Quaternary history of the Estancia Valley, central New Mexico

Frederick W. Bachhuber

1982, pp. 343-346. https://doi.org/10.56577/FFC-33.343

in:

Albuquerque Country II, Wells, S. G.; Grambling, J. A.; Callender, J. F.; [eds.], New Mexico Geological Society 33 rd Annual Fall Field Conference Guidebook, 370 p. https://doi.org/10.56577/FFC-33

This page is intentionally left blank to maintain order of facing pages.

QUATERNARY HISTORY OF THE ESTANCIA VALLEY CENTRAL NEW MEXICO

F. W. BACHHUBER
Department of Geoscience
University of Nevada, Las Vegas
Las Vegas, Nevada 89154

INTRODUCTION

The Estancia valley lies within a closed physiographic and structural basin near the geographic center of the state of New Mexico (fig. 1). This arid valley presently has a deficit water budget of 122 cm annually which precludes the existence of natural perennial-water bodies. Geomorphic, sedimentologic, and paleontologic evidence, however, indicates that major climatic oscillations occurred during the Quaternary.

The geologic history of the Estancia valley has been synthesized over a period of almost 80 years following Keyes' (1903) observation that the valley contained ". . . evidences of the existence of old lakes." Keyes and other researchers in the valley believed that the pluvial system, while of considerable areal extent and water depth, did not overflow into adjacent basins. Consequently, it was assumed that the lake system never evolved into a fresh-water body.

The highest elevations (over 3,050 m; 10,000 ft) within the Estancia valley occur along the western rim of the watershed; whereas, the lowest elevations (1,842 m; 6,045 ft) are found along the central topographic axis. Along the valley axis a series of wind-excavated playas, arranged in an elliptical pattern, are incised into the valley floor (fig. 1). The deflation basins are cut into lacustrine sediment exposing a complex stratigraphic sequence of up to 10.5 m in thickness. In the southeastern corner of the basin a broad, gently-sloping saddle, termed the topographic sill, separates the Estancia valley from the Pinos Wells basin. Presently, the topographic sill has a minimum elevation of 1,929 m (6,330 ft), rendering a total topographic closure of 87 m.

GEOMORPHIC EVIDENCE

Geomorphic evidence of a pluvial system within the Estancia valley has been recognized since the turn of the century (Keyes, 1903). Meinzer (1911) describes a geomorphic complex of well-preserved wave-cut cliffs, terraces, beaches, spits, and bars. Many of these features are obvious on aerial photographs. Significantly, the highest shoreline features described by Meinzer occur 30 m below the present topographic sill. Meinzer's observations led later researchers (Leopold, 1951; Harbour, 1958) to conclude that the pluvial lake had no outlet and, therefore, was saline. Bachhuber (1971) refers to this geomorphic complex as "younger shoreline features."

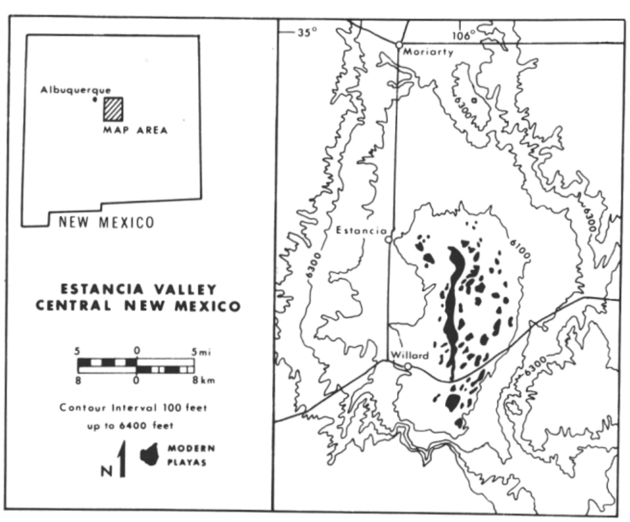

Figure 1. Index map of the Estancia valley in central New Mexico.

More recent work in the basin (Lyons, 1969; Titus, 1969) suggests that the pluvial system was much deeper and greater in areal extent than originally proposed. Titus, in particular, reports suspected shoreline features at an elevation of 1,939 m (6,360 ft), 10 m above the topographic sill. The features described by Titus are highly dissected, and the widely-scattered remnants can be interpreted as resulting from other geomorphic processes. Because of their questionable origin these features and others termed "older shoreline features" by Bachhuber (1971) are not conclusive evidence of a higher lake stand. Nonetheless, they do suggest the possibility of a lake level at one time being above the topographic sill.

