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DATING OF HOLOCENE STRATIGRAPHY WITH SOLUBLE AND INSOLUBLE ORGANIC FRACTIONS AT THE LUBBOCK LAKE ARCHAEOLOGICAL SITE, TEXAS: AN IDEAL CASE STUDY

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ABSTRACT. The Lubbock Lake site, on the Southern High Plains of Texas, contains one of the most complete and best-dated late Quaternary records in North America. A total of 117 ^{14}C dates are available from the site, determined by the Smithsonian and SMU Laboratories. Of these dates, 84 have been derived from residues (humin) and humates (humic acids) of organic-rich marsh sediments and A horizons of buried soils. Most of the ages are consistent with dates determined on charcoal and wood, and with the archaeologic and stratigraphic record. The dates on the marsh sediments are approximate points in time. Dates from the top of buried A-horizons are a maximum for burial and in many cases are close to the actual age of burial. Dates from the base of the A-horizons are a minimum for the beginning of soil formation, in some cases as much as several thousand years younger than the initiation of pedogenesis. A few pairs of dates were obtained from humin and humic acid derived from split samples; there are no consistencies in similarities or differences in these age pairs. It also became apparent that dates determined on samples from scraped trench walls or excavations that were left open for several years are younger than dates from samples taken from exactly the same locations when the sampling surfaces were freshly excavated.

INTRODUCTION

The Lubbock Lake site, in northwestern Texas, contains a cultural, geologic, pedologic, paleontologic, and paleobotanic record beginning ca 11,000 years BP and continuing through the founding of the city of Lubbock near the end of the last century. The site has one of the most complete late Quaternary records in North America (Holliday *et al,* 1983, 1985), which serves as a model for the latest Pleistocene and Holocene cultural and environmental history of the Southern High Plains.

Establishing the cultural chronology and geochronology of the site is essential in reconstructing the local and regional late Quaternary history. This requires frequent use of ^{14}C dating but relatively few of the traditional and most reliable dating materials, eg, charcoal and wood, have been recovered from the site. Shell and bone are much more abundant but have been avoided as much as possible due to the uncertainties in interpreting ages from these materials. Since the site contains a considerable amount of organic-rich sediments and soils, most of the ^{14}C dates were determined on these materials.

Techniques and problems involving the dating of the soluble and insoluble fractions of organic-rich sediments and soils were discussed previously (Burleigh, 1974; Alexander & Price, 1980; Geyh, Benzler & Roeschmann, 1971; Goh & Malloy, 1978; Matthews, 1980; Scharpenseel, 1971, 1979; Sheppard *et al,* 1979; Cambell *et al,* 1967). We have encountered several of these common difficulties as well as others that may be unique to Lubbock Lake. In spite of numerous uncertainties, ages determined on the organic-rich sediments and ages measured on charcoal and wood or

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derived from stratigraphic and archaeologic evidence show generally good agreement.

SETTING AND LATE QUATERNARY HISTORY

The Lubbock Lake site is in the city of Lubbock, Lubbock County, Texas, in the east-central part of the semi-arid Southern High Plains (Fig 1). The site is within an entrenched meander of Yellowhouse Draw, an ephemeral tributary of the Brazos River. The site was discovered in 1936 during the excavation of a U-shaped reservoir cut along the inside of the meander. The cut exposed late Quaternary fill containing abundant archaeologic material (Holden, 1974). Most of the archaeologic excavations were concentrated along the walls of this cut (Fig 1) which provide excellent stratification. Numerous trenches were also dug along Yellowhouse Draw upstream, downstream, and near the 1936 excavation (Fig 1).

Sedimentologic, pedologic, cultural, and environmental data at Lubbock Lake were discussed elsewhere (Holliday *et al,* 1983, 1985; Holliday, 1982, 1983, 1985a, b, c; Johnson, 1976, 1983; Stafford, 1981). The

