QUATERNARY GEOLOGY OF LAKE ANIMAS,
HIDALGO COUNTY, NEW MEXXO

by

Henry Louis Fleischhauer, Jr.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

Lake Animas occupied the Lower Animas Valley in Hidalgo County, New Mexico. Parallel or subparallel ridges of sand and gravel on piedmont toeslopes of the Pyramid and Peloncillo mountains indicate three main stages of Lake Animas. The high shore lies in an elevation interval of 4190 - 4195 feet and indicates a high stage level at 4193 feet. The intermediate shore ridge lies between 4175 - 4190 feet. The elevation for this stage is considered to be 4185, the mode of observations and the lowest observed value on the west side of the valley. The low shore ridge ranges in elevation from 4165 - 4185 feet. The low stage is assigned to the interval 4175 - 4180. At high stage, Lake Animas drained 2190 square miles and had a surface area of about 150 square miles.

Beach deposits conform to the contour of the surface on which they were deposited and consist of homogeneous gravelly sand where modified by pedogenesis. In thicker, undisturbed sections, horizontal stratification is produced by parallel alignment of platy gravel. Such sediments comprise most of the high and intermediate shore ridges. The low shore ridge has a complex evolutionary history. Basal deposits consist of horizontally stratified mud and fine sand of offshore origin, overlain by landward-dipping, cross-stratified sand and gravel of longshore bar origin. The sequence is capped by beach deposits and indicates a progressive shallowing, or lowering, of lake level during development.

Haplargids have developed on the high shore ridge and Camborthids on the intermediate and low shore ridges. Soils of the fan piedmont are Haplargids, Calciorthids, and Paleorthids. A variety of soil taxa are developed in post-lake alluvium deposited in two or more episodes of sedimentation.

Comparison of soil morphologies in shore ridges with dated soils in the Las Cruces, New Mexico, area suggest a minimum age of 7000 - 4000 years. Lake Animas is tentatively assigned an age of latest Wisconsinan to middle Holocene.

INTRODUCTION

Purpose

Lake Animas is the name applied by A. T. Schwennesen (1918) to an ancient lake that occupied the Lower Animas Valley. The former extent of the lake is delimited by ridges or embankments bordering the basin at elevations between 4160 and 4200 feet. Schwennesen, however, postulated the high stage to have reached an elevation of 4390 feet based on his interpretation of sand and gravel ridges in the vicinity of Animas, New Mexico. At least one subsequent worker (Flege, 1959) has postulated a high stand of the lake above 4200 feet of elevation based on interpretation of topographic features.

There has been no systematic study of the Quaternary deposits and topographic features associated with Lake Animas. Speculations regarding the relation of the lake to ancestral drainage, plus the identification of high-level stages based on interpretations of ambiguous topographic features, indicate a need to examine this area more closely. The purpose of this study is to provide a map of shoreline features of Lake Animas, to interpret the origin of these features based on descriptions of internal and external morphology, to determine the geologic history of the lake based on stratigraphic relationships between lacustrine and alluvial sediments, and to relate degrees of soil development to ages of various deposits and landscapes.

Location

The area encompassed by this report lies within the Lower Animas Valley in Hidalgo County, New Mexico (Fig. 1). It is contained within

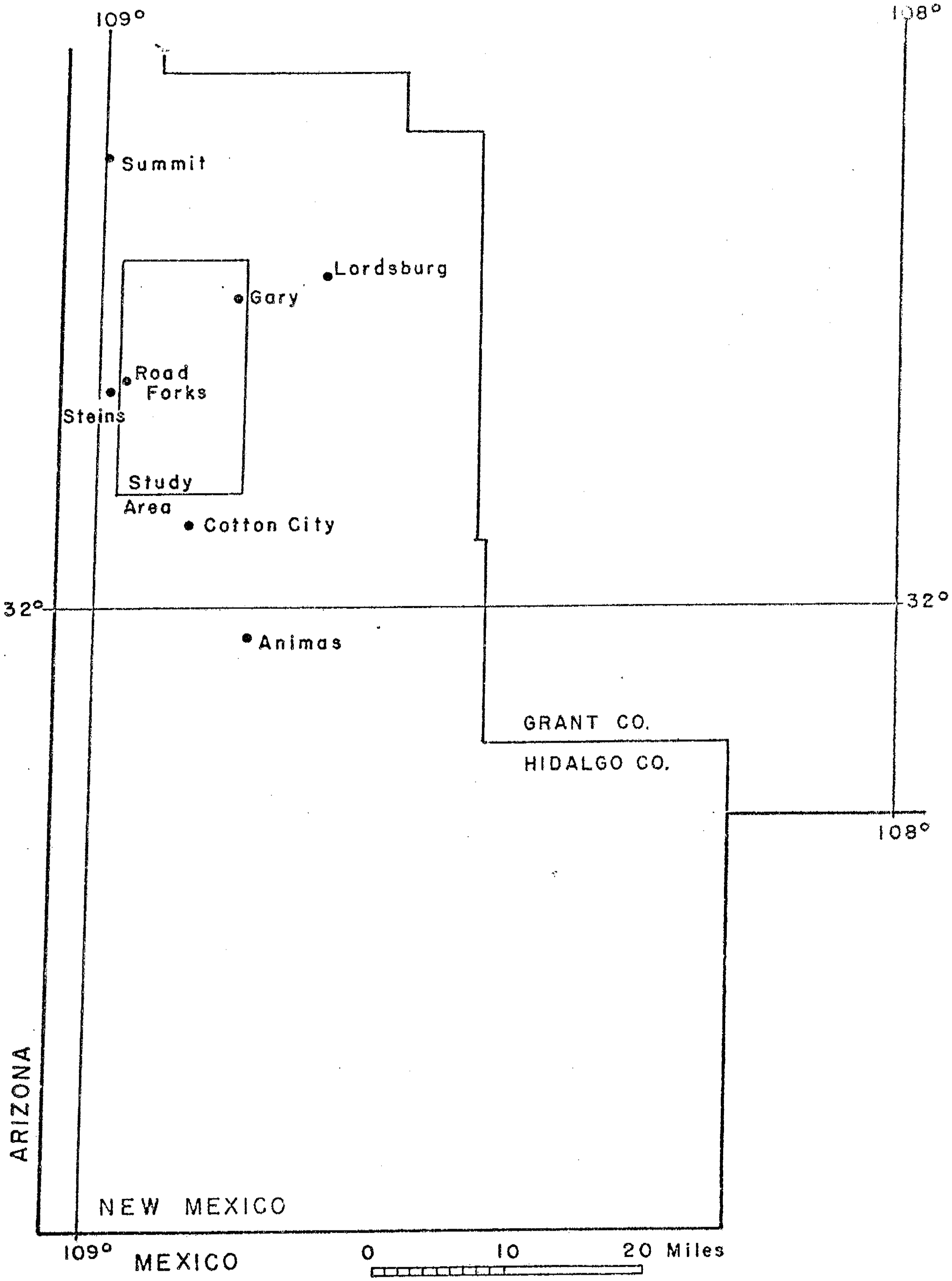


Fig. 1. Location of map area and place names. See Fig. 8 for location of physiographic features.

north latitudes 32°07'30" and 32°22'30" and west longitudes 108°45' and 109°00'. Topographic coverage is provided by the Gary, Mondel, Steins, and Swallow Fork Peak 7.5' quadrangle maps. Detailed study was limited to the shore zone of Lake Animas.

Setting

The Animas Valley trends in a north-south direction for 60 - 70 miles and varies in width from 6 miles in the south to 11 miles in the north. The western boundary is formed by the Peloncillo Mountains, and the eastern boundary is formed by the Animas Mountains in the southern or upper valley, and by the Pyramid Mountains in the northern or lower valley.

The Upper Animas Valley is separated from the San Luis Valley to the south by a low mid-valley divide. From this point, Animas Creek flows northward along a line approximating the intersection of piedmont slopes of the Animas and Peloncillo mountains. The creek has incised the valley fill and has formed a narrow floodplain bordered by low bluffs. At least one terrace is observable along the course of the drainage, and in many areas, what appears to be the surface of the pre-incision valley forms the top of the bluffs marginal to the present floodplain. Incision of alluvial slopes is more extensive in the piedmont of the Peloncillo Mountains where most streams tributary to Animas Creek rise. This piedmont is broader, giving the valley a steeper-on-the-east asymmetry.

The floodplain of Animas Creek widens northward as the bluffs bordering it decrease in height and definition. Just south of Animas

Station, the creek disappears in the alluvium and the valley begins to open onto a central plain or alluvial flat that slopes down the axis of the valley with gradients of 9 to 15 feet/mile. The plain is bordered on both sides by coalescent fan-piedmonts sloping toward it with gradients of 100 to 150 feet/mile. In some areas, a prominent slope break marked by an oversteepening of the fan toe separates the alluvial flat from the piedmont.

In the vicinity of Road Forks, the alluvial flat merges with a large playa referred to as South Alkali Flat. This is the southernmost of three playas aligned on a roughly north-south axis at the toe of the Peloncillo piedmont. Here, the asymmetry of the valley is reversed from that of the Upper Animas Valley. The South Alkali Flat is bounded on its north side by a low, discontinuous ridge. A well-developed, nearly continuous ridge with as much as 10 feet of relief on the playa side forms the eastern and southern boundary of the central playa. Local residents refer to the central playa as Hackberry Lake, after the Hackberry windmill on its northern margin. The central playa will be referred to in this report as Hackberry Playa.

Lordsburg Draw enters the northeast side of South Alkali Flat. This alluvial flat curves around the hills north of the Gary and Pyra railroad sidings and closes east of Lordsburg. Lordsburg Draw was the site of a small, natural lake in the early part of this century (Pete Kerr, personal communication; Note: some older residents refer to the draw as "the slough").

Lordsburg Draw and the central and north playas form the fork of a "Y" that joins the main stem in the south playa. The crook of the "Y" is occupied by a slightly higher area covered with eolian sand and mesquite thickets. This area is referred to locally as the "sand hills".

The divide between the Gila River Valley and the Lower Animas Valley extends from the Peloncillo Mountains to the Summit Hills, and across a broad tableland referred to on maps as Lordsburg Mesa. The lowest point of the divide lies at an elevation of 4215 feet near Summit railroad siding northwest of the north playa.

Climatic data is presented in Appendix IV.

General Geology

The Pyramid Mountains expose a variety of volcanic and plutonic igneous rocks. This range may be subdivided into three areas based on the outcrop of dominant lithologies. These are: 1) a northern area characterized by basalt intruded by granodiorite; 2) a central area dominated by pyroclastic volcanics with lesser rhyolite, rhyolitic welded tuff, and basalt; and 3) a southern area with extensive outcrops of andesite and lesser rhyolite and basalt (Flege, 1959).

The northern Animas Mountains to the south consist largely of sedimentary rocks. These include 10,000 - 15,000 feet of Cretaceous shale and sandstone and 3,500 feet of Paleozoic limestone, dolostone, sandstone, and shale. Also exposed is a minor igneous section of quartz monzonite porphyry, quartz latite, and rhyolite (Soule, 1972).

The area between Steins and Cowboy Pass in the Peloncillo Mountains exposes about 5,000 feet of Paleozoic sedimentary rocks and about 2,500 feet of Crataceous sedimentary rocks. North of Steins and south of Cowboy Pass, the range is comprised of volcanic rocks (Gillerman, 1958).

Previous Work

In his descriptions of the physiography of the Lower Animas Valley, Schwennesen (1918, p. 83, 86) noted the abruptness with which otherwise gently sloping alluvial fans pitched into the central plain. This slope break, he noted, was accompanied in many areas by a ridge or bank, which he identified as a lacustrine beach ridge. Thus, Schwennesen appears to have been the first to describe evidence of an ancient lake in the northern part of the Animas Valley. This lake he named Lake Animas.

He was able to trace the old beach around much of the valley. On the west side of the valley he traced it from Sec. 31, T22S, R20W, near Salt Well (Plate 1), to Sec. 18, T24S, R20W, south of Road Forks, a distance of 9 miles. He also identified the beach in the sand hill area, along the north side of Lordsburg Draw, and traced it on the east side of the valley as far south as Sec. 18, T24S, R19W (Plate 1). In two areas along the east side (Sec. 6, T24S, R19W and Secs. 19 and 30, T23S, R19W), he observed multiple beach ridges, but he did not mention their presence elsewhere (Schwennesen, 1918, p. 86 - 87).

Elevations of shorelines described in the northern part of the valley fall in an interval between 4160 and 4200 feet. Schwennesen (1918, p. 88), however, placed the maximum stand of the lake at 4390 feet on the basis of sand and gravel ridges in the southern part of the valley near Animas, New Mexico. He recognized that:

> "...features making up the southern group cannot be fitted to any body of water which could exist under present topographic conditions. A lake conforming to the gravel ridge 1 1/2 miles northwest of Animas would be approximately 4390 feet above sea level, and would therefore stand about 190

> feet above the divide [Summit] that separates the Animas drainage basin from that of the Gila River and would submerge the old beaches in the lower part of the valley to a depth of 200 feet. To bring the shore features in the lower and upper parts of the valley into position so that they could have formed contemporaneously along the same body of water would therefore necessitate a relative vertical displacement of 200 feet."

He found no evidence for such a body of water in the Gila Valley, and stated that more precise leveling would be necessary to resolve the problem of high-level stands.

Gillerman (1958) mapped beach deposits in a zone about 0.25 mile wide just below elevation 4200 in the vicinity of Road Forks. He described the sediments as consisting of horizontally-bedded, well-sorted sand and gravel (Gillerman, 1958, p. 75 - 76).

Flege (1959) mapped the bedrock geology of the Pyramid Mountains. In addition, he included the trace of shorelines on the east side of the valley in the 4175 to 4200 contour interval, and mapped a higher one at about 4240 feet altitude. This one he described as a wave-cut terrace averaging only a few feet in height and marking the highest level of Lake Animas (Flege, 1959, p. 2).

Morrison (1965) identified what he considered to be lake gravel in the Gila River drainage north of the study area. The lake gravel is mapped in an inset position against an extensive pediment gravel (his Qp5 map unit) containing a well developed pedocal that he tentatively correlated with Yarmouth Interglaciation. In the vicinity of the drainage divide at Summit, the gravels are found at elevations of 4240 feet, some 50± feet above the high shoreline of Lake Animas (Morrison, 1965, p. 5, 6).

Kottlowski and other (1965, p. 291), citing a personal communication from R. H. Weber, suggested that the combined Gila-San Francisco Rivers flowed south to join Lake Animas in mid-Pleistocene time.

Reeder (1975) discussed ground water hydrology.

Methods

Shore ridges were mapped on 1951 air photos (scale 1:20,000) and contacts were transferred to a base map (scale 1:48,000) using a Reed Focalmatic projector. Field checking was confined to the shore ridges and inter-ridge troughs. Other contacts were obtained by interpretation of air photos and the Hidalgo County Soil Survey (Cox and others, 1973) after considerable field observation.

The map units employed are morphostratigraphic (Frye and Willman, 1962), but they also have characteristics of rock-stratigraphic and soil-stratigraphic units. Map units of alluvial sediments and landforms are generalized and include a number of landscape settings. Detailed maps of specific areas are included as text figures to demonstrate the local complexity and variability encountered in the generalized mapping.

Key outcrops were described and sampled for textural analysis. Terminology and methods of analysis employed are those outlined in Folk (1974).

Backhoe pits were excavated for soil description. Relative ages had been previously established through mapping and stratigraphic work. Comparison of soil morphologies from pit descriptions with those of dated soils in the Las Cruces, New Mexico, area suggest possible absolute ages of soils in the Animas Valley, and hence, of Lake Animas as well.

DESCRIPTION OF MAP UNITS

Qd - Eolian Dunes

Eolian sand, forming dunes and mesquite coppice dunes (Gile, 1975, p. 350), covers a 3 - 4 square-mile area between Hackberry Playa and Lordsburg Draw. Older surfaces, soils, and sediments are buried by the sand, but local exposures may occur in deflation basins. In the Hidalgo County soil survey, Qd is included in the Pintura-Berino complex (map unit PR) which consists of about 60% Pintura loamy fine sand (eolian) and 30% eroded Berino sandy clay loam (Cox, and others, 1973, p. 31). The Berino sandy clay loam is a Typic Haplargid developed on a older surface that has been buried by the eolian sand in which the Pintura soil is formed (see profiles in Cox, and others, 1973, p. 10 - 11, 31). Qd is more extensive on Lordsburg Mesa north of the map area, and is apparently correlative with the Qe unit of Morrison (1965).

Stabilized longitudinal dunes are a prominent feature of Qd outside of the study area and are especially common northeast of the north playa in the Summit 7.5' quadrangle. The dunes are not well developed, being closely spaced and having short crests that bifurcate and intersect other dunes. A few, however, do have relatively long straight crests. A semi-controlled photo mosaic reveals a distinct linear trend of about N30°E.

Qp - Playa

Three playas aligned on a roughly north-south axis occupy the lowest part of the Animas Valley. South Alkali Flat is the largest of the three and has an area of about 16.2 square miles. Hackberry Playa has an area of about 5 square miles of which 3.7 occur within the study area.

Air photos reveal giant desiccation cracks forming a polygonal network on the surface of the South Alkali Flat. Lang (1943) was apparently the first to describe these and noted that the average diameter of the polygons is 80 - 90 feet. During the fall, 1976, the writer observed recently opened cracks in Sec. 26, T23S, R20W. These were about 6 inches wide and traceable for tens of feet. Depth is not known. Once open, the cracks are sealed by a crust of playa sediments washed in from the adjacent area, and a straight trough or sag is formed. This may be as much as 3 feet wide (Lang, 1943), but those observed during this study were only 1 - 1.5 feet wide. Sag margins are favored sites for vegetation, and it is apparently the vegetation lines that are visible on air photos. No desiccation cracks are visible in Hackberry Playa.

A shingle beach borders Hackberry Playa along its east and south margins. The shingle consists of pebbles, probably a lag accumulation, that are heavily stained by desert varnish. The dark color of the stained pebbles causes the beach to appear as a black band on air photos.

Qsy - Younger Shore Ridges of Playa Margins

In places, shore ridges younger than those of Lake Animas border the margins of modern playas. These are referred to here as playa shore ridges.

The best developed playa shore ridge occurs along the south and east margin of Hackberry Playa. It is continuous for a distance of 5 miles and rises 10 feet or more above the playa surface. Relief on the landward side is only 3 - 4 feet in places. Sediments comprising the ridge are sand, silt, and clay that resemble playa sediments, and exposures reveal fine cross-stratification. Presumably, this ridge is the product of eolian deposition with sediments produced by deflation of the playa and beach.

Another lower, discontinuous ridge is developed along the northern margin of the South Alkali Flat. It is barely visible on air photos, and is not included on Plate I.

Other ridge-like features on the northwest side of South Alkali Flat are indicated on Plate I by special symbol. On air photos these appear as alternating light and dark bands, with dark areas representing crests. Relief between the crest and trough is probably less than 1 foot. These features also consist of fine-grained, playa-like material with scattered gravel on the surface.

The arcuate traces of crest-lines broadly parallel the present playa margin, but do not strictly parallel topographic contours. Outer ridges are locally truncated by inner ones, especially near the northeast terminus (Sec. 33, T22S, R20W), which probably indicates that they become successively younger toward the playa. This suggests that they represent former playa margins. However, they occur at elevations between 4150 - 4160 feet, or 5 - 15 feet higher than the modern playa surface. They also decrease in elevation along their crests toward the northeast. These two facts might argue against such an origin.

Qvf - Valley Flat

The valley flat or alluvial flat is the level plain that occupies the central part of the valley exclusive of the playa. As a surface, it comprises very gently sloping areas that are transitional from the piedmont toeslopes to the playa, areas between playas, and areas that slope down the valley axis as opposed to those that slope toward the valley axis. Gradients in the southern part of the map area are less than about 10 feet/mile, or 0.2%.

Sediments of the valley flat consist of fine-grained sand, silt, and clay that resemble playa sediments. Gravel is found at shallow depth within the former delta of the ancestral Animas Creek, though north of the delta front, lake clays are found (Plate I).

Major soil series occurring in this setting include Verhalen, Hondale, and Yturbide. The Verhalen series, a Mollic Torrert, forms in fine-grained sediments of alluvial bottoms (Cox, and others, 1973, p. 40), and is limited principally to Lordsburg Draw. The Hondale series, classified as a Typic Natrargid, occupies areas transitional from fan piedmonts to playas as well as much of the delta. It is the dominant soil of Qvf. Yturbide soils, Typic Torripsamments, and Typic Torriorthents, are found south of the delta front overlying former stream channels.

Qfy - Younger Alluvial Fan Complex

Qfy delineates surface elements of the fan piedmont that have formed since the disappearance of Lake Animas. Hence, it delineates areas of most recent deposition, which as shown on Plate I, are confined mostly to the toe of the piedmont and along major washes. As the term complex implies, Qfy is not a single unit, either lithologically or geomorphically. Local detail and complexity of the unit are shown in Figs.

2, 3, and 4. Geomorphic elements included within the unit are inter-ridge trough, modern fan and wash, and ridge-front slope.

The ridge-front slope is a concave surface graded from the ridge to the valley flat. The surface may owe its form to wave erosion as the lake level fell. At Loc. 11 (Fig. 13), for example, horizontally stratified lacustrine mud and sand deposited during a deeper stage are truncated lakeward by the surface. Since the disappearance of the lake, it has been subjected to alluvial processes of rill and sheet erosion, and deposition. Rill erosion is a significant process since it appears responsible for breaching the shore ridges in areas between major washes and initiating modern fan deposition (Figs. 2 and 3).

Sediments and soils of the ridge-front slope resemble those of the low shore ridge in both texture and composition. Most of the few exposures reveal non-stratified sand and gravel modified by soil formation. Thickness of the deposits is on the order of 2 feet.

Inter-ridge troughs are linear, low-lying areas interjacent to shore ridges. They are the site of deposition of fine-grained sand, silt, and clay, and are somewhat analogous to playas (Fig. 11).

Small alluvial fans have developed where gullies and washes have breached the low shore ridge. The individual fans usually have surface areas less than 0.25 square miles and are coalescent where closely spaced. The largest occur at the mouths of major washes rising in the mountains, but most are formed where headward-eroding rills and gullies of the ridge-front slope breached the low shore ridge. In these instances, the volume of fan sediment is small and is approximately equal to that removed in gully cutting.

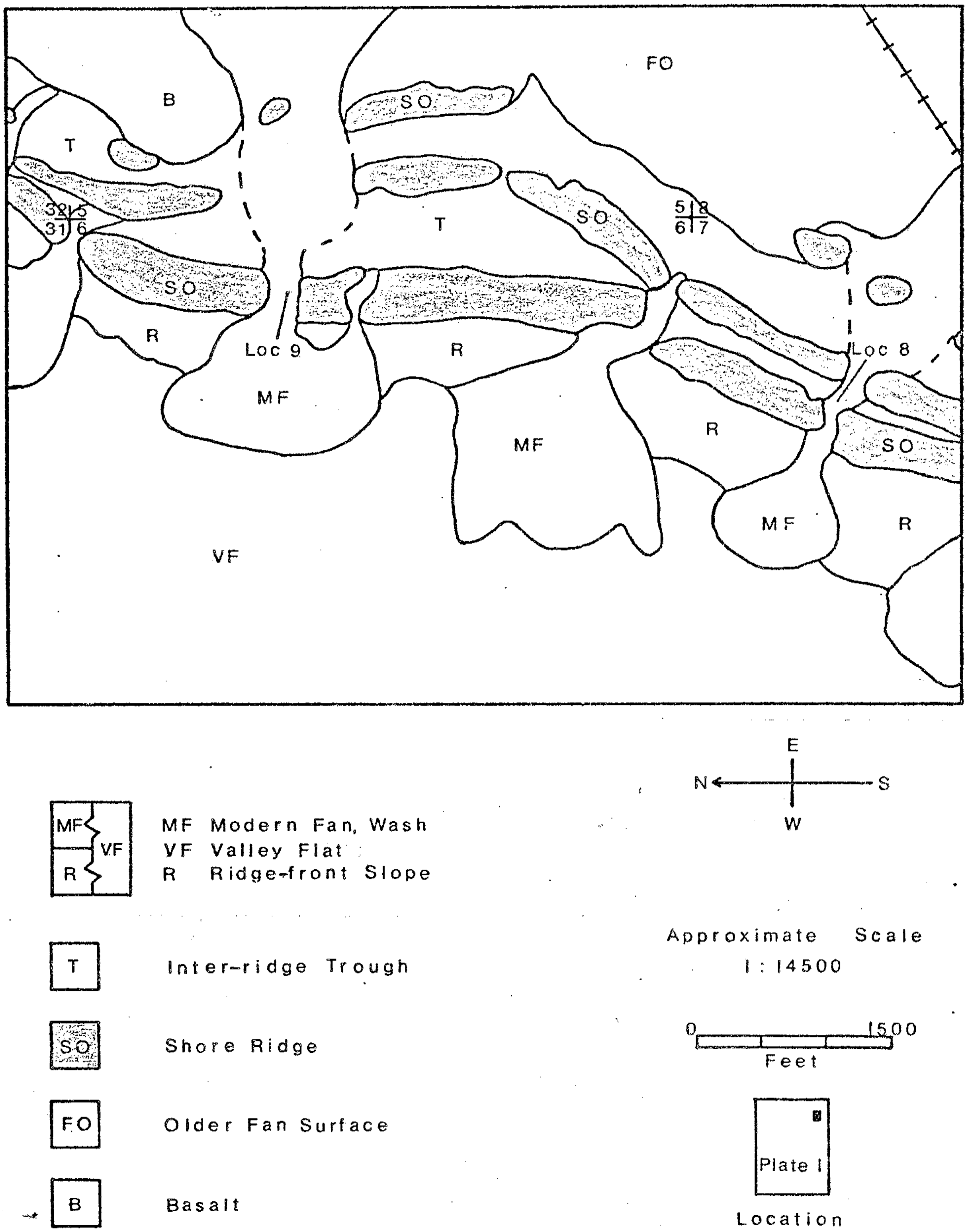


Fig. 2. Detailed morphostratigraphic map of the east shore of Lake Animas, vicinity of Gary, showing member units of Qfy. The map is contained largely within Secs. 5 and 6, T23S, R19W (Plate I).

