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GEOLOGY OF THE WILLCOX PLAYA, COCHISE COUNTY, ARIZONA*

JOSEPH F. SCHREIBER, JR.
Department of Geosciences
University of Arizona
Tucson, Arizona

INTRODUCTION

Pluvial Lake Cochise, located in Cochise County, southeastern Arizona, was one of many lakes present during the late Pleistocene Epoch in the Basin and Range province of the western United States (Feth, 1964). Lake Cochise later dried up; the desiccated lake bed is now known as Willcox Playa or Willcox Dry Lake.

Willcox Playa and surrounding area was studied by the author and his students for three years in 1962-65 (Pine, 1963; Pipkin, 1964; Robinson, 1965; Wilt, 1965). A paper covering the results of these investigations was printed in the *Playa Lake Symposium* volume by the International Center for Arid and Semi-Arid Land Studies (ICASALS) and Department of Geosciences, Texas Tech University, Lubbock, Texas, in 1972 (Schreiber and others, 1972). These studies provided a framework for the interpretation of the sedimentation history of the Willcox Playa area during the late Wisconsin and in post-pluvial times. Field and laboratory work has been continued intermittently by the writer since mid-1965.

0. E. Meinzer first studied the Willcox Playa area as part of a larger investigation of the geology and water resources of Sulphur Springs Valley in 1910-1911 (Meinzer and Kelton, 1913). He gave the name Lake Cochise to the Pleistocene lake that had once occupied Willcox basin. Meinzer's thorough work was a constant guide and inspiration throughout our 1962-65 field studies. More recent U.S. Geological Survey publications include a reconnaissance geological map of the playa and surrounding area by J. R. Cooper (1960), a study of the fluoride content and salinity by Kister and others (1966), and a water-supply paper by Brown and Schumann (1969) that covers the geohydrology in text discussion and with maps.

Location and Climate

Willcox Playa is located a few kilometers south of Willcox in north-central Cochise County (fig. 1). This barren flat, elevation 1260 m (4,135-4,136 ft), is the lowest part of Willcox basin, which is the northern end of Sulphur Springs Valley. The U.S. Geological Survey topographic map of the Cochise quadrangle depicts the playa and a small part of the surrounding area. Although much of the central part of the playa is managed by the U.S. Army command at Fort Huachuca, Arizona, the south tip and the east and west edges may be visited by following ranch and other unimproved roads leading from U.S. Highway 666 on the west or the Kansas Settlement road on the east.

The climate of the area is semi-arid. Willcox, elevation 1277 m (4,190 ft), for example, records a mean annual precipitation of 28-30 cm (11-12 in) and a mean annual temperature of 14.8°C (58.7°F). Over half the annual precipitation falls during the convective-type thunderstorms of July, August and early September when warm, moist tropical air moves into the state from a southeasterly direction from the Gulf of Mexico. Winter precipitation includes rain and snow from frontal-type storms that move in from the Pacific Ocean across southern California. Both storm periods are accompanied by strong winds although they are usually of short duration. Summer temperatures frequently exceed 38°C (100°F), but average closer to 32°C (90°F). Winter lows for December, January and February are near 0°C; monthly means range from 4 to 9°C (Green and Sellers, 1964).

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GEOLOGIC-PHYSIOGRAPHIC SETTING

Sulphur Springs Valley trends about north-northwest and is flanked by mountain ranges on the east and west sides. The mountain ranges are the cumulative result of large-scale faulting and uplift during the mid-Tertiary. During and after this tectonism detritus eroded from the uplifted blocks was deposited in the adjacent valleys and basins (Cooley and Davidson, 1963; Peirce and others, 1970).

The highest and most rugged range—the Pinaleno, Dos Cabezas and Chiricahua mountains—lies on the east side of the basin (fig. 2). Mount Graham in the Pinalenos, elevation 3265 m (10,713 ft), is the highest peak in the drainage area. On the west the range includes the southern Galiuro, Winchester, Little Dragoon and Dragoon mountains with Reiley Peak, elevation 2336 m (7,631 ft) in the Winchester Mountains the highest point in these mountains. From the playa none of the mountains seem to be very high because the loftier range on the east is also a greater distance from the playa than the lower range on the west. If any one feature of the mountains stands out, it would have to be the two peaks of the Dos Cabezas Mountains, which are visible from many directions.