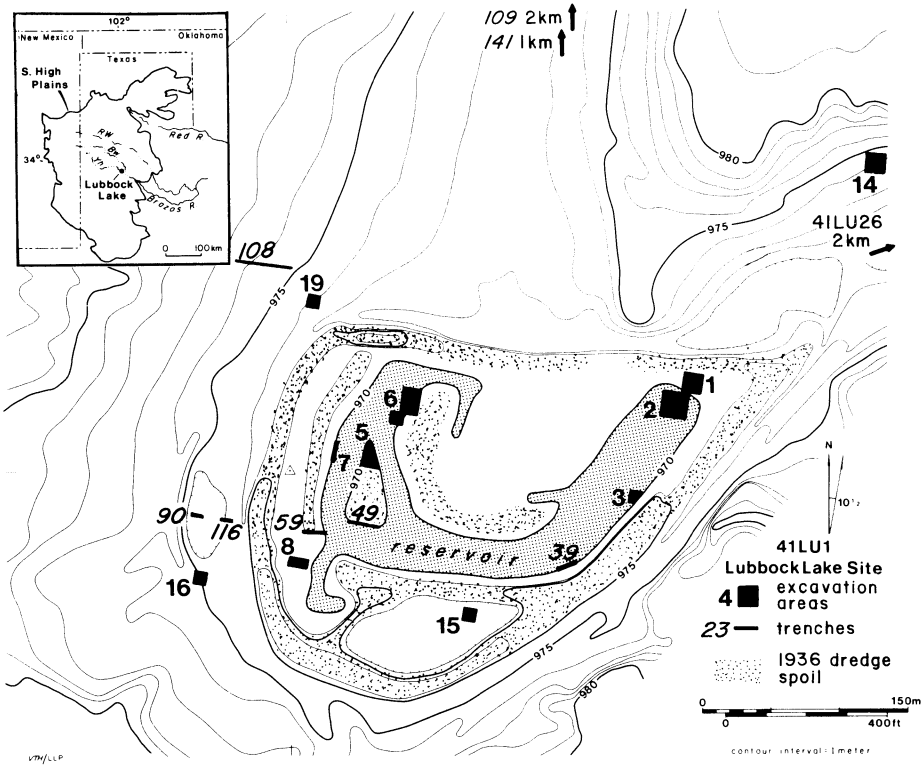

Fig 1. Topographic map of the Lubbock Lake site reservoir cut with an entrenched meander of Yellowhouse Draw (contours within the reservoir not shown). The excavation areas and trenches sampled for the ^{14}C dates listed in Table 1 are shown. The inset shows the location of the site on the Southern High Plains.

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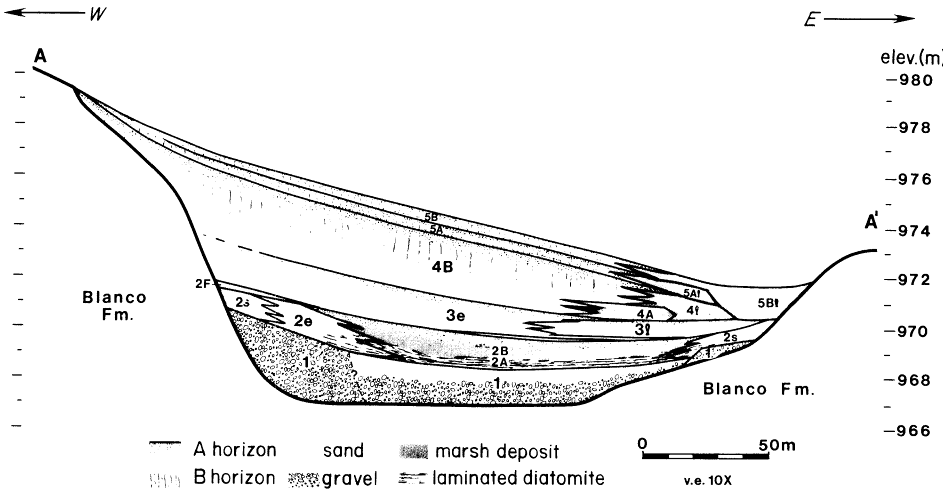

Fig 2. Generalized geologic cross-section of the Lubbock Lake site on the west side of Yellowhouse Draw. Vertical subdivisions of strata are identified by uppercase letters in alphabetical order oldest to youngest. Facies changes are indicated by lowercase letters as follows: e = eolian; l = lacustrine; s = slopewash.

entrenchment of Yellowhouse Draw ended in the latest Pleistocene. Since then, it has been filling episodically with a variety of sediments containing cultural, floral, and faunal remains (Figs 2, 3).

Five principle strata were identified, 1 (oldest) to 5 (youngest), as well as substrata (Fig 2). Soils formed in these units were named and several facies within the strata were identified (Fig 3).

The juxtaposition of the reservoir cut and trenches with complex stratigraphic relationships presented problems in geologic correlations from one exposure to another. The ^{14}C dating program was quite important in establishing these correlations.