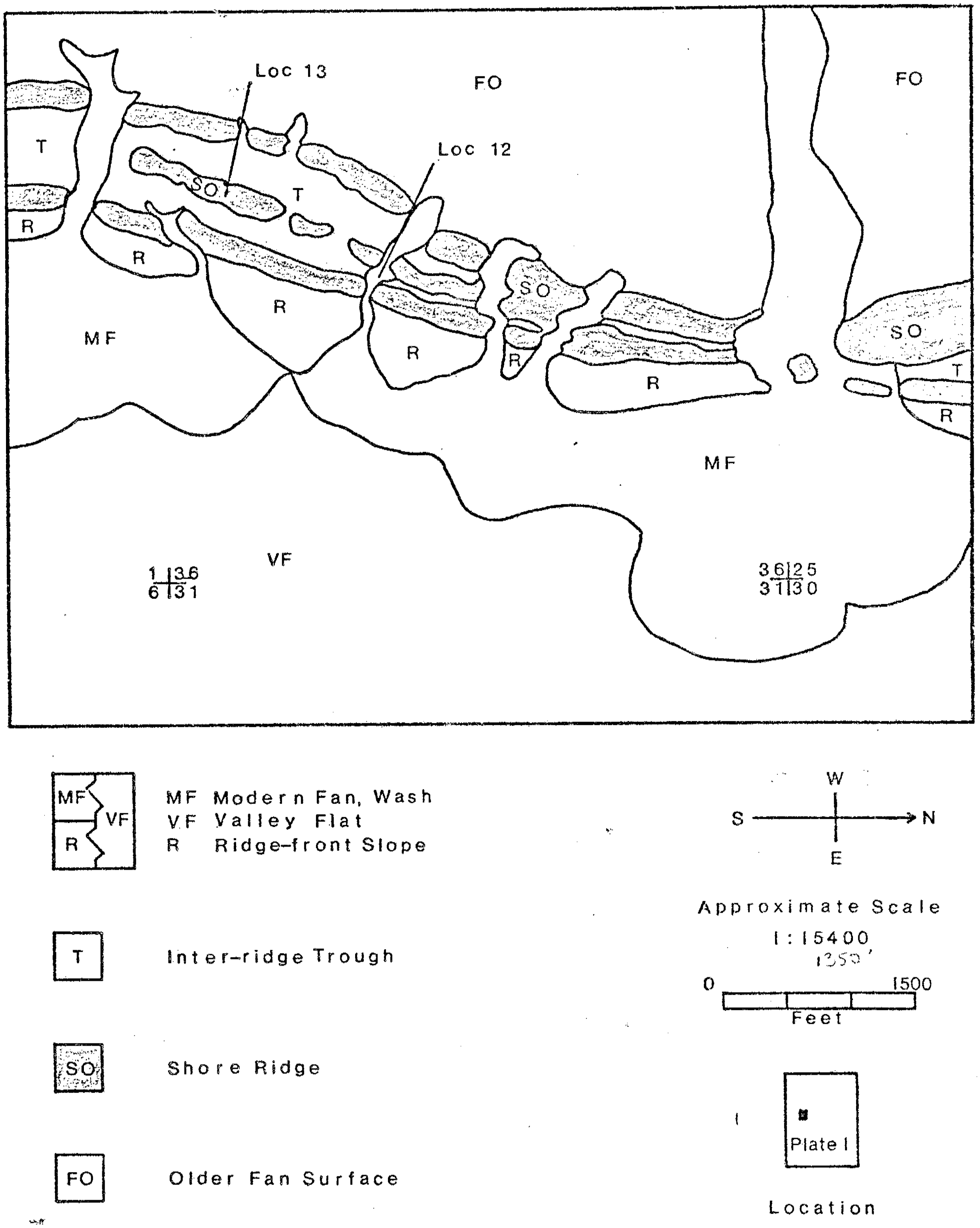


Fig. 3. Detailed morphostratigraphic map of the west shore of Lake Animas vicinity of Robinson Windmill, showing member units of Qfy. The map is contained largely within Sec. 36, T23S, R21W (Plate I).

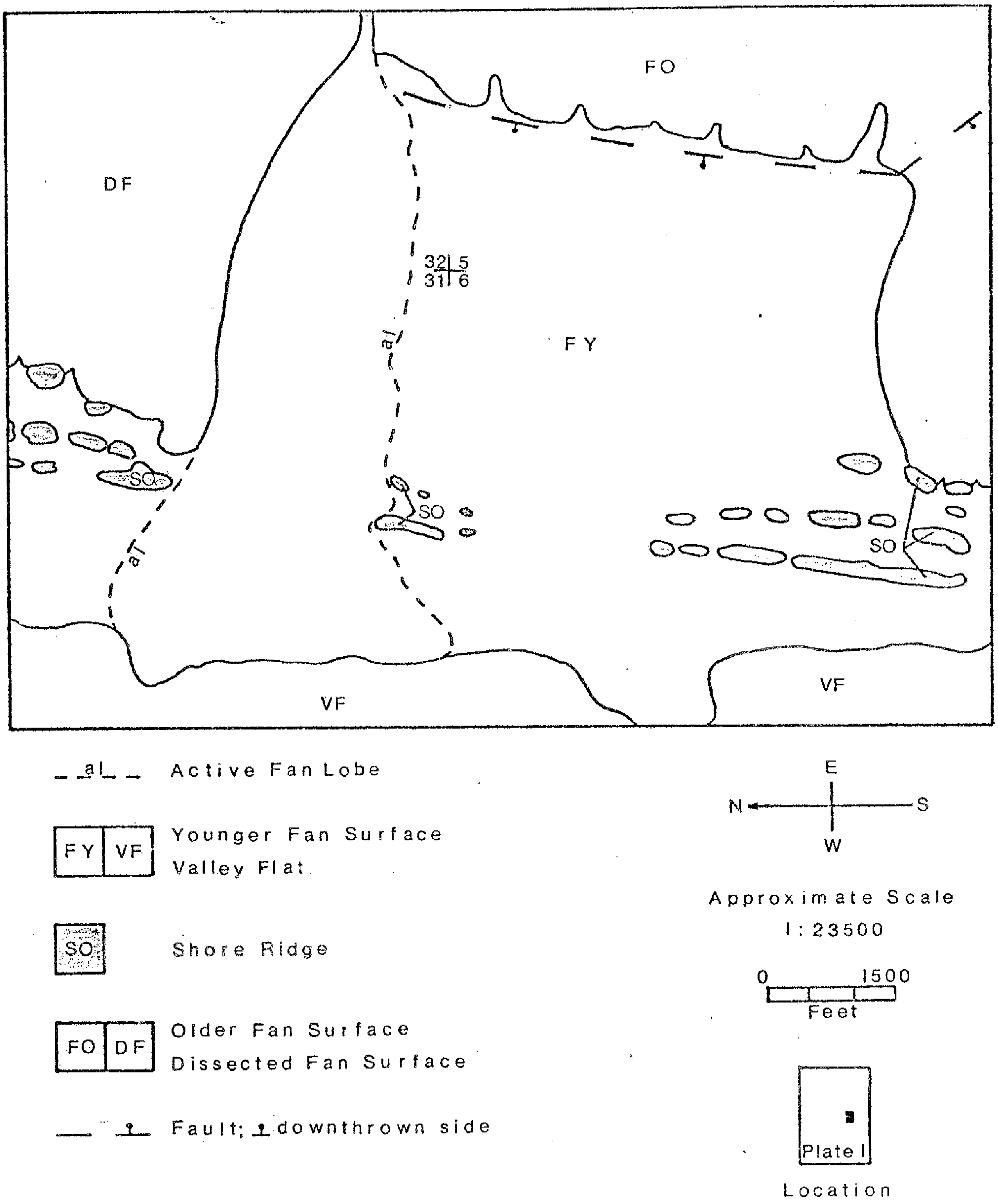


Fig. 4. Detailed morphostratigraphic map showing development of Qfy, vicinity of Gore Canyon. The map is contained largely within Secs. 31 and 32, T23S, R19W and Secs. 5 and 6, T24S, R19W (Plate I).

Figures 2 and 3 illustrate the similarity in the occurrence of Qfy on the east and west sides of the valley. This is regarded as typical of the shore zone. Figure 4, however, shows a deviation from this parallelism in the vicinity of Gore Canyon and Mansfield Wash (Plate I). Here post-lacustral sedimentation has been enhanced by the drainage base-level fall created by faulting.

The fault-line is marked by a scarp 3 feet or more high. On air photos, it may be identified by a vegetation line along the fault trace, a change in vegetation and tone across the fault, and/or a line separating the dissected surface of the upthrown side and the non-dissected surface of the downthrown side. The fault also separates soils of different taxonomic categories. For example, in places the fault separates Haplargids on the upthrown side from younger, more poorly developed Torrifluvents on the downthrown side (Cox, and others, 1973). The movement of the fault may be pre-lacustral since shore ridges downslope are not downdropped relative to contiguous ridges away from the fault. Deposition of modern fan sediments is apparently post-lacustral since shore ridges have either been buried by fluvial sedimentation or obliterated by stream action.

Discontinuous ephemeral streams occur in the active fan lobe. Upon crossing the fault, Gore Canyon Wash branches into a distributive drainage pattern. Downstream these channels regroup into a single straight channel. This again branches downstream near the distal end of the fan lobe. Shorter entrenched gullies with headcuts occur on the active lobe away from the main channel. The presence of the discontinuous ephemeral stream system points to the youthfulness and instability of this surface.

Dominant soil series identified by Cox, and others (1973) in this setting include Gila, Mimbres, Glendale, Hondale, and minor Yturbide and Verhalen.

Qso - Older Shore Ridges

Subparallel ridges of lacustrine sand and gravel marking shorelines of Lake Animas occur along the margin of the valley on the toes of piedmont slopes of the Pyramid and Peloncillo mountains. Throughout much of the study area three such ridges occur and are referred to in ascending order as the low, intermediate, and high shore ridges.

The low shore ridge is the most prominent of the three, and may have relief of up to 30 feet on the lakeward side, and as much as 10 feet on the landward side. The profile of the ridge is asymmetric with a gentle, concave lakeward slope and a steep landward slope. Higher shore ridges are not as conspicuous and form symmetrical convex swells that may rise no more than a foot above the surrounding area.

The shore ridges are easily recognizable in the field, forming low mounds with dark, gravelly soil bordered by flat, low areas with light-colored, silty soils. Cox, and others (1973) consistently mapped Yturbide soils on shore ridges. The writer disagrees with this usage inasmuch as representative profiles described by them do not match those observed in the field (Profiles 1, 2, and 4, Appendix III). Furthermore, soils of the shore ridge are largely Camborthids and Haplargids whereas Yturbide soils are Torripsamments and Torriorthents.

Qfo - Older Alluvial Fan Complex

Qfo groups surfaces of the piedmonts that formed prior to the high stage of Lake Animas. Like the younger fan complex, Qfo is probably not a single unit, nor is it of one age. Detailed mapping and subdivision, however, was not attempted.

The older fan complex is a relatively stable surface although it is undergoing slow erosion. No discontinuous ephemeral streams occur on it and most of the washes that head within the fans form contributive networks.

Soils of Qfo have well developed profiles with either argillic horizons, calcic horizons, or both, and most are classified as Haplargids or Calciorthids. Major soil series found within it include Tres Hermanos, Mohave, Stellar, Forrest, Berino, Upton, and Nickel. The Tres Hermanos soil frequently occurs near the mountain front and Mohave, Stellar, or Forrest farther downslope. The Upton soil, a Typic Paleorthid, occurs in the extreme southwest part of the map area, south of Bobcat Hill (Plate I). It has a petrocalcic horizon and may form one of the oldest member surfaces of Qfo. The Nickel soil, a Typic Calciorthid, usually occurs at the toe of piedmonts. South of the study area in the vicinity of Weatherby Ranch (T26S, R20W), it occurs extensively on the fan piedmont in low-carbonate parent material.

SHORE FEATURES OF LAKE ANIMAS

Terminology and Synonomy

Wave-cut Slope:

A wave-cut slope is an oversteepened hillslope with slight convexity formed by wave erosion. In the Animas Valley the oversteepened portion is usually less than 10 feet high. A wave-cut slope is analogous to the sea cliff of Gilbert (1890, p. 34) and wave-cut cliff of Johnson (1919), but differs in that it is not a cliff, i.e. it does not have a vertical slope. In addition, there is no evidence of undercutting usually associated with a sea cliff (Fig. 5).

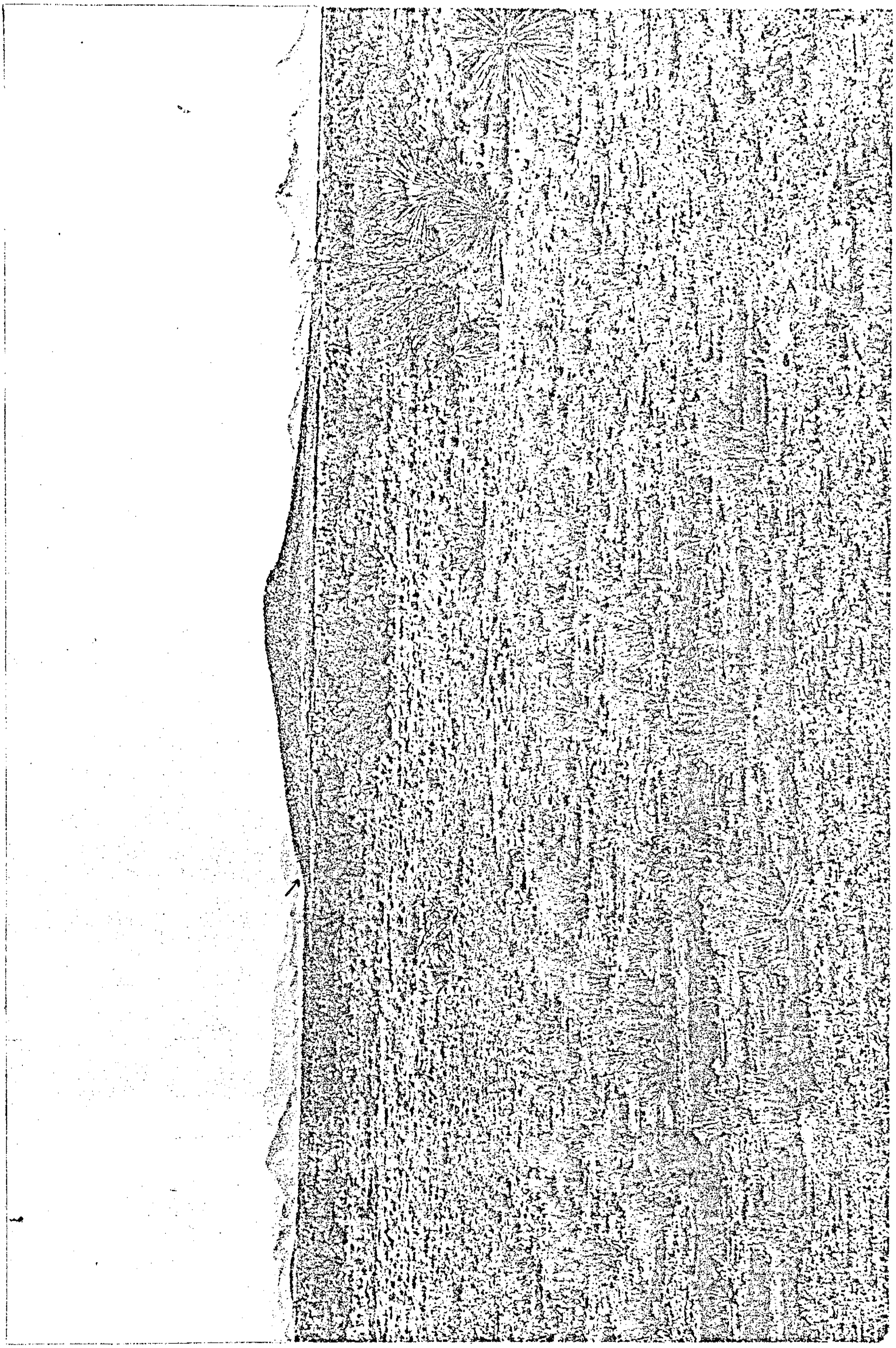
Wave-cut Bench or Terrace:

Associated with a wave-cut cliff is a platform that slopes gently toward deeper water. The platform is produced by erosion and retreat of the cliff, and is called a wave-cut terrace (Gilbert, 1890, p. 35, 36) or wave-cut bench (Johnson, 1919, p. 162). In the Animas Valley, similar platforms are associated with wave-cut slopes, but these are usually considered under other categories since the amount of retreat of the wave-cut slope is considered small.

Beach:

Gilbert (1890, p. 39) defined the beach as "the zone occupied by shoredrift in transit" extending from slightly above the level of still water to just below maximum wave base. This is a process-oriented definition, though he apparently intended it to apply to both a deposit (the shoredrift) and a topographic feature (the beach). Accompanying his text

Fig. 5. Example of a wave-cut slope in the Animas Valley. Arrow points to an over-steepened hillslope on the south side of the hill in SW1/4 Sec. 20, T22S, R19W. This slope faces the mouth of Lordsburg Draw and is believed to have been steepened by wave-erosion of Lake Animas. Constructional lacustrine shoreline features can be traced to the foot of the slope segment (Plate I).



is a cross-section of a beach showing a concave slope lying below water and convex ridge lying above water on the landward margin. The term is used here to refer to a ridge of sand and gravel piled on the shore above the level of still water by the action of waves. The ridge occupies a narrow elevation interval and conforms to the contour of the surface on which it was deposited. Because the ridge form is characteristic of a number of features, a certain internal morphology is also necessary for identification.

The term "beach ridge", though adequately descriptive, is not applied to the shore features of Lake Animas. This term is generally applied to ridges constructed by wave action on prograding coasts with high sediment supply (Johnson, 1919, p. 404 - 453, Psuty, 1965, 1966).

Headland Beach:

A headland beach is a beach formed at the base of a headland cliff or sea cliff (Johnson, 1919, p. 283). The headland beach occupies the same position as a wave-cut terrace, but is an emergent deposit rather than a submerged erosion feature.

Bayside Beach:

A bayside beach is a beach formed along the margin of a bay from material eroded from a headland (Johnson, 1919, p. 283, 284). The only modification imposed here is that the material comprising the bayside beach need not be derived entirely from a headland. The term is used here to denote position only.

Embankment:

An embankment is a ridge or mound built by the deposition of shoredrift at its terminus (Johnson, 1919, p. 285). The transporting agent is a longshore current, and deposition results from a separation of the current and wave action when a current continues past a shoreline reentrant, or when a current turns from the shore toward deeper water (Gilbert, 1890, p. 46). Because it is constructed by the action of currents, the length of the embankment parallels the direction of their line of movement. The side of the embankment facing open water may be modified by waves and assume the profile of a beach. The distal end of the embankment and the side facing closed or restricted water will have a slope determined by the angle of repose of the sediment (Johnson, 1919, p. 287).

Spit:

A spit is an embankment with a free or unattached terminus (Johnson, (1919, p. 302).

Baymouth Bar:

A baymouth bar is an embankment that extends across the mouth of a bay and is attached at both ends to headlands (Johnson, 1919, p. 302). This is included by Gilbert (1890, p. 48) under the more general term of bar which he used to denote any embankment attached at both ends.

Longshore Bar:

A longshore bar is a subaqueous ridge of detrital sediment roughly paralleling the shoreline. Usually associated with it is a longshore trough lying on the side facing closed water (Shepard, 1950; McKee and Sterrett, 1961; Price, 1968). These lie in the breaker zone and are presumably formed by the action of waves, though longshore currents may contribute to their formation. Terminology equivalent to longshore bar and trough are: ball and low (Evans, 1940), ridge and runnel (King and Williams, 1949), subaqueous ridge (Gilbert, 1890), submarine bar (Johnson, 1919), and bar (Russell, 1885).

Barrier:

A barrier is an emergent ridge of detrital sediment paralleling, and lying some distance lakeward from, the shoreline (Gilbert, 1890, p. 40). Between the barrier and the shoreline is an enclosed body of water referred to as a lagoon which may become a trap for fine sediment.

Shore Ridge:

A shore ridge is a ridge-form topographic feature constructed by processes operating in the shore zone. The term is non-generic and is used here to refer to a variety of features with a variety of origins, but unified by a common topographic expression. Nothing of genesis is implied except that the feature originated in the shore zone.

Lake Stages

Shoreline positions of Lake Animas are indicated by parallel or sub-parallel ridges of sand and gravel on piedmonts of the Peloncillo and Pyramid mountains (Plate I). Three ridges are present throughout much of the valley indicating that there were three main lake stages. Locally, the ridges number as few as two or as many as five because of special conditions existing in that area, but not because of distinct lake stages. Regardless of the number of ridges, all evidence of the ancient lake shorelines is confined to an elevation interval of 4200 - 4165 feet. Younger ridges associated with the margins of modern playas are confined to an interval of 4150 - 4145 feet.

Approximate shoreline elevations, estimated to the nearest 5 feet from a preliminary map of scale 1:24000, are listed in Tables 1 and 2. One elevation from each of the three shore ridges is listed from each section in which they occur. In two sections, two values were listed for the intermediate shore ridge because of significant changes in elevation along its length (Table I, Plate I). All elevation estimates are taken from the lakeward margins of the ridges. This procedure essentially interprets all of these features as beaches. Such an interpretation is not strictly valid at all localities, but it provides consistent, minimum values for lake stages. Figure 6 shows the frequency occurrence of shoreline elevations from the data of Tables 1 and 2.

Figure 6 indicates that the high shoreline lies at nearly identical elevations on both sides of the lake basin. This negates significant post-lacustral movement between the Peloncillo and Pyramid mountains, and indicates that differences in elevation between the lower shorelines on opposite sides of the valley are probably a result of local conditions existent during the lacustral period rather than differential movement. The bases of wave-cut slopes in Secs. 22 and 20, T22S, R19W (Fig. 7) provide a firm lower limit at 4190 for this stage. The shore ridge on the protected, north side of the hill in Sec. 32, T22S, R19W (Plate I)

Table 2. Approximate elevations of lake stages as indicated by the lower margins of shore ridges, west side of Lower Animas Valley.

Location	Lake Stage		
	Low	Intermediate	High
<u>T22S, R20W</u>			
Sec. 19	4175	4185	4190
Sec. 30	4170	4185	4190
Sec. 32	4170	----	----
<u>T23S, R20W</u>			
Sec. 5	4170	----	----
Sec. 6	4170	----	4190
Sec. 7	4180	----	4195
Sec. 18	4180	----	----
<u>T23S, R21W</u>			
Sec. 13	4180	----	4195
Sec. 24	4180	4190	4195
Sec. 25	4180	4185	4195
Sec. 36	4180 4185	4190	4195
<u>T24S, R21W</u>			
Sec. 1	4180	4185	4195
Sec. 12	4175	4185	4190
<u>T24S, R20W</u>			
Sec. 7	4175	4185	----
Sec. 18	4180	----	----

Table 1. Approximate elevations of lake stages indicated by the lower margins of shore ridges, east side of Lower Animas Valley.

Location	Lake Stage		
	Low	Intermediate	High
T22S, R19W			
Sec. 20	4175	----	4195*
Sec. 28	4165	4175, 4180	----
Sec. 29	4170	----	----
Sec. 32	4170	4180, 4190	4195
T23S, R19W			
Sec. 5	----	4185	4195
Sec. 6	4175	4185	----
Sec. 7	4180	4185	4190
Sec. 18	4180	4185	4195
Sec. 19	4180	4185	----
Sec. 30	4175	4180	4190
Sec. 31	4180	4185	4190
T24S, R19W			
Sec. 6	4180	4190	----
Sec. 7	4180	4185	4190
Sec. 18	4180	4185	----
Sec. 19	4180	4185	4195
Sec. 30	----	----	----
Sec. 31	----	4185	----

*elevation from wave-cut bench.

$\bar{X}$ = 4176.55 or 4177
s = 4.84 or 5
N = 29

$\bar{X}$ = 4184.78 or 4185
s = 3.53 or 4
N = 23

$\bar{X}$ = 4192.57 or 4193
s = 2.52 or 3
N = 19

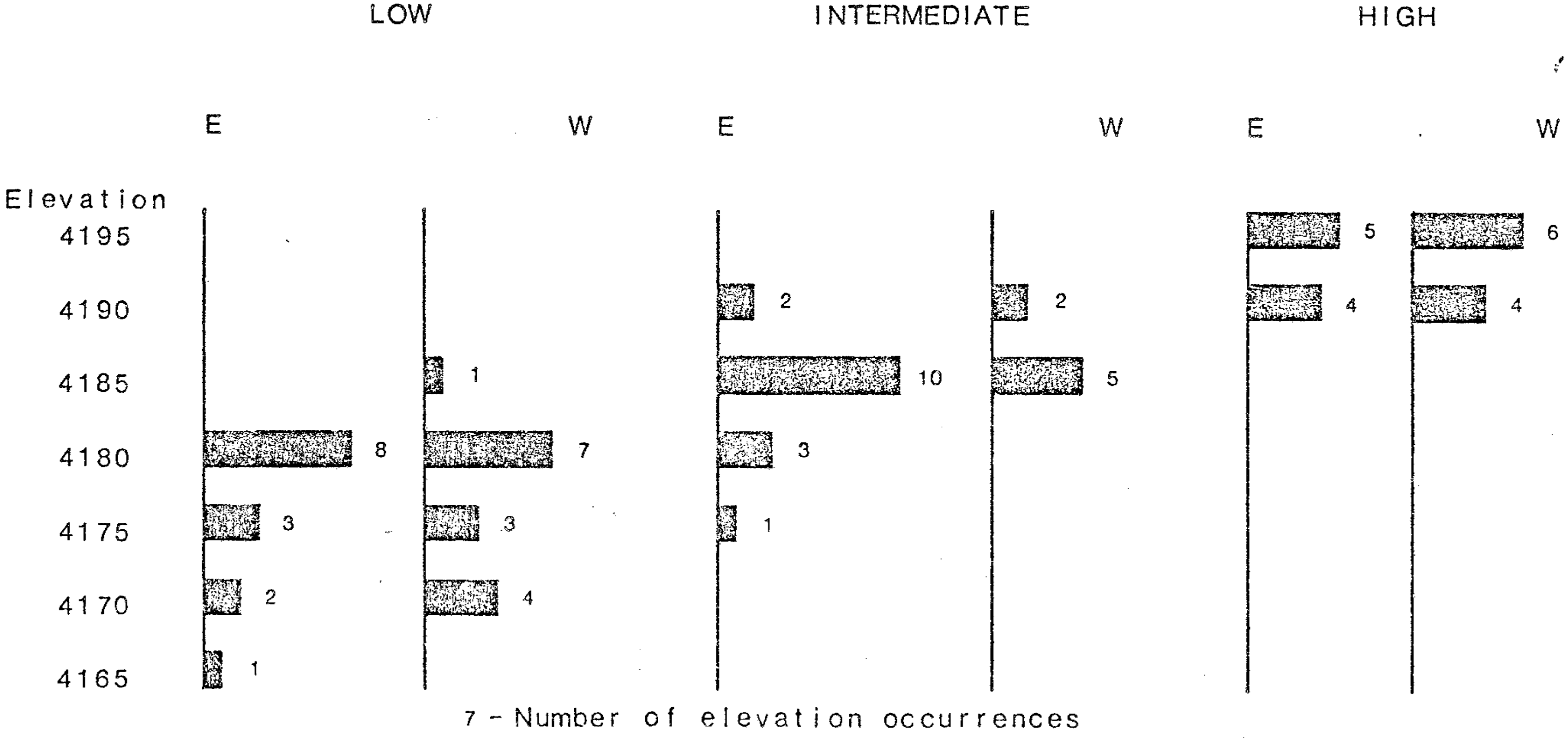


Fig. 6. Frequency occurrence of lake-stage elevations as indicated by shore ridges on the east (E) and west (W) sides of the Lower Animas Valley. Data are listed in Tables 1 and 2.

indicates a strong possibility for an actual stillwater level as high as 4195. It is not unlikely that the water level of this stage fluctuated between the two extremes so that the mean of 4193 is probably a reasonable estimate of the high-stage water level.

The intermediate shoreline averages somewhat lower, and is more variable, in elevation on the east side of the valley than on the west (Fig. 6). Much of the variability found on the east side may be attributed to special conditions encountered at the entrance to Lordsburg Draw where the intermediate shore ridge decreases in elevation from 4190 to 4175 feet in a distance of about 1 mile. This accounts for four of the six values deviating from the 4185 mode. If these four values are disregarded, the 4185 mode is considerably strengthened. Only one locality is lower on the east side, and none are lower on the west side, so it is considered to be the best indicator for the level of the intermediate stage.

The assignment of the elevation of the low stage is more tenuous owing to a greater range and variability in elevation. This is further complicated by an internal morphology which in many areas indicates a more complex history of development than is evidenced in higher shore ridges. A variety of depositional environments seem to be represented by the ridge, so it is here that the assumption of a beach origin introduces the most error.