The rocks of the mountain blocks range in age from Precambrian to Cenozoic and almost all rock types are represented. Included are Precambrian granites and gneiss; Paleozoic sandstones, limestones and shales; Cretaceous sedimentary rocks; Cretaceous-Tertiary granitic intrusives; volcanic rocks of Cretaceous-Tertiary and Tertiary age; and late Cenozoic sedimentary rocks. The southern Galiuro-Winchester Mountains are almost entirely composed of Tertiary volcanic rocks. Across the valley to the east the higher Pinaleno Mountains are dominated by Precambrian granite and gneiss. The rocks in the Chiricahua Mountains consist chiefly of Tertiary volcanic rocks of rhyolitic composition. The remaining mountains are complex mixtures of sediments, igneous intrusives and volcanic rocks (Wilson and others, 1969).

The alluvial deposits that have filled Willcox basin consist of moderately consolidated conglomerate, sandstone and mudstone of Tertiary age; poorly consolidated gravel, sand, silt and clay of Quaternary-Tertiary age; unconsolidated stream deposits of gravel, sand, silt and clay of Quaternary age; and lake muds and associated sediments of the playa of Quaternary age (Brown and Schumann, 1969).

Deeper wells in the basin, for which good sample logs are available, penetrate more than 300 m of gravel, sand, mud-