RADIOCARBON SAMPLES AND SAMPLING PROCEDURES

At the end of 1984, 117 ^{14}C dates were determined from the Lubbock Lake site, almost all measured by Southern Methodist University (SMU) and the Smithsonian Institution (SI) laboratories (Holliday *et al,* 1983, 1985). Only 13 samples were charcoal and 4 were wood, representing nearly all of such materials found at the site. Bone was abundant but only 12 samples were selected for dating because of often uncertain results (Taylor & Slota, 1979). A number of the bone dates were experimental (Haas & Banewicz, 1980; Holliday *et al,* 1985) and several were determined in the first decade of ^{14}C dating (Holliday *et al,* 1983). Shell was common in some strata, but used for only 4 dates, 2 of which were determined in 1957 at Lamont and 1962 at Isotopes, Inc, when dating was done on solid carbon (Holliday *et al,* 1983). Two samples were dated only recently due to problems inherent in dating shell (Michels, 1973; Taylor & Slota, 1979).

Eighty-four dates (Table 1) were from organic-rich lacustrine and

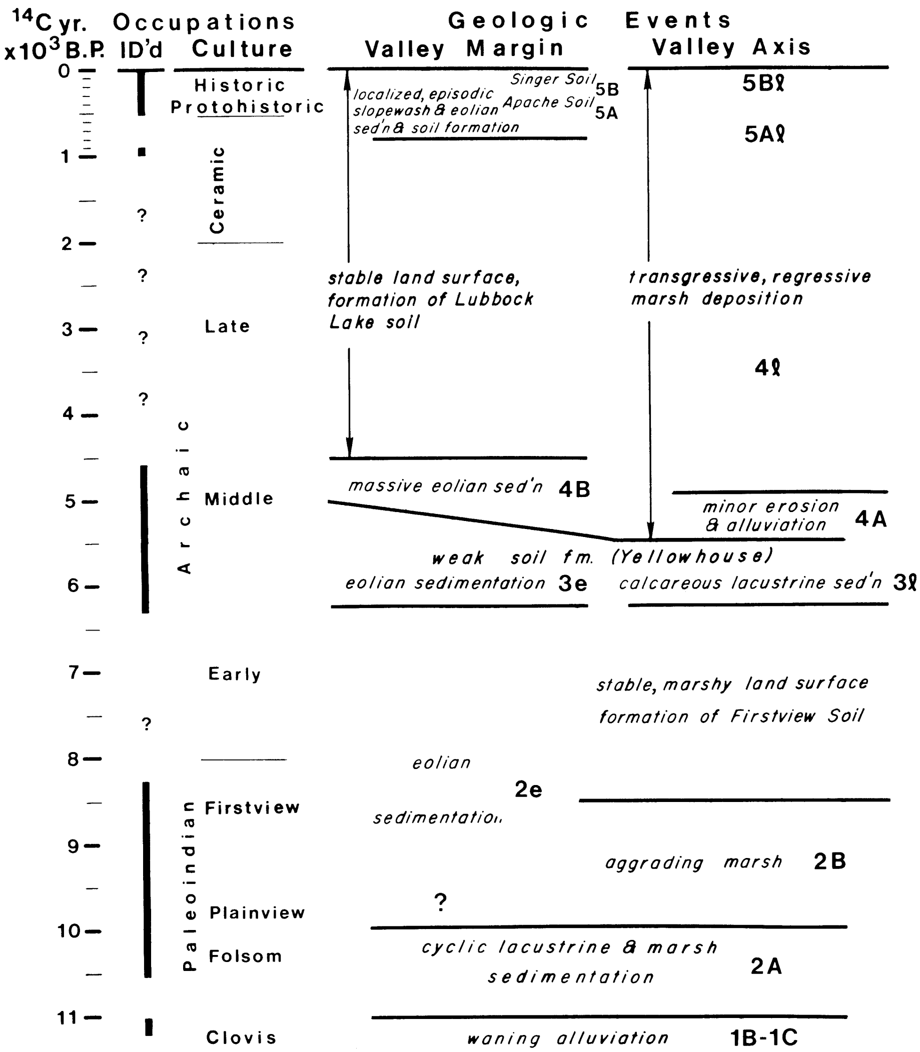

Fig 3. Schematic illustration of the geologic and cultural history of Lubbock Lake (the five named soils are also indicated) (Holliday *et al*, 1985, Fig 4).

marsh sediments (57 samples) and organic-rich soil A-horizons (27 samples). There were two types of sediments:

1) measured by volume, most of the sediments were up to 1m thick, clayey, homogeneous deposits which accumulated in a slowly aggrading environment,

2) thin lenses, 10cm thick, clayey, organic-rich material deposited relatively rapidly. Most of these lenses were within the diatomite (2A) and the shore facies (2s) of Stratum 2.