The three elevations below 4175 (Fig. 6) on the east side of the lake basin occur at the mouth of Lordsburg Draw (Table 1; Plate 1). The decrease in elevation of the ridge through Secs. 32, 29, and 28, T22S, R19W, parallels that observed in the intermediate shore ridge. The four elevations occurring at 4170 (Fig. 6) on the west side of the lake basin are found in the vicinity of Butterfield Tank at the distal margin of the Doubtful Canyon fan (Table 2; Plate I). The elevation of the ridge rises in either direction from this point. The localization of extreme values such as these suggests the influence of local conditions, or a change in depositional environment (e.g., beach to embankment), and a corresponding low reliability as stage indicators. The lack of an elevation occurrence above 4180 on the east side of the basin suggests that this is a maximum value for this stage. Thus, the elevation interval for the low stage is reduced to 4175 - 4180 feet. Because the mode is also the highest elevation, it is not necessarily the best indicator. The low shore ridge represents the last stabilized level of the receeding lake. The lake level in reality occupied all elevations below the highest observed value, 4185, during desiccation. In this sense, the assignment of this stage to an interval of 4180 - 4175 is probably more reasonable than assigning a specific value.

Classification and Origin of Shore Features

Within the Lower Animas Valley, two areas with different physiographies created coastal settings in which different shore features evolved. The low-lying area along the north side of Lordsburg Draw gave rise to an embayed shoreline where the influence of currents was strong. In contrast, a comparatively smooth, regular shoreline, apparently dominated by wave action, existed on the piedmonts bordering the main body of the lake.

Figure 7 is a map of shore features in a bay on the north side of Lordsburg Draw. Wave erosion was sufficient to form wave-cut slopes on

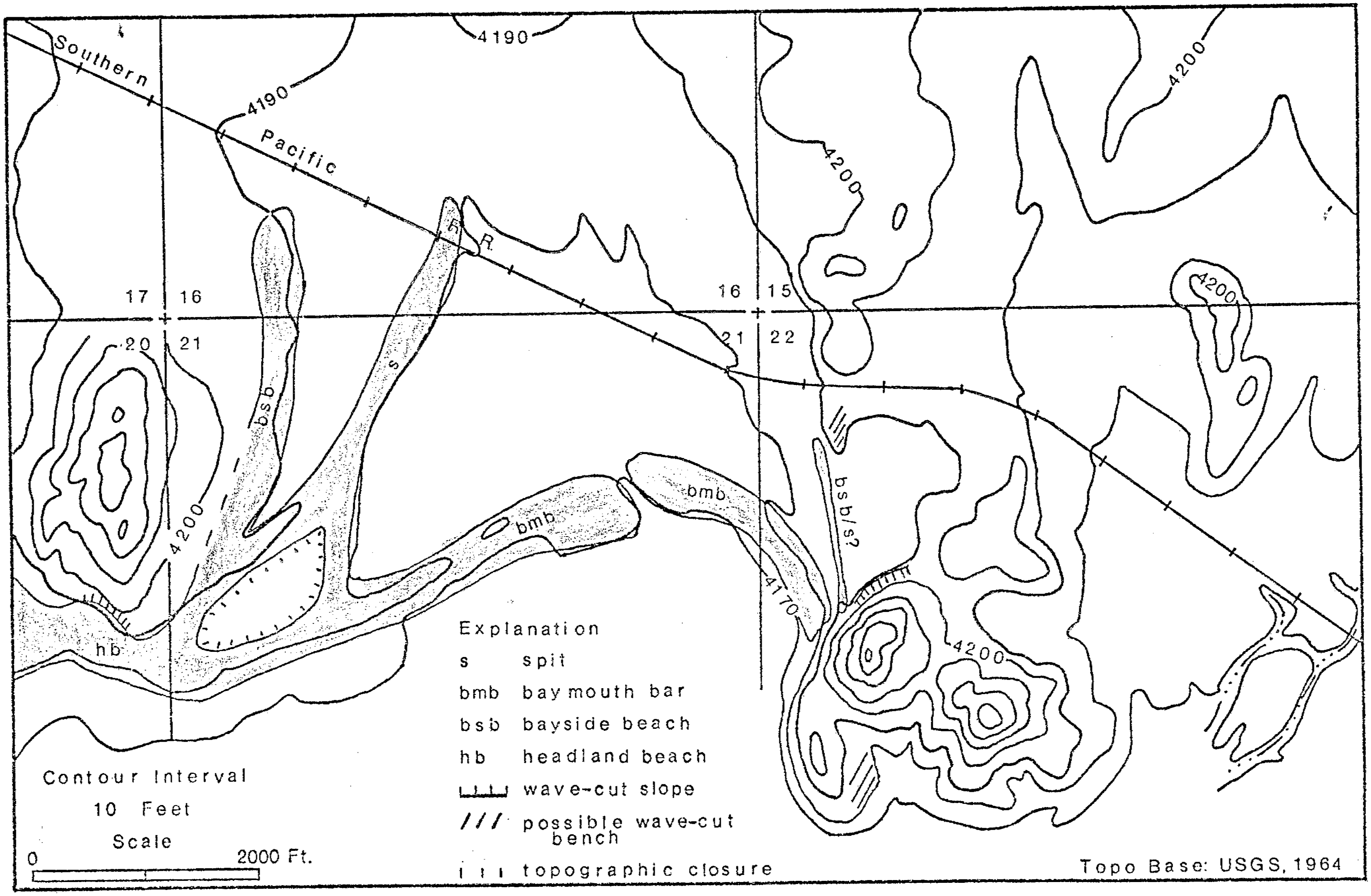


Fig. 7. Development of shore features in an embayment along the north side of Lordsburg Draw, T22S, R19W.

headlands in Secs. 20 and 22. Another wave-cut slope exists on the south side of the hill in SW1/4 Sec. 20, T22S, R19W facing the mouth of Lordsburg Draw (Fig. 5; Plate I). Occasional small, rounded pebbles of various volcanic lithologies are found on the wave-cut slope of the basalt hill in NE1/4 Sec. 20 (Fig. 7) and were presumably tossed there by waves scouring the headland beach.

Spit growth in the bay initally proceeded northeastward from the headland in Sec. 20 (Fig. 7). Subsequent development proceeded eastward and recurved to enclose a small basin. With continued eastward development, the bay was closed and a baymouth bar was formed. The decrease in elevation along the crest of this bar from both ends toward the center probably indicates that transport of debris occurred in both directions along its length.

A small shore ridge of uncertain origin partly encloses a cove on the north side of the hill in Sec. 22 (Fig. 7). The ridge is only a few feet wide and less than a foot high along most of its length except where it attaches to the headland. The decrease in elevation along its length is suggestive of a spit origin. However, the platy gravel that comprises it consists of a single volcanic lithology (that of the hill) unlike the mixed lithologies in gravel of the spit and baymouth bar. The platy gravel is also coarser and less rounded. This is suggestive of a beach origin.

Shore ridges developed on piedmont slopes bordering the main body of the lake are somewhat more difficult to classify on the basis of form and topography. Shore ridges in this setting maintain fairly constant elevations and crest heights, and broadly parallel the contour of the alluvial fans on which they were constructed. This is particularly true of the high shore ridge while the lower shore ridges become successively smoother and straighter with respect to the topography of the fan piedmont. The lateral spacing of shore ridges is variable, being closely spaced where they round the noses of alluvial fans, and more widely spaced in re-entrants (Plate I).

The high shore ridge in Sec. 25, T23S, R21W (Plate I) bends sharply into a re-entrant defined by the 4200 and higher elevation contours on the fan slopes above. A similar occurrence is found in Sec. 5, T23S, R19W. The close relationship of the trace of the high shore ridges to the topography of the lower fan piedmonts indicates that this topography existed prior to the high stage of Lake Animas. It suggests further that the high shore ridge is a beach since current-produced embankments and longshore bars would tend to ignore such irregularities in the shoreline. The low shore ridge in these two localities is straighter and continues past irregularities outlined by the high shore ridge, suggesting (though not requiring) an embankment or longshore bar origin.

The straightness of the low shore ridge on the west side of the lake from the vicinity of Braidfoot Tank to the Butterfield Tank (Plate I) is strongly suggestive of a longshore bar or embankment origin. In places, the crest rises above an elevation of 4190 suggesting the existence of a barrier along parts of the ridge during the intermediate stage, and implying the existence of a lagoon behind it. The intermediate shore ridge may never have formed here if a barrier was present, so its absence in this area is not necessarily due to erosion or burial.

From the point of highest crest elevation (4190+, Sec. 13, T23S, R21W), the toe and crest of the low shore ridge decrease in elevation northward to the vicinity of Butterfield Tank. Coupled with this is a decrease of maximum clast size from cobbles to pebbles, and pebbles at the distal end are also more rounded. These facts strongly suggest that transport direction, i.e. current direction, was north-northeast along this part of the shore, and that distally the emergent barrier became a submerged embankment. The splayed terminus of the ridge in Sec. 6, T23S, R20W is reminiscent of a recurved spit, or hook, and also points to a north-northeast transport direction. No suitable exposures occur along this segment of the ridge from which paleocurrent measurements from sedimentary structures can be obtained to corroborate this.

The usual number of three shore ridges is exceeded at two localities in the study area (Sec. 7, T24S, R19W, and Secs. 30 and 19, T22S, R20W; Plate 1). Such occurrences must have resulted from special, local conditions and probably do not represent distinct lake stages.

At the locality north of Butterfield Tank, the shore ridges have an irregular, merging and diverging pattern. This continues along the entire length of this part of the shore as far as Summit. The reasons for the higher number of shore ridges here are not clear, but speculation offers some possibilities.

First, if the dominant winds were from the south or southwest, then the west shore of Lake Animas north of Butterfield Tank would have occupied a protected position due to the prominent nose of Doubtful Canyon fan. East winds would not have had a large enough fetch to produce large waves, and southeast winds would have produced wave trains that essentially paralleled the northwest shore. Hence, wave energy in this arm of the lake would have been minimal. A minimal energy condition coupled with annual and long term fluctuations in lake level might have produced the observed pattern of ridges.

A second possibility is that Doubtful Canyon may have delivered a large volume of sediment to Lake Animas. A high sediment supply at this point plus northwest-moving longshore currents could produce multiple ridges through coastal progradation. Such ridges would be largely unrelated to long term lake stages. If this were the case, however, the number of ridges and the width of the zone they occupy should decrease downcurrent from the sediment source (Psuty, 1965, 1966). This characteristic is not observed.

A third possibility is that a continuous sheet of sediment was deposited across the shore zone in this area and that subsequent erosion produced the irregular ridges.

None of the above possibilities seem to apply to the area between Gore Canyon and Mansfield Wash. For the present, the origin of multiple shore ridges in this part of the lake is obscure.

No shore ridges are observed in the southern part of the study area. In this area, the ancestral Animas Creek emptied into the lake forming a delta. Because of the low gradient of the valley flat and the shallowness of the lake, the classical "Gilbert delta" did not form, and the delta front is not marked by any break in slope.

Plate I shows the approximate front of the delta and the position of some of the former stream channels as indicated by meandering belts of mesquite. A small gravel pit (Loc. 1) within the mesquite belts exposes fluvial gravel overlain by pebbly soil. An auger hole to a depth of 5 feet in a clearing within a nearby meander loop encountered no gravel whatsoever. Thus, the belts apparently mark the position of channel gravel. The meandering pattern suggests perennial flow rather than ephemeral.

The lakeward margin of the delta is defined by the termination of mesquite belts and thickets. Beyond this limit is a grassy plain. Of interest is that the delta extends well into the area formerly covered by the lake. This indicates that fluvial activity continued in the delta during desiccation of the lake.

Other features indicating extensive, ancient fluvial activity in the valley flat are found in the vicinity of Cotton City south of the study area. An air photo mosaic shows a plexus of light-toned, sinuous to straight bands, some of which bifurcate down valley. Some are prominent enough to appear on topographic maps as linear ridges. One such ridge that rises 3 - 4 feet above its surroundings trends northwest through Secs. 22, 21, and 16, T26S, R20W, just east of the lava flow in the vicinity of Alf Windmill. A gravel pit at Alf Windmill exposes fluvial gravel and sand. These ridges also mark the position of ancient stream channels and are apparently produced by wind deflation of inter-ridge (inter-channel) areas. The reason for the resistance of the soil over the channel to erosion is not clear.

The Question of a Higher Shore

Previous workers in the Animas Valley have interpreted various topographic features at elevations above 4200 feet as representing ancient shorelines. Lacustrine shoreline features are often similar in appearance to topographic features produced by other geologic processes, and care must be taken to discriminate between them. Gilbert (1885) discussed the distinguishing characteristics of lacustrine shoreline features.

Flege (1959) mapped a high shoreline on the east side of the valley at an elevation of about 4240, and identified it as a wave-cut terrace. In this study, this feature has been identified as a fault-line scarp (Plate I). The trace of the scarp ranges in elevation from about 4230 to 4270 and in places cuts sharply across topographic contours (e.g., Secs. 5 and 8, T24S, R19W). This is not consistent with a shoreline origin. A wave-cut terrace should parallel contours, and as a result, maintain a fairly constant elevation (Gilbert, 1885). No shoreline feature is found at the same elevation on the west side of the valley, which contrasts sharply with the nearly parallel development of lower shoreline features of opposite sides of the valley. Although wave-cut terraces may be formed on alluvial fans, the gradient of the piedmont slope, about 1.5%, or less than 1°, is probably too gentle.

Schwennesen (1918, p. 87 - 88) mentioned a line of low bluffs on the west side of the valley south of Cowboy Pass. These were examined just south of Weatherby Ranch in Sec. 18, T26S, R21W and are likewise interpreted as fault-line scarps. Gillerman (1958) also mapped these as faults, and his map indicates that the scarps cut across contours.

Exposed in these bluffs is a soft limestone or marl. The limestone contains silicified "root tubes" that may be fossilized reeds or rushes, and a molluscan fauna of gastropods and pelecypods. Southward the limestone grades into noncalcareous diatomaceous earth.

From all appearances, this deposit is of lacustrine origin, but its extent and relation to Lake Animas are unknown, Its original attitude and elevation are not precisely known because of faulting, although displacement along the faults is probably not great. The limestone and diatomite are now exposed above 4250 feet of elevation, but no shoreline feature can be found to tie this deposit with the main body of Lake Animas. The southernmost shore ridge of Lake Animas is 8 miles north of this locality (Plate 1, NW1/4 Sec. 6, T25S, R19W) and it seems unlikely that the lake extended this far south. One possibility is that a series of connected smaller lakes, ponds, or marshes occupied the valley flat during the lacustral period and that this is a deposit of one of these lakes.

Schwennesen (1918, p. 88) also described sand and gravel ridges similar to those mentioned previously in this area. He regarded these as shore ridges, and on this basis postulated a high stage of 4390 feet. These ridges are considered to be exhumed stream channels on the basis of gravel-pit exposures examined by the writer.

Morrison (1965, p. 7) interpreted gravelly deposits at high elevations in the Duncan Valley to the north as being lacustrine on the basis of alien lithologies. He considered the alien lithologies to indicate transport by longshore currents. These gravel deposits occur on the west side of the Summit Hills at an elevation of 4240 feet. The writer has examined them briefly, but no evidence was found that distinctly labels them as lacustrine. In any event, Morrison (personal communication, 1977) has found no evidence for spillover into the Animas Valley.

It seems from the above that previous ideas regarding high stages of Lake Animas are in error. No evidence of lake stages above 4200 feet has been found within the study area, either as topographic features or as sedimentary deposits. If older lakes did exist, they either did not rise to the levels of Lake Animas, or former shoreline features and sediments are no longer recognizable.

Extent of Lake Animas

At high stage, Lake Animas had a length of about 17 miles along the valley axis, and a width of 7 miles at the latitude of Robinson Windmill. On the basis of present topography, the depth near the middle of South Alkali Flat is estimated at 50 feet. During the existence of Lake Animas, the floor of the lake probably rose due to sedimentation. Since the disappearance of the lake, the floor may have continued to rise through sedimentation in periodic floods on the playa, or it may have been lowered by eolian deflation.

Figure 8 shows the relation of the lake to its inferred drainage basin. Planimetric analysis using the lakeward margin of the high shore ridge in the study area and the approximated 4195 contour in unmapped areas to the north and east indicates a surface area of about 150 square miles at high stage.

Total basin area was about 2340 square miles, which gives a tributary or catchment area of about 2190 square miles. The basin was comprised of the Animas Valley of 1460 square miles, and a smaller basin of 880 square miles extending southeast of Lordsburg. A playa occupies the lowest part of this smaller basin (4197 - 4198 feet) near Lordsburg, and

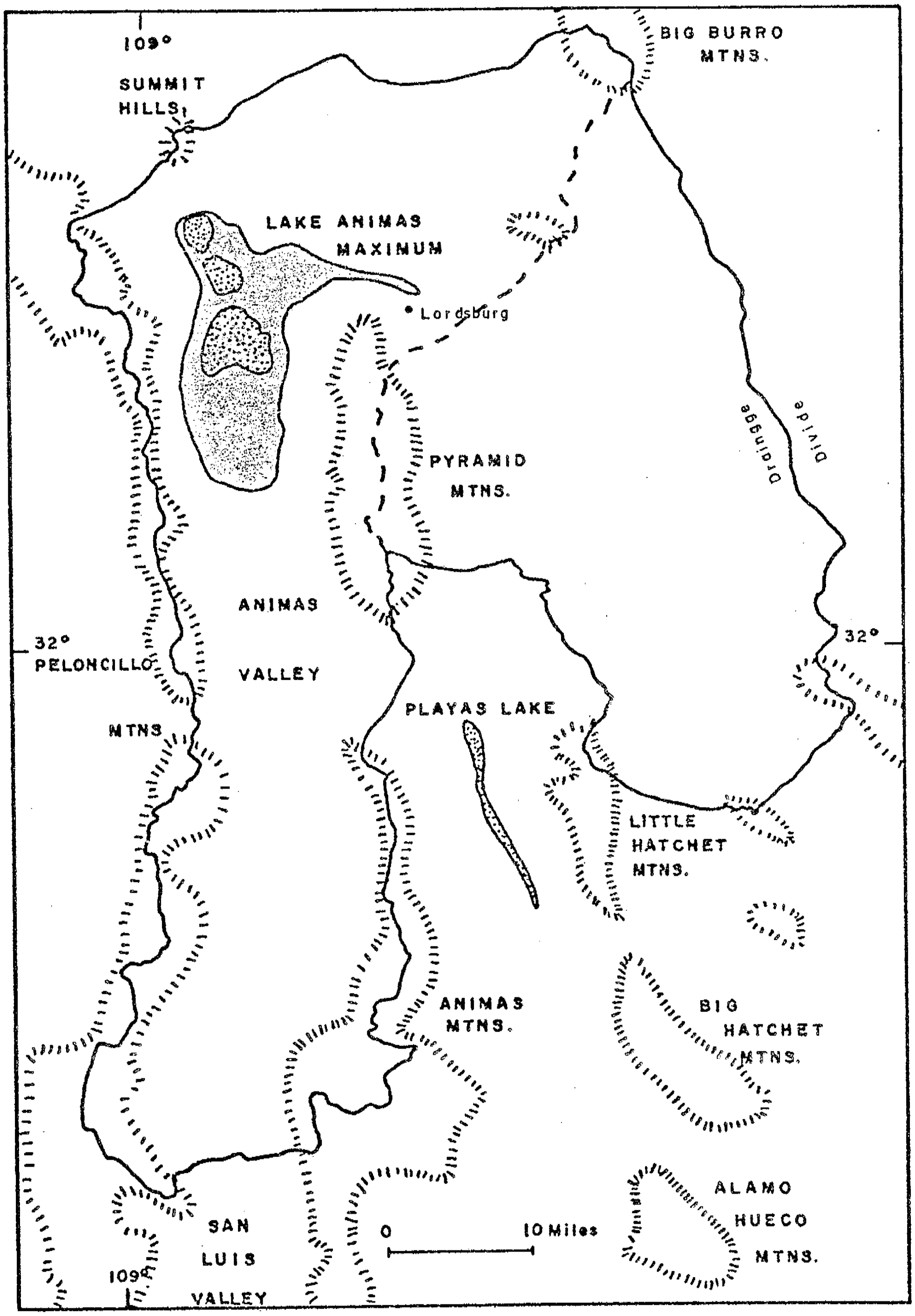


Fig. 8. Extent of Lake Animas at high stage (4193 feet) and inferred former drainage basin. Dashed line is the present divide between the Animas Valley and a smaller basin which were probably connected during the Lake Animas maximum. Total basin area is 2340 square miles; Lake Animas surface area is about 150 square miles. Stippling indicates modern playas.

a divide between 4198 - 4200 feet currently separates it from Lordsburg Draw and the Animas Valley. Lacustrine sediments exposed in borrow pits along Interstate 10 in this area indicate the presence of a lake in the lower end of the smaller basin. Because of the lowness of the divide and the thickness of lacustrine sediments in the borrow pits, it is hypothesized that this lake was connected to the Animas Valley by spillover, at least intermittently, and possibly by ground water seepage on a perennial basis.

It is speculated that there was also intermittent connection between the Upper Animas Valley and the San Luis Valley. The San Luis Valley was occupied by Lake Cloverdale during at least one of the lacustral periods (Schwennesen, 1918). Air photos indicate that shoreline features of Lake Cloverdale extend almost to the divide, at which point they terminate. If spillover did occur then Lake Animas also grained the San Luis Valley, and the catchment area was perhaps 200 - 300 square miles larger.

STRATIGRAPHY AND SEDIMENTOLOGY

Stratigraphic relations of lacustrine and alluvial sediments are shown in Fig. 9. Briefly, alluvial sediments post-dating Lake Animas are deposited in inter-ridge troughs and in front of the low shore ridge. Shore sediments bury a well-developed soil formed in alluvium. This soil, referred to here as soil B, is extant as a land-surface soil upslope from the high shore ridge. In some areas, soil B is seen to overlie a still older soil developed in alluvium. This soil is referred to as soil A.

Soil A

Representative exposures of soil A are found at Locs. 8 and 9 in the vicinity of Fox Windmill (Plate I). The original sediment was probably a gravelly sand or sandy gravel, possibly muddy or slightly muddy, and was deposited by streams on alluvial fans.

Soil development has modified the sediment so that its most distinctive characteristics are soil properties. Dominant color is reddish brown with a 5YR hue. Clay content is high, and clay fills most interparticle areas and acts as a binder. A distinctive feature at Loc. 9 is prominent mottling due to calcium carbonate nodules. The nodules are both cylindroid (oriented vertically) and spheroid. The top of the unit is an undulatory erosion surface, and gravelly parent material of soil B fills depressions in the surface.

Similar properties are exhibited at Loc. 12. Here the soil may be traced continuously upstream from the low shore ridge past the intermediate shore ridge. Prominent mottles and nodules of calcium carbonate

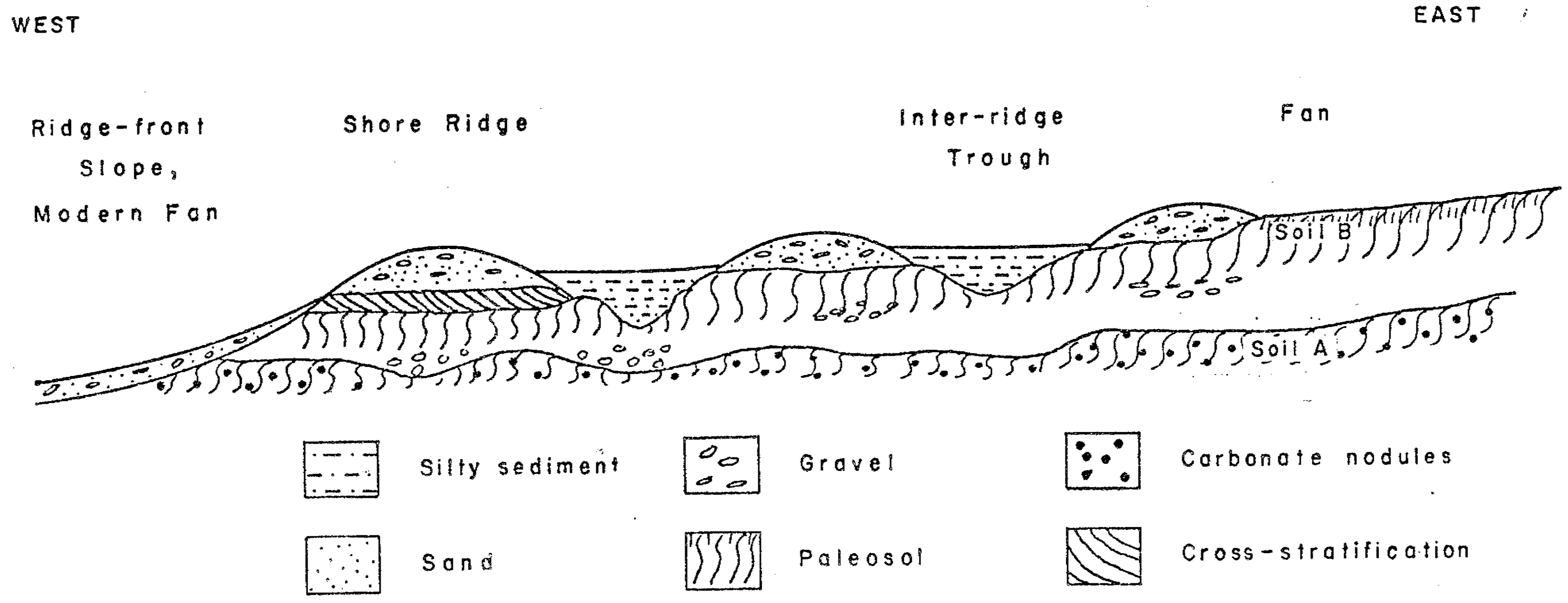


Fig. 9. Diagramatic cross-section showing stratigraphic relationships of lacustrine and alluvial sediments. Soil A and soil B are developed in alluvial fan sediments, and the latter is buried by shoreline sediments. Younger alluvium is found in inter-ridge troughs and on ridge-front slopes.

in a reddish brown, noncalcareous matrix are characteristic (see unit IIIB, Profile 6, Appendix III; Fig. 29).

At Loc. 14, a reddish brown (5YR 5/5D), clay loam B horizon overlies a gravelly calcic horizon. The calcium carbonate forms an almost continuous medium in the calcic horizon and appears to have engulfed the lower part of the B horizon.

A similar and possibly correlative calcic or petrocalcic horizon in gravelly sediments is found at Loc. 16 (Fig. 16). No reddish brown B horizon with carbonate nodules occurs. The calcic horizon is directly overlain by uncemented, gravelly parent material of soil B.

In each occurrence, soil A has been identified in a buried position as the second soil beneath shore ridge sediments. Its most distinctive chracteristic is a reddish brown B horizon with calcium carbonate nodules. Southward along the west side of the valley, the B horizon disappears and is replaced by a calcic horizon. This may result from truncation of the B horizon to expose the calcic horizon beneath. However, parent material seems to become more gravelly southward, so this may result instead from a change in soil type (e.g., Haplargid to Calciorthid).

No definite relict or exhumed land-surface analog has been identified. A possible surface analog may exist south of Bobcat Hill in the area of Secs. 35 and 36, T24S, R21W and Secs. 1 and 2, T25S, R21W (Plate I). The soils here are dominantly of the Upton Series, a Typic Paleorthid (Cox, and others, 1973). It is tempting to regard the totally impregnated calcic horizon of soil A at Loc. 16 (Fig. 16) as a buried equivalent of the Upton Series. This, however, is speculative.

