid (f), same as SMU-975
	SMU-1144	21	$10{,}090 \pm 100^{?}$		8140 B.C.	marsh sediment, humic acid (f)
	SI-4592	6	9040 ± 90^{u}		7090 B.C.	marsh sediment, humin, same as SI-4976 & 3200
	SI-4976	6	$10{,}195 \pm 165$		8245 B.C.	marsh sediment, humin, same as SI-4592 & 3200
2A, base	SMU-1110	2	$10{,}300 \pm 70^{?}$		8350 B.C.	marsh sediment, humic acid base
Stratum 1						
1C	SMU-1109	2	9660 ± 100^{u}		7710 B.C.	marsh sediment, humic acid

*Calibrated following Stuiver (1982)
**Calibrated following Klein et al. (1982), age range is 95% confidence level
(f) = corrected for C-13/C-12 fractionation
u = age considered unreliable
? = reliability uncertain

transgressive. The lenses of sand and gravel often are complexly convoluted, possibly due to local spring discharge from the bedrock (Blanco Formation) exposed along the valley walls. In Area 5, the interbeds in 2s were designated as local beds.

An eolian facies of Stratum 2 (substratum 2e) was identified. The unit was observed on the west side of the valley and generally seems to be a facies of 2B.

Much of the recent radiocarbon dating of Stratum 2 was aimed at refining the geochronology of the various local beds of substrata 2A and 2s and the 2A-2B contact in the excavation areas. The radiocarbon samples were taken from the organic-rich clay interbeds which are the deposits that commonly contain the archaeological material in these substrata. Multiple ages are available on some organic-rich local beds in given excavation areas, and the interpretation is that the oldest age is generally the closest approximation of the actual age of the sediment. This interpretation is because such ages are often considered minimum ages due to the presence of mobile constituents in organic matter which can contaminate older organic sediments (Scharpenseel 1979; Sheppard et al. 1979). That is, it is much easier to introduce younger contaminates, and, therefore, younger ages from a group of ages determined on a given sample are more likely to be in error. A case in point are those ages on samples taken from the same exposure over a period of several years. Almost invariably the longer the area was exposed the younger the resulting age, even though the exposure was cleaned back at least 10 cm. Additional research into this particular phenomena is currently under way.

Two new ages are available from 2ALB2 in Area 6 (Fig. 2). Sediments associated with an extensive *Bison antiquus* kill/butchering locale (FA6-8) have yielded ages of 9040 ± 90 years B.P. (SI-4592) and $10{,}195 \pm 165$ years B.P. (SI-4976), in addition to a previously reported age of about 10,360 years B.P. (SI-3200). The two older ages are statistically identical and are from fresh exposures, whereas SI-4592 was taken from an exposure open for several years.

Radiocarbon ages were secured on samples from substratum 2ALB2 in other excavation areas and commonly associated with *Bison antiquus* bone beds. Two new