SEDIMENTOLOGIC EVIDENCE

A maximum of 10.5 m of stratigraphic section (fig. 2) is exposed along the flanks of the more centrally located deflation basins. This section contains a number of distinct sedimentologic and biostratigraphic units which indicate that the Estancia valley had not one but a series of pluvial lakes.

The lower portion of the exposed section consists of interbedded clay, silt, and gyparenite, capped by massive-bedded flint-gray clay. This sediment represents various stages of the development of late Lake Estancia, the highest lake stand within the basin. The late Lake Estancia sediment is subdivided into four units, or phases: (1) a pre-pluvial phase which consists of thin- to thick-bedded gyparenite, silt, and silty clay, some of which appears to be of turbidite origin; (2) a pluvial maximum phase characterized by a dominance of flint-gray clay; (3) a partial drawdown phase consisting of interbedded gyparenite, silt, and clay; and (4) a final high-water phase characterized by massive-bedded flint-gray clay. In general, the late Lake Estancia sediment represents maximum glacio-pluvial conditions.

The late Lake Estancia sediment is overlain conformably and unconformably by red to brown, finely-intercalated silt, clay, and gyparenite. This unit, referred to as the Estancia playa complex, is easily delineated from the underlying and overlying sediment by color alone. The Estancia playa complex represents an inter-pluvial period which led to the desiccation of late Lake Estancia. Following intermittent flooding of the basin, the sediment of the interval accumulated in a playa-like environment.

The sediment of the Estancia playa complex is transitional with a flint-gray clay of the Lake Willard unit. The change in sediment character indicates that basin flooding and the ephemeral lakes, characteristic of the preceding inter-pluvial stage, became more persistent and eventually evolved into the Lake Willard pluvial stand. Although water level probably fluctuated drastically during early and late developmental stages, Lake Willard at its maximum stand occupied much of the Estancia valley.

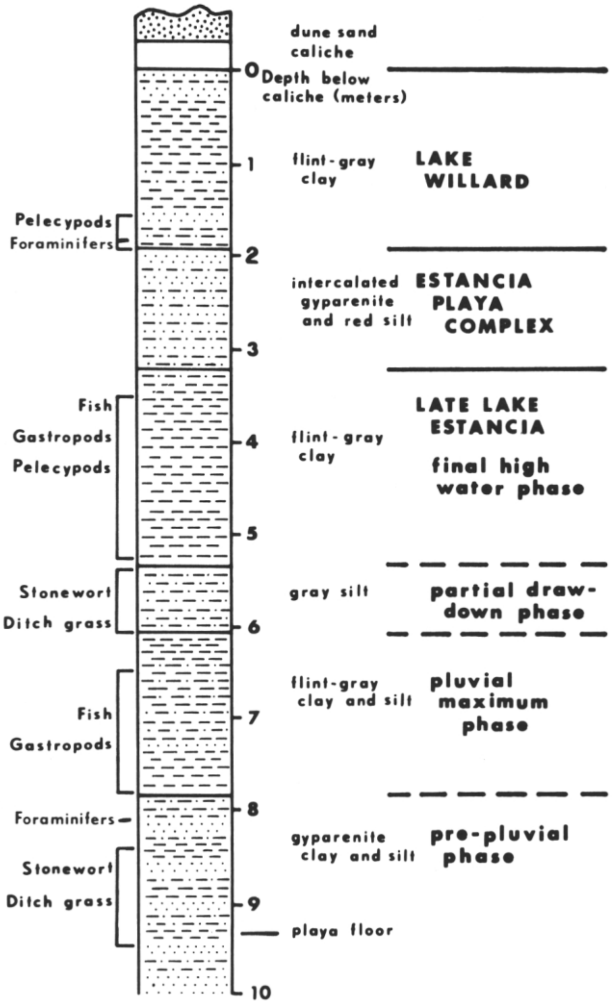

Figure 2. Stratigraphic and biostratigraphic column of pluvial and inter-pluvial sediment of the Estancia valley.