Soil B

In most exposures, shoreline sediments overlie a strongly developed soil referred to here as soil B. Typical exposures of this soil occur near Robinson Windmill, especially Loc. 12 (Figs. 14 and 29) where it may be traced upstream from the low shore ridge past the intermediate shore ridge. Along the exposure, soil B parent materials disconformably overlie the eroded surface of soil A and are disconformably overlain by shore ridge and younger alluvial sediments. Thickness of the unit ranges between 3 and 4.5 feet.

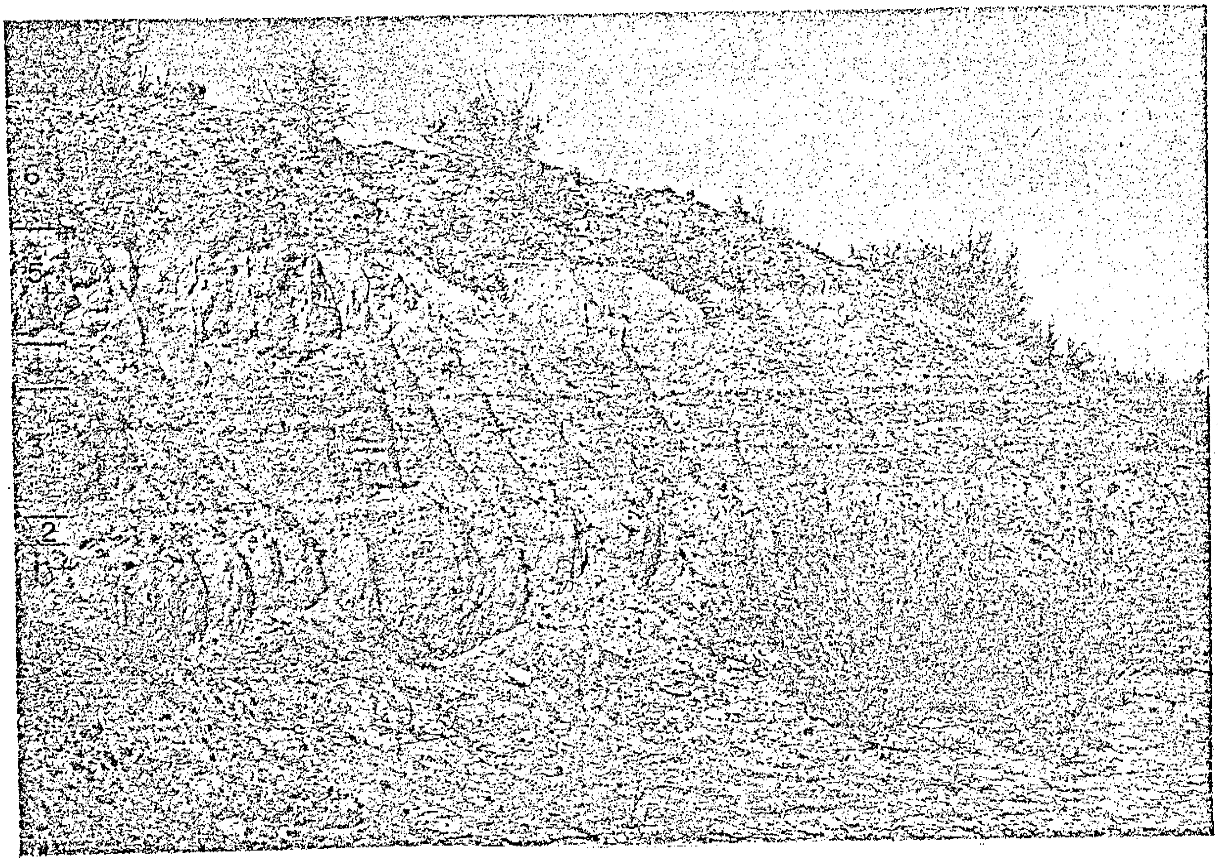
Soil colors are reddish brown with 5YR hues. Clay content in B horizons ranges up to 35%. The B horizon, where preserved, has angular blocky or prismatic structure, and lacks the prominent mottles of calcium carbonate present in soil A. The C horizon is gravelly and usually has pedogenic carbonate in the form of continuous coatings on clasts with some interclast fillings. A representative description of the soil in buried position is given in the 42 - 79 inch interval of Profile 6 (Appendix III).

Similar exposures are found at Locs. 8, 9, 11, and 16 (Figs. 13, 16; Appendix I). At Loc. 11, the upper part of the B horizon appears to have been reduced to a grayish or greenish color. This may also be the case in the questionable paleosol of Loc. 10 (Appendix I). In both localities, the soil is overlain by laminated, lacustrine mud and sand.

A comparison of the soil of the fan surface with soil B indicates that soil B is a buried counterpart. The piedmont is, therefore, a relict feature. Soil B is considered to be the dominant component of Qfo.

Fig. 10. Low shore ridge at Loc. 4. Basal paleosol (1) is overlain by offshore mud (2) and longshore bar deposits (3). Numbers at left refer to units of measured section (Appendix I).

Fig. 11. Fine-grained alluvium of inter-ridge trough at Loc. 4. These sediments are inset against the low shore ridge and bury the paleosol.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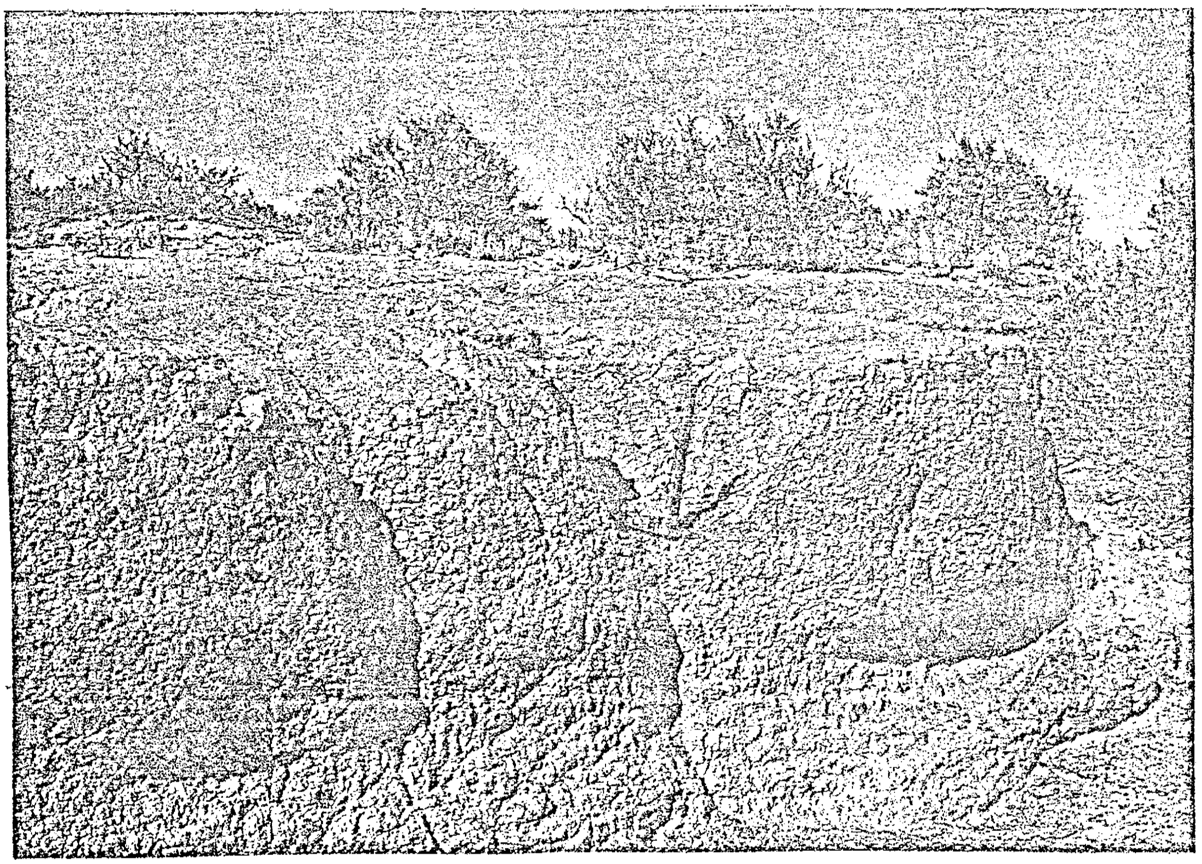
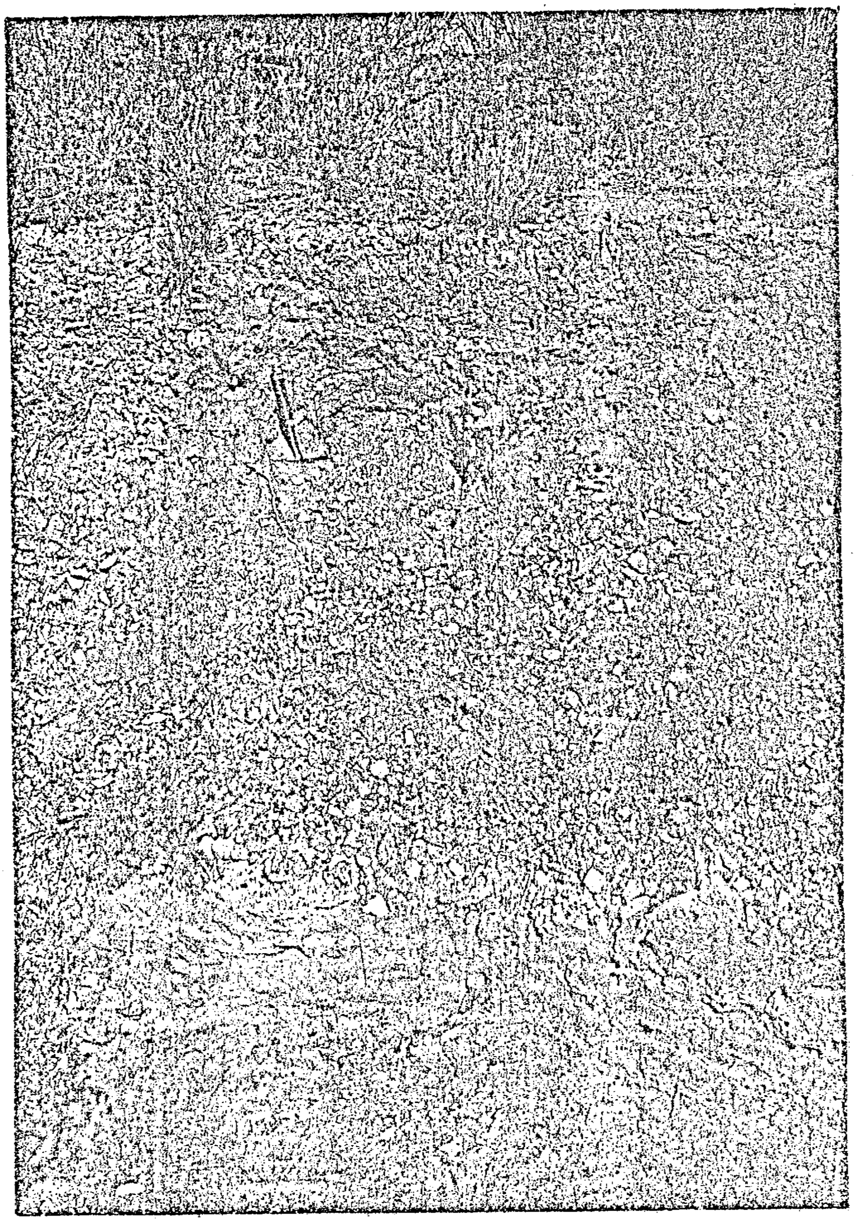


Fig. 12. Low shore ridge at Loc. 6. Alluvial fan deposits (1) are overlain by offshore mud (2), in turn overlain by cross-stratified gravel (3). Numbers at left refer to units of measured section (Appendix I).

Fig. 13. Low shore ridge at Loc. 11. A-paleosol (soil B) forms the first bench above the arroyo channel. Hammer is lying on offshore mud and sand (unit 3 of measured section, Appendix I) which exceed 3 feet in thickness.

Fig. 14. Low shore ridge at Loc. 12. About 3 feet of lacustrine gravelly sand overlie a paleosol, soil B.

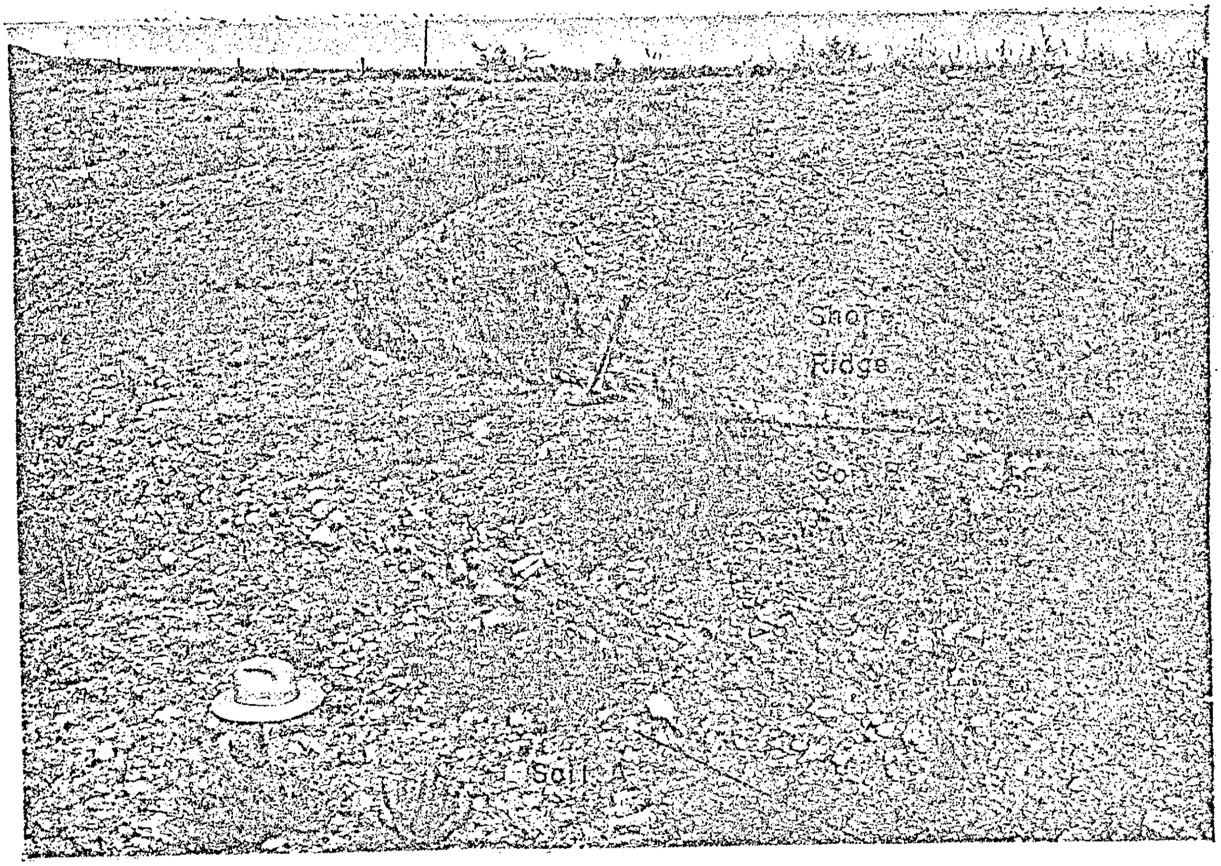
Fig. 15. Intermediate shore ridge at Loc. 13. Sandy gravel overlies a laminated muddy sand or silty mud. This is the only exposure of the intermediate shore ridge in which a basal mud occurs (Appendix I).

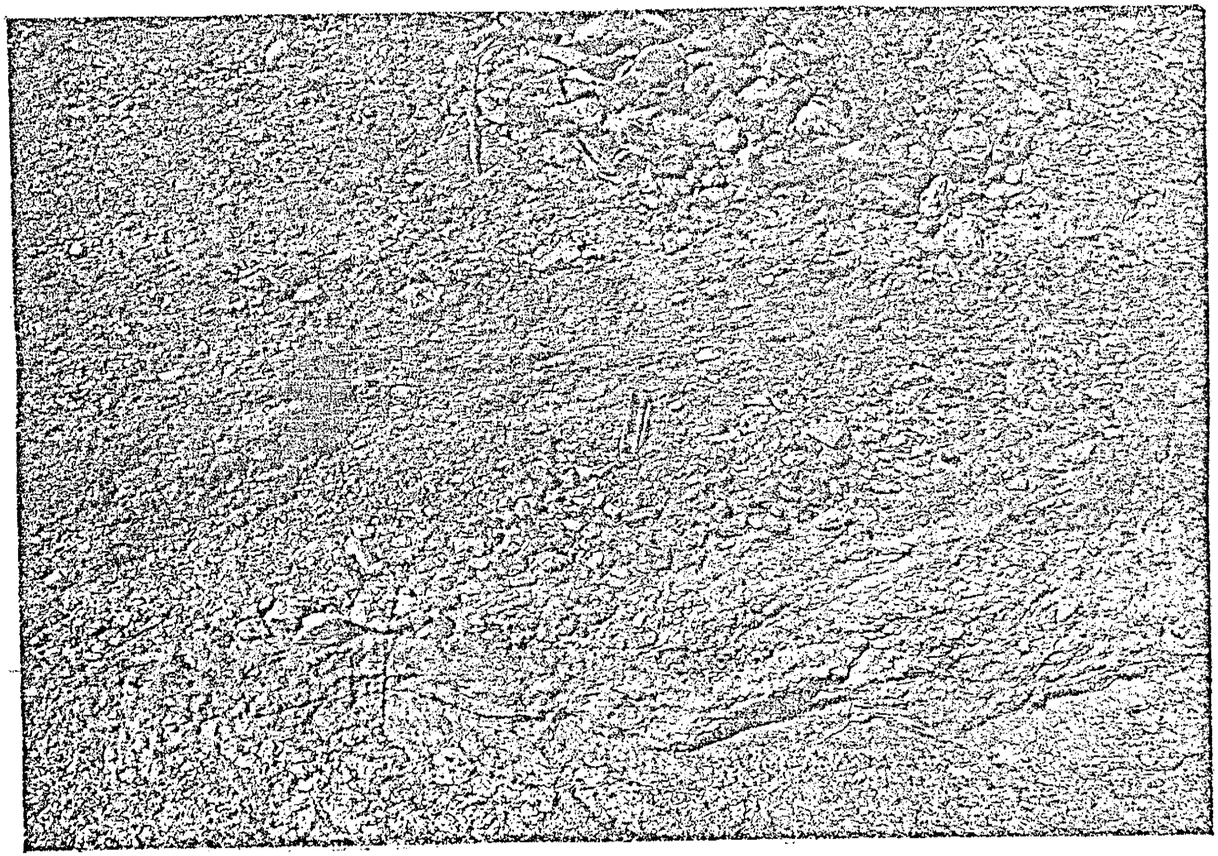



Soil B

Fig. 16. High shore ridge at Loc. 16. Sediments of the high shore ridge overlie a paleosol correlated with soil B. Hat rests on a calcium carbonate-cemented conglomerate which is regarded as an older paleosol correlative with soil A (Appendix I).

Fig. 17. Cross-stratified sand and gravel at Loc. 17. Cross-strata average 3 - 4 inches thick and range up to 7 inches thick. Dip is landward at about 27° (Appendix I).


Shore
Ridge
Soil
Salt



Lacustrine Shoreline Sediments

Sediments comprising the shore ridges are thin and usually do not exceed 3 or 4 feet, especially in the high and intermediate shore ridges. Processes of soil formation and the activities of soil fauna and flora have destroyed primary sedimentary structures and modified original textures by the addition of silt and clay. The result is typically a homogeneous, muddy sandy gravel or gravelly sand. The thickest exposures are found along the low shore ridge and it is here, too, that primary structures and stratification are best preserved.

High Shore Ridge:

Exposures in the high shore ridge are few. Loc. 16 (Fig. 16, Appendix I) exposes 3 feet of homogeneous, slightly gravelly, muddy sand overlying eroded soil B. Profile 4 (Fig. 26; Appendix III) from a backhoe pit has only 2 feet of shore ridge deposits overlying soil B. In neither exposure do primary sedimentary structures occur.

Intermediate Shore Ridge:

The sediments of the intermediate shore ridge are similar to those of the high shore ridge. Representative exposures are found at Locs. 8 and 9 where 3.8 and 3.5 feet, respectively, of sediment overlie soil B. The lower 7 inches at Loc. 12 (Fig. 29; Profile 6, Appendix III) consists of horizontally stratified gravelly sand that probably approaches the original texture. Locality 13 (Fig. 15) differs from the norm in that 6 - 7 feet of lacustrine sediments are found. The lower contact with a paleosol is not exposed so that this value is a minimum thickness. A basal laminated silty unit, probably lacustrine, is overlain by gravelly sand. Less than 50 yards south of here another exposure shows only 3 feet of the upper gravelly sand overlying soil B. In this distance the lower fine-grained unit has pinched out and the thickness has been halved. The thickness increase at Loc. 13 suggests infilling of a former surface irregularity, possibly an old stream channel. Such thickness variations along the length of the high and intermediate shore ridges may be common, but poor exposure does not permit identification.

Low Shore Ridge:

Extreme variability of thickness is common in the low shore ridge deposits which may range from 3 feet to 10 feet or more. Though internally variable as well, an idealized vertical sequence of deposits from bottom to top is: 1) paleosol of pre-lake surface, 2) thinly bedded lacustrine clay, silt, and very fine sand, 3) cross-stratified sand and gravel, and 4) homogeneous sand and gravel. Each unit is thought to represent a separate environment, and the sequence shows the evolutionary nature of parts of the low shore ridge. A discussion of individual localities follows.

About 6.7 feet of lacustrine sand, gravelly sand, and sandy gravel occur at Loc. 3 (Plate 1; Appendix 1). The upper unit comprises about 4.7 feet of the total section with four thinner units forming the remainder. Bedding is apparently horizontal and thin zones of calcium carbonate, or white calcareous mud, separate gravelly layers. The outcrop parallels the length of the ridge and the exact attitude of bedding is not known.

Locality 4 (Fig. 10; Appendix 1) most nearly approaches the idealized section. About 2 feet of thinly bedded, silty, very fine sand pinch out eastward (landward) over a paleosol so that the overlying cross-stratified unit rests on the paleosol on the east end of the outcrop. Above is a homogeneous sand which is overlain by a grayish muddy sand or sandy mud. The upper muddy unit has a high silt content and a sparse snail fauna. The sequence is capped by homogeneous gravelly sand.

The muddy unit containing the snail fauna is also found at Locs. 5 and 7. At Loc. 5 (Appendix I), snails are more abundant than at Loc. 4 and consist largely of <u>Succinea</u> and a few unidentified pupaeform types. The cross-stratified unit seems to be absent here as well as the basal lacustrine mud. The paleosol is overlain by gravelly sand instead.

Localities 6 and 7 yield incomplete sections due to gravel pit operations. Locality 6 (Fig. 12) matches the lower part of ideal sequence (Appendix I) with a paleosol overlain by lacustrine mud containing ostracodes, overlain by cross-stratified gravel. The base of lacustrine shore ridge deposits is not exposed at Loc. 7. Approximately 5 - 6 feet of cross-bedded sand, gravelly sand and sandy gravel comprise most of the exposure in the pits. In places, the cross-stratified deposits are overlain by horizontally-bedded sediments, and in some areas in the pits, a muddy unit similar to unit 5 of Loc. 4 and Loc. 5 (containing the snail fauna) is found at the top of the sequence.

Localities 8 and 9 expose homogeneous gravelly sand overlying a paleosol correlated with soil B.

Figure 18 is a correlation of sections at Locs. 4 - 9. A variable datum is used by necessity since a common marker is not present at all localities. For Locs. 4, 5, 8, and 9 the base of the upper homogeneous

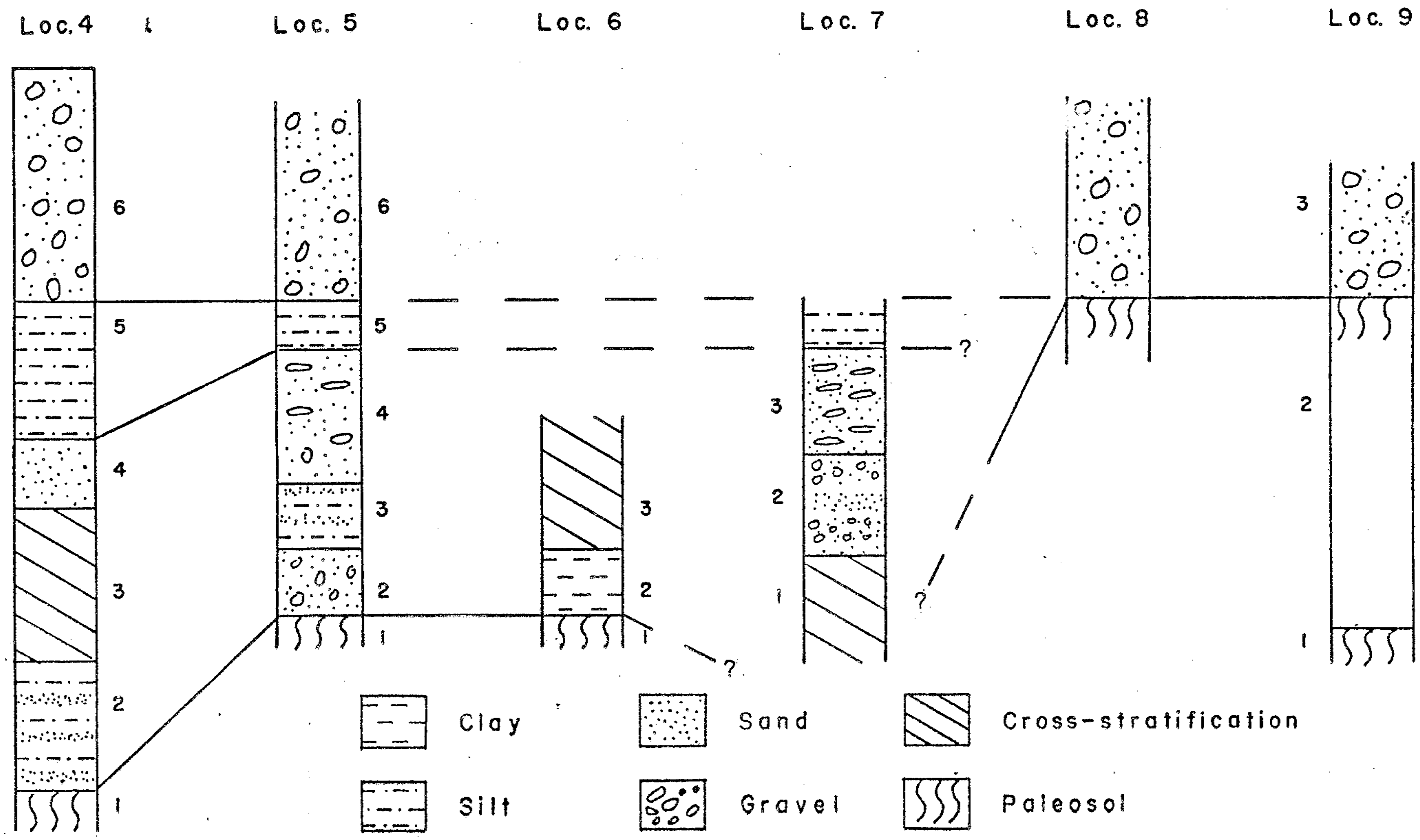


Fig. 18. Correlation of measured and described sections in the low shore ridge, east shore of Lake Animas. Principle datum is the base of unit 6 of Loc. 4. Vertical scale: 1 inch = 2.5 feet.

gravelly sand is used. Locality 6 is positioned approximately by correlating the top of the paleosol with that of Loc. 5. The base of the upper muddy unit of Loc. 7 is correlated with the base of the upper muddy unit (unit 5) of Loc. 5. The figure shows that a considerable thickness of the section is missing at Locs. 8 and 9, probably as a result of change to another depositional environment.

