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SHORT PAPER

Buried Trees, Water Table Fluctuations, and 3000 Years of Changing Climate in West-Central Oklahoma

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A sequence of radiocarbon-dated buried trees, buried soils, a carbonate zone, and a molluscan fauna from Carnegie Canyon indicate that between 3200 and 2600 yr B.P. the climate of west-central Oklahoma was drier than today. A high water table accompanied a period of moister climate 2000 to 1000 yr B.P. The water table dropped after 1000 yr B.P. due to a change toward dry conditions.

An extensive system of canyons was cut 30 to 60 m into the soft Rush Springs Sandstone of Caddo County, Oklahoma, during some undetermined episode of the Pleistocene. Erosion of the sandstone canyons was complete by at least 11,200 yr B.P., the age of the Domebo mammoth kill site which was excavated from sediments just above the bedrock floor of one of the canyons (Albritton, 1966). The sandstone weathers readily, furnishing a vast amount of sand that, during the Holocene, partly filled the canyons. Today some hillsides are denuded of soil and sand, exposing the red sandstone bedrock or "sand rock" as it is called by local residents. The canyon system, known in the region as the Caddo Canyons, harbors stands of sugar maple (*Acer saccharum*) that may be relics from a period of more mesic climate when the maple ranged west of its present distribution in eastern Oklahoma (Little, 1939).

Carnegie Canyon (E½ Sec. 10, T. 7N, R. 13W), located about 4 km east of the town of Carnegie (Fig. 1), has been extensively eroded by recent scouring and headwall cutting, exposing about 11 m of Holocene sand fill. The canyon is short, extending as a tributary only 2.7 km south of its master stream, the Washita River. Bore holes through the sand fill to bedrock indicate that the canyon is 120 m wide with vertical walls extending to a depth of 30 m below the top of the canyon fill (Lintz and Hall, 1983).

A remarkable feature of Carnegie Canyon is the presence of 63 trees buried by 6 to 11 m of canyon fill (Fig. 2). Fifty of the trees are junipers, exhibiting a growth form similar to that of eastern red cedar (*Juniperus virginiana*) which occurs in the area today. Wood samples from 13 nonjuniper trees were submitted to the Forest Products Laboratory, Minneapolis, for identification. Eight of these are American black walnut (*Juglans nigra*), two are cottonwood (*Populus* sp.), one is oak from the white oak group (*Quercus* sp.), another is possibly an oak, and the last is possibly mulberry (*Morus* sp.). These trees grow in the area today (Williams, 1972). Sugar maple was not identified in the Carnegie

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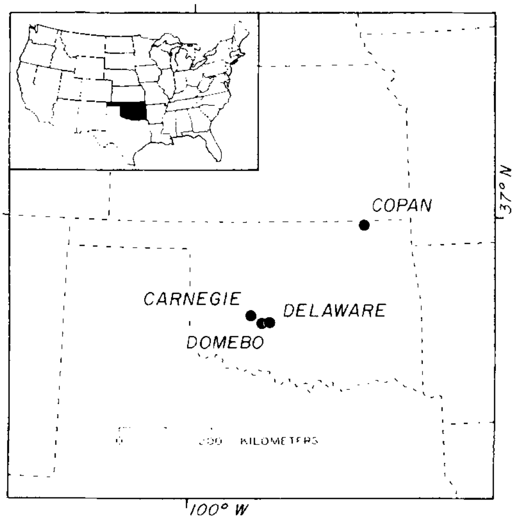

FIG. 1. Map of Oklahoma showing location of alluvial sites mentioned in text: Carnegie Canyon (Lintz and Hall, 1983; this paper), Delaware Canyon (Hall, 1982a), Domebo (Albritton, 1966), and Copan (Hall, 1977).

Canyon series of buried trees. Of the 63 trees found in the canyon, 42 are rooted *in situ*. The others have become dislodged and eroded from their former positions and were observed protruding horizontally from the canyon fill, lying loose on the canyon slopes and floor, or buried in brush accumulations on the bottom of the canyon. They are distinguishable from recent wood by the dark-brown color of both the surface and the interior.