The Lake Willard sediment is capped by a 0.5-m-thick caliche (Willard soil) which marks the desiccation of the last major pluvial stand within the Estancia valley. Based on correlations with other areas, the Willard soil is believed to have formed during the Altithermal. During this time, in addition to the development of caliche, an early sequence of shallow deflation basins (cut into the Willard soil and underlying lacustrine sediment) and sand dunes was being formed. Subsequently, with a return to more mesic conditions, the valley floor was flooded again during a sub-pluvial episode. The sub-pluvial episode (Lake Meinzer) resulted in the filling of the shallow deflation basins with intercalated clay and coarse elastics, modifications of the sand dunes by wave erosion, and the development of the lowest elevational shoreline features found within the valley. The chronology of Lake Meinzer is unknown, except the lake must postdate the Altithermal. The short sub-pluvial episode, evidenced by Lake Meinzer, was followed by a return to post-pluvial dry climate. The present deflation basins and associated sand dunes began to form following the desiccation of Lake Meinzer. The process has been intermittent up to today.

PALEONTOLOGIC EVIDENCE

Fossil evidence within the Quaternary lacustrine sediment of the Estancia valley is abundant. The pluvial and inter-pluvial sediment records the occurrence of pollen (50 taxa), seeds (4 taxa), other plant parts, algae (3 taxa and 37 species of diatoms), foraminifers (2 species), ostracods (8 species), insects (3 taxa), mollusks (5 species), fish, and salamander (Bachhuber, 1971). The identification of the highly varied floral and faunal elements and recognition of their paleoecologic requirements permit a reconstruction of paleoenvironmental conditions. Although virtually all of the organisms have some paleoecologic significance (e.g., pollen and diatoms appear to be very sensitive indicators of changing conditions), only the most diagnostic ones are mentioned in this report.

The four developmental phases recognized in the late Lake Estancia sedimentologic sequence have distinctly different fossil assemblages. The pre-pluvial phase is characterized by the occurrence of stonewort *(Chara canescens)* and ditch grass *(Ruppia maritima)*. These aquatic plants grow in brackish, shallow-water environments, and their occurrence in the late Lake Estancia basin appears to represent a life population. In addition, the upper portion of the pre-pluvial sediment contains marine foraminifers (Bachhuber and McClellan, 1977). The salinity and thermal requirements of the foraminifers, which are extant species, along with the other fossils suggest that the pre-pluvial phase was a period of low water level, had a salinity corresponding to that of marine conditions, and had a water temperature of about 10°C during the warmest months of the year.

The sediment of the pluvial maximum phase of late Lake Estancia records the first occurrence of mollusks and the arrival of fish into the lake basin. The sparse assemblage of gastropods and pelecypods is not diagnostic by itself, but the occurrence of cutthroat trout *(Salmo clarki)* in association with the mollusks indicates the high likelihood of fresh-water conditions. More significantly, the occurrence of trout in the Estancia valley pluvial system is evidence that, at least on one occasion, the lake system had a drainage outlet.

The sediment of the partial drawdown phase does not contain the faunal elements found in the preceding pluvial maximum phase. Instead, stonewort and ditch grass return as the dominant megafossil types. The disappearance of fish and mollusks and their replacement by brackish-water aquatic plants signify that lake level was lowered below the topographic sill and through time the lake became more saline.

The flint-gray clay of the final high-water phase is characterized by the reappearance of mollusks and cutthroat-trout fossils. The unit also records the first and last appearance of *Cytherissa lacustris,* an ostracod presently found in large, cold-water, glacial lakes of Scotland, Norway, Sweden, and Siberia (Moore, 1961). The fossils of the final high-water phase show that late Lake Estancia water levels rose, perhaps to an overflow stage, with an accompanying lowering of salinity.

In contrast to the sediment of late Lake Estancia, the inter-pluvial Estancia playa complex sediment has a low density and diversity of fossils. Other than pollen the only fossils recorded are an alga *(Botryococcus)* and one species of ostracod *(Limnocythere staplini)*. Both of these organisms are thought to be saline tolerant. Their sporadic occurrence in the Estancia playa complex sediment apparently represents periodic blooms following heavy rains and flooding of the basin floor. Upon desiccation of the ephemeral ponds the organisms were eliminated, only to reappear during the next rainy season.