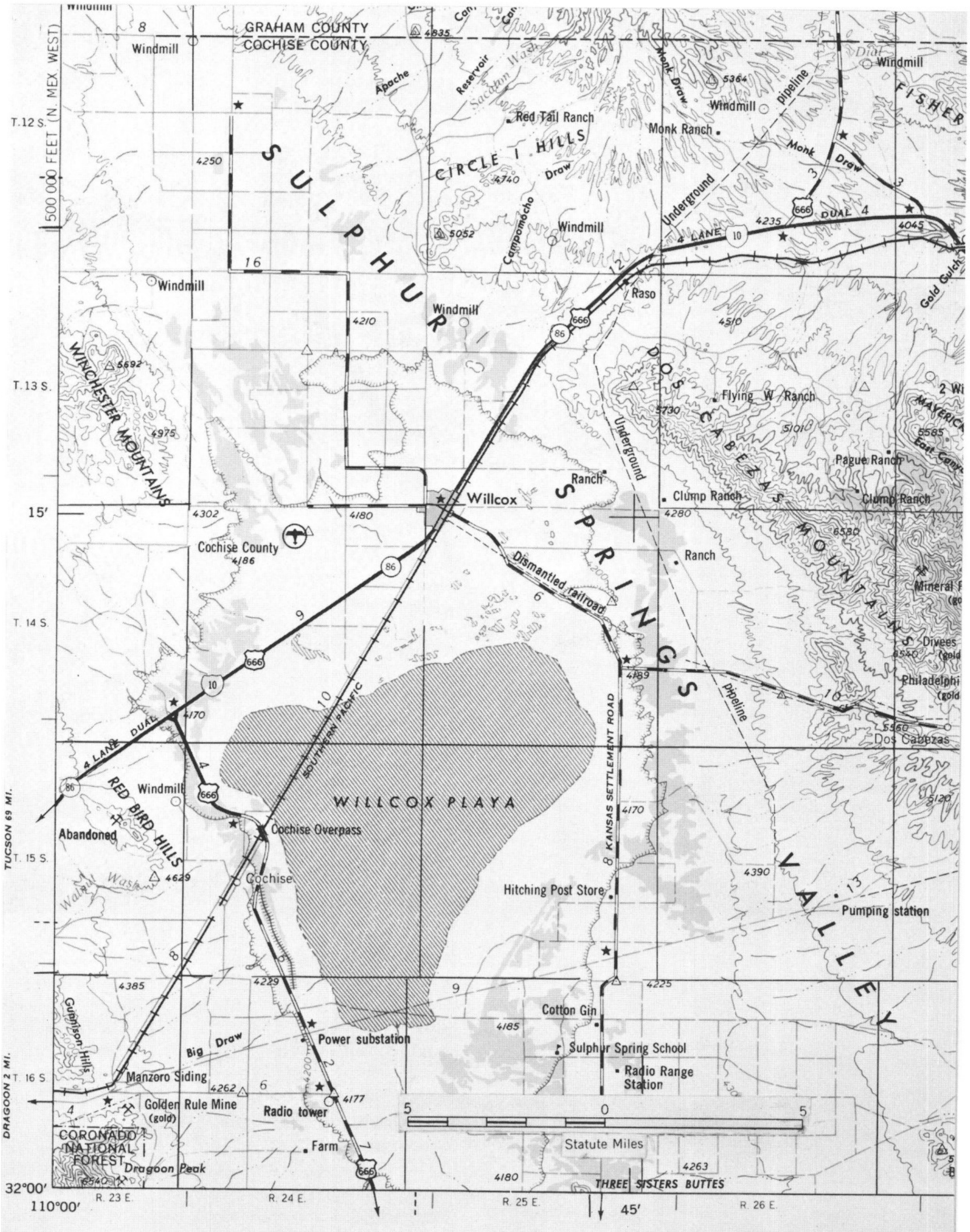

Figure 1. Index map of Willcox Playa area and part of Willcox basin.

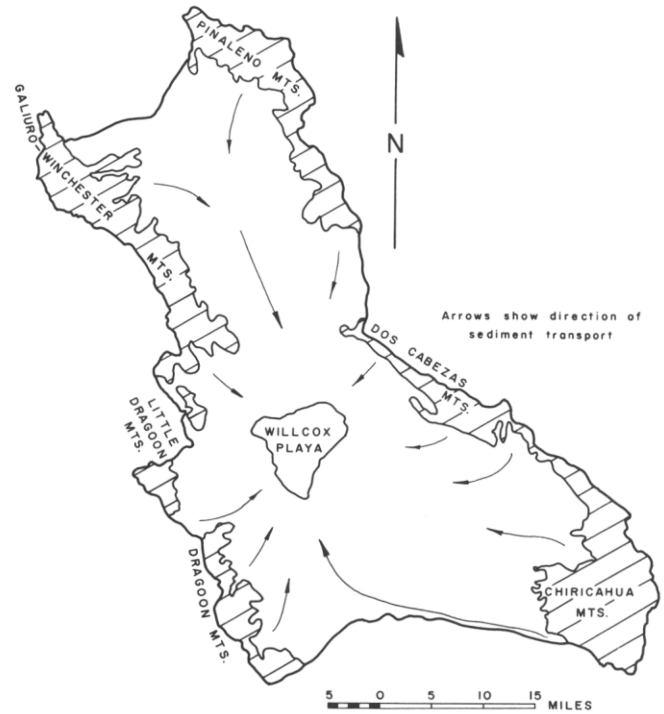

Figure 2. Willcox basin drainage area.

stone, silt and clay. Because greater thicknesses of sediments (900 to 1500 m or more) are known in other nearby valleys and basins with similar histories, it is probable that the basin-fill sediments are actually much thicker than shown in the wells drilled to date in Willcox basin (Heindl and DeCook, 1952, p. 8).

Alluvial fan slopes between the mountains and the playa consist chiefly of the unconsolidated stream deposits cited above. To the east the alluvial slopes are much wider than those on the west side of the basin because the larger mountain range on the east has supplied a greater quantity of sedimentary debris. This activity has moved the playa and valley axis closer to the west boundary of the basin (Meinzer and Kelton, 1913, p. 26).

Sedimentation has also been responsible for the formation of drainage divides at the north and south edges of Willcox basin. To the north the Pinaleno and Galiuro-Winchester mountains have shed sediments to form the divide with the Arivaipa Valley. From this divide southward the basin floor slope is very gentle and shows little erosion, but north of the divide Arivaipa Creek has eroded the basin fill extensively. Arivaipa Creek is a tributary of the San Pedro River that flows north through the next large valley to the west. The southern drainage divide lies between the Chiricahua and Dragoon mountains with the divide taking a somewhat sinuous path south of the hills near Pearce and thence eastward on the south side of Turkey Creek.

The length of the basin between divides along the north-northwest axis is 93 km (58 mi). Overall Willcox basin occupies about 3900 km^2 (1500 mi^2) of which 2500 km^2 (950 mi^2) are valley floor (Brown and Schumann, 1969). Willcox Playa occupies about 130 km^2 (50 mi^2).

PLEISTOCENE FLUVIAL SEDIMENTATION

0. E. Meinzer first recognized the presence of one lake and suggested an older larger lake in Willcox basin. He tentatively assigned the younger lake to the Pleistocene, pointing out that the lake must have owed its existence to a more humid climate than prevails at present (Meinzer and Kelton, 1913, p. 74-76). A more humid climate also meant increased rates of weathering, soil formation, erosion and sedimentation.