A similar situation exists on the west side of the valley. Locality 10 (Plate I; Appendix I) is an exposure of the basal part of the shore ridge and shows a paleosol (?) overlain by horizontal, thinly bedded sand and mud overlain by sandy gravel. A basal mud up to 3 feet thick overlies soil B at Loc. 11 (Fig. 13). Gravelly sediments with discontinuous, textural laminations and parallel-oriented platy gravel make up the upper part of the section. Stratification in the gravelly sediments has a shallow landward dip of about 10°.

Three feet of lacustrine sandy gravel overlies soil B at Loc. 12 (Fig. 14; Plate I). This outcrop is similar to those at Locs. 8 and 9 in thickness and lack of internal bedding. There does seem to be some shape sorting of clasts and preference for platy gravel. Profile No. 1 (Fig. 22; Appendix III) from a nearby backhoe pit is thicker and shows stratification produced by parallel, horizontal orientation of platy gravel.

Cross-stratified sand occurs at Locs. 15 and 17. At Loc. 15, cross-strata are lakeward-dipping while at Loc. 17, they are landward-dipping. The cross-stratified deposits at Loc. 17 (Fig. 17) are among the thickest observed being at least 3 - 4 feet. The upper half of the 8 feet of section is covered.

Depositional Environments:

The basal muddy sand that overlies paleosols at Locs. 4, 6, 10, and 11 is interpreted as an offshore, low energy deposit because of its fine texture and thin stratification. The grayish or greenish tint that is usually present indicates reducing conditions and its presence in thicker sections as the first deposit over the pre-lake surface may point to a rapid rise of lake level.

The basal mud is overlain by landward-dipping cross-stratification at Loc. 4 and 6, and similar deposits occur at Locs. 7 and 17, and possibly at Loc. 11. Lakeward-dipping cross-stratified sediments are found only at Loc. 15. Dip angle and direction data are presented in Appendix I, and mean dip directions for each locality are indicated on Plate I.

Cross-strata range in thickness from less than an inch to 7 inches or more, and may be either straight or concave. Strata may occur as discrete beds or laminae with well-defined boundaries, or vaguely defined laminae with gradational boundaries. As indicated on Plate I, the dip direction is invariably oblique to the trend of the shore ridge, although it is almost normal at Locs. 4, 7, and 11.

The idealized transverse cross-section of an embankment illustrated by Gilbert (1890, p. 49) has an "anticlinal" structure with both landward- and lakeward-dipping beds. Landward-dipping cross-strata of Lake Animas shore ridges, however, have no lakeward-dipping counterparts, nor are topset beds preserved. In overall appearance, they closely resemble the stratification of longshore bars produced by McKee and Sterrett (1961) in wave tank experiments. These bars were comprised solley by landward-dipping cross-strata. Under conditions of high sediment supply to the seaward face, the "anticlinal" structure described by Gilbert (1989) was produced, and the bar accreted both seaward and landward. Under laboratory conditions these bars commonly built upward to water level and migrated landward. Davidson-Arnot and Greenwood (1974, p. 699 - 670) described similar structures in longshore bars of a micro-tidal coast. During periods when waves break over the bar, lunate megaripples form on the seaward slope and plane beds on the top and crest. Under high energy the lunate megaripples advance onto the bar crest to form landward-dipping, planar cross-stratification with dips as steep as 25°. Sets of cross-strata formed in this position can have a thickness equal to the height of the bar, a width of several meters, and length equal to the length of the bar. The trough to the landward of the bar is filled with somewhat finer-textured sediment with small scale cross-stratification. Trough sediments are buried as the bar migrates landward.

On the basis of the landward-dipping cross-stratification, these sediments are best interpreted as a longshore bar deposit. Implied is the construction by wave activity, and since the bars parallel the shore, avalanche face cross-bedding should dip approximately normal to the bar length. The oblique dip directions in the low shore ridge requires a parallel-to-shore transport component and implies the influence of currents. At Locs. 4, 7, and 11, dip directions are almost normal to bar length. The southeast measurement at Loc. 4 is from cross-stratification within an eastward dipping cross-bed, and may represent return currents in the troughs. If the thickness of the sets may be taken as a rough approximation of bar height, bar height may have been only 2 feet high at Loc. 4, and may have exceeded 5 feet at Loc. 7, and 4 feet at Loc. 17 (Appendix 1).

The position of longshore bar deposits low in the sequence indicates that formation was initiated during a higher stage. As lake level fell bars formed the nucleus for portions of the low shore ridge.

The homogeneous, sandy gravel or gravelly sand that forms the uppermost unit of the shore ridges is interpreted as a beach deposit. In the lower parts of Profiles 1 and 2, (Fig. 22, 23) stratification is produced by horizontal orientation of platy clasts. This type of stratification was presumably present in all localities initially, but was destroyed by pedogenesis.

The interpretations of depositional environments in the low shore ridge indicate a progressive shallowing. The upper muddy unit at Locs. 4, 5, and 7 (Appendix 1) might indicate an interval of rising lake level. However, the lack of a parallel deposit in the low shore ridges of the west side argues against this. The deposit may represent a local environment such as a lagoon or longshore trough.

Inter-ridge Troughs

The best exposures of younger alluvium are generally in the inter-ridge troughs. At Loc. 3, silty mud overlies questionable lake sediments and is inset against the ridge. Fine sedimentary structures are lacking and have been replaced by soil structure. At Loc. 4 (Fig. 11), silty, non-gravelly alluvium is inset against the low shore ridge and the paleosol it overlies. A continuous exposure of these sediments occurs between the low and intermediate shore ridges at Loc. 8. Near the intermediate shore ridge, soil B is overlain by less than a foot of sandy sediment apparently eroded from the shore ridge. At the contact is a lag of varnished pebbles. Laterally toward the low shore ridge the trough sediments thicken abruptly where they fill a gully cut into soil B. The sediments here are silty and non-gravelly and have grayish or tan colors. Slight tonal changes in vertical sections suggest the presence of buried, weakly developed soils. In addition stone lines with a few, overturned, varnished pebbles suggest a hiatus in the section. The varnished pebbles may be derived from the lag developed on soil B. This lag is apparently post-lacustral in age since it is not found beneath the shore ridge sediments.

Near Loc. 16, younger alluvial sediments are coarser and consist of interbedded muddy sand and sandy gravel. Muddy sand strata range up to 3 inches thick, but average 1 inch, and sandy gravel strata average 3 to 4 inches. Gravel ranges up to cobble size but has a median in the small pebble range. Nearby bedding is thicker and a buried soil occurs.

In general, sediments of the inter-ridge trough are fine-grained with high silt content, and usually, very low gravel content. Buried soils with weak profile development are common to most exposures and indicate multiple sedimentation events or episodes in this landscape setting, and intervening periods of surface stability.

Sedimentology

Sediments from several localities were sieved to determine if there were significant textural differences that might be used to distinguish lacustrine from non-lacustrine sediments. Analyses were conducted according to procedures outlined in Folk (1974). Data are presented in Appendix II.

Figures 19 and 20 are cumulative distribution curves of representative samples of fluvio-deltaic, alluvial, and lacustrine sediments. In general, no particular curve shape can be said to be distinctive for any depositional environment. The S-shaped curve, regarded as typical of fluvial sediments by Visher (1969), is also obtained for lacustrine sand. A plot of inclusive graphic standard deviation(sorting) versus graphic mean for different depositional environments is shown in Fig. 21. These parameters were chosen because they can be estimated with some degree of accuracy in the field. Some separation into fields does occur. Fluvio-deltaic sand from Loc. 2 is generally finer-grained and better-sorted than sand from lacustrine shore ridges. Samples from ephemeral stream channels in modern alluvial fans plot in the same field as lacustrine sand. This suggests that sediments comprising the shore ridges were derived largely from reworking of alluvial fan material. Thus the poor sorting and coarser grain size is inherited.

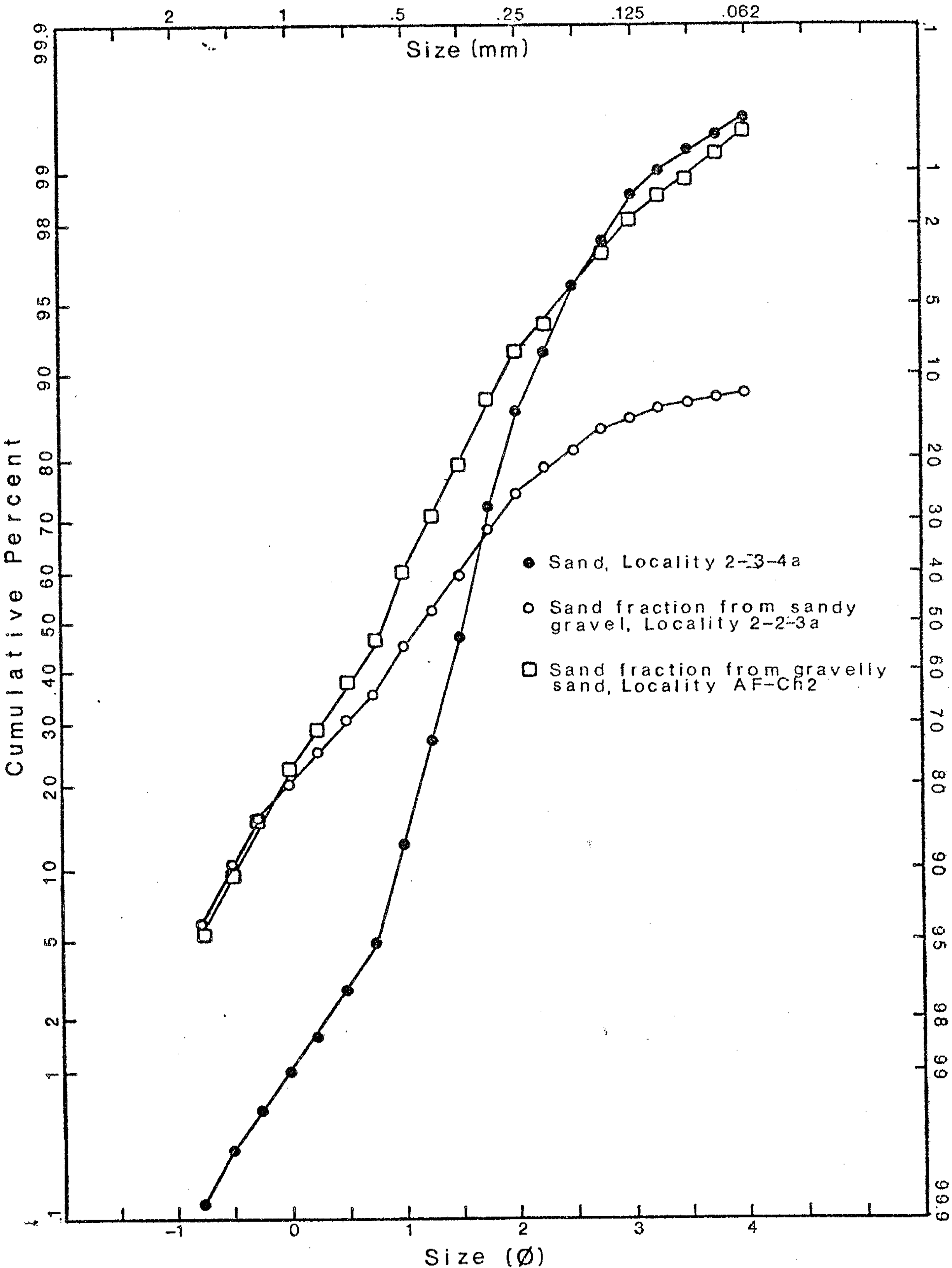


Fig. 19. Representative cumulative frequency distribution curves of sand from fluvio-deltaic and ephemeral stream channel sediments. Data are listed in Appendix II.

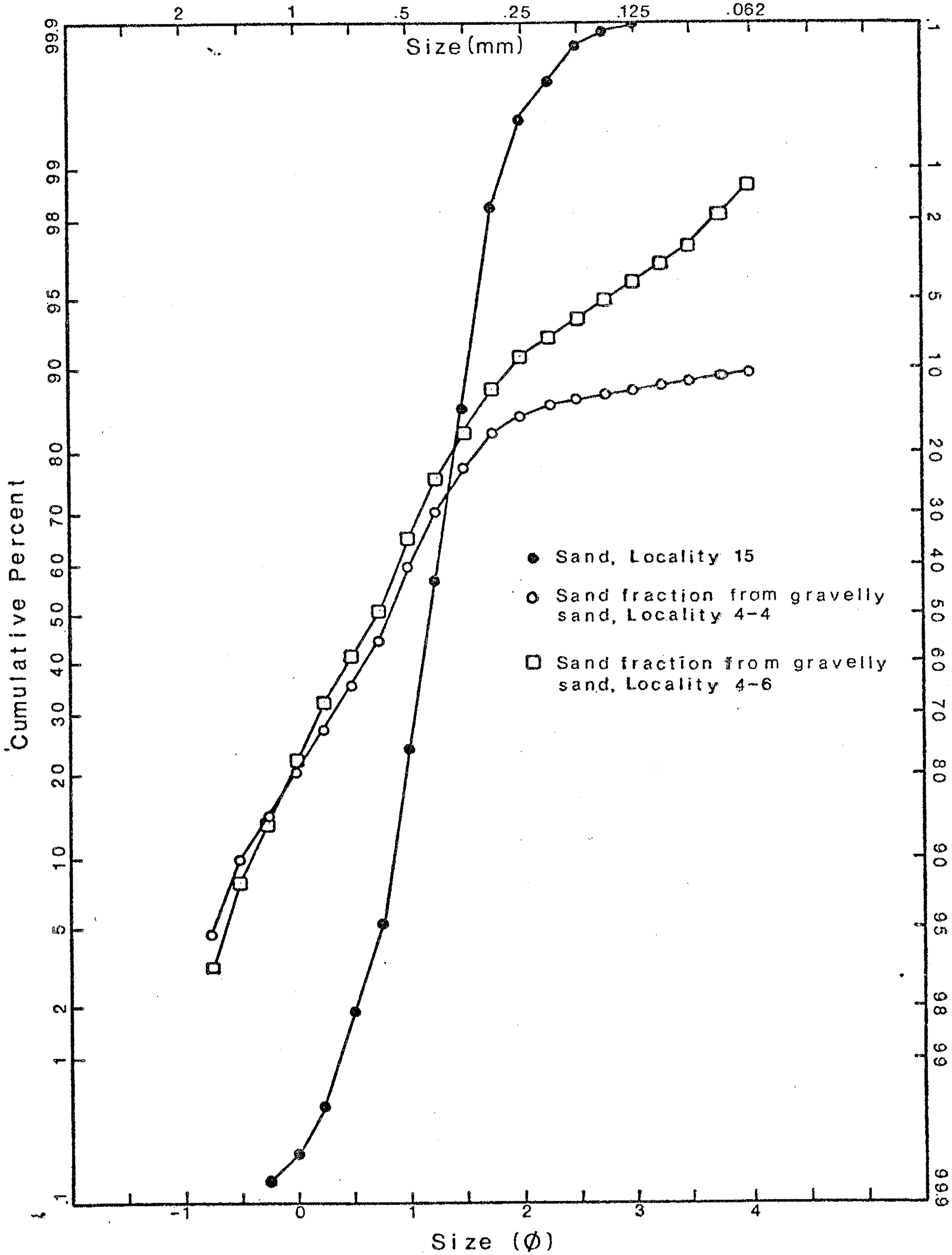


Fig. 20. Representative cumulative frequency distribution curves of sand from lacustrine shoreline sediments. Data are listed in Appendix II.

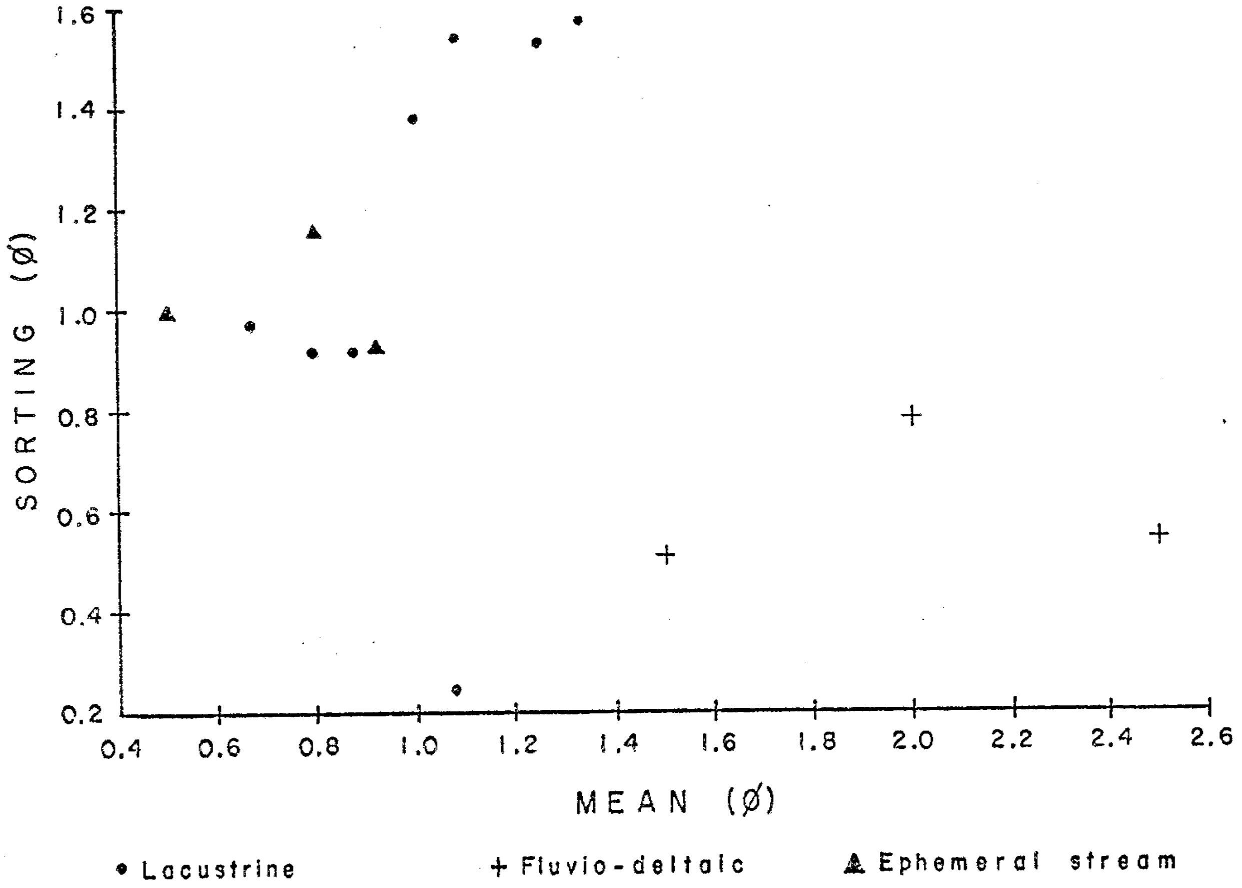


Fig. 21. Plot of inclusive graphic standard deviation (sorting) versus inclusive graphic mean for lacustrine, fluvio-deltaic, and ephemeral stream channel sand. Some separation into fields is evident. Data are listed in Appendix II.

SOILS DEVELOPED IN LACUSTRINE AND ALLUVIAL SEDIMENTS

The study of soils developed in sedimentary deposits in important in several respects. First, pedogenesis modifies the original depositional texture of sediments and obliterates primary sedimentary structures. Such modification must be taken into account in sampling for sedimentologic analysis and in interpreting depositional environments. Second, once characteristics of a soil or soil association are recognized, it may be treated as a local stratigraphic unit. Stratigraphic relationships of soils may then be used to determine the relative ages of landscapes and to identify sedimentation-erosion cycles. Third, the degree of soil development may be used to determine the relative ages of landscapes where stratigraphic relationships are not clear, and can be used to set absolute-time brackets on soil age through comparison with dated soils. This establishes minimum ages of geologic deposits.

Soils in the study area were examined with these in mind. Five pits were dug with a backhoe in a transect across the shore zone in Sec. 36, T23S, R19W (Plate I). One pit was excavated in each of the three shore ridges, one in the inter-ridge trough between the high and intermediate shore ridges, and one in the fan surface above the high shoreline. Stratigraphic relationships exhibited here typify many areas of the Lake Animas shore zone (Fig. 9).

Descriptions of soil profiles, textural data, and an outline of laboratory procedures are presented in Appendix III. The description and classification systems are from Soil Survey Staff (1975). Morphologic stages of carbonate accumulation are from Gile, and others (1966) (for discussion, see Age and Correlation). Qualitative descriptions of soil development are summarized below (Birkeland, 1974, p. 23):

1) Weakly developed soil - Horizon sequence is A - C, or A - Bcambic - C or Cca. Carbonate may have a Stage I morphology
2) Moderately developed soil - Horizon sequence is A - Bargillic - C or Cca. Carbonate may have a Stage II morphology.
3) Strongly developed soil - Horizon sequence similar to moderately developed soil. Carbonate may have Stage III morphology. B horizon is thicker, redder, has more clay and better developed structure.

Soils of Shore Ridges

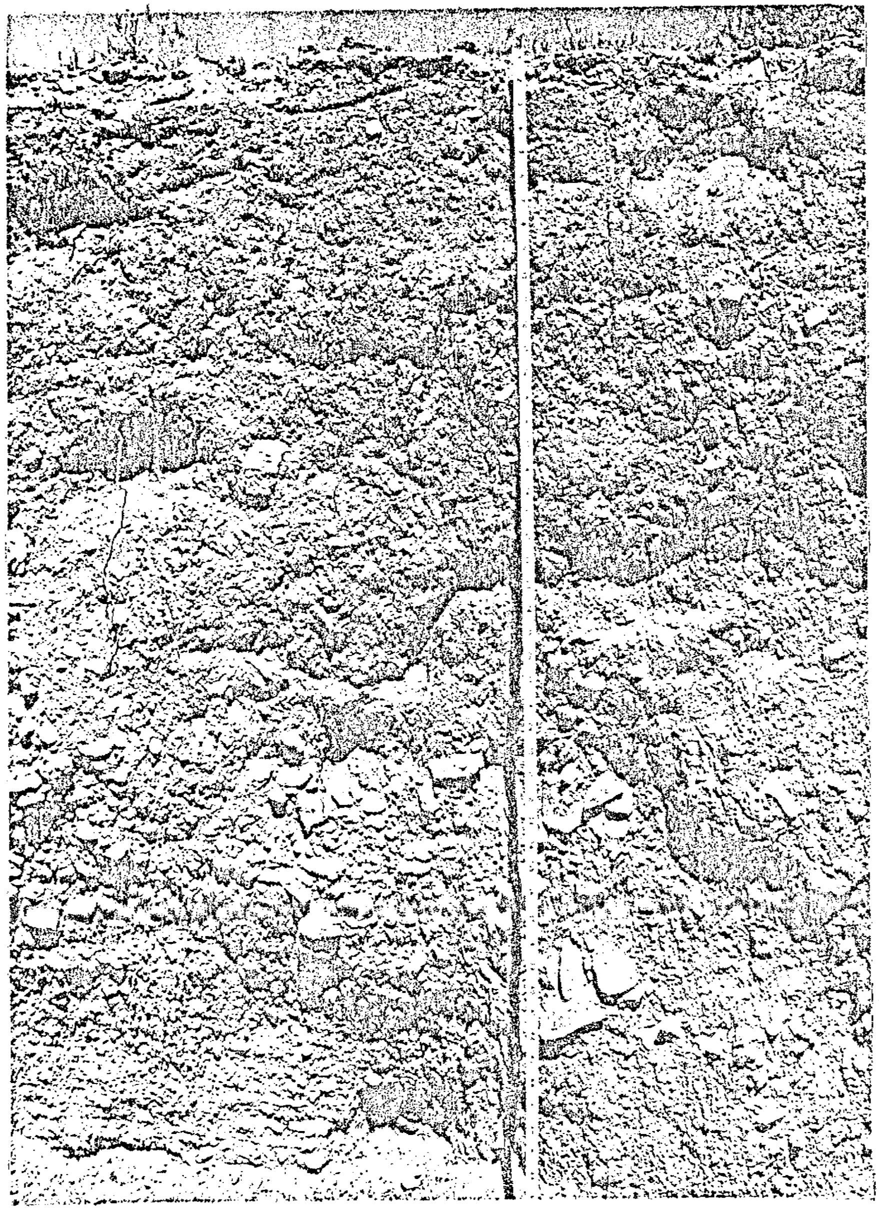
Profiles 1 and 2 (Appendix III; Figs 22 and 23), from the low and intermediate shore ridges, respectively, have similar horizon sequences. The A horizon in both extends to a depth of about 2 inches, below which is a massive B1 horizon. The B2 horizon has a higher clay content and evidence of illuviated clay in the form of discontinuous clay skins on pebbles. Pedogenic carbonate in the upper C horizons is characterized by Stage I morphology. In both profiles, the parent material becomes stratified near the base of the pit. The unmodified parent material in Profile 1 occurs in the C2ca horizon where stratification is exhibited by parallel, horizontal orientation of platy gravel.

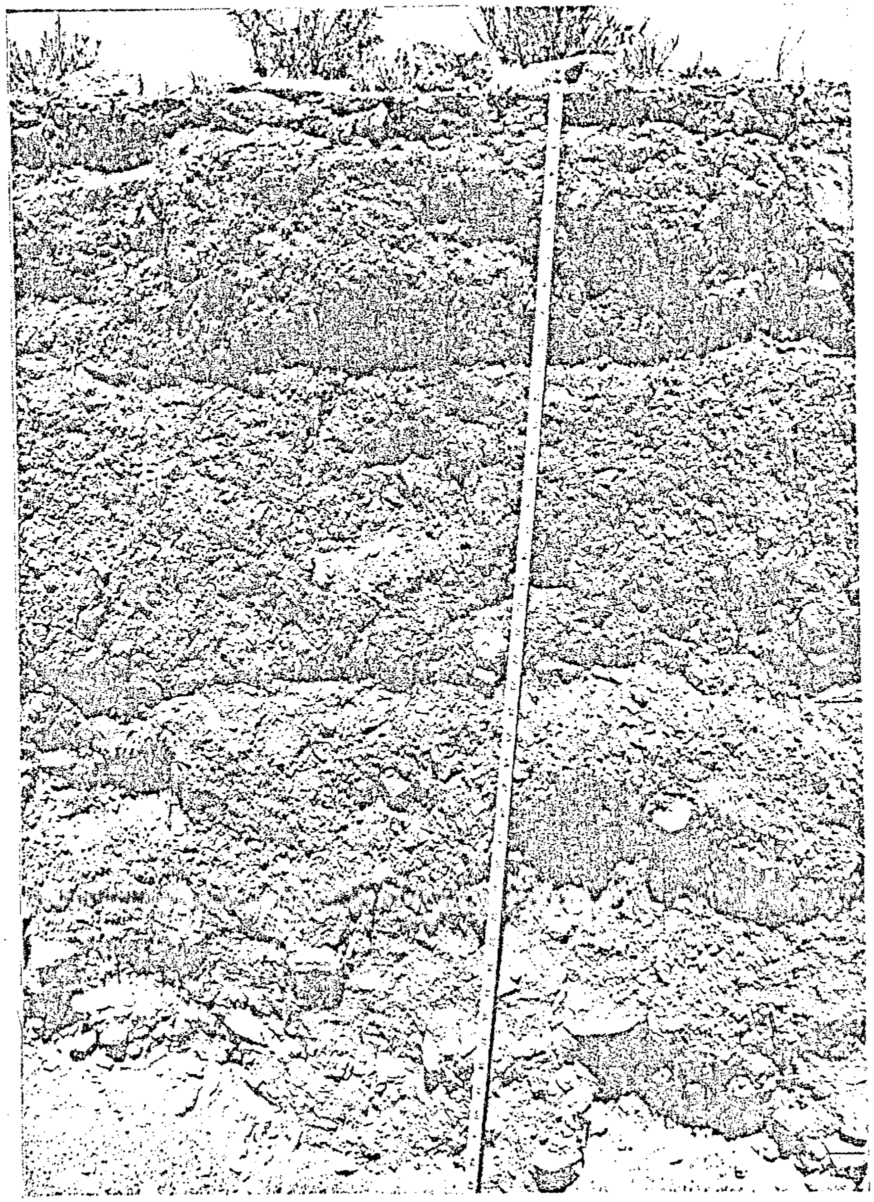
Soil colors have 10YR hues in all horizons and range from brownish gray in the C horizons to grayish brown, brown, and yellowish brown in the A and B horizons. The colors of the B2 horizons are slightly darker, possibly as a result of increased clay content.