Twelve *in situ* trees have been radiocarbon dated; the ages range from 3200 to 2600 yr B.P. (Table 1), except for tree No. 29, which dates anomalously late, and tree No. 49, which dates too early, based on the sedimentation rate of 0.64 cm per year determined for the other 10 trees. A detailed discussion of the Carnegie Canyon buried trees, along with their dimensions, is given in Lintz and Hall (1983).

The presence of juniper trees on the canyon floor 3200 to 2600 yr B.P. is strong testimony that the water table was lower than today. Junipers are common old-field invaders in the dry uplands of central Oklahoma. They seldom thrive on poorly drained soils where their roots would be drowned. Mature junipers in the area are generally found on surfaces 2 m or more above the water table. The Carnegie Canyon buried junipers occur at least 11.2 m below the present surface. Thus, at the time of juniper growth about 3200 yr B.P., the water table was probably at least 2 m below the canyon floor, placing the water table at least 13 m below the top of the canyon fill or a minimum of 4.5 m below the present water-table level (Fig. 2). During the next 600 yr nearly 5 m of sand was deposited on the floor of Carnegie Canyon, burying many generations of trees.

By 1950 yr B.P., the water table at Carnegie Canyon had risen to a position about 9 m higher than its minimum lowest depth 1200 yr earlier. Four lines of evidence document the higher water table: (1) carbonate accumulation in a prominent paleosol, (2) carbonate crust on bedrock canyon walls, (3) a fossil spring conduit, and (4) aquatic mollusks. A conspicuous light-gray layer in the arroyo wall, associated with the prominent paleosol, is composed of calcium carbonate granules and carbonate coatings on sand grains. These are not concentrated in a uniform zone of calcic accumulation, as in a pedogenic soil, but are present because of a high water table, thus occurring at different stratigraphic positions within the paleosol and, in one case, disseminated in a band 2.7 m thick. The calcium carbonate may have had several origins: the calcareous fraction of eolian-transported dust, the leaching of upland Pleistocene soils, or the dissolution of the calcite cement of the Rush Springs Sandstone. The carbonate in solution is concentrated in groundwater and moves through the sand fill of the canyon. The calcium carbonate is then precipitated on the sand grains as the water table is periodically lowered in response to seasonal or year-to-year fluctuations in precipitation. When the water table rises seasonally, the initially precipitated carbonate is not completely redissolved, probably owing to the carbonate already present in