Ages on these samples are considered approximate. There was

TABLE 1

^{14}C dates on wood, charcoal, and organic-rich soils and sediments from fresh exposures at Lubbock Lake

Substratum	Lab no.	Age (yr BP)	Area	Material
5B1	SMU-716	210 ± 40	6	Wood
	SMU-831 f*	390 ± 50	6	Humic acid (marsh sediment)
	SMU-715	400 ± 110	6	Wood
5B	SMU-343	160 ± 60	7	Humic acid (modern A horizon)
5A	SMU-314	720 ± 40	7	Humic acid (buried A horizon)
	SMU-968	440 ± 40	7	Charcoal
	SMU-970	380 ± 50	7	Charcoal
	SMU-893f	450 ± 50	7	Charcoal
	SMU-345	300 ± 60	8	Charcoal (same as SI-2700)
	SI-2700	380 ± 40	8	Charcoal (same as SMU-345)
	SI-2701	505 ± 55	8	Charcoal
	SI-3208	640 ± 75	8	Humin (buried A horizon)
	SI-2704	315 ± 50	14	Charcoal
	SI-2703	285 ± 60	15	Charcoal
	SMU-546	320 ± 60	19	Charcoal
	SMU-555	220 ± 50	Tr108	Humic acid (buried A horizon)
5A1	SMU-698	600 ± 50	Tr108	Humic acid (marsh sediment)
4B	SMU-1090 f	1270 ± 40	7	Humic acid (buried A horizon)
	SI-4169	880 ± 70	8	Humin (buried A horizon)
	SI-3201	1215 ± 65	Tr 59	Humin (buried A horizon; top)
	SI-4174	1955 ± 75	Tr 59	Humin (bottom A horizon; top)
	SMU-534	870 ± 40	Tr108	Humic acid (buried A horizon; top)
	SMU-651	890 ± 70	Tr108	Humic acid (buried A horizon; top)
	SMU-1177 f	1550 ± 50	Tr108	Humic acid (buried A horizon; top)
	SMU-1191 f	2070 ± 130	Tr108	Humic acid (buried A horizon; middle)
	SI-4171	4700 ± 65	16	Ash and Humin (same as SMU-492)
	SMU-492	4960 ± 50	16	Ash and humic acid (same as SI-4171)
4A	SMU-1200 f	5270 ± 150	Tr116	Humic acid (marsh sediment)
41	SI-4588	980 ± 60	1	Humin (marsh sediment)
	SI-4971	1910 ± 75	Tr109	Humin (marsh sediment)
	SI-4970	5010 ± 95	Tr109	Humin (marsh sediment)
	SMU-697	2600 ± 50	Tr108	Humic acid (marsh sediment)
	SI-4972	2500 ± 165	Tr141	Humin (marsh sediment)
	SI-3206	3925 ± 80	Tr 39	Humin (marsh sediment)
	SI-3205	5545 ± 100	Tr 39	Humin (marsh sediment)
31	SMU-1093 f	5220 ± 50	Tr 49	Humic acid (buried A horizon; top)
3e	SMU-531	4900 ± 60	Tr108	Humic acid (buried A horizon; top)
	SMU-545	5770 ± 80	Tr108	Humic acid (marsh sediment)
2B (upper)	SMU-544	6400 ± 80	Tr108	Humic acid (buried A horizon; top)
	SI-4178	6705 ± 95	6	Humin (buried A horizon; top)
	SMU-262	7970 ± 80	3	Humic acid (buried A horizon; middle)
	SMU-302	7890 ± 100	3	Humic acid (buried A horizon; bottom)
	SI-3204	7255 ± 75	Tr 90	Humin (marsh sediment)
	SMU-830 f	8210 ± 240	6	Humic acid (marsh sediment)
	SI-4177	8655 ± 90	6	Humin (marsh sediment)
(lower)	SMU-275	9960 ± 80	2	Humic acid (marsh sediment)
	SMU-828	9870 ± 140	6	Humic acid (marsh sediment)
	SI-4974	9605 ± 195	6	Humin (marsh sediment)
	SMU-728	9990 ± 100	6	Humic acid (marsh sediment)
	SI-4179	9075 ± 100	5	Humin (marsh sediment; same SMU-829)
	SMU-829 f	9170 ± 80	5	Humic acid (same as SI-4179)
2e	SMU-1192 f	8730 ± 240	Tr108	Humic acid (marsh sediment)
2sLBc	SMU-699	9780 ± 100	5	Humic acid (marsh sediment)
2sLBb	SMU-1261 f	9950 ± 120	5	Humic acid (marsh sediment)
2A (upper)	SI-3203	10015 ± 75	Tr 90	Humin (marsh sediment)
2ALB4	SI-4975	9905 ± 140	6	Humin (marsh sediment)
2ALB2	SMU-251	10060 ± 70	3	Humic acid (marsh sediment)
	SI-3200	10360 ± 80	6	Humin (marsh sediment)
	SI-4976	10195 ± 165	6	Humin (marsh sediment)
2ALB1	SMU-285	10530 ± 90	2	Humic acid (diatomite)
1B	SMU-263	11100 ± 80	41LU26	Wood
	SMU-548	11100 ± 100	2	Wood