Figure 24 shows the vertical distribution of clay in these profiles.

Fig. 22. Profile 1, a Camborthid developed in sediments of the low shore ridge of Lake Animas. Tick marks at right indicate approximate horizon boundaries (Appendix III). Scale is in inches.

Fig. 23. Profile 2, a Camborthid developed in sediments of the intermediate shore ridge of Lake Animas. Tick marks at left indicate approximate horizon boundaries (Appendix III). Scale is in inches.





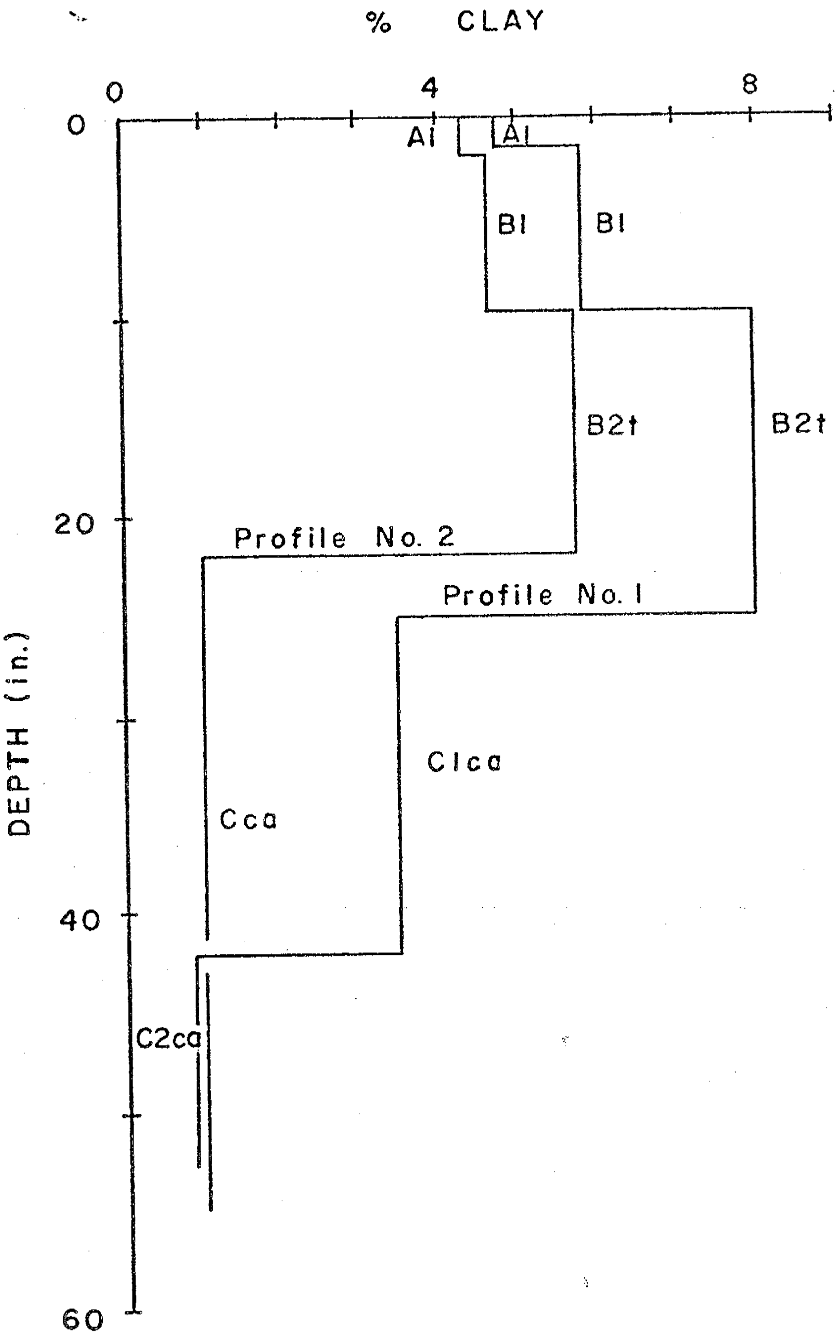
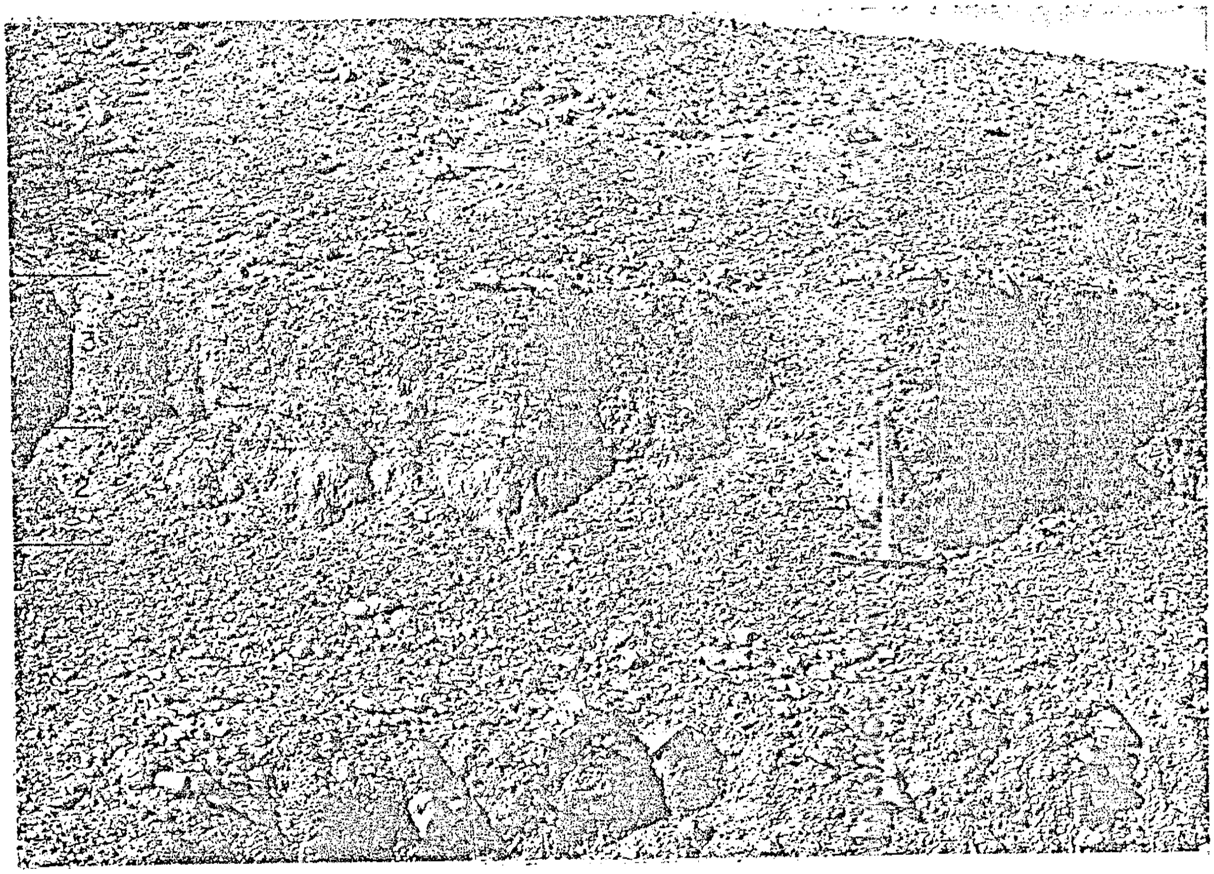


Fig. 24. Vertical distribution of clay in Profiles 1 and 2 of the low and intermediate shore ridges respectively.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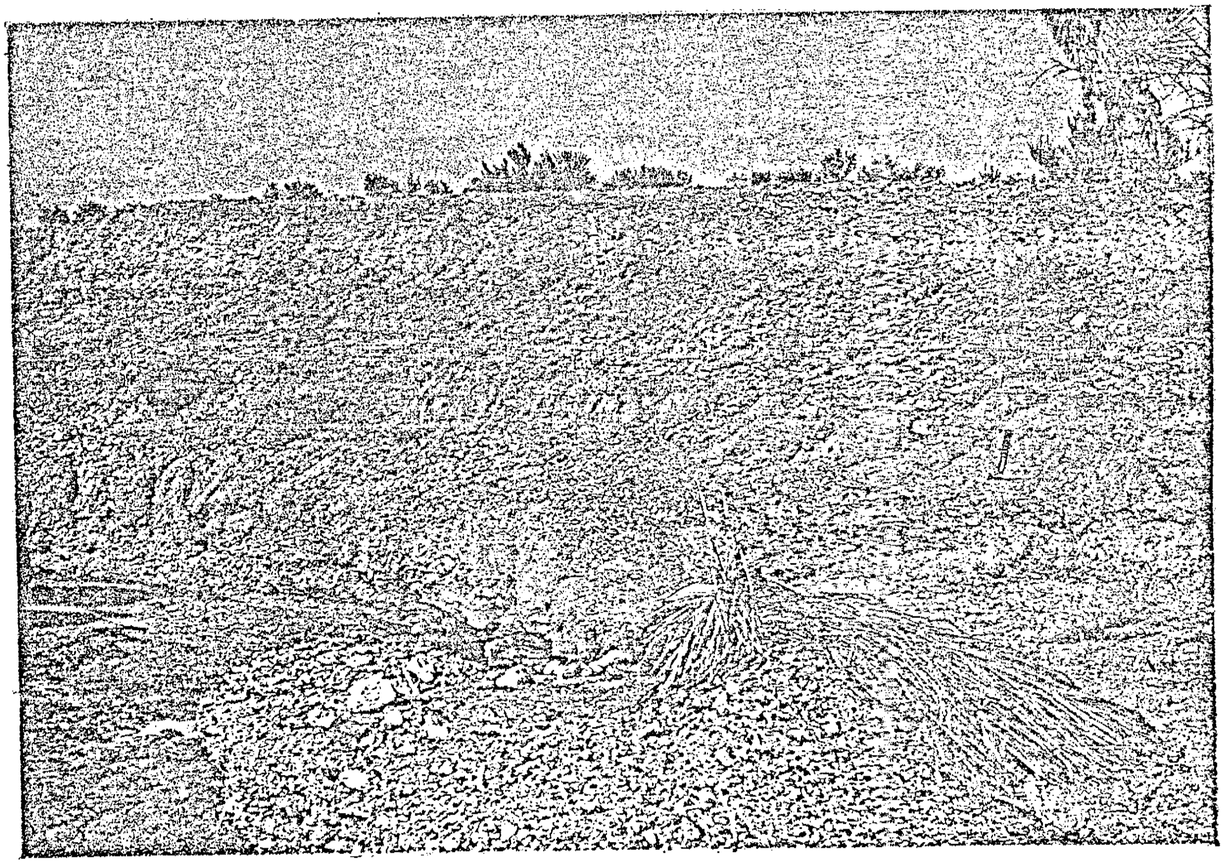


The C2ca and Cca horizons of Profiles 1 and 2, respectively, contain about 1% clay. This value includes calcium carbonate so that the amount of silicate clay is less than 1%. The low clay content of the parent material indicates that any silicate clay accumulation in the A1, B1, and B2 horizons is almost entirely pedogenic. Although some staining of sand grains has occurred, lithic fragments containing weatherable minerals do not seem to be severely weathered. Hence, it is believed that the source of clay is dust fall rather than weathering of parent material. The clay bulge in the B2 horizons and the clay skins on pebbles emphasize the effect of illuviation.

The B1 and B2 horizons comprise a cambic horizon in both profiles. By definition, a cambic horizon occupies the B position, has a texture of loamy very fine sand or finer, and has a lower boundary 10 inches or more below the surface, unless the surface is eroded. It is chiefly a horizon of physical and/or chemical alteration that does not qualify as one of the other diagnostic subsurface horizons (Soil Survey Staff, 1975, p. 33 - 36). In the case of Profiles 1 and 2, alteration is exhibited by the lack of primary stratification usually found in undisturbed parent material, and by the presence of a horizon of pedogenic carbonate accumulation indicating its solution and movement through the profile. Though not described as a form of alteration in Soil Survey Staff (1975), textural alteration of parent material has occurred by the addition of clay. The textures of the B1 horizon of Profile 1, and of the B1 and B2 horizons of Profile 2 are actually coarser than the definition allows. The textural restriction was introduced in consideration of the difficulty of recognizing alteration in sand, and its purpose is to insure uniformity in application by different workers (Soil Survey Staff, 1975, p. 35). This restriction is waived here because most of the other requirements seem to be fulfilled.

Soils of Profiles 1 and 2 are classified as Camborthids and probably belong to the typic subgroup. Profile development is weak. Natural exposures of soils of the low and intermediate shore ridges elsewhere exhibit similar horizonation and development (Profile 6, upper 42 inches, and Profile 7, Appendix III). For this reason, these profiles are regarded as being fairly representative of soils on the lower shore ridges.

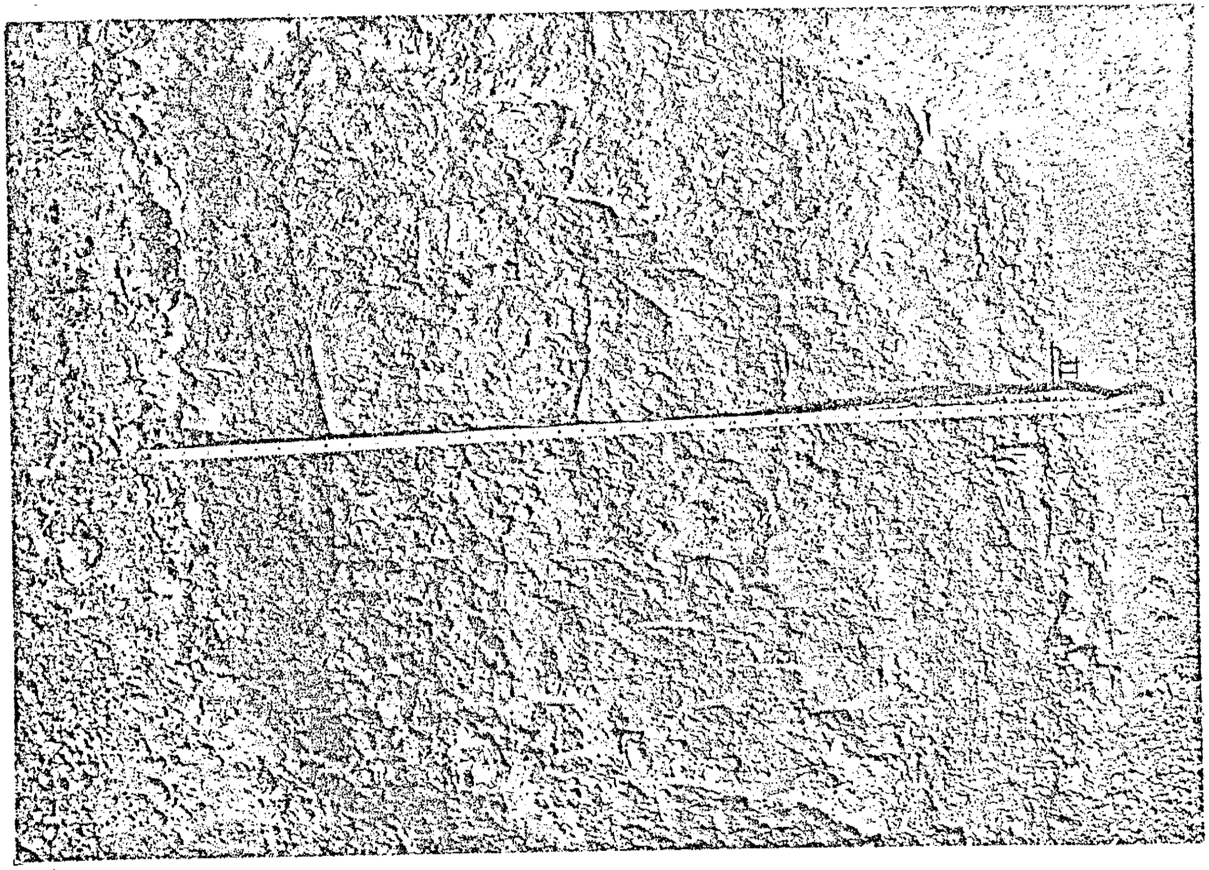
The soil developed in sediments of the high shore ridge is described in the upper 28 inches of Profile 4 (Appendix III; Fig. 26). An A1 horizon 3 inches thick overlies a B21t horizon that has weak, coarse prismatic structure. The C horizon is noncalcareous and nonstratified. A lag of coarse pebbles and cobbles overlies an eroded paleosol developed in fan alluvium. This buried soil has a redder, more highly developed B horizon and a C horizon with Stage II or Stage III carbonate accumulation.

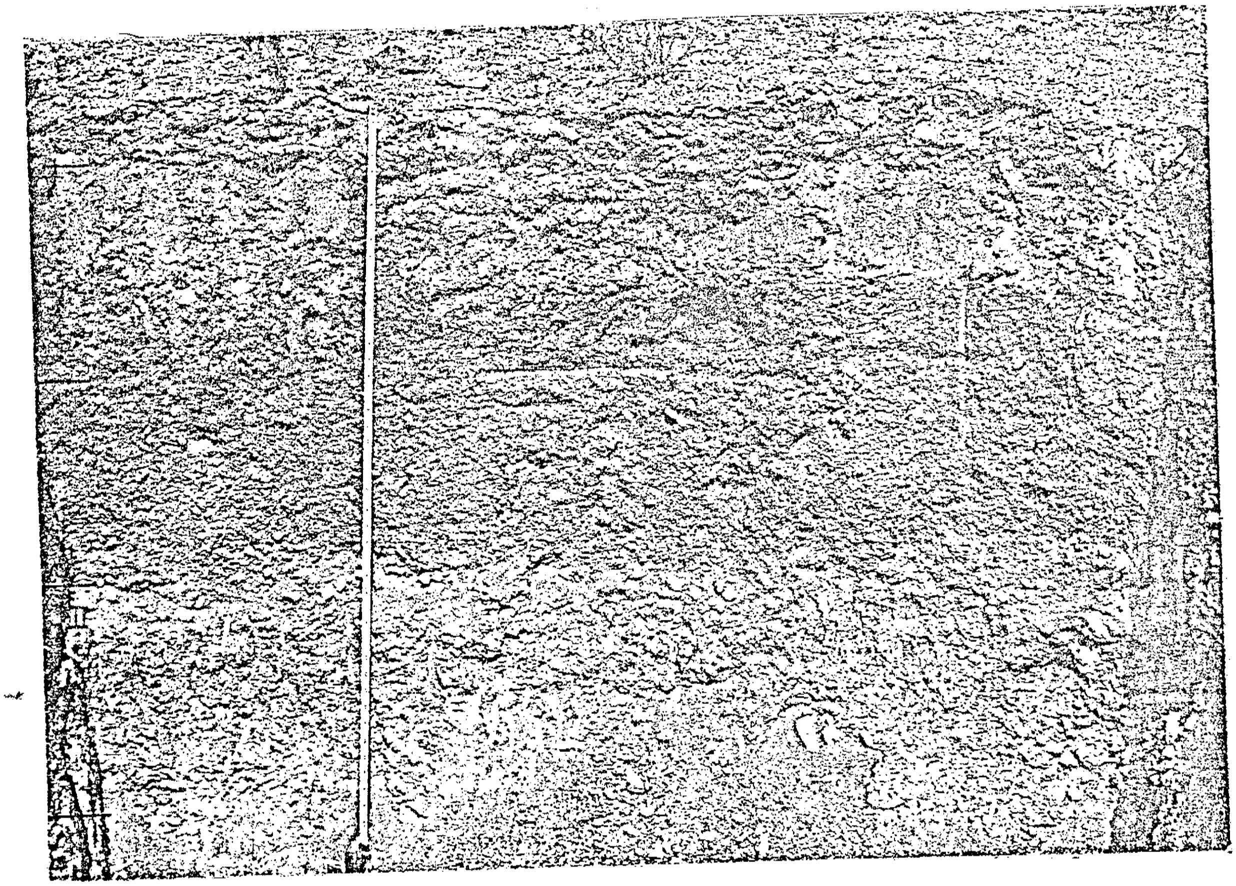
The colors of the soil developed in the shoreline sediments are similar to those of Profiles 1 and 2. Though listed as 10YR in the profile description, the hue of the B21t horizon of Profile 4 is actually somewhat redder, but is not as red as 7.5YR, except perhaps locally. The colors of the buried soil have 5YR hues.

Figure 27 shows the vertical clay distribution in this soil. The C horizon has nearly 7% clay, a value regarded as higher than that initially present in the parent material. The A1 horizon has about 6% clay which, though higher, is comparable with the A1 horizons of Profiles 1 and 2. The B21t horizon contains nearly 22% clay at its center, which

Fig. 25. Profile 3, a Camborthid developed in silty alluvium of an inter-ridge trough. Tick marks as right indicate approximate horizon boundaries. A paleosol (soil B?) is indicated by II (Appendix III). Scale is in inches. Top is at left of page.

Fig. 26. Profile 4, a Haplargid developed in sediments of the high shore ridge. Tick marks at left indicate approximate horizon boundaries. A paleosol (soil B) is indicated by II (Appendix III). Scale is in inches.





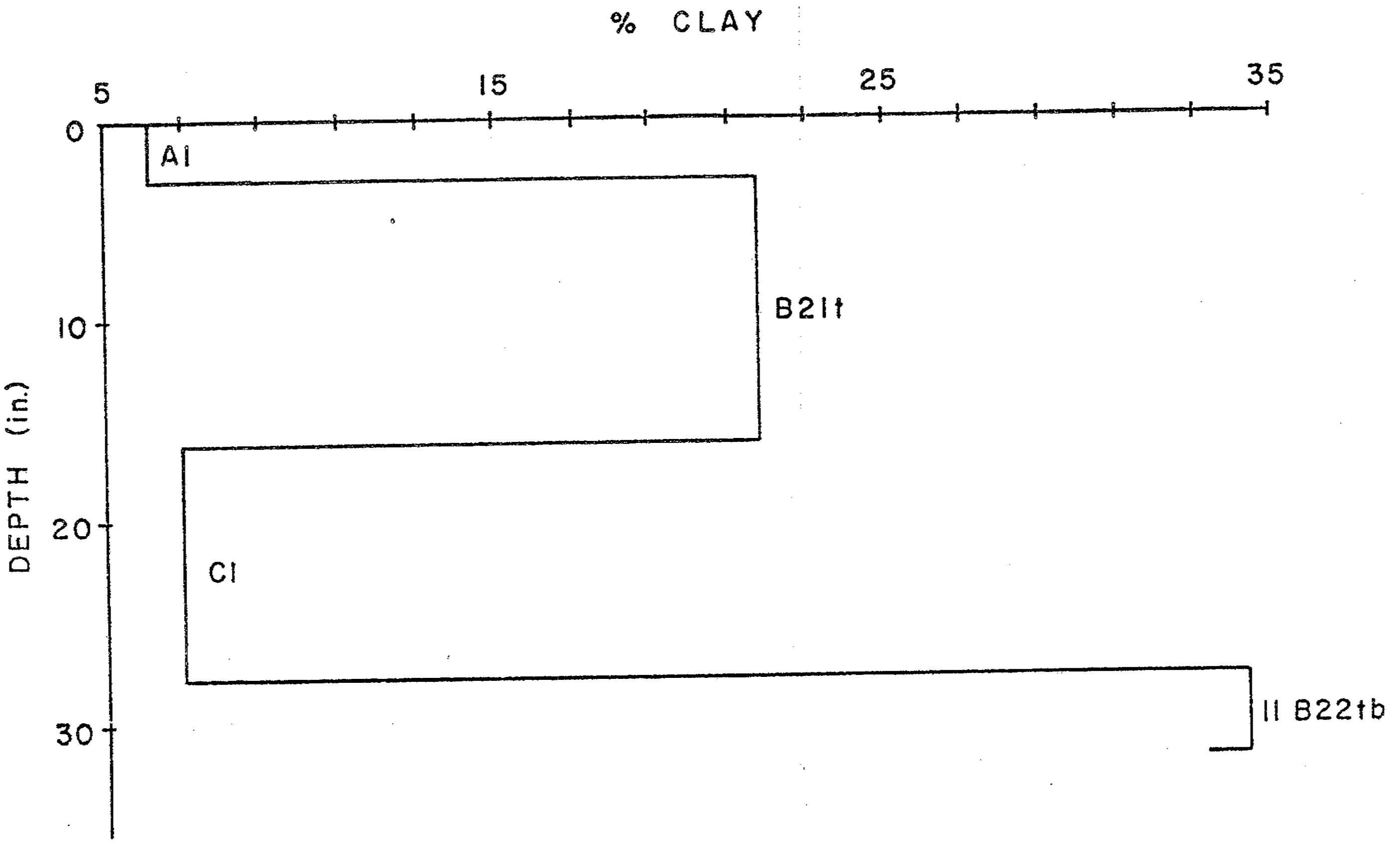


Fig. 27. Vertical distribution of clay in Profile 4, a soil developed on the high shore ridge. The IIB22tb horizon is developed in the buried equivalent of Profile 5 (soil B).

is 13% to 16% higher than corresponding horizons of Profiles 1 and 2. The clay maximum in Profile 4 occurs in the B22t horizon of the buried soil. This value, however, was apparently achieved prior to burial, and the buried soil is largely unaffected by present illuvial processes as evidenced by the sharp clay decrease in the C horizon below the B21t.

The B21t is an argillic horizon by definition for sandy soils (Soil Survey Staff, 1975, p. 25). Evidence for clay illuviation is provided by clay skins on pebbles and clay bridges between sand grains.

The soil developed in the sediments of the high shore ridge is classified as a Typic Haplargid (Soil Survey Staff, 1975, p. 159 - 160). Profile development is more advanced than in the soils of the low and intermediate shore ridge by virtue of clay content and structure. Color may be slightly redder in the B horizon but carbonate in the C horizon is notably lacking in comparison to Profiles 1 and 2. This soil is regarded as exhibiting moderate profile development.