Abundant evidence exists for fluvial sedimentation during the late Tertiary and Quaternary in the form of the alluvial deposits described in the preceeding section. Pleistocene stream deposits may be studied in wide stream meander belts north and south of the playa where numerous sand and gravel pits are located in the valley floor. In all areas where exposed, stream deposits display these characteristics: cut and fill-type deposition, trough cross-stratification in sands and gravelly sands, laminated fine-grained sands, and graded bedding in sands. One pit in the north, active in the early 1960's, furnished Pleistocene camel teeth and bones, horse teeth, and mammoth bones and one tusk. Closer to the playa at either end subsurface augering and driller's logs show these stream deposits to interfinger with clay and mud of Pleistocene Lake Cochise. Fluvial sediments, in the classification of R. L. Folk (1974, p. 28), plot chiefly as sandy gravel, gravelly sand or sand. Folk's terminology for mixtures of gravel-sand-mud and sand-clay-silt is used throughout this report.

RECENT FLUVIAL SEDIMENTATION

Stream flow in Willcox basin is intermittent with flow occurring during winter rainy periods and following summer thunderstorms. Although many streams flow, only a few deliver water to the playa surface because water is lost to infiltration of streambeds and porous slope alluvium, retention in tanks and behind dams, or evaporation. Gravel and sand are usually left high on the surrounding slopes, and only muddy waters reach the playa in a few locations.

LAKE COCHISE SEDIMENTS

General Setting

The streams transporting the gravels and sands described in the previous section also transported silt and clay to Pleistocene Lake Cochise. Toward the middle, and presumably the deeper part of Lake Cochise, clay and mud accumulated. Closer to the north and south ends, where the main streams contributed their loads, and along the western and eastern shores, clay and mud mixed with sand or interfingered with sand, gravelly sand, and sandy gravel lenses and beds. These are the lithologies encountered beneath the playa surface to the north and south and between beach ridges on the east and west sides. Robinson (1965) has documented the nearshore facies changes from extensive augering on the east and west sides.

In addition to 105 auger holes put down to depths of 3 to 7 m (10 to 22 ft) on the playa or near the playa margin, a core was obtained from a 43-m (140-ft) hole drilled in the middle of the playa. Core recovery amounted to 85 percent for this deep hole. The core material and auger samples were used for a variety of mineralogic studies, size analyses, a pollen chronology, radiocarbon dating and an ostracode study.

The Playa Clay

Sediments sampled in the 43-m hole and from other auger holes located in the west-central playa consisted exclusively of clay and some mud. Wherever encountered on the playa the unoxidized clay and mud are black in color, but nearer to the surface (within a few meters) downward-percolating waters have oxidized the sediments to shades of brown. Layers between the less oxidized clay and mud are commonly gray and greenish gray in color. Oxidation of the black clay and mud is rapid once exposed to air.

Over 200 paired Eh and pH measurements were made on the cores from the 43-m hole. Hydrogen ion (pH) values were between 9.0 and 9.5 for all but a few samples; Eh values below the oxidized surface zone were between -106 and -326 millivolts.

The black and greenish-gray clay and mud owe their color in part to preserved organic matter, but chiefly to a black iron-sulfide mineral. Organic matter content ranged from 0.44 to 2.20 percent and averaged about one percent. The presence of a black iron-sulfide mineral is predicated from the black color, the strong evolution of H_2S when treated with dilute hydrochloric acid, negative Eh values and oxidation characteristics. The iron-sulfide mineral could not be identified by X-ray diffraction techniques probably because of its low content, low degree of crystallinity and masking by other minerals, but this mineral could be the ferrous sulfide hydrotroilite described from marine, marginal marine and lacustrine sedimentary environments.

In playa clay and mud, illite dominates the clay minerals (-211 fraction); minor amounts of montmorillonite, mixed-layer illite-montmorillonite, and vermiculite occur; kaolinite and chlorite are present in trace amounts. The clays are of a detrital origin. Authigenic analcime is also common in the -2,u fraction. Pipkin (1964) regards the analcime as a diagenetic alteration of kaolinite, which is unstable in an alkaline environment.