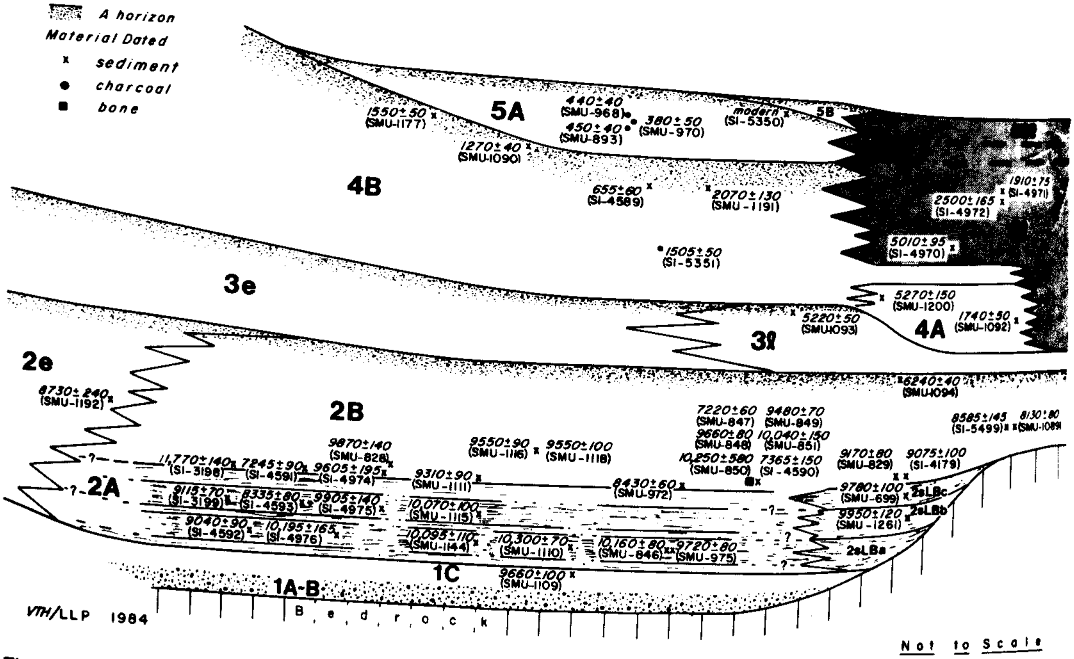

Fig. 3. Generalized stratigraphic relationships of radiocarbon ages from Lubbock Lake, 1981-1984.

ages are available from Area 3 (Fig. 2): 10,160 ± 80 years B.P. (SMU-846f) and 9720 ± 80 years B.P. (SMU-975f). An age of about 10,060 years B.P. (SMU-251) was reported previously, and, again, the sample that produced the younger age was taken several years after the area was opened. This particular local bed in Area 3 produced several Folsom points in association with a bison bone bed (Holliday and Johnson 1985; Sellards 1952). In Area 21 (Fig. 2) a sample from 2ALB2, which also contained a bison bone bed and was exposed for several years, was dated to 10,090 ± 100 years B.P. (SMU-1144f).

In Area 2 (Fig. 2), which has been open for a number of years, sediments from the lowermost organic-rich zone, immediately above a basal diatomite unit, yielded an age of 10,300 ± 70 years B.P. (SMU-1110). The basal diatomite provided an age, reported previously, of about 10,530 years B.P. (SMU-285; mistakenly reported as being from Area 6 by Holliday et al. 1983:174).

Substratum 2ALB4, which was not dated previously, yielded four radiocarbon ages. Three of these ages were determined on samples from Area 6: 9115 ± 70 years B.P. (SI-3199), 8335 ± 80 years B.P. (SI-4593), and 9905 ± 140 years B.P. (SI-4975). The samples for the two younger ages were from old exposures, and the older age was determined on a sample from a fresh exposure. Substratum 2ALB4 in Area 21 yielded an age of 10,070 ± 100 years B.P. (SMU-1115f), determined on a sample from an exposure open for several years.

A number of new radiocarbon ages were determined on samples recovered from the lower portion of substratum 2B. In Area 6, a number of samples were taken from sediments associated with FA6-11, a Plainview *Bison antiquus* kill/butchering locale (Johnson and Holliday 1980; Holliday and Johnson 1981). Samples from the base of the feature (just above the contact with 2A) yielded ages of 11,770 ± 140 years B.P. (SI-3198), 7245 ± 90 years B.P. (SI-4591), and 9605 ± 195 years B.P. (SI-4974). This zone also yielded an age reported previously of about 9990 years B.P. (SMU-728). Sediments from the top of the feature yielded an age of 9870 ± 140 years B.P. (SMU-828). This age is a re-run determined on humic acid that yielded an age reported previously of about 9330 years B.P. (SMU-759). The samples that yielded

SI-3198 and SI-4591 were taken from exposures that had been open for several years. The samples for SI-4974, SMU-728, SMU-828, and SMU-759 were from fresh exposures.

The other radiocarbon ages from lower substratum 2B are 8430 ± 60 years B.P. (SMU-972f; 2B base) from the old exposure in Area 3, 9310 ± 90 years B.P. (SMU-1111; 2B base) from the old exposure in Area 21, and 9550 ± 90 years B.P. (SMU-1116f) and 9550 ± 100 years B.P. (SMU-1118f), determined on the same sample from just below a lens of silicified plants in the middle of 2B in an old exposure in Area 2.