Soils in Alluvial Settings

A soil developed in fine-grained alluvium deposited in a interridge trough or swale is described in Profile 3 (Appendix III; Fig. 25). The A1 horizon is thicker than the A horizons of other soil profiles. The B2 and B3b horizons have subangular blocky structure, and the B3b is calcareous near its lower boundary. The C horizon is sandier than the overlying horizons. Exposed in the bottom of the pit is a reddish brown horizon of a paleosol. This buried soil is developed in gravelly alluvium and is presumably correlative with the soil in the lower part of Profile 4.

Figure 30a shows the vertical distribution of clay through Profile 3. The clay maximum of 33% occurs in the B2, below which there is a sharp decrease to almost 15% in the B3 and C horizons. The ratio of clay in the B2 and Al is 1.23, which is just sufficient to define an argillic horizon in the B2 position (Soil Survey Staff, 1975, p. 24). This is the definition used for medium-textured soils, but for consistent application the ratio should be higher. The definition also assumes isotropic or homogeneous parent material, with no lithologic discontinuity. Examination of textural data for this profile suggests lithologic discontinuities (Appendix III). Specifically, the sand and silt separates change irregularly with depth. This contrasts with the regular increase of sand and decrease of silt with depth in Profiles 1, 2, and 4 whose parent material more nearly approaches homogeneity. The size distribution of the sand separates from each horizon also suggests nonuniformity of parent material in Profile 3. The distributions of the Al and B2 are fine-skewed and have modes in very fine sand grade. The similarity suggests a genetic relation. However, the B3 is coarse-skewed with a mode in coarse and very coarse grades. The C horizon is the most poorly sorted and exhibits a weak bimodality. It is possible that these dissimilarities reflect depositional stratification and that the horizonation is not completely the result of pedogenesis.

The presence of buried soils is common in this setting in other areas where stronger color differences make identification easier. The B3b is regarded as a buried horizon here because of the textural difference between it and the overlying horizon, and because of the presence of carbonate at its base. It is unlikely that carbonate could have been translocated to a depth of 28 inches within a profile of this age and texture since the depth to carbonate is only 8 inches in coarser soils of presumed similar age but different geomorphic setting.

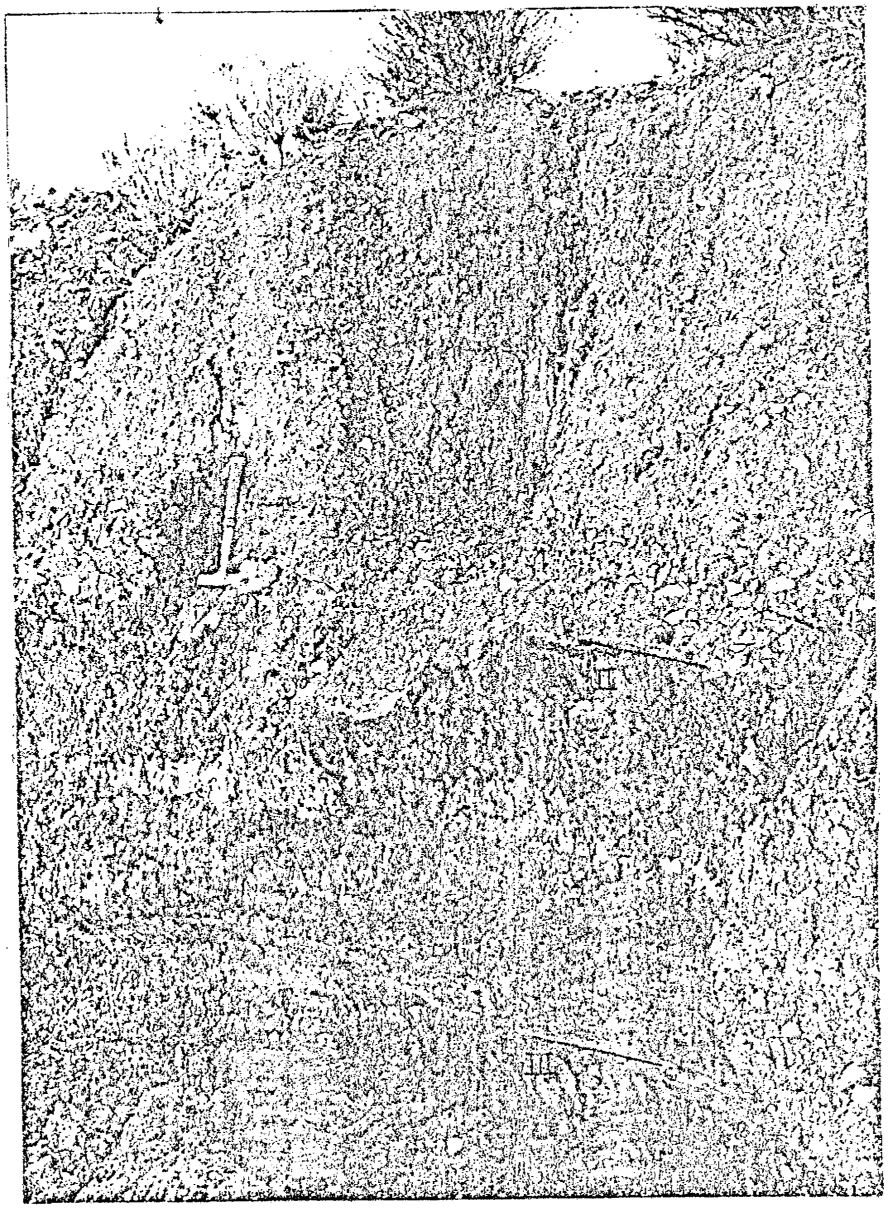
The classification of this soil is somewhat problematic owing to stratification and a buried soil. Though the B2 horizon has enough clay to qualify as an argillic horizon, it lacks the required evidences of illuviation. The development of soil structure in the B2 horizon, the lack of fine stratification, and a lower boundary deeper than 10 inches qualifies it as a cambic horizon. For this reason, the soil is considered to be a Camborthid. Profile development is weak.

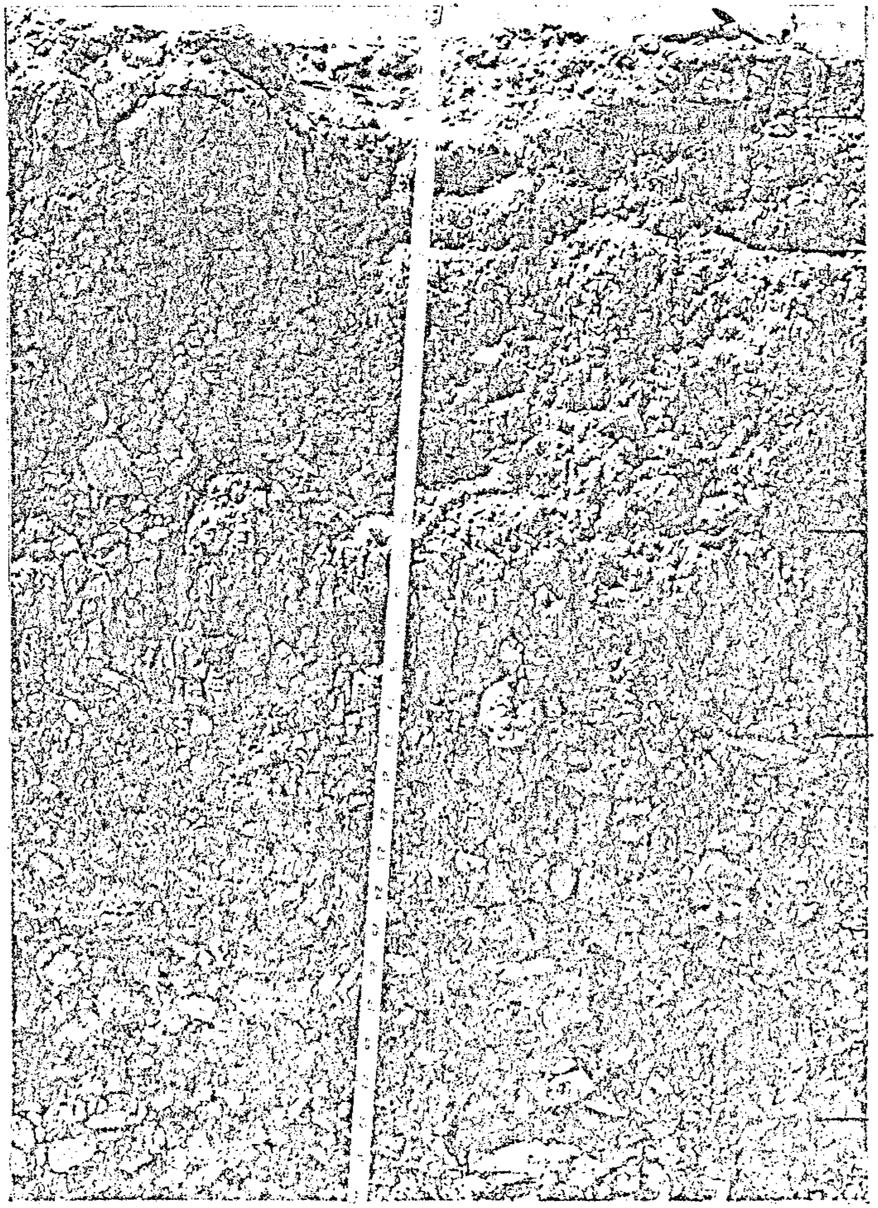
Profile 5 (Appendix II; Fig. 28) illustrates a soil developed in alluvium on a stable fan surface. The A1 horizon is thin and terminates abruptly over the B21 horizon. The B horizons are medium to moderately fine-textured and possess angular blocky and prismatic structure. Evidences of illuviation are few, consisting chiefly of a few clay films on pebbles and one or two cutans on ped faces. This is to be expected in soils of this texture due to the disruptive stresses generated by wetting and drying, and plant and animal activity (Gile and Grossman, 1968, p. 12 - 21). Figure 30b shows the vertical distribution of clay. A 14% increase occurs between the A1 and B21t, and a maximum of 35% occurs in the B23t which is also the horizon with prismatic structure.

The C horizon is marked by prominent accumulation of $CaCO_3$. Pebbles are continuously coated and some interpebble fillings occur. This development corresponds to a Stage II accumulation (Gile, and others, 1966). Local cementation of gravel by continuous carbonate filling may also occur.

Fig. 28. Profile 5, a Haplargid developed in alluvial fan sediments upslope from the high shore ridge of Lake Animas. Tick marks at right indicate approximate horizon boundaries. The lower part of this profile matches that of the buried soil in Profiles 4 and 6 (Appendix III). Scale is in inches.

Fig. 29. Profile 6, an exposure of the intermediate shore ridge at Loc. 12 (Plate I) showing a Camborthid developed in shore sediments, soil B (II), and soil A (III) (Appendix III).


II
III



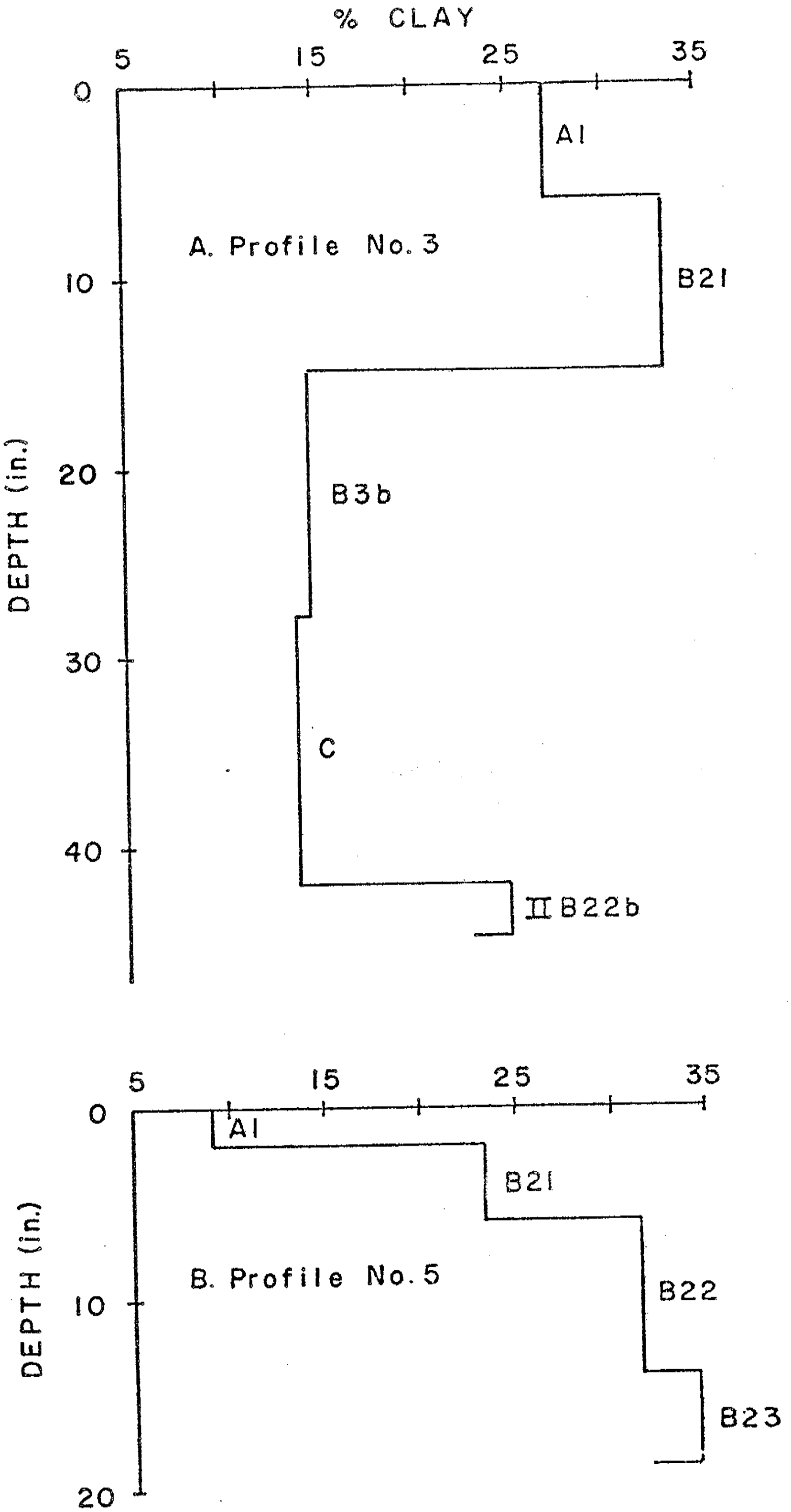


Fig. 30. Vertical distribution of clay in soils developed in alluvium. A. Profile 3 in inter-ridge trough. B. Profile 5 on surface of alluvial fan upslope from the high shore ridge.

This soil exhibits a strongly developed profile. The B21t, B22t, and B23t comprise the argillic horizon, and the Cca has enough carbonate to qualify as a calcic horizon. The soil is classified as a Typic Haplargid.

This soil exhibits a morphology similar to that buried by the high shore ridge (Profile 4) and the intermediate shore ridge (Profile 6). The buried soil in Profile 4 has an upper horizon with prismatic structure and 34% clay. This is almost identical to the B23t horizon of Profile 5. The IIB22b of Profile 6 also has prismatic structure. In all three profiles, the prismatic Bt horizon overlies a Cca. Thus, the fan surface continues beneath shore ridges. Of particular significance is that Profiles 4 and 6 indicate that the morphology of the soil of Profile 5 had been achieved prior to the rise of Lake Animas.

AGE AND CORRELATION OF LAKE ANIMAS

In the absence of suitable archeologic or paleontologic evidence to pinpoint the age of Lake Animas, an attempt was made to date the lake by comparing the morphology of soils developed in shoreline sediments with dated soils in the Las Cruces, New Mexico, area. Soil age provides a minimum age of parent material, and therefore, a minimum age of Lake Animas. The underlying assumption of the approach is that rates of soil formation in the two areas are approximately equal for soils in parent materials of similar texture and composition. The assumption is reasonable in this instance because of the proximity of Las Cruces to the Lordsburg area, a rough equivalence of latitude and altitide, and similar climate (Appendix IV) and geology. Furthermore, many of the soil series occurring in the study area also occur at Las Cruces (Maker and others, 1970; Maker and others, 1971), which reinforces the assumption of equal rates and possibly implies a similar climatic history.

Climate reconstructions have been made from studies of flora preserved in packrat (Neotoma) middens. These indicate that woodlands existed in desert lowlands of the Southwest about 8,000 years ago and that vegetation had been fairly stable for 30,000 years prior to that (Van Devender, 1976). Chihuahuan Desert vegetation consisted of pinyon-juniper woodlands to about 11,000 B.P., after which pinyon disappeared. From 11,000 - 8,000 B.P. juniper-oak woodlands were predominant, and were replaced by more xeric communities after 8,000 B.P. (Van Devender and Wiseman, in press).

Van Devender (1976) inferred more equable climates in southwestern deserts during the Pleistocene. Changes were not drastic and can be explained by a southward shift of the winter storm tract. The Mohave Desert may have lacked summer precipitation as it presently does and the Sonoran Desert probably had mixed summer-winter precipitation as at present. Annual precipitation in the Chihuahuan Desert may have been more equally distributed. Fauna and flora preserved in deposits of Howell's Ridge Cave in the Little Hatchet Mountains of New Mexico (Fig. 8) suggest wet conditions in the Playas Valley until 4,500 years ago, and again about 3,000 years ago and 1,100 - 500 years ago (Van Devender and Wiseman, in press).

Age-Significant Properties of Soils

One of the most time-sensitive properties of soils in arid regions is the degree of accumulation of calcium carbonate. Briefly, the sequence in gravelly material is: Stage I - thin, discontinuous coatings on pebbles; Stage II - continuous coatings on pebbles, some interpebble filling, and local cementation; Stage III - interpebble areas filled and horizon plugged; Stage IV - laminar horizons formed above plugged horizons (Gile, and others, 1966, p. 349 - 350). The sequence differs slightly in nongravelly parent material. In Stage I, thin filaments are formed and in Stage II, carbonate nodules are formed. Stage III and Stage IV morphology are analogous to those in gravelly material (Gile, and others, 1966, p. 352 - 353). Time for development and geomorphic setting at Las Cruces are summarized in Table 3.

Gile (1975) presented a chronology for the development of diagnostic horizons of Holocene soils at Las Cruces. A summary for low-carbonate parent material is given in Table 4, Argillic and cambic horizons can form in as little as 1,000 - 2,000 years and have been observed in the oldest and stablest parts of the Fillmore surface (Gile, 1975, p. 338). Argillic horizons form rapidly in gravelly parent material, but require more time in nongravelly material. Incipient argillic horizons in nongravelly Organ alluvium occur at the Isaack's radiocarbon site where dates of about 4,200 B.P. have been obtained (Gile, 1975, p. 346 - 350). In sediments greater than 7,000 years old, argillic horizons are continuous through facies changes from gravelly to nongravelly material.

Soil color is another age-significant property, but is of less dependability. In general, soils of arid regions become redder with age, as demonstrated by Walker (1967) in the Gulf of California region. Gile (1975, p. 338, 340) has noted that soils as red as 5YR form in rhyolite alluvium of Fillmore age. However, he observed that Holocene soils are not redder than this and do not have chromas as high as 4. Soils with hues as red as 2.5YR are invariably Pleistocene in age at Las Cruces (Gile, 1975, p. 350).

Soil Ages

Table 5 summarizes the age-significant properties of soils along the transect in Sec. 36, T23S, R21W (Profiles 1 - 5, Appendix III). Most shore ridge soils have hues of 10YR with slightly redder hues occurring in the high shore ridge. Colors redder than 7.5YR have not been observed in the shore ridges. Argillic horizons are found in the high shore ridge and cambic horizons are predominant in the lower shore ridges. Carbonate, for some reason, is best developed in the lower two shore ridges, but at best displays a Stage I morphology.

Shore ridge soils appear youthful, and of the three ridges, the highest has the best developed and oldest soil. Correlation with Gile's (1975) chronology of Holocene pedogenesis in the Las Cruces area suggests that the low and intermediate shore ridges may be less than 7,500 years old because of the Stage I carbonate morphology, and possibly less than 7,000 years old because they lack argillic horizons. They might be regarded as being at least 4,000 years old. The soils suggest a minimum age of 7,000 - 4,000 years for Lake Animas shore ridges.

Because of redness, degree of development of argillic horizon, and calcic horizon development, the soil of the fan surface in the transect area (soil B) is probably Late Pleistocene. The soil A at Loc. 16 might date from mid-Pleistocene on the basis of carbonate morphology (Gile, 1970). The soils of the inter-ridge trough are stratigraphically younger than the shore ridges and therefore must be younger than 7,000 - 4,000 B.P. if the shore ridge date is accurate.

Lacustral Chronology and Correlation

Radiocarbon dating of Quaternary lake deposits in the western United States has shown that the timing of fluctuations of lake levels are broadly similar, although they are not necessarily in phase. If stage fluctuations were controlled by regional trends in climate, then the timing of fluctuations of Lake Animas should have paralleled those in other western lakes. More specifically, the dates of high stages in other lakes are possible dates for the high stage of Lake Animas.

Studies of cores from Searles Lake, California, have revealed several stratigraphic units (Smith, 1962). From the surface downward these are: 1) overburden mud (30 feet), 2) upper salt (40 feet), 3) parting mud (14 feet), 4) lower salt (36 feet), 5) bottom mud (100 feet), and mixed layer (655+ feet). Mud layers indicate lacustral periods and saline layers indicate periods when the basin was occupied by saline or dry lakes (Smith, 1968, p. 295). Radiocarbon dates reported by Flint and Gale (1958) and Stuiver (1964) date the lower salt at 32,000 B.P. The lacustral interval represented by the parting mud began about 24,000 B.P. and ended about 10,000 B.P.

Studies by Smith (1968, p. 297 - 299) of shorelines and exposed lake sediments of Searles Lake suggest four lake rises separated by lower stages during the parting mud interval. The earliest of these filled the basin to overflow level just after 24,000 B.P. Secondary high levels peak just prior to 16,000 B.P. and just prior to 12,000 B.P. The 12,000 B.P. rise was followed by an abrupt recession. About 10,500 B.P. there occurred a rapid rise to overflow level. A Holocene lake existed from about 6,000 B.P. to 2,000 B.P. in which a depth of about 100 feet was achieved just after 4,000 B.P.

Lakes Bonneville and Lahontan existed during an interval from about 25,000 to 8,000 B.P. In the Lahontan basin, the lacustral period is represented by the Sehoo Formation from which six fluctuations have been identified on the basis of inter-fingering with subaerial sediments. In the Bonneville basin, the Bonneville and Drapper formations provide a record of the interval. Lake maxima occurred roughly 18,000 B.P., 14,000 - 13,000 B.P. and about 10,000 B.P. By 8,000 B.P., the lakes were dry, but post 5,000 B.P. lakes also occurred. In the Lahontan basin a maximum occurred about 3,500 B.P. during which the lake was 150 feet deep (Morrison and Frye, 1965).

Radiocarbon dating by Long (1966, p. 53) indicates that Lake Cochise, Arizona, existed from prior to 30,000 B.P. to 13,000 B.P. The lake was at low stage or dry from 13,000 B.P. to about 11,500 B.P. A post-11,500 B.P. rise followed, and by 10,000 B.P., Lake Cochise was dry.

Figure 31 summarizes the lacustral chronologies of the four lakes. Lake maxima occurred 18,000 - 16,000 B.P., 13,500 - 12,500 B.P., 10,500 - 10,000 B.P. and 4,000 - 3,500 B.P. These may be regarded as probable periods during which the Lake Animas maximum occurred.

The 7,000 - 4,000-year minimum age estimated from the soil morphologies on the low and intermediate shore ridges includes an interval during which lakes existed in the western United States, and it is an interval during which a small permanant lake may have existed in the Playas Valley. However, dated lake maxima fall around 4,000 B.P., a date that seems too young for the soil of the high shore ridge. The widespread occurrence of the 10,500 - 10,000 B.P. lacustral event is hard to ignore as a possibility. Rises much older than this seem unlikely on the basis of soils.

In conclusion, the age of Lake Animas is still in question. The high shore ridge is probably no older than latest Wisconsinan. The low and intermediate shore ridges are possibly middle Holocene in age.

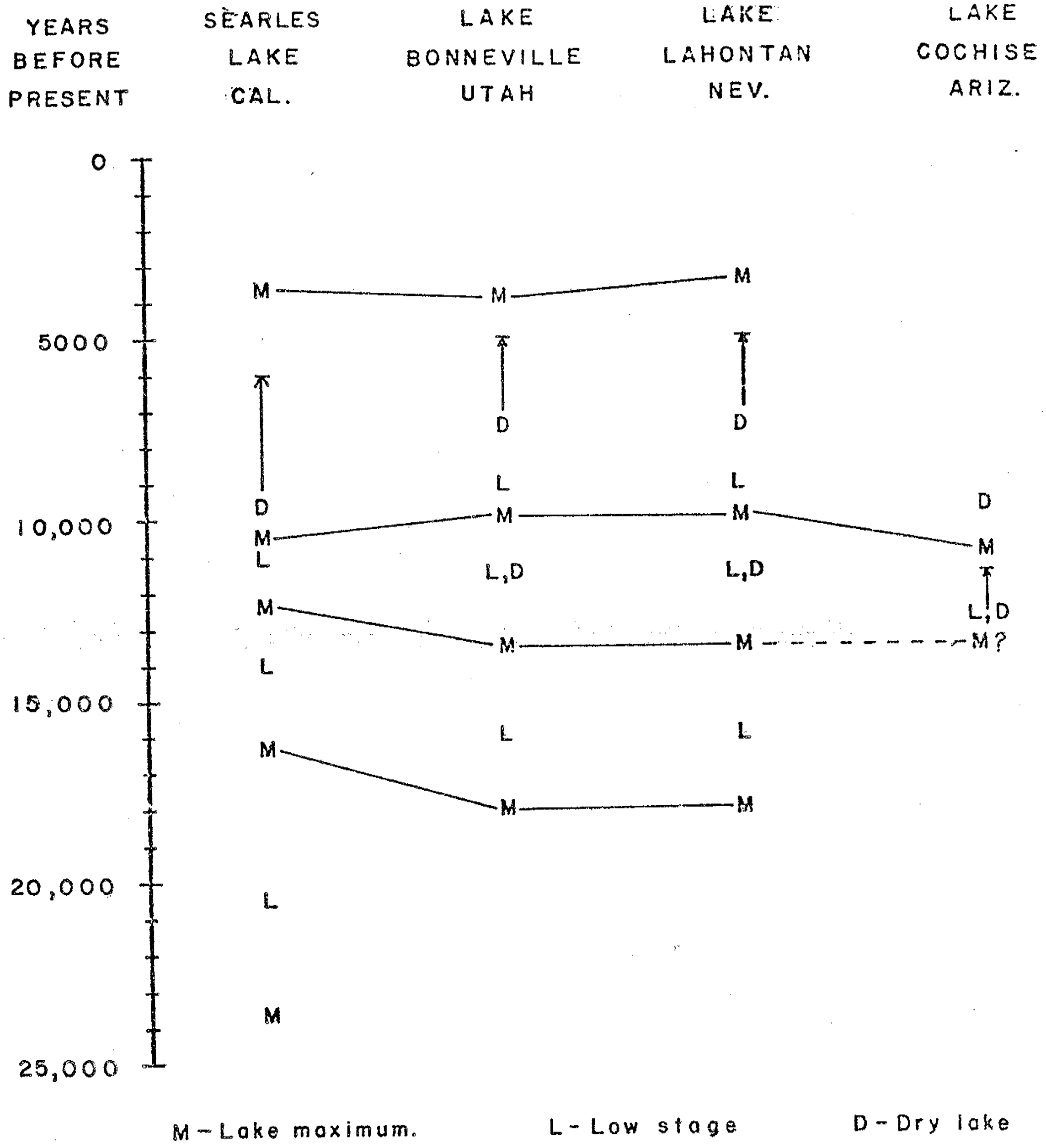


Fig. 31. Chronology and correlation of lake maxima in the western United States. The late Wisconsinan lacustral interval extended from 24,000 to 10,000 B.P. with maxima occurring 18,000 -16,000 B.P., 13,500 - 12,500 B.P., 10,500 - 10,000 B.P. Holocene maxima occur about 4,000 - 3,500 B.P.