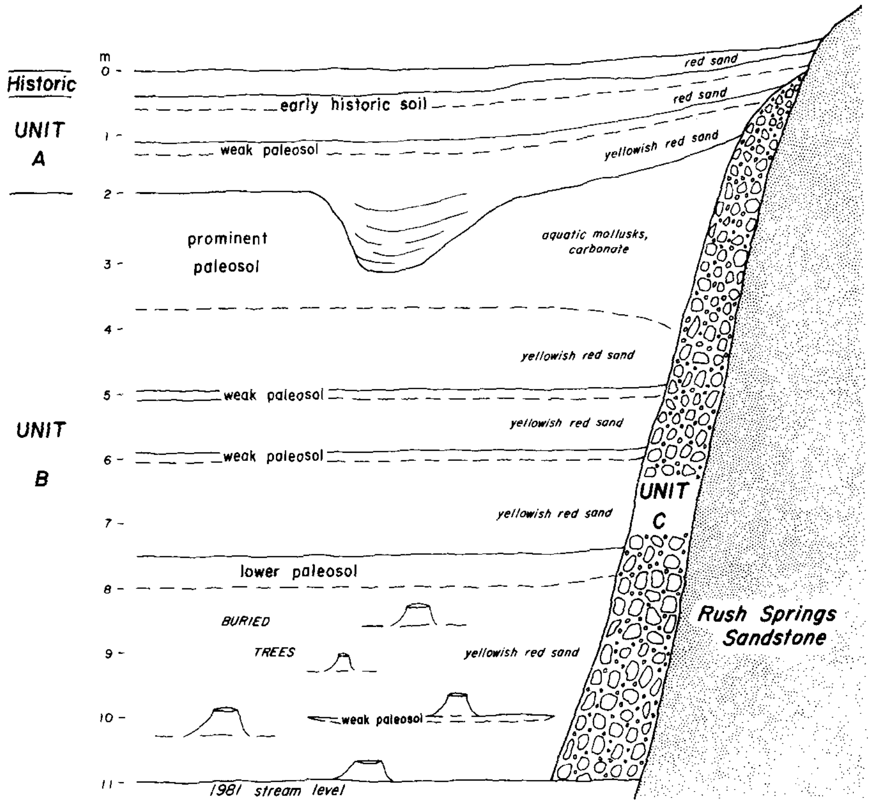

FIG. 2. Composite stratigraphy of Carnegie Canyon fill. Buried trees occur *in situ* below 6.5 m depth and more frequently below the lower paleosol. Units are described in Lintz and Hall (1983): The Rush Springs Sandstone (Permian), a regional aquifer 60 to 100 m thick, is a reddish-brown silty very fine quartz sand with iron oxide and calcite cement (Tanaka and Davis, 1963). In this composite section, the modern (May 1981) water table lies at a depth of about 8.5 m.

the groundwater. Thus, through time, if the water table remains at the same general position, calcium carbonate will build up in the form of grain coatings and small concretions in a zone corresponding to the fluctuating water table. The comparatively thick zone of carbonate granules (up to 2.7 m) may indicate moderate fluctuation of the water table during the general period of high water-table levels 1950 to 1000 yr B.P. This age for the carbonate zone and prominent paleosol is based on a correlation with a well-dated paleosol and associated stratigraphy at Delaware Canyon, about 33 km southeast of Carnegie Canyon (Hall, 1982a). The stratigraphy, radiocarbon chronology, geomorphology, and environment of deposition of the conspicuous paleosol at Carnegie Canyon and Delaware Canyon are identical to those of the Copan paleosol of northeastern Oklahoma (Hall, 1977).

The second evidence for a higher water table is carbonate encrustation on the bedrock canyon wall, visible where the unconsolidated sand fill has been removed by erosion. The carbonate is as much as 3 cm thick, cementing colluvial sands and gravels that have accumulated along the sides of the canyon. The carbonate crust, which extends over a 2-m zone, is probably the same carbonate that accumulated during the period of a high water table at the time of formation of the prominent paleosol.

The third evidence is a spring conduit preserved as a vertical, cone-shaped passageway, wider at the top, formed by pressurized groundwater boiling upward at the

TABLE 1. RADIOCARBON DATES OF BURIED TREES AT CARNEGIE CANYON, OKLAHOMA

Lab No.	^{14}C age (yr B.P.)[a]	Height above canyon floor (cm)	Wood dated	Tree inventory No.[b]
Beta-2784	2290 ± 70	180	*Populus* sp.	29
Beta-2776	2620 ± 60	370	*Juglans nigra*	5
Beta-2783	2710 ± 60	310	*Juniperus* cf. *virginiana*	28
Beta-2782	2760 ± 60	270	*Juniperus* cf. *virginiana*	22
Beta-2775	2870 ± 50	180	*Juniperus* cf. *virginiana*	4
Beta-2779	2870 ± 50	83	*Juniperus* cf. *virginiana*	14
Beta-2780	2910 ± 50	95	*Populus* sp.	16
Beta-2777	3010 ± 50	30	*Juniperus* cf. *virginiana*	7
Beta-2781	3020 ± 50	200[c]	*Juniperus* cf. *virginiana*	20
Beta-2624	3060 ± 50	45	*Juniperus* cf. *virginiana*	1
Beta-2778	3150 ± 60	100	*Juniperus* cf. *virginiana*	13
Beta-4637	4590 ± 70	−40	*Juniperus* cf. *virginiana*	48

[a] Half-life 5568 yr; adjusted for $^{13}C/^{12}C$ ratios, except Beta-2624.
[b] From Lintz and Hall (1983).
[c] Tree exposed in tributary channel at canyon margin; height given is relative to main canyon axis.

side of the canyon. The top of the conduit terminates in the prominent paleosol where it is 1.5 m wide and from which it extends to a depth of 2.4 m below the base of the paleosol.