Calcium carbonate as the mineral calcite is ubiquitous in Lake Cochise sediments. In clay and mud, calcite occurs as ostracode valves and fragments and as authigenic crystals and crystal aggregates.

Halite was the only readily soluble salt detected in playa clay and mud. Gypsum was not encountered in clay and mud, but did occur in one auger hole where euhedral gypsum crystals enclosed quartz grains. Gypsum is probably more common than our sampling indicates.

Black clay and mud are known to reach a depth of 146 m (480 ft) with a thickness of 107 m (350 ft) in a water well drilled on the north edge of the town of Willcox.

Sand Fraction Mineralogy

Sand becomes more abundant in sediments deposited nearer to shore in Lake Cochise. Quartz and feldspar grains dominate the sand. Texturally the sands are chiefly fine- to very fine grained, moderately well sorted where not mixed with clay and silt, and angular to subangular with some rounded and subrounded grains. Heavy mineral crops are dominated by pyrobles, chlorite, biotite and epidote-clinozoisite-zoisite from mafic-igneous and metamorphic rock terrains. Apatite was more abundant in samples containing basaltic hornblende. Zircon and tourmaline, in spite of their greater stability, were absent from many samples.

Beach Ridges

Beach ridges border the playa on the east and west sides and are the major preserved shore features of Pleistocene Lake Cochise. The ridges stand out when viewed both from the ground and from the air because they support a good growth of mesquite trees and yucca (fig. 3). Of the 80 km (50 mi) of shoreline, only about 47 km (29 mi) are defined by this shoreline feature. The beach ridge is about 24 km (15 mi) in length on the west side. On both sides the ridges follow the 1273-m (4,175-ft) contour, although their crests are 1.5 to 3 m (5 to 10 ft) higher. At the north and south ends of the playa it does not appear that the ridges were ever built because these were the sites of influx of fluvial sediments during the late Pleistocene.

Figure 3. Vertical air photo of the northwest corner of the playa near the Interstate 10-U.S. 666 overpass; U.S. 666 parallels the left side. The beach ridge is located by the line of dark mesquite trees that parallel U.S. 666 for a short distance before swinging to the right. Photo taken May 1, 1975 by the Arizona Department of Transportation.

Beach ridges are best developed and well exposed by erosion on the west side. U.S. Highway 666 occupies the crest of the ridge for a short distance just northwest of the Cochise overpass. On the east side the Kansas Settlement road crosses the ridge twice in a distance of 2.6 km (1.6 mi). The first crossing occurs at a point 3.2 km (2 mi) south of the intersection of State Highway 186 and the Kansas Settlement road.

At several localities on the west side the beach ridge rests on calcium carbonate-cemented beach sandy gravels. The beach ridge sediments range in composition from relatively mud-free gravelly sands to slightly gravelly sandy muds. This range in composition suggests a complex origin for the ridges. They are most likely the product of intense storm wave activity which not only piled up sand and gravel but also moved large amounts of lake mud shoreward. The storms must have been rapid events with rapid ridge construction so as to build the ridge just above lake level. In this position the winnowing of mud and sand and gravel would be at a minimum.

THE PLEISTOCENE LAKE ENVIRONMENT

Lake Characteristics

Lake Cochise covered about 190 km^2 (75 mi^2) in the northern Willcox basin, extending from a few kilometers north of Willcox to about 6 km south of the present southern tip of the playa. An estimate of the depth of the lake can be made if the thickness of unstratified sediments forming the top of the beach ridge can be presumed to represent material deposited above the highest lake level. Using an average beach ridge elevation of 1274 m (4,180 ft) with a 3 m (10 ft) drop to the highest lake level and a playa surface elevation of 1260 m (4,135 ft), the lake was thus about 11 m (35 ft) deep. Lake Cochise was thus a long and wide (about 18 by 32 km in maximum dimensions) and very shallow lake.

Streams transported clastic sediments and other debris and dissolved materials to the lake from all directions, with the largest amounts of sediment probably coming from the north and south-southeast (fig. 2). Gravel, sand and mud were dumped into the lake transport system. The gravels were left near shore or drifted along the beaches with sand. Storm wave activity built up the pronounced beach ridges. In an offshore direction sands were deposited as relatively clean sands or mixed with muds. Still farther offshore muds and clays settled out.