* f indicates dates corrected for fractionation

undoubtedly some mixing and uneven rates of accumulation as the material was deposited, but the geologic and archaeologic evidence suggests that resulting variations in age would be smaller than the overall uncertainty of the sediment dating technique. Organic material in the A-horizons was incorporated into the surface of the soil parent material during a period of landscape stability. A ^{14}C age from such "homogenized" horizons is the "mean residence time" of organic material in this layer, plus the time since burial by overlying sediments (Scharpenseel, 1971). Most samples from buried A-horizons were taken in pairs: 1) from the top of the horizon, in order to determine the maximum age of burial by overlying sediments and, 2) from the base of the horizon, to provide a minimum age for the deposit in which the soil formed.

Sediment and soil samples used for ^{14}C dating were taken from walls or floors in the excavation areas. Along the circumference of the reservoir and along Yellowhouse Draw trenches were used for sampling. Samples were collected with metal tools and placed in airtight plastic bags, holding ca 750g (dry weight). Sample size was 1 or 2 bags for organic-rich sediments and 3 bags for buried A-horizons.

LABORATORY PROCEDURES AND INTERLABORATORY COMPARISONS

The two ^{14}C laboratories participating in this research used very different dating procedures. The Smithsonian laboratory used nonsoluble organic residues contained within the matrix and the SMU laboratory used base-soluble humic acids.

The Smithsonian laboratory pretreatment is as follows:

1) Grind sample to powder.

2) Stir with 6N HC1 to remove initial carbonates and to reduce sample bulk; filter and wash with distilled water.

3) Boil in 2% NaOH for 30 minutes; filter and wash with distilled water.

4) Re-acidify overnight with 2N HC1 filter and wash with distilled water.

5) Oven dry at 105 C.

The following procedure was used at the SMU laboratory for the extraction of humic acids:

1) Break large soil pieces in mortar, handpick roots and carbonaceous inclusions.

2) Dissolve sediment in distilled water and remove floating roots with spoon and suction apparatus. Frequent stirring will release additional roots trapped in the sediment.

3) Acidify sample with HC1 (ca 4N) to hydrolize carbonates. Digest acidified sample in hot water bath for 8 hours. Replenish HC1 if its concentration is lowered through reaction.

4) Neutralize sample through decantations and refillings of container with distilled water.

5) Boil in 5L of 5% NaOH solution for 8 hours. Container remains covered and sample is stirred every hour.

6) Humate solution decanted into glass bottles and kept sealed. Let suspended clay particles settle for one day, continue to decant solution between bottles until no more settled clays are visible. These decantations are performed in lieu of vacuum filtering in Buchner funnels. Filtering clay-rich solutions with glass filter paper is a very slow process, which may extend over more than a week.

7) Residual humates in sediment are diluted with distilled water. These diluted solutions are treated as indicated in 6) and are repeated until the strength of these solutions has declined to the appearance of weak coffee.

8) The combined and purified humate solutions are acidified with phosphoric acid (ca 2%). After floculation and settling of humates, the solutions are filtered. The filter cake of retained humates is then dried at 85°C for 24 hours.

9) The remaining sediment is neutralized through numerous decantations and refills of distilled water. Final procedure is acidification with phosphoric acid and drying. The sample is then stored for possible later dating of the residue fraction.

The yield of humic acids varies according to the stratigraphic position of the sample. From an A-horizon soil sample of 2kg dry weight, ca 35g of quite pure humates can be expected. These humates have the appearance of shiny, angular and black crystals. Ash content, after combustion, is ca 60% and is mostly clay. Carbon yield, as CO_2, of the organic content usually lies between 40 and 50%, thus, 10 to 13L of CO_2 may be expected.