The middle of substratum 2B in Area 5 was sampled in order to radiocarbon date a *Bison antiquus* bone bed (FA5-5) that was tested and considered to be the one investigated in the early 1950s by the Texas Memorial Museum at their "Station M" (Holliday and Johnson 1985; Sellards 1952) (Fig. 2). This bone bed is particularly important as it was considered to be a Folsom feature. A radiocarbon age of 9883 ± 350 years B.P. (C-558; Libby 1955), determined on charred bone from the feature, was considered to be the first radiocarbon age on the Folsom culture in North America (Sellards 1952; Wormington 1957; Holliday and Johnson 1985). Testing was carried out immediately adjacent to Station M, and sediment samples were taken directly from the bone bed. The samples yielded ages of 8585 ± 145 years B.P. (SI-5499) and 8130 ± 80 years B.P. (SMU-1089). These ages and new stratigraphic evidence (Holliday and Johnson 1985) demonstrate that the feature is not from the Folsom period but is the result of a late Paleo-Indian occupation.

The new radiocarbon ages from substrata 2A and 2B essentially confirm the geochronology for the units outlined by Holliday et al. (1983). Several refinements can be made following the principles that the oldest of duplicate samples and those from fresh exposures are the most reliable and taking into account the previously reported ages, most all of which came from fresh exposures. The initial stage of lacustrine sedimentation and deposition of the basal diatomite lens (local bed 1 in most areas) appears to have lasted from about 11,000 to 10,500 years B.P. This is probably equivalent to the early Folsom occupation of the region. The first cycle of marsh deposition, producing organic-rich clay (local bed 2 in most areas), lasted from 10,500 to about 10,200 years B.P., equivalent to the later Folsom occupation of the site. Deposition of diatomite, with intervals of sedimentation of organic-rich clay, continued until about 10,000 years B.P. or shortly thereafter. Deposition of 2B then began and continued until about 8500 years B.P. The contact of 2A and 2B is coincident with the Plainview occupation of the site.

It is noteworthy that a number of the ages determined on samples from exposures that had been opened for some time fit well into the sequence defined by samples from fresh exposures (SMU-1110 and SMU-846 from 2ALB2; SMU-1115 from 2ALB4; SMU-1116 and SMU-1118 from lower 2B). This suggests that exposure does not necessarily affect a sample. However, once the samples from fresh exposures have been sorted out from those taken from older exposures the single remaining problematic date from 2A and 2B is that of about 11,770 years B.P. (SI-3198) from the base of 2B in Area 6. This age is undoubtedly in error. The only explanation that has been developed is that older organic material, incorporated into the surface soils on the adjacent uplands, was eroded and redeposited as 2B began to form. Area 6 is within 10 to 15 m of the valley wall. This explanation is not entirely satisfactory, however, because if it is true, the problem should be more common.

Stafford (1981, 1983) considered the contact of 2A and 2B to be time-transgressive, but this is apparently not the case. An unconformity between 2A and 2B is locally apparent, but whatever amount of time this represents does not seem to be within the resolving power of the radiocarbon method. Stafford (1981, 1983) postulated that 2B is 2A that was churned due to bioturbation. However, very few diatoms occur in 2B, contrary to what would be expected in bioturbated 2A, and some bedding is apparent in 2B along the south and east walls of the reservoir cut. Futhermore, it is difficult to imagine animals consistently and uniformly churning only the upper half of a deposit which is scores of hectares in extent.

Several radiocarbon ages were determined on samples from substratum 2s in association with *Bison antiquus* kill/butchering locales. These bone beds are in Area 5 and Area 9 (Fig. 2), which were isolated by the dredging in 1936 from the more usual 2A-2B stratigraphic sequence, making correlations of the facies very difficult. In Area 9, substratum 2s could be traced to the east along the wall of the reservoir cut. The bone bed (FA9-1) in 2s in Area 9 appears to be at about the same stratigraphic position as the substratum 2A-2B contact and should be about 10,000 years old or slightly younger. In view of these data, a radiocarbon age of 7365 ± 150 years B.P. (SI-4590) appears to be entirely too young.