Lake waters must have been somewhat brackish judging from the sodium chloride content of the sediments. However, the waters were not so brackish as to prevent ostracodes from thriving in the lake. The waters were also alkaline enough to permit the ostracode valves of calcium carbonate to grow and persist and to promote the precipitation of calcium carbonate in sizes ranging from mud to crystals of 1-2 mm length.

It cannot be determined with any certainty that these lake waters were stratified physically or chemically. The organic matter content of lake muds suggests deposition in a low oxygen to reducing environment at least in bottom waters, or perhaps organic matter was buried rapidly enough to become part of the very reducing diagenetic environment. Once part of the mud, organic matter was metabolized by anaerobic bacteria which in turn converted sulfate to hydrogen sulfide.

Climatic Episodes

P. S. Martin (1963) studied the fossil pollen in the 43-m core from the middle of the playa and interpreted the vegetation history of the surrounding region in terms of Pleistocene climatic changes. To Martin high pine pollen counts indicate a cool-wet (pluvial) climate and relatively low pine counts or poor pollen preservation, and oxidized sediments indicate interglacial or interpluvial climates.

Martin placed the upper 23 m (77 ft) of core sediment in the Wisconsinan glacial interval. Although the upper 2 m (6 ft) was barren of pollen, probably due to oxidation, the sediment below contained up to 99 percent pine pollen. A radiocarbon date of > 20,000 B.P. was obtained at the top of this pine pollen zone (Damon and others, 1963). Martin placed the 23 to 29-m (77 to 96-ft) interval in the Sangamon interglacial interval and thought that the remainder of the core represented pluvial conditions of the Illinoisan glacial interval (Martin, 1963). During the Sangamon interglacial interval the lake dried up periodically, destroying the pollen by oxidation.

S. P. Cameron's (1971) work with the ostracode fauna of the core sediments above 15 m (49 ft) confirms the presence of a permanent lake in the late Wisconsin. Below a depth of 15 m and down to 25 m (82 ft) she interpreted the faunal record to show a series of temporary lakes of moderate salinity, but with good ostracode populations. The record below 25 m represents a series of highly saline temporary lakes.

AGE OF LAKE COCHISE SEDIMENTS

The palynological techniques of Martin (1963) and the radiocarbon dating of Austin Long (1966) have provided a more definite age for the last lake epoch in the northern Sulphur Springs Valley. Seven dates for Lake Cochise clays are given in Table 1. The ages for samples A-221 and A-351 can be rejected for the reasons stated, i.e., low organic content and modern contamination, respectively. Regarding samples A-352 and A-363, Long (1966, p. 120) states that they "... may represent the age of the sediments, but because of ground water movement in the area and the extremely small size of the carbonate crystals, mixing is probable." Samples SI-176, SI-177A, and SI-177B are also from shallow depths along the eastern edge of the playa. Again some mixing with ground waters is possible at these locations.

Long (1966) also obtained radiocarbon dates on marls, caliche, carbonate nodules and organic matter from the beach ridge and surfaces above the beach ridge at localities chiefly on the east side but also from localities on the west side and north end. A complete discussion of the geological and geochronological significance of the materials dated and all the dates obtained is beyond the scope of this report. However, Long (1966, p. 82) infers that pluvial conditions existed from before 30,000 years B.P. to about 13,000 years B.P. and perhaps as recently as 11,500 to 10,500 years B.P.

If we take into account the fact that the playa surface is being eroded by the wind today, then we can point out that we walk on a late Wisconsin lake bottom.

REFERENCES

Brown, S. G., and Schumann, H. H., 1969, Geohydrology and water utilization in the Willcox basin, Graham and Cochise Counties, Arizona: U.S. Geol. Survey Water-Supply Paper 1858-F, 32 p.

Cameron, S. P., 1971, Ostracodes of pluvial Lake Cochise, Cochise County, Arizona [M.S. thesis] : Tempe, Arizona State University, 65 P.

Cooley, M. E., and Davidson, E. S., 1963, The Mogollon Highlands—their influence on Mesozoic and Cenozoic erosion and sedimentation: Arizona Geol. Soc. Digest, v. 6, p. 7-35.