At Lubbock Lake, sediments not classified as soils have a much lower organic content. Complete extraction using the SMU method yields a dried humate filter cake with 80 to 90% clay content. Up to 150g of this dull black humate-clay concentrate must be combusted for a sample size of 3 to 5L CO_2 gas.

Data on organic carbon content is available from some of the ^{14}C samples (Table 2). The measured organic carbon contents range from 1.4% to

TABLE 2

Radiocarbon dates with available organic carbon data*

Lab no.	Date	OC %**
SMU-343	160 ± 60	1.4
SI-4971	1910 ± 75	0.7
SMU-314	720 ± 40	0.7
SI-4972	2500 ± 165	0.6
SMU-1191	2070 ± 130	0.5
SMU-1090	1270 ± 40	0.5
SI-4970	5010 ± 95	0.4
SI-3208	640 ± 75	0.4
SMU-1192	8730 ± 240	0.3
SI-4174	1955 ± 75	0.3
SI-3201	1215 ± 65	0.3
SI-4169	880 ± 70	0.2
SMU-1200	5270 ± 150	0.1

* From Holliday (1982)
** Walkley-Black technique (Allison, 1965)

0.1%, mostly from buried soil A-horizons, and span most of the Holocene record.

Only one pair of humate and residue dates, a diatomite sample from substratum 2ALB2 (Table 3), was measured by the SMU laboratory. The humate date, 10,060 ± 70 BP, appears correct according to stratigraphic position. The residue date (7840 ± 170 BP) is much too young. A possible explanation is that the diatomite, slightly more porous than over-and underlying clayey strata, may have functioned as an aquifer filtering younger organic particles from slowly migrating ground water.

Comparison dates measured by the Smithsonian and SMU laboratories are shown in Table 3. The pair of dates on charcoal shows that there is no significant calibration discrepancy between the two laboratories. The remaining dates fail to demonstrate a consistent difference between humate and residue ages. In these comparisons, each laboratory applied its preferred dating method to a split sediment sample. Two humate ages are older by at least 2σ, 1 residue age is older by 3σ, and 1 pair of dates is within 1σ. All of these samples were taken from fresh exposures.

Fractionation corrections were applied systematically to all SMU dates since 1981 (Table 4). Most earlier SMU dates and all Smithsonian dates are therefore lacking this correction.

GENERAL DISCUSSION OF RADIOCARBON DATES

^{14}C samples of organic-rich soils and sediments of the Lubbock Lake site were collected from 1974–1984. The dates include duplicate analyses made by both laboratories on split samples as well as analyses made on samples re-collected from exactly the same locations and positions at intervals of one to several years.

Generally, the ^{14}C sequence determined from these materials is consistent with stratigraphic and archaeologic evidence and with the few available wood and charcoal dates. There seems to be no correlation between the organic content and the reliability of the dates (Table 2).

TABLE 3
List of pairs of residue and humate and charcoal dates

Locale	Substrat	Residue	Humate	Material
Area 3	2ALB2	7840 ± 170 (SMU-247)	10,060 ± 70 (SMU-251)	Organic lens in diatomite
Area 5	2B, base	9075 ± 100 (SI-4179)	9170 ± 80 (SMU-829)	Organic marsh sediment
Area 6	2B, base	9605 ± 195 (SI-4974)	9990 ± 100 (SMU-728)	Organic marsh sediment
Area 6	2B, middle	8655 ± 90 (SI-4177)	7980 ± 180 (SMU-827)	Organic marsh sediment
Area 16	4B	4700 ± 65 (SI-4171)	4960 ± 50 (SMU-492)	Ash
		Charcoal		
Area 8	5A	380 ± 40 (SI-2700)	300 ± 60 (SMU-345)	

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TABLE 4
Stable carbon isotope ratios

SMU no.	Substratum	Material	$^{13}C/^{12}C$, ‰
831	5BL	Humic acid (marsh sediment)	−25.5
1090	4B	Humic acid (buried A horizon)	−14.0
1177	4B	Humic acid (buried A horizon top)	−15.5
1191	4B	Humic acid (buried A horizon middle)	−15.7
1200	4A	Humic acid (marsh sediment)	−17.3
1093	3L	Humic acid (buried A horizon top)	−14.0
830	2B (upper)	Humic acid (marsh sediment)	−22.8
829	2B (lower)	Humic acid (marsh sediment)	−22.7
1261	2sLBb	Humic acid (marsh sediment)	−23.2
893	5A	Charcoal	−25.5
263	1B	Wood	−27.4