The flint-gray clay of the Lake Willard pluvial episode is depositionally transitional with the gyparenite and silt of the Estancia playa complex. Similar to that of the late Lake Estancia sequence, the Lake Willard sediment and enclosed fossils illustrate a developmental phase as the lake expanded. The lower-most sediment, in littoral and profundal facies, contains the same foraminifers as found in the late Lake Estancia pre-pluvial phase. This indicates that an initial phase of lake development consisted of a persistent, shallow, saline-water body. As climatic conditions continued to change, Lake Willard water level rose. Geomorphic evidence indicates that the lake did not reach an overflow stage, but the occurrence higher in the section of a pelecypod *(Pisidium)* and an alga *(Pediastrum)* attest that salinity was greatly reduced from that of the earlier infilling stage.

Following the highest water-level stage, a return to inter-pluvial climatic conditions resulted in the shrinkage of Lake Willard and the formation of recessional strandlines. Fossil evidence which could support a gradual lowering of water level and accompanying increase in salinity is not found. That desiccation did occur, however, is evidenced by the Willard soil.

PALEOLIMNOLOGY

The various pluvial and inter-pluvial phases, recorded in the stratigraphic section of Quaternary fill in the Estancia valley, are delineated by sedimentologic, geomorphic, and paleontologic evidence. The exposed stratigraphic section records two major pluvial episodes and a sub-pluvial episode, each of which was followed by inter-pluvial conditions. The abundance and character of plant and animal fossils provide a unique opportunity for a limnological reconstruction of the pluvial episodes. By inference, a climatological framework can also be established for Quaternary events.

Late Lake Estancia

Late Lake Estancia was characterized by four distinct developmental phases, each of which was related to climatic oscillations. Since only a few radiocarbon dates are available from the Estancia valley sediment, the chronology and duration of the individual phases is somewhat speculative. It is clear, however, that late Lake Estancia is correlative with the Wisconsin glacio-pluvial maximum estimated to have occurred between 18,000 to 10,500 years B.P.

Prepluvial phase

The pre-pluvial phase was a period of initial flooding of the Estancia basin floor. Interbedded clay lamina associated with gyparenite units indicate that this phase of lake development was characterized by rather rapid fluctuations in lake level. The occurrence of an abundance of aquatic plants, in a life population, indicates that water depth was on the order of 1 to 8 m. The aquatic plants and the existence of marine foraminifers near the top of the pre-pluvial section document a paleosalinity range of 25 to 35 parts per thousand. In addition, the thermal tolerance of the foraminifers, which at present have a holarctic distribution, suggests a water temperature during the warmest month of approximately 10°C (Bachhuber and McClellan, 1977). The shallow-water nature of the emerging lake and high seasonal wind would have precluded thermal stratification; therefore, it is probable that atmospheric temperature was also 10°C or about 10°C below that of the present. A lowering of temperature of this magnitude would have assured the growth of the lake even without a significant increase in precipitation.

Pluvial maximum phase

With greatly reduced temperatures, late Lake Estancia expanded. The occurrence of cutthroat-trout fossils in the sedimentologic record is conclusive evidence that the lake expanded to an overflow stage. Drainage flowed eastward across the topographic sill and entered the Pinos Wells basin, the Encino basin, Pintada Canyon, and eventually into the Pecos River drainage system (fig. 3). This is presumably the water route by which fish were introduced into the Estancia basin. At the time of overflow the lake was oligotrophic. This implies among other things that cold, fresh-water conditions existed. Late Lake Estancia had a minimum depth of 90 m and covered an area of 2,340 km^2. The total lake pool including the flooded Pinos Wells and Encino basins encompassed 2,860 km^2.