Some experimental studies on dating of bone were carried out using the material from FA9-1. Two ages were determined using the standard acid-hydrolization technique (Haynes 1968), and three ages were yielded using the new thermal-release method (Haas and Banewicz 1980). The first fraction of CO_2 from acid-hydrolization, which is usually unreliable because it is off of the outer, more easily contaminated portion of the bone, provided an age of 9480 ± 70 years B.P. (SMU-849). The second fraction of CO_2 yielded an age of 10,040 ± 150 years B.P. (SMU-851). In the thermal-release method ages were determined on fractions yielded at three temperatures. The first fraction of CO_2 was from collagen and other organic material heated to 520° C, which provided an age of 7220 ± 60 years B.P. (SMU-847). At 710° C (which probably does not destroy all of the secondary carbonate, a contaminate), an age of 9660 ± 80 years B.P. (SMU-848) was determined. At 780° C the resultant assay (probably on apatite) was 10,250 ± 580 years B.P. (SMU-850). The large standard deviation of the last age was the result of a small carbon sample. All of the ages except SMU-847 generally are consistent with the estimated age range of around 10,000 year B.P. Further evaluation of the ages is not possible in view of the uncertainties concerning the exact stratigraphic position of FA9-1.

Area 5 is an island of late Quaternary fill isolated during the dredging for the reservoir (Fig. 2). Substratum 2s, therefore, cannot be correlated directly with 2A-2B. In Area 5, substratum 2s was subdivided in local beds. Substrata 2sLBa, at the base, and 2sLBc, at the top, are composed of organic-rich clay with some carbonate clasts. Substratum 2sLBb is a sandy clay with common gravel-sized carbonate clasts. A *Bison antiquus* kill/butchering locale (FA5-17) associated with projectile points of an unknown type occurs at the contact of 2sLBb and 2sLBc. A sediment sample from this feature yielded an age of 9950 ± 120 years B.P. (SMU-1261f). The middle of substratum 2sLBc was dated to 9780 ± 100 years B.P. (SMU-699) in association with another bison kill/butchering locale (FA5-12). The base of substratum 2B, immediately overlying 2sLBc, has yielded ages of 9170 ± 80 years B.P. (SMU-829f) and 9075 ± 100 years B.P. (SI-4179) in association with a third bison kill/butchering locale (FA5-7) that contained yet another unknown type of projectile point. All of the radiocarbon ages from 2s in Area 5 are in proper stratigraphic order and considered to be reliable.

The radiocarbon ages associated with substratum 2s demonstrate that the local bed sequence in this facies of Stratum 2 is not the equivalent of the local beds in substratum 2A. In addition, the distribution of 2s varies in time and space, and in exposures where 2B overlies 2s, the contact is time-transgressive, spanning much if not all of the period 10,000 to 9000 years B.P.

Holliday et al. (1983:175) reported an age of about 7100 years B.P. (SMU-648) determined on a sample recovered from Trench 108E (Fig. 2). The sample came from an organic-rich lens within a sandy, eolian unit considered to represent a valley-margin facies of 2B (substratum 2e). Stafford (1981:Fig. 3) considered the sample to be from Stratum 3. The unit was resampled and yielded an age of 8730 ± 240 years B.P. (SMU-1192f). This indicates that the deposit is in fact a facies of substratum 2B and that SMU-648 is falsely young by about 1500 years. Furthermore, the new radiocarbon age suggests that eolian deposition was occurring at the site as early as perhaps 9000 years B.P.

A sample from the upper portion of the A horizon of the Firstview Soil in Area 5 produced an age of 6240 ± 40 years B.P. (SMU-1094f). This age is consistent with one previously reported of about 6400 years B.P. (SMU-544) from the same stratigraphic position and another age of about 5770 years B.P. (SMU-545) from the base of overlying Stratum 3. These data indicate that burial of Stratum 2 and the Firstview Soil by Stratum 3 may not have begun until as late as 6300 to 6200 years B.P. (7200 to 7000 calendar years ago).

Stratum 3

Stratum 3 consists of two facies. Along the valley axis of Yellowhouse Draw, Stratum 3 consists of highly calcareous, silty, lacustrine sediments (substratum 3*l*). Along the valley margin Stratum 3 is a sandy eolian deposit (substratum 3e). Substratum 3e, although observed only in trenches away from the reservoir cut, is considerably more extensive that 3*l*, which is quite conspicuous along the walls of the old reservoir. A weakly developed soil (Yellowhouse Soil) formed in upper Stratum 3 in both facies of the unit. The previously published radiocarbon ages indicate that the maximum age range for deposition of and pedogenesis in Stratum 3 is 6500 to 5500 years B.P. (7000 to 6000 calendar years ago). Archaic cultural remains were recovered from Stratum 3.