There are some discrepancies which are especially noteworthy in duplicate analyses. In investigating these inconsistent dates, all aspects of sampling and processing as well as timing and circumstance of each action were considered. It became evident that dates derived from samples taken in freshly cut trenches or newly opened excavation areas were most reliable. Resampling and dating these exposures in subsequent years resulted in generally younger ages, although a few samples from many old exposures were contaminated even though the exposures were cleaned before resampling. Contamination of the walls of the excavation from penetration is not well understood; thus, a new research program is being planned to investigate this phenomena. Further, Table 5 demonstrates that repeated humic acid dates from Area 3 are not as different (maximum 440 yr) as residue dates repeated in other areas (750–1300 yr difference).

Because of these discrepancies, only dates derived from soils and sediments of freshly cut exposures were included in Table 3 and Figure 4, and were considered in the discussions of the dates in the final section. All wood samples, most charcoal samples, and a single shell sample produced internally consistent ^{14}C dates.

TABLE 5
Resampling chronology and resultant dates at Lubbock Lake

Substratum	Location	Age: Date BP	Lab #	Area exposed	Sample taken
2ALB2	Area 6	10,360 ± 80	SI-3200	Summer, 1976	July, 1976
		9,040 ± 90	SI-4592	Summer, 1976	June, 1980
		10,195 ± 165	SI-4976	July, 1981	July, 1981
2ALB2	Area 3	10,060 ± 170	SMU-251	Summer, 1973	Summer, 1974
		10,160 ± 80	SMU-846	Summer, 1973	April, 1976
		9,720 ± 80	SMU-975	Summer, 1973	August, 1979
2ALB4	Area 6	9,115 ± 70	SI-3199	Summer, 1976	July, 1976
		8,335 ± 80	SI-4593	Summer, 1976	June, 1980
		9,905 ± 140	SI-4975	July, 1981	July, 1981
4L (upper)	Tr 39	3,925 ± 80	SI-3206	Summer, 1976	Sept, 1976
		3,175 ± 85	SI-4175	Summer, 1976	August, 1979
4L (lower)	Tr 39	5,545 ± 100	SI-3205	Summer, 1976	Sept, 1976
		4,355 ± 80	SI-4176	Summer, 1976	August, 1979

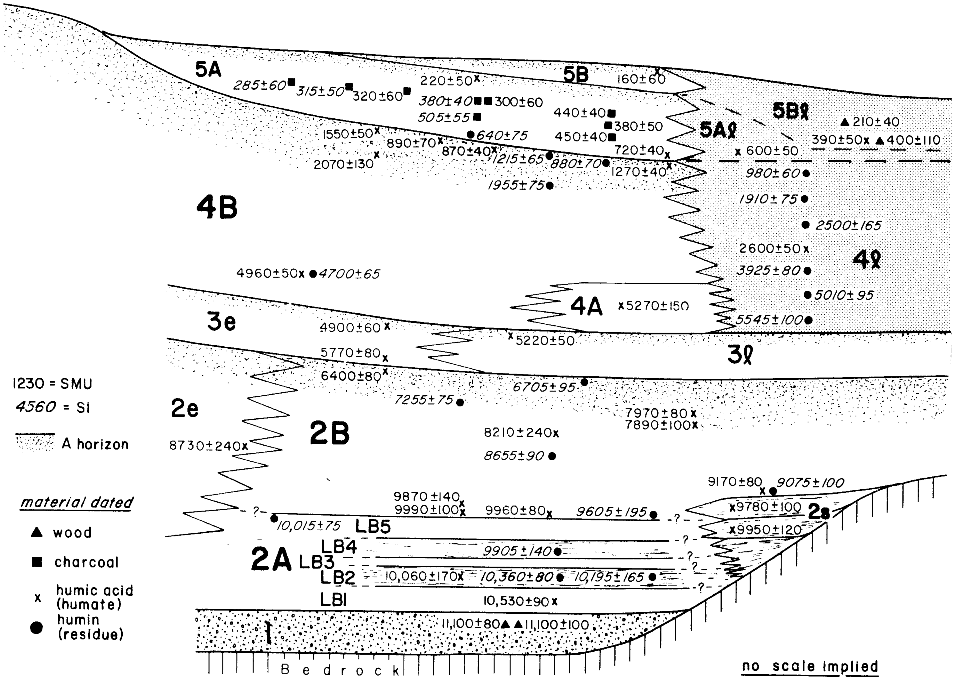

Fig 4. Stratigraphic relationships of the ^{14}C dates determined on extracted humic acids (SMU) and on residual organic matter (SI).