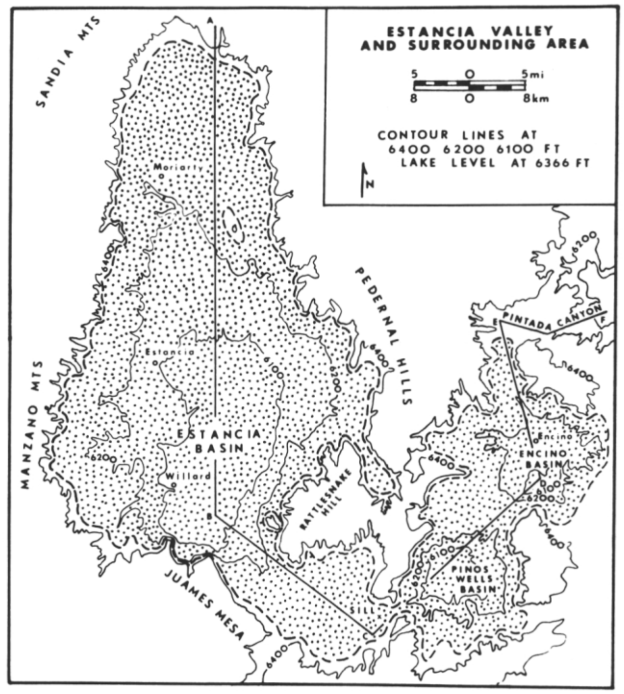

Figure 3. Inferred areal extent of late Lake Estancia during the pluvial maximum phase indicating overflow into Pintada Canyon.

Partial drawdown phase

The partial drawdown phase represents a period of rapid water-level lowering. A reduction of water level from that of the pluvial maximum phase is evidenced by an increase in coarse-clastic deposition, the reoccurrence of certain aquatic plants and, indirectly, by the disappearance of the fresh-water aquatic fauna. The aquatic-plant fossils are found near the axis and deepest water portion of the basin, but the assemblage does not represent a life population. Instead, the plant material was carried into the profundal zone, perhaps by turbidity currents. This suggests that minimum water depth was somewhat greater than that of the pre-pluvial phase. It is likely that water quality was brackish to saline and air temperatures were higher than in the preceding developmental phases. A radiocarbon date of 12,400 ± 450 years B.P. derived from *Ruppia achenes* places the partial drawdown phase in the late Wisconsin.

Final high-water phase

The final high-water phase of late Lake Estancia was characterized by the repopulation of the lake by cutthroat trout and other freshwater species. Lake level rose and water quality improved significantly. Lake overflow, however, during the final high-water phase cannot be demonstrated, and it is not a prerequisite for the reestablishment of trout. It is conceivable that during the partial drawdown phase, as salinity increased, trout dispersed into perennial streams draining from the western highlands. This stream population was then free to disperse from the streams into the lake basin as water level rose and salinity decreased. It is inferred that, with or without overflow, lake morphometry would have been similar to that of the pluvial maximum phase. If the lake overflowed, the "older shoreline features" could have formed at this time. Conversely, if the lake did not overflow, the geomorphically old shoreline features would have formed during the pluvial maximum phase. A radiocarbon date on fish bones of 11,740 ± 900 years B.P. places the final high-water phase near the close of the *late* Wisconsin.

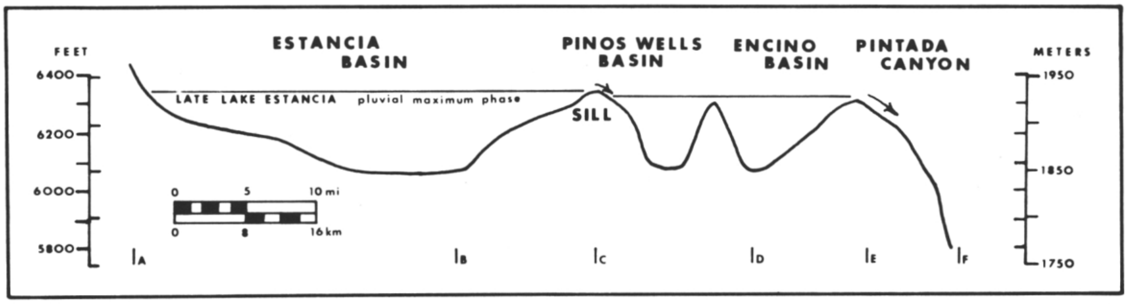

Figure 4. Long-profile through the Estancia basin to Pintada Canyon (A to F, fig. 3) indicating lake level during the pluvial maximum phase of late Lake Estancia.