One new radiocarbon age is available from Stratum 3. Organic matter from the top of the A horizon of the Yellowhouse Soil formed in 3*l* and exposed in Trench 49 (Fig. 2) yielded an age of 5220 ± 50 years B.P. (SMU-1093f). This age indicates that the Yellowhouse Soil existed along the floor of the draw until as late as about 5200 years B.P. (about 6000 calendar years ago).

Stratum 4

Stratum 4 is composed of several types of deposits with a superimposed soil. A deposit consisting of interbedded alluvial sand and marsh clay (substratum 4A) occurs along the valley axis of Yellowhouse Draw at the base of Stratum 4. These sediments probably were the result of episodic spring discharge. A thick deposit of sandy eolian material (substratum 4B) overlies 4A along the valley axis and interfaces with 4A and buries Stratum 3 along the valley margin. A clayey marsh deposit (substratum 4*l*) occurs along the lowermost portion of the valley axis and interfingers with 4A and 4B. A moderately well-developed soil (Lubbock Lake Soil) formed within substratum 4B. The previously published radiocarbon ages suggested that substratum 4A was deposited beginning about 5500 years B.P. (about 6000 calendar years ago) and that deposition of the unit occurred over a short period of time. Deposition of substratum 4B terminated by about 4500 years B.P. (about 5000 calendar years ago) or a little later. Formation of the Lubbock Lake Soil then began in 4B. Where Stratum 4 is buried by Stratum 5, formation of the soil halted about 750 years B.P. (700 calendar years ago). Otherwise the soil continues to form today. Archaeological material from the Archaic and Ceramic periods was recovered from Stratum 4.

Two new radiocarbon ages are available for substratum 4A. The samples were from laminae of organic-rich sediments. A sample from Trench 95 (Fig. 2) was assayed at 1740 ± 50 years B.P. (SMU-1092f). Material from substratum 4A in Trench 116 yielded an age of 5270 ± 150 years B.P. (SMU-1200f). Available radiometric and stratigraphic evidence suggests that SMU-1092 is entirely too young. The trench from which the sample was recovered was open for several months prior to sampling, and this exposure may account for some contamination. The age of SMU-1200 is considered to be accurate.

One new radiocarbon age is available from substratum 4B below the A horizon of the Lubbock Lake Soil. A lens of charcoal and ash from Trench 95 (Fig. 2) provided an age of 1505 ± 50 years B.P. (SI-5351). This age is entirely inconsistent with all other ages from this unit.

Along the valley axis of Yellowhouse Draw upstream from the reservoir cut, the stratigraphic evidence indicates that shortly after deposition of substratum 4B the draw slowly filled with the organic-rich clay of substratum 4*l*. This aggradation resulted in the formation of an overthickened, cumulic A horizon for the Lubbock Lake Soil in this landscape position. New radiocarbon ages from 4*l* support this intepretation. A sample from the base of 4*l* in Trench 109 (Fig. 1) yielded an age of 5010±95 years B.P. (SI-4970). A sample from the middle of 4*l* in Trench 109 was dated at 1910±75 years B.P. (SI-4971) and from the middle of 4*l* in Trench 141 (Fig. 1) dated at 2500±165 years B.P. (SI-4972). All of these ages are considered valid considering the stratigraphic and pedologic evidence. The difference between the two ages from the middle of 4*l* is probably due to variation in rates of aggradation along the valley floor.

The A horizon of the Lubbock Lake Soil, where buried by Stratum 5, has provided several additional radiocarbon ages. The samples for these ages were taken from various positions within the horizon (i.e., top, middle, bottom) under the assumptions that the lower portion of the A horizon would contain older organic matter, the top of the A horizon would contain the youngest organic matter, and an age from the top of the A horizon would be a maximum age for burial. The results from the previous attempts at dating this buried A horizon generally supported these assumptions. The base of the A horizon in Area 8 (Fig. 2) yielded an age of 655±60 years B.P. (SI-4589). The middle of the A horizon in Trench 108E (Fig. 2) was assayed at 2070±130 years B.P. (SMU-1191f). The top of the buried A horizon in Trench 108E was dated to 1550±50 years B.P. (SMU-1177f), and a sample from the top of the buried A horizon in Area 7 (Fig. 2) yielded an age of 1270±40 years B.P. (SMU-1090f). These ages generally suggest that organic matter persists in buried A horizons for several thousand years and that burial of the Lubbock Lake Soil and substratum 4B (hence, deposition of Stratum 5) occurred less than about 1200 years B.P. Based on these data, the age from Area 8 (SI-4589) is not reliable. Previously reported ages on sediment samples from Area 8 have been spurious. The area has been opened for excavation since 1959, and this exposure may have resulted in some contamination.