The stable carbon isotope measurements made on the later SMU humate dates are shown in Table 4 and indicate a pattern of changing vegetation. $\delta^{13}C/^{12}C$ values between -22.7 and -23.2‰ are observed on marsh sediments in Substratum 2B and 2A indicating the growth of C-3 type grasses and reeds during a period of increased moisture. Values between -14.4 and -15.7‰ occur in the buried A-horizon of substratum 4B, suggesting growth of C-4 type prairie grasses during this semi-arid period (van der Merve, 1982). In substratum 5B1 the value of -25.5‰ indicates a return of C-3 type vegetation in recent times. This must be considered a local effect.

Correction of the dates for isotope fractionation results in older ages for all humate samples. The increase in age is ca 150 years for samples with $\delta^{13}C/^{12}C$ ca -15‰ and ca 30 years for those with -23‰.

DATES ON ORGANIC-RICH SOIL HORIZONS

^{14}C ages were secured on samples taken from the A-horizons of all principal soils at Lubbock Lake (Fig 4). Most of the samples were from the Firstview Soil, in upper substratum 2B, and the Lubbock Lake Soil, in upper substratum 4B. Most of these ages can be considered reliable, even in view of the vagaries of dating A-horizons, eg, the five ages from the tops of the buried Lubbock Lake Soil range from 1550–870 yr BP. Such a spread is to be expected in a buried A-horizon which can be subjected to bioturbation and burial at varying rates and times. However, 3 of these 5 dates lie close together, between 890 and 870 yr BP, and can be compared with 9 dates on charcoal, ranging from 505–285 yr BP, extracted as solid lumps from a hearth in the overlying sediments. Here, the two stratigraphically lowest dates are also the oldest, 505 and 450 years, respectively. Thus, the age difference between the latest stage in the development of the Lubbock Lake Soil and the construction of the hearth averages at least 400 years. This is not a significant difference if one considers mixing in the buried A-horizon and some sedimentation of 5A prior to emplacement of the hearth.

The ages from the top of the Firstview Soil (6400–6705 yr BP) are also consistent with an age from overlying Stratum 3 (5770 yr BP), but there are fewer dates from this soil and no check dates on charcoal or wood.

Looking at the ^{14}C dates from the bases of the A-horizons, there is again a consistent age relationship for both the Firstview and the Lubbock Lake Soils. These dates should indicate the beginning of pedogenesis, but their usefulness depends on the local environment. Dates from the base of the Firstview A-horizon (ca 7900 yr BP) are consistent with those from 2B just below the A-horizon and dating between 8500 to 8000 yr BP. This soil formed in a marshy, reducing, organic-rich environment where organic matter from the earliest stages of pedogenesis appears to have been preserved (Holliday, 1985a).

^{14}C dates from the base of the Lubbock Lake Soil A-horizon, however, are considerably younger than ages determined for the underlying substratum 4B (ca 2000 yr BP *vs* 5000–4000 yr BP, respectively). The Lubbock Lake Soil formed in a well-drained, semi-arid and oxidizing environment in which plant growth is sparse and production of organic matter consequently is slow. Further, due to the oxidizing condition, a significant portion of the organic matter is lost within a few thousand years or even sooner, as studies of organic carbon build-up and decay in the soils at Lubbock Lake suggest (Holliday, 1982). ^{14}C dates from the base of an A-horizon formed in an environment similar to that of the Lubbock Lake Soil will, therefore, only provide an intermediate age between the beginning and end of pedogenesis and have no stratigraphic significance.

CONCLUSIONS

The applicability of organic-rich sediments and soils for ^{14}C determinations at the Lubbock Lake site is now well demonstrated. The dates from these sediments can serve, essentially, as fixed points in time on a relative time scale for the complete sedimentary column. Dates from buried soil A-horizons can provide maximum ages for the time of burial and, with some restrictions, provide an estimate for the beginning of pedogenesis. These materials have made it possible to determine the cultural chronology and geochronology in considerably greater detail than would have otherwise been possible using charcoal and wood. The usefulness of Lubbock Lake as a model for the cultural and natural history of the late Quaternary of the region is due in large measure to the successful dating of the abundant organic-rich sediments and soil at the site.

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