Finally, shells of a rich molluscan fauna are restricted to the gray sandy prominent paleosol in the canyon. Twenty-four species have been identified (by S.A.H.) from the paleosol, including aquatic forms which, at one collecting locality in the canyon, are one-fourth of the total number of shells. The aquatic elements in the fauna include an unidentified fragment of a unionid mussel, the pill clam *Sphaerium*, and the freshwater snails *Physa virgata*, *Fossaria dalli*, *Gyraulus* sp., *Amnicola integra*, and *Helisoma trivolvis*. They indicate that the canyon floor was moist, perhaps with permanently flowing water. The presence of the aquatic mollusks in the paleosol and their absence from the remainder of the canyon fill provide firm evidence for a high water table in the canyon and indicate that the episode of a higher water table and the accompanying carbonate precipitation coincide with the development of the prominent paleosol.

The water table at Carnegie Canyon was at least 13 m below the top of the cayon fill 3200 yr B.P. and perhaps earlier. By 2600 yr B.P., the water table had risen at least 4 m and by 1950 yr B.P., it was an additional 5 m above its 3200 yr B.P. position (Fig. 3). During the next 950 yr, from 1950 to 1000 yr B.P., the water table remained at a high position, possibly at the surface of the canyon floor, as indicated by the presence of aquatic mollusks at that level. After 1000 yr B.P., the water table dropped, resulting in trenching of the prominent paleosol. The

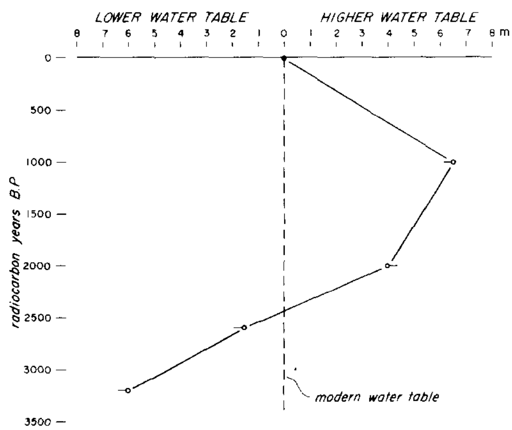

FIG. 3. Chronology of water-table fluctuations. Scale in meters above and below May 1981 water-table position; left-pointing lines indicate minimum depth, right-pointing line indicates maximum depth.

present-day (May 1981) water table is about 6 m below the 1000 yr B.P. position.

The history of water-table levels at Carnegie Canyon is probably related to past precipitation or effective moisture availability. Present average annual precipitation is 760 mm and average annual temperature is 17°C. The low water table from 3200 to 2600 yr B.P. may reflect a climate drier than that of today. From 2600 to 1950 yr B.P. the climate changed to conditions of greater available moisture. The evidence of buried trees does not indicate whether the rise in water table or the increase in precipitation was gradual or stepwise. Nevertheless, the moist period persisted until about 1000 yr B.P. The 950 yr of moist climate resulted in a water table that was at or very near the level of the canyon floor at that time, resulting in the slow development of the prominent paleosol and the flourishing of a diverse molluscan fauna, including seven aquatic forms. After 1000 yr ago the climate changed again, but to drier conditions like those of today, causing a fall in the water table and trenching of the canyon floor that had been slowly aggrading during the previous 950 yr. The paleoclimatic sequence from Carnegie Canyon corresponds well to the paleoenvironmental record from other sites in the southern plains (Hall, 1982b) and provides new evidence that the climate, prior to the moist period of 1950 to 1000 yr B.P., was drier than today.

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