The new radiocarbon ages from Stratum 4 generally support the conclusions previously reported with a few modifications. The radiocarbon ages from the top of the A horizon in the Yellowhouse Soil and from substratum 4A overlap in several instances, suggesting that some erosion of the top of Stratum 3 and deposition of substratum 4A was occurring simultaneously along the valley axis while the Yellowhouse Soil continued to form in Stratum 3 along the valley margins until buried by younger 4A or 4B deposits. The age of about 5200 years B.P. (SMU-1093) and a previously reported age of about 4900 years B.P. (SMU-531) from the top of the buried Yellowhouse Soil (top of Stratum 3) suggest that perhaps the soil was at the surface in some areas until as late as 5000 years B.P. (about 5500 calendar years ago) or even later. The age of about 5000 years B.P. (SI-4970) for the base of 4*l*, which buries 4B, further indicates that 4B deposition began in some areas of the draw prior to 5000 years B.P. and that 4*l* began to accumulate in some reaches of the draw while 4B continued to be deposited in other reaches. Substratum 4*l* then slowly accumulated throughout the late Holocene.

Stratum 5

Stratum 5 is subdivided into older (5A) and younger (5B) substrata, found on the upslopes, and each with a lowland lacustrine facies (5A*l*, 5B*l*, or 5*l*). Both upslope facies are composed of sandy eolian sediments and, locally, gravel from slopewash. Substratum 5A covers much of Stratum 4 west of the reservoir, but substratum 5B covers only a portion of 5A. The Apache Soil developed in substratum 5A and the Singer Soil formed in substratum 5B. The lowland, lacustrine facies of Stratum 5 is an organic-rich clay, identical to substratum 4*l* and considered to be a continuation of the localized marshy, valley axis environment that produced 4*l*. Deposition of 5A began about 700 calendar years ago (A.D. 1250) and ceased about 450 to 400 calendar years ago (A.D. 1500 to A.D. 1550) The Apache Soil then began to form. Deposition of 5B began between 300 and 250 calendar years ago (A.D. 1650 and A.D. 1700) and ended in the late 1800s. The Singer Soil has been forming in 5B for the past 100 years.

Stratum 5 contains a considerable amount of cultural debris. Substratum 5A yielded material from the late Ceramic and Protohistoric periods (Johnson et al. 1977). Substratum 5B contains evidence of occupation from the Historic period including both aboriginal and European material.

Four new radiocarbon ages from Stratum 5 are from substratum 5A. Three of these new ages are from a double hearth in Area 7 (Fig. 2), which was excavated in 1960 during investigations by the West Texas Museum (now The Museum, Texas Tech University) directed by Green (1962). Charcoal and ash from the double hearth were discovered during the course of a reevaluation, cataloging, and curation effort by Kaczor (1978), who designated the feature GA7-5. Information available to Kaczor (1978:272-273) suggested that the feature consisted of two superimposed hearths similar to the double hearth recovered in Area 8 (FA8-6; Johnson et al. 1977). The charcoal and ash were separated by excavation level in the lab with the resulting samples representing the lower hearth, the upper hearth, and a sample that is either a mixture of the two or is from the lower portion of the upper hearth. The samples yielded ages of 450 ± 50 years B.P. (SMU-893f, lower hearth), 380 ± 50 years B.P. (SMU-970, middle sample), and 440 ± 40 years B.P. (SMU-968, upper hearth). The three ages are statistically the same and are in good agreement with other ages determined on charcoal from substratum 5A. Immediately following the 1960 excavations a radiocarbon age of about 160 years B.P. (I-208; Trautman and Walton 1962) was determined on charcoal (rather than charred bone as stated by Holliday et al. 1983:178, Table 1) recovered from the lower hearth. That age is not considered a reliable one given the ages of the charcoal samples from 5A in areas 7 and 8 and elsewhere.