Cooper, J. R., 1960, Reconnaissance map of the Willcox, Fisher Hills,

Table 1. Radiocarbon dates—Lake Cochise sediments

Sample No.	Location and Remarks	Age, years B.P.
A-221	N½ sec. 1, T. 15 S., R. 24 E., near center of playa; depth—5 feet; very low organic content necessitated dilution; age is a minimum one.	> 20,000
A-351	E½ sec. 12, T. 15 S., R. 24 E.; 140-foot hole; ground elevation 4,136 feet; carbonate fraction; depth—19 to 27 inches below surface; above water table with modern contamination; minimal age.	8615±110
A-352	Same location as A-351; depth—75 to 84 inches below surface.	23,000±500
A-353	Same location as A-351; depth—92 to 101 inches below surface.	22,000±500
SI-176	SW¼ sec. 35, T. 14 S., R. 25 E.; ground elevation 4,143 feet; ostracode fragments; depth—42 to 48 inches below surface.	> 30,000
SI-177A	SW¼ sec. 35, T. 14 S., R. 25 E.; 270 feet from SI-176; ground elevation 4,138 feet; ostracode fragments; depth—63 to 72 inches below surface.	> 30,000
SI-177B	Same location as SI-177A within 70 feet; depth—63 to 66 inches below surface.	> 30,000

Cochise, and Dos Cabezas quadrangles, Cochise and Graham Counties, Arizona: U.S. Geol. Survey Min. Inv. Field Stud. Map MF-231.
Damon, P. E., Long, A., and Sigalove, J. J., 1963, Arizona radiocarbon dates IV: Radiocarbon, v. 5, p. 283-301.
Feth., J. H., 1964, Review and annotated bibliography of ancient lake deposits (Precambrian to Pleistocene) in the Western States: U.S. Geol. Survey Bull. 1080, 119 p.
Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Texas, Hemphill's, 182 p.
Green, C. R., and Sellers, W. D. (eds.), 1964, Arizona climate: Tucson, Univ. Arizona Press, 503 p.
Heindl, L. A., and DeCook, K. J., 1952, Principles of ground water occurrence, *in* Halpenny, L. C., and others, Ground water in the Gila River Basin and adjacent areas, Arizona—a summary: U.S. Geol. Survey Open-File Rep. (duplicated), p. 8-14.
Kister, L. R., Brown, S. G., Schumann, H. H., and Johnson, P. W., 1966, Maps showing fluoride content and salinity of ground water in the Willcox basin, Graham and Cochise Counties, Arizona: U.S. Geol. Survey Hydrol. Inv. Atlas HA-214.
Long, Austin, 1966, Late Pleistocene and Recent chronologies of playa lakes in Arizona and New Mexico [Ph.D. dissertation] : Tucson, Univ. Ariz., 141 p.
Martin, P. S., 1963, Geochronology of pluvial Lake Cochise, southern Arizona, II. Pollen analysis of a 42-meter core: Ecology, v. 44, p. 436-444.
Meinzer, 0. E., and Kelton, F. C., 1913, Geology and water resources of Sulphur Springs Valley, Arizona: U.S. Geol. Survey Water-Supply Paper 320, 231 p.
Peirce, H. W., Keith, S. B., and Wilt, J. C., 1970, Coal, oil, natural gas, helium, and uranium in Arizona: Ariz. Bur. Mines Bull. 182 p. 90-98.
Pine, G. L., 1963, Sedimentation studies in the vicinity of Willcox Playa, Cochise County, Arizona [M.S. thesis] : Tucson, Univ. Ariz., 38 p.
Pipkin, B. W., 1964, Clay mineralogy of the Willcox Playa and its drainage basin, Cochise County, Arizona [Ph.D. dissertation] : Tucson, Univ. Ariz., 160 p.
Robinson, R. C., 1965, Sedimentology of beach ridge and nearshore deposits, pluvial Lake Cochise, southeastern Arizona [M.S. thesis] : Tucson, Univ. Ariz., 111 p.
Schreiber, J. F., Jr., Pine, G. L., Pipkin, B. W., Robinson, R. C., and Wilt, J. C., 1972, Sedimentologic studies in the Willcox Playa area, Cochise County, Arizona, *in* Reeves, C. C., Jr. (ed.), Playa lake symposium, Lubbock, Texas Tech University, p. 133-184.
Wilson, E. D., Moore, R. T., and Cooper, J. R., 1969, Geologic map of Arizona: Arizona Bur. Mines and U.S. Geol. Survey.
Wilt, J. C., 1965, Some features of wind deposits near Willcox Playa, Cochise County, Arizona [Honors Program Senior Thesis] : Tucson, Univ. Ariz., 41 p.