Estancia Playa Complex

The sediment of the Estancia playa complex marks the advent of full inter-pluvial conditions. The desiccation of late Lake Estancia was probably a gradual process, but eventually the whole lake floor was exposed subaerially. The intercalated nature of gyparenite, red clay, and silt indicates that alluviation alternated with shallow-water deposition. During periods of seasonal rainfall the basin floor was flooded. Initially water quality of the emphemeral ponds was conducive to ostracodal and algal blooms. Upon evaporation, however, hypersaline conditions and eventually desiccation caused their elimination. Reappearance of the organism followed the next episode of basin flooding. No radiocarbon dates are available from the Estancia playa complex sediment. Based on correlation with other areas, it is believed that the interval began at about 10,500 years B.P. and closed at about 8,500 years B.P.

Lake Willard

A return to pluvial conditions resulted in the growth and expansion of Lake Willard. Sedimentologic aspects suggest that an early phase of lake development was characterized by widely fluctuating water level and salinity. The occurrence of Foraminifera in the lowest portion of the section has the same paleoecologic implications as that of the pre-pluvial phase of late Lake Estancia. The most critical of these was greatly depressed water and atmospheric temperatures. As water level rose, salinity decreased and the foraminifers were replaced by a fresh-water pelecypod. At this time the highest "younger shoreline feature" was formed. Since it is 30 m below the topographic sill, Lake Willard did not reach an overflow stage. The highest, geomorphically young strandline in the Estancia basin shows that during maximum expansion Lake Willard covered 1,170 km'. The maximum water depth was approximately 46 m. From this point water level was gradually reduced with the resultant formation of recessional strandlines.

No radiocarbon dates have been obtained directly from the Lake Willard stratigraphic sequence. Nonetheless, two mammoth-tusk dates (Lyons, 1969) from what is believed to be associated marginal sediment range from 7,950 ± 300 years B.P. to 6,000±200 200 years B.P. These dates represent a fairly accurate chronology of Lake Willard.

Later Events

The desiccation of Lake Willard brought to a close full glacio-pluvial conditions in the Estancia valley. The valley floor was subaerially ex posed, and caliche development occurred throughout the area. During the time of formation of the Willard soil at least two large deflation basins were carved to a depth of 7 m into the lacustrine sediment. Wind-blown material also accumulated in a series of small sand dunes.

After calichification, deflation, and deposition of the small dunes, the Estancia valley was influenced again by a more mesic climatic oscillation. The valley floor was flooded with the resulting growth of Lake Meinzer. No paleontologic evidence of this particular sub-pluvial episode has been found, but geomorphic evidence indicates that Lake Meinzer rose and formed a beach complex that nearly rings the central portion of the basin. The previously formed deflation basins were filled with sediment and wave action modified and cemented the series of small dunes. At its highest stand Lake Meinzer would have been 20 m deep, covering an area of 520 km'.

The present major topographic surfaces and geomorphic features were formed after desiccation of Lake Meinzer. The complex of deflation basins and associated parabolic dunes and sand sheets is the result of the modern arid climate.

REFERENCES

Bachhuber, F. W., 1971, Paleolimnology of Lake Estancia and the Quaternary history of the Estancia valley, central New Mexico (Ph.D. thesis): University of New Mexico, Albuquerque, 238 p.

Bachhuber, F. W. and McClellan, W. A., 1977, Paleoecology of marine Foraminifera in the pluvial Estancia valley, central New Mexico: Quaternary Research, v. 7, p. 254-267.

Harbour, J., 1958, Microstratigraphy and sedimentational studies of an early man site near Lucy, New Mexico (M.S. thesis): University of New Mexico, Albuquerque, 111 p.

Keyes, C. R., 1903, Ephemeral lakes: American Journal of Science, v. 16, p. 377-378.

Leopold, L. B., 1951, Pleistocene climate in New Mexico: American Journal of Science, v. 249, p. 152-168.

Lyons, T. R., 1969, A study of the Paleo-Indian and desert culture complexes of the Estancia valley area, New Mexico (Ph.D. thesis): University of New Mexico, Albuquerque, 355 p.

Meinzer, 0. E., 1911, Geology and water resources of Estancia valley, New Mexico; with notes on ground-water conditions in adjacent parts of central New Mexico: U.S. Geological Survey Water-supply Paper 275, 89 p.

Moore, R. C., ed., 1961, Treatise on invertebrate paleontology, part Q, Arthropoda 3: Geological Society of America, p. Q1-Q442.

Titus, F. B., 1969, Late Tertiary and Quaternary hydrogeology of the Estancia basin, central New Mexico (Ph.D. thesis): University of New Mexico, Albuquerque, 179 p.