The double hearth (FA8-6) found in substratum 5A in Area 8 was about 70 m south of Area 7. Charcoal from this feature yielded ages very similar to those from GA7-5 (Holliday et al. 1983:178). The hearths from Area 8 are associated with the Garza (Protohistoric) occupation of the site (Johnson et al. 1977), and the Area 7 feature probably also is related to the Garza occupation.

A radiocarbon sample was taken from the top of the A horizon of the buried Apache Soil from Trench 95. The resulting age was "modern" (SI-5350). This trench was open for some time prior to sampling, and this exposure may account for contamination.

The new radiocarbon ages from Stratum 5 confirm the age of substratum 5A and provide further documentation for the Protohistoric habitation of the site.

CONCLUSIONS

Forty-eight new radiocarbon ages are available from Lubbock Lake. These ages, combined with 69 ages previously reported (Holliday et al. 1983), bring the total number of radiocarbon ages for the site to 117. The new radiocarbon ages generally confirm the chronologic sequence outlined by Holliday et al. (1983) and help to refine specific aspects of the geochronology and cultural sequence (Fig. 4).

Several modifications are made to the depositional history of Stratum 2. The initial stage of lacustrine sedimentation, represented by the diatomite, lasted from about 11,000 to 10,500 years B.P. or perhaps a little less, coinciding with the early Folsom occupation of the site. The first stage of marsh (organic-rich clay) deposition occurred between about 10,500 and 10,200 years B.P., during the later Folsom occupation. The change from deposition of interbedded marsh and lake sediments (substratum 2A) to deposition of homogeneous, organic-rich silt and clay (substratum 2B) occurred about 10,000 years B.P. or a little later. The Plainview occupation of the site is coincident with the 2A-2B contact. Substratum 2s, the shore facies of Stratum 2, varies considerably in age and can be a lateral equivalent of all or only parts of the 2A-2B sequence. A new radiocarbon age

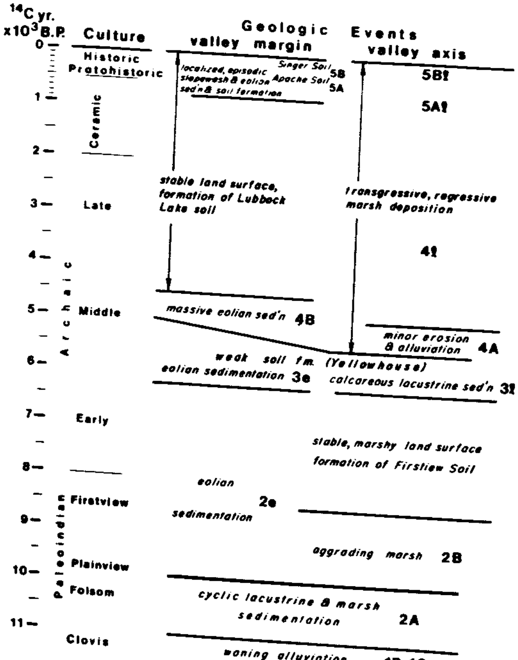

Fig. 4. Summary of cultural and geological events at Lubbock Lake (revised from Holliday et al. 1983: Fig. 6).

also indicates that Stratum 2 began to accumulate eolian sediments (substratum 2e) as early as 9000 years B.P. Burial of Stratum 2 and the Firstview Soil by Stratum 3 may not have occurred until as late as 6200 years B.P. (about 7000 calendar years ago) in the early Archaic.

New radiocarbon ages also suggest that the strata 3-4 contact is time-transgressive. Along the valley axis Stratum 3 was eroded and buried by substratum 4A about 5500 years B.P., and substratum 4B was beginning to cover 4A and fill the draw prior to 5000 years B.P. Along the valley margin, Stratum 3 was exposed at the surface until as late as 5000 years B.P. Accumulation of marsh sediments (substratum 4*l*) began along the valley axis at around 5000 years B.P. All of these events occurred in the middle Archaic.

A number of the new radiocarbon ages from Lubbock Lake pose some problems of interpretation, and some of the assays are considered unreliable. These problems underscore the necessity for careful sampling procedures and proper evaluation of the field conditions of each sample. However, the 48 new radiocarbon ages from Lubbock Lake, even with the problematic dates, further serve to document Lubbock Lake as having among the best age-control for one of the most complete cultural, geological, and biological records spanning the past 11,500 years in North America.

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