CONCLUSIONS

Soil A is the oldest stratigraphic unit recognized and is the second buried soil beneath shore sediments. Colors are reddish brown (5YR) and the most prominent characteristic is mottling produced by spheroid and cylindroid calcium carbonate nodules. Southward along the west shore, this soil becomes more calcic. Though not traced to a definite landsurface position, a possible correlative surface exists in the southwest part of the study area where Typic Paleorthids occur.

Overlying soil A is soil B, a Typic Haplargid which formed on the pre-lake surface of the piedmonts. The soil, which is buried by the shore sediments of Lake Animas, exists as a surface soil immediately upslope from the high shore ridge and comprises most of the Qfo map unit. The piedmonts of the Pyramid and Peloncillo mountains are therefore largely relict features.

Three stages are represented by shoreline features of Lake Animas. Stage elevations derived from the elevation of the landward margins of the shore ridges are: 1) high stage - 4193 feet, 2) intermediate stage - 4185 feet, 3) low stage - 4175 - 4180 feet. The high shore ridge lies at nearly identical elevations on both sides of the valley which negates post-lacustral movement between the Peloncillo and Pyramid mountains. The lower shore ridges vary in elevation along their lengths and between opposite sides of the valley, but this variation is apparently the result of environmental conditions extant during the lacustral interval.

Beach deposits generally consist of homogeneous sandy gravel. The homogeneity is apparently a result of pedogenesis for in thicker sections, these sediments display horizontal orientation of clasts giving the aspect of stratification. Beach deposits are typically less than 4 feet thick and comprise most of the high and intermediate shore ridges. The sediments comprising the low shore ridge vary in thickness from 3 feet to more than 10 feet. Thicker sections indicate a vertical sequence of several depositional environments beginning with offshore or deep water sediments followed by longshore bar deposits. The latter are characterized by a single set of cross-stratified sand and gravel sometimes more than 5 feet thick. Cross-strata dip in a landward direction although the dip directions are oblique to the trend of the shore ridges. Such structures closely resemble those produced in wave-tank experiments of McKee and Sterrett (1961). Longshore bars of Lake Animas were presumably sub-aqueous and produced largely by wave action although the influence of currents is indicated by dip components parallel to shore. Beach deposits occupy the uppermost position in the sequence.

The sequence of environments in the low shore ridge indicates a progressive shallowing, i.e., the lake rose to high level and then receded with temporary stabilization at the position of the intermediate and low shore ridges. Although fluctuations certainly occurred, they were not of sufficient magnitude or duration to leave a record.

A comparison of soils in the shore ridges indicate that the high shore ridge is the oldest. Haplargids have developed here and Camborthids dominate the intermediate and low shore ridges. Profile development of shore ridge soils is weak to moderate. Carbonate has a stage I morphology and colors are dominently 10YR with slightly redder hues occurring in the high shore ridge. The youthful morphology of shoreline soils suggests a minimum age of 7,000 - 4,000 years through comparison with dated soils of the Las Cruces area. A well documented rise of closed lakes in the West and Southwest occurs during the latter part of this interval, partly confirming the age as a reasonable estimate. However, most lakes in the western United States experienced a final rise to high levels centering about 10,500 B.P. If, for some reason, rates of soil formation were slower here than at Las Cruces, this may be a reasonable date. It is considered unlikely at the present time that Lake Animas could be much older than this, and its age is tentatively assigned as latest Wisconsinan to middle Holocene. Although older lakes probably existed in the Lower Animas Valley, associated shore features are not preserved.

Appendix I

List and Description of Localities

Locations and descriptions of areas mentioned in the text are presented. The type of deposits examined are listed as fluvio-deltaic, lacustrine, or alluvial for each locality. Following this is the location and a one-sentence description of the locality. References to figures and other appendices are also included, and each locality is identified on Plate I. Units in measured sections for which there are particle-size analyses are indicated by "sieve analysis" at the end of the unit description, and the reader should refer to Appendix II for these data. Numbering of units in measured sections follows the depositional sequence, i.e. 1 is the oldest and lowest unit, with unit numbers increasing upward through the sequence. Locality 2 is a sampling locality and the numbering is the reverse.

<u>Locality 1</u> - Fluvio-deltaic. Small gravel pit along north side of road to McCants Ranch, 2.2 miles west of Valley View Church, SW1/4 SE1/4 SE1/4 Sec. 5, T25S, R20W. Exposes fluvial, sandy gravel in base of pit, overlain by brown pebbly soil.

<u>Locality 2</u> - Fluvio-deltaic. South wall of east side of gravel pit east of NM 338, about 1 mile north of Valley View Church, SW1/4 SE1/4 Sec. 35, T24S, R20W. Fluvial sand and gravel were sampled for sedimentologic analysis (Appendix II). Sampling stations are briefly described below.

Station 1

Unit	Description
1-1	soil.
1-2	1.3' pebbly sand.
1-3	4.8' sandy pebble gravel to base of exposure. Sieve analysis.

Station 2

Unit	Description
2-1	soil.
2-2	1.1' pebbly sand.
2-3	5.8' sandy pebble gravel to base. Sieve analyses for upper (2-3A) and lower (2-3B) parts of unit.

Station 3

Unit	Description
3-1	soil.
3-2	1.5' pebbly sand.
3-3A	2' sandy pebble gravel correlative with the upper 2' of 2-3.
3-4B	0.3' sand; horizontally laminated with heavy mineral placers; slightly graded. Sieve analysis.
3-4C	1.8' sand; faintly ripple-laminated; ripple sets 0.5" thick; parallel, nearly horizontal set boundaries. Sieve analysis.
3-4D	0.8' silt.
3-3B	0.8' sandy gravel to base, correlative with lower part of 2-3.

Locality 3 - Lacustrine. Gully on east side of low shore ridge, approximately 0.25 mile north of where Mansfield Wash crosses the low shore ridge, NE1/4 NW1/4 NW1/4 Sec. 18, T24S, R19W. Exposes lacustrine sand and gravel overlying a paleosol, and fine-grained alluvium of Qfy (Profile 7, Appendix III).

Unit	Description
6	4.7' gravelly medium sand, sand moderately sorted. Median gravel consists of pebbles with maximum dimension of 1". Largest clast measures 3.5" X 3" X 2". Gravel content decreases downward and lower part is vaguely stratified. Sieve analysis.
5	0.3' soft calcareous mud or calcium carbonate.
4	1' sandy gravel. Sand fraction similar to unit 6. Median gravel has maximum dimension of about 0.5". Largest clast measures 3.75" X 1.5" X 1".
3	0.2' soft calcareous mud or calcium carbonate.
2	0.5' slightly gravelly, medium sand, possibly bimodal coarse and very fine. Gravel consists of small pebbles.
1 base	Muddy sand. Reddish brown (5YR 5/4); angular blocky structure. Paleosol.

Locality 4 - Lacustrine. Exposure of low shore ridge on north bank of Banner Canyon about 0.75 mile south of pipeline road, SW1/4 SE1/4 Sec. 19, T23S, R19W. Exposed are about 10' of lacustrine sediments overlying a paleosol, fine-grained alluvium of Qfy, and a remnant of the intermediate shore ridge (Figs. 10, 11; Appendix II).

Unit	Description
6	3.3' gravelly coarse sand, poorly sorted. Gravel consists of angular to rounded pebbles and cobbles, some with coatings of carbonate. Homogeneous. Sieve analysis.
5	2.1' muddy sand or sandy mud, light gray (10YR 7/2). Upper 0.5' has angular blocky structure and is somewhat finer than the rest of the unit. Meager snail fauna is present.

4	1' gravelly coarse sand, moderately sorted. Sand is loose and non-coherent due to lack of clay. This unit is homogeneous except for the basal part where pebbles and granules have normal graded bedding. Sieve analysis.
3	0.75' on west of outcrop thickening to 2.2' on east end sandy gravel and gravelly coarse sand; sand poorly sorted. Cross-stratified. Cross-strata are generally concave up, tangential to base of unit, and have high degree of lateral continuity, one lamina being traceable for 15'. Thickness of cross-strata ranges from 0.25" to 6", with strata generally becoming thicker landward (east). Thicker cross-strata consist of gravel. Thinner ones are defined by alternating coarse and fine textures, and in some instances are enhanced by rust-colored stains. Sieve analyses - 3(A) from gravelly part and 3(B) from sandy part. Paleocurrent measurements.
2	2' on west end of outcrop, thinning to 0.5' near middle, silty very fine sand; thinnly bedded, 1-2" thick. Light gray.
1 base	Paleosol. Upper surface has lag of cobbles and pebbles. Color hue is 5YR.

Paleocurrent data (unit 3)

Dip Direction	Dip Angle.
N76°E	24°
N73°E	20°
S35°E*	6°

*From cross-stratification within a thicker cross-bed.

Locality 5 - Lacustrine. Roadcut through low shore ridge on south side (east-bound lane) of Interstate 10, SW1/4 NE1/4 Sec. 18, T23S, R19W. Stratified sand and gravel of low shore ridge overlie a paleosol. Silty unit in upper part of shore ridge contains a molluscan fauna.

Unit	Description
6	3+' gravelly sand. Gravel is angular, poorly sorted. Base has a 2" layer of brown sand.
5	0.8' silty very fine sand or sandy mud with a minor amount of pebbles. Lower part consists of very fine sand and becomes finer upward. Upper part has blocky structure. Snail fauna consists largely of <u>Succinea</u>.
4	2' sandy gravel or gravelly sand. Sand is very coarse- to very fine-grained with mode in medium grade. Gravel angular to subangular; smaller clasts are rounded. Platy gravel horizontally oriented.
3	1' coarse sand and silty, very fine sand, thinly bedded. Lower part consists of coarse sand layers 2 - 3" thick with thinner layers of fine sand. Upward, the coarse sand strata decrease to 1" thick and fine sand strata increase to 3" thick.
2	1' gravelly, medium sand, poorly sorted.
1 base	1.4' sandy, muddy gravel with 5YR color. Contains soft white calcium carbonate. Paleosol.

<u>Locality 6</u> - Lacustrine. North bank of gully cutting through low shore ridge just north of Interstate 10 and south of gravel pits, SW1/4 NW1/4 NE1/4 Sec. 18, T23S, R19W (Fig. 12).

Unit	Description
3	2' muddy, sandy gravel. Gravel consists of pebbles, moderately sorted, angular to rounded, with median diameter 0.5 - 1". Largest clast measures 2" X 1" X 1". Sand is coarse-grained, moderately sorted. Mud is reddish brown (5YR - 7.5 YR) and forms coating on pebbles; it may not be part of original deposit. Unit is cross-stratified with cross-strata dipping landward, concave, tangential to base.
2	1' clay, light gray. Contains gastropod fragments and ostra-

	codes.
1 base	5+', sand and muddy, cobble-boulder gravel. Gravel occurs in beds, lenses, and stringers separated by muddy units, and was deposited in arroyo channels. Gravel is partly cemented by calcium carbonate. Older alluvial fan sediments.

Locality 7 - Lacustrine. Gravel pits in low shore ridge, north of Interstate 10 and southwest of Gary, SW1/4 SW1/4 SE1/4 Sec. 7, T23S, R19W. Exposes cross-bedded sand and gravel. Sample profile is given below (Appendix II).

Unit	Description
3	1.6' sandy gravel. Sand is medium-grained and poorly sorted. Horizontal stratification produced by parallel alignment of platy gravel. Sieve analysis.
2	1.5' interbedded sand, sandy gravel, gravelly sand. Sand is coarse to medium-grained, poorly sorted. Contains two thin layers 0.5" thick of calcium carbonate of calcareous mud. Horizontally stratified, truncating unit below. Sieve analyses 2(A) and 2(B) from two sandy gravel beds.
1 base	2' to base of exposure, sandy gravel and gravelly sand. Sand is coarse-grained, poorly sorted. Gravel consists of pebbles, angular to rounded, with smaller pebbles better rounded. Cross-stratified. Individual beds range from 2.5 - 4" thick and have vague boundaries. Sieve analysis.

Note. In places, a grayish mud containing sparse snail fauna overlies unit 3. This mud is correlated with unit 5 of Locs. 4 and 5.

Paleocurrent measurements were obtained from several places in the gravel pits. Cross-strata range from 1/4" - 9" thick and generally become thicker to the north. Boundaries between strata range from well defined to poorly defined, and individual layers of sand of gravel may be separated by thin layers of clay. Exact thickness of the cross-stratified unit is not known due to poor exposure but it does exceed 5 feet.

Paleocurrent Data

Dip Direction	Dip Angle	Dip Direction	Dip Angle	Dip Direction	Dip Angle
N79°E	33°	N76°E	26°	N81°E	31°
N78°E	34°	N82°E	32°	N82°E	34°
N74°E	28°	S80°E	34°	N81°E	34°
N69°E	29°	N76°E	32°	N72°E	31°
N68°E	29°	N66°E	23°	S88°E	29°

Locality 8 - Lacustrine and alluvial. Small gully cutting through low and intermediate shore ridges, west of Fox Windmill and about 0.5 mile north of railroad tracks, NE1/4 Sec. 7, T23S, R19W. Exposes sediments of the low and intermediate shore ridges, paleosols developed in older fan alluvium, and younger alluvial sediments.

Description

Intermediate shore ridge sediments consist of about 3.8' of homogeneous slightly muddy, gravelly sand. These overlie a paleosol (soil B) developed in fan alluvium. The paleosol has a high clay content, a reddish brown (5YR) color, and calcium carbonate coatings on pebbles. In less gravelly parts, prismatic structure is developed and calcium carbonate occurs in nodules.

The paleosol may be traced downstream to the low shore ridge where less than 3 feet of beach sediments overlie it. Beneath this paleosol is a still older one (soil A) with similar texture, color, and morphology but separated by obvious disconformity.

Fine-grained alluvium is inset against the low shore ridge and fills ancient channels cut into the paleosol.

Locality 9 - Lacustrine. South bank of gully cutting through low shore ridge about 1.2 miles north of railroad tracks, north half of SE1/4 NE1/4 Sec. 6, T23S, R19W. Exposes shore ridge sediments and two paleosols.

Unit	Description
3	2' slightly muddy, gravelly sand. Shore ridge sediments.

2	4 - 5' sandy gravel, muddy sand, and gravelly mud. Gravel ranges up to boulders. Upper part has prismatic structure and soft caliche. Lower part is crudely stratified. Overlies unit 1 with erosional disconformity and gravel fills depressions cut into it. Paleosol (soil B).
1 base	3 - 4' sandy gravel and muddy sand. Color is reddish brown (5YR) and mottled by calcium carbonate nodules, spheroid and cylindroid. Gravel is mostly pebbles, ranging up to cobble size, and is finer than gravel in unit 2. Paleosol (soil A).

<u>Locality 10</u> - Lacustrine. West side of low shore ridge where Rustler Draw cuts through, about 1.2 miles east of New Tank and 1.1 miles north-northeast of Braidfoot Tank dam, NE1/4 SE1/4 Sec. 13, T23S, R21W. Exposes offshore mud and sand.

Unit	Description
9	3.5+' gravelly, coarse sand, poorly to moderately sorted. Gravel consists of pebbles and cobbles. Base of unit horizontally laminated.
7	3" sandy silt or silty very fine sand, light gray (2.5Y 7/2).
6	1" clay or silty clay, light gray (2.5Y 7/2), subangular blocky structure. Top and bottom wavy; uniformly thick.
5	2" silty fine sand, light gray (2.5Y 7/2).
4	6" very fine sandy silt, light gray (2.5Y 7/2), occurring in 3 beds about 2" thick and separated by 0.25" thick clay seams. Horizontal laminations are visible in the uppermost 2" bed.
3	0.5" clay, pale yellow (5Y 7/3), very fine angular blocky structure.
2	0.5" silty very fine sand, light gray (10YR 7/2).
1 base	2' clayey silt, basal part light gray (10YR 7/2), hue becoming yellower toward the top. Basal part has subangular blocky structure; upper part is astructural, massive. Possibly a paleosol (gleyed ?) of pre-lake surface.

<u>Locality 11</u> - Lacustrine. Gully cutting through low shore ridge 0.6 mile north-northeast of dam of Braidfoot tank, SE1/4 SW1/4 SE1/4 Sec. 13, T23S, R21W and NE1/4 NW1/4 NE1/4 Sec. 24, T23S, R21W. Exposes shore ridge sediments overlying a paleosol developed on fan alluvium. Section is a composite of both sides of the gully (Fig. 13).

Unit	Description
5	4.2' sandy gravel or gravelly sand showing soil development.
4	3' sandy gravel or gravelly sand, gravel content increasing upward. Sand is medium to coarse-grained, poorly sorted. Gravel consists of pebbles and cobbles; largest clast measures 4.5" X 2.5" X 2". Many are somewhat platy or bladed and oriented parallel to each other. Also present are discontinuous, textural laminations. These and platy gravel have a gentle dip of about 10° on the south side and appear horizontal on the north side. Paleocurrent measurements have a mean of about N65°W.
3(B)	1' slightly pebbly sand, coarse- to medium-grained, moderately to poorly sorted; fine, horizontal to inclined laminae of alternating sand and fine pebbles and granules. Abrupt lower boundary.
3(A)	1' sandy silt mud, pink to pinkish gray (7.5YR 7/3); calcareous with slight effervescence. No internal sedimentary structures. Lakeward, (east) 3A and 3B become difficult to distinguish, and together they thicken to 3.3'. At this point, unit 3 is dominantly a sandy silt with 1" laminae of sand and zones of pebbly mud. Also present are tubiform accumulations of calcium carbonate, 1/8" in diameter, resembling roots. Possibly algal.
2	1.5' sandy mud. Upper part is pale yellow (5Y 8/3D), grading downward to light reddish brown (5YR 6/3D); no mottling is present. Has strong, medium blocky structure and medium prismatic structure. Calcareous with slight effervescence, and contains discrete concentrations of powdery white calcium

	carbonate. This is apparently the argillic horizon of a soil on the pre-lake surface. Color change to yellower hue may represent reducing of iron under subaqueous conditions.
1 base	4.2' muddy, sandy gravel. Gravel ranges up to boulder size, angular and subangular, and occurs in lenticular and channel-form bodies. Most clasts have coatings of calcium carbonate. Fan alluvium and arroyo channel sediments.

<u>Locality 12</u> - Lacustrine and alluvial. Gully cutting through low and intermediate shore ridges, south of fence-line and about 0.6 mile northwest of Robinson Windmill, NE1/4 SW1/4 Sec. 36, T23S, R21W. Displays stratigraphic relations of lacustrine sediments and paleosols (Figs. 14, 29; Profile 6, Appendix III).

Description

About 3.1' of slightly muddy, gravelly sand of the low shore ridge overlie the argillic horizon of a paleosol. The same soil is also overlain by about 3.5' of similar-textured sediments comprising the intermediate shore ridge. The paleosol (soil B) is characterized by prismatic and angular blocky structure and a 5YR color hue, and is developed in fan alluvium. Beneath this is an older paleosol (soil A) with similar color but containing prominent nodules of calcium carbonate.

<u>Locality 13</u> - Lacustrine. Small gully cutting through intermediate shore ridge, south of road, and about 0.6 mile east of Robinson Windmill, SE1/4 SW1/4 Sec. 36, T23S, R21W. Exposes gravelly sediments overlying offshore or quiet water silt (Fig. 16).

Unit	Description
3	4' sandy gravel or gravelly sand, homogeneous with soil development. Lower part (parent material) lacks silt and clay.
2	Medium sand, poorly to very poorly sorted, containing some pebbles.
1 base	Silty very fine sand or sandy silt, pinkish gray to pink

(7.5YR 7/3), calcareous; thin, parallel, horizontal laminae containing tubiform calcium carbonate nodules about 1/8 - 1/4" thick resembling roots.

Total thickness of section is about 7'. About 50 yards to the south, the gravelly sand of unit 3 directly overlies a paleosol developed in fan alluvium and has thinned to about 3'.

Locality 14 - Alluvial. Small gully breaching low shore ridge about 0.7 mile southwest of Robinson Windmill and 0.4 mile northwest of where railroad crosses low shore ridge, NW1/4 NW1/4 NW1/4 SE1/4 Sec. 1, T24S, R21W. Vertical sequence of alluvial soils exposed.

Description

Four soils developed in alluvial sediments are exposed in gully walls. Two pre-date Lake Animas and two post-date it. The oldest (soil A) is marked by a K2 horizon (Stage III carbonate accumulation) developed in gravel and an overlying Bca. The Bca has reddish brown color (5YR 5/4) and carbonate nodules. This soil is overlain unconformably by gravelly alluvium with another well-developed soil (soil B). This soil likewise has 5YR hues but has only a Stage II accumulation with local cementation. Some stratification is observable in the parent material. The younger two soils are developed in sandy gravel and muddy alluvium. Colors have 7.5YR hues and the soils lack prominent accumulations of calcium carbonate. These soils thin upslope and presumably pinch out so that soil B is at the surface.

Locality 15 - Lacustrine. Railroad cut through low shore ridge on south side of tracks, northeast of Road Forks, SE1/4 SE1/4 Sec. 1, T24S, R21W. Sandy lacustrine shore deposits with lakeward dipping cross-strata. Paleocurrent measurements. Sieve analysis.

Paleocurrent Data

Dip Direction	Dip Angle
N20°E	7°
N15°E	7°

Measurements are from laminae, 0.25 to 2.25" thick, in very well sorted, medium-grained sand. This is the only locality where lakeward dip is observed.

Locality 16 - Lacustrine. Small gully cutting through high shore ridge 0.4 mile north of pipeline road, near orange pipe marker, NE1/4 SE1/4 Sec. 12, T24S, R21W. Exposes high shore ridge sediments and two paleosols (Fig. 16).

Unit	Description
5	3' slightly gravelly, muddy sand, poorly sorted, homogeneous. Modified by pedogenesis. Base is sharp, even, horizontal.
4	0.25' muddy sand. Very hard, almost indurated. Non-calcareous.
3	1' slightly gravelly, muddy sand. Exhibits angular blocky and prismatic structure. Paleosol (B horizon, soil B).
2	1.3' slightly muddy, sandy gravel. Gravel consists of angular to subangular pebbles and cobbles with calcium carbonate coatings (C horizon, soil B).
1 base	1.0 - 1.5' to floor of gully, conglomerate, cemented by calcium carbonate. This is regarded as an older paleosol and possibly correlates with the oldest soil of Loc. 14 (soil A).

Locality 17 - Lacustrine. Gully cutting through low shore ridge 0.4 mile south of pipeline road, SW1/4 NW1/4 Sec. 18, T24S, R20W. Exposes landward-dipping, cross-stratified sand and gravel (Fig. 17). Paleocurrent measurements. Sieve analysis.

Description

Shore sediments are about 7' thick but only lower half is exposed. Sediments are dominantly sand and sandy gravel forming cross-strata. Cross-beds average 3" - 5" and range up to 7" and possibly 11" and 12". Internally, they may be either homogeneous or laminated. Internal laminations are 0.5" to 1" thick and consist of alternating coarse sand, fine pebbles, and granules with gradational boundaries between different textures. Cross-beds terminate both abruptly and tangentially to the base of the unit. Sand in the sand layers is medium-grained and moderately sorted.

Paleocurrent Data

Dip Direction	Dip Angle
S53°W	26°
S48°W	24°
S53°W	31°

Appendix II

Data from Sieve Analyses

Data from analyses of the sand fractions of fluvio-deltaic, lacustrine, and alluvial sediments are presented. Each locality and unit are described in Appendix I, except for AF samples. These are grab samples from an ephemeral stream channel in a modern alluvial fan (Sec. 36, T23S, R21W). Analytical procedures and statistical parameters employed are outlined in Folk (1974). Abbreviations of statistical parameters are:

Mo - mode
Md - median
Mz - inclusive graphic mean
Si - inclusive graphic standard deviation (sorting)
Ski - inclusive graphic skewness
Kg - inclusive graphic kurtosis

Statistics which could not be calculated are indicated by "N.C." (not calculated). These are limited to samples for which the 5 and/or 95 percentiles could not be obtained from the distribution for use in the formulas. Representative cumulative frequency distribution curves are shown in Figs. 19 and 20. A plot of sorting versus mean grain size is shown is Fig. 21.

0	mm	Wentworth grade
-1	2	
		very coarse sand
0	1	
		coarse sand
1	0.5	
		medium sand
2	0.25	
		fine sand
3	0.125	
		very fine sand
4	0.062	

Locality 2 Unit 1-3 Remarks Fluvio-deltaic

Mo 1.750 Md 1.250 Mz 1.29 Si N.C. Ski N.C. Kg N.C.

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.92	2.92	3.97	3.97
-0.50	3.06	5.98	8.13	4.16
-0.25	2.92	8.90	12.10	3.97
0.00	2.96	11.86	16.13	4.02
0.25	3.41	15.27	20.76	4.64
0.50	4.40	19.67	26.74	5.98
0.75	3.71	23.38	31.79	5.04
1.00	7.13	30.51	41.48	9.69
1.25	6.62	37.13	50.48	9.00
1.50	6.47	43.60	59.27	8.80
1.75	7.46	51.06	69.42	10.14
2.00	4.66	55.72	75.76	6.34
2.25	2.66	58.38	79.37	3.62
2.50	2.59	60.97	82.90	3.52
2.75	1.53	62.50	84.98	2.08
3.00	1.22	63.72	86.63	1.66
3.25	0.56	64.28	87.40	0.76
3.50	0.44	64.72	87.99	0.60
3.75	0.47	65.19	88.63	0.64
4.00	0.30	65.49	89.04	0.41
Pan	8.06	73.55	100.00	10.96

Locality 2 Unit 2-3A Remarks Fluvio-deltaic

Mo 1.000 Md 1.250 Mz 1.250 Si N.C. Ski N.C. Kg N.C.

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	3.84	3.84	5.85	5.85
-0.50	3.21	7.05	10.74	4.89
-0.25	3.06	10.11	15.41	4.66
0.00	3.03	13.14	20.03	4.62
0.25	3.24	16.38	24.97	4.94
0.50	3.88	20.26	30.88	5.91
0.75	3.26	23.52	35.85	4.97
1.00	5.92	29.44	44.87	9.02
1.25	5.00	34.44	52.49	7.62
1.50	4.86	39.30	59.90	7.41
1.75	5.76	45.06	68.68	8.78
2.00	4.00	49.06	74.78	6.10
2.25	2.44	51.50	78.49	3.72
2.50	2.15	53.65	81.77	3.28
2.75	1.47	55.12	84.01	2.24
3.00	1.10	56.22	85.69	1.68
3.25	0.54	56.76	86.51	0.82
3.50	0.44	57.20	87.18	0.67
3.75	0.50	57.70	87.94	0.76
4.00	0.29	57.99	88.39	0.44
Pan	7.62	65.61	100.00	11.61

Locality 2 Unit 2-3B Remarks Fluvio-deltaic

Mo 1.000 Md 1.000 Mz 0.920 Si 1.450 Ski 0.12 Kg 1.75

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	4.81	4.81	6.73	6.73
-0.50	4.09	8.90	12.45	5.72
-0.25	3.79	12.69	17.76	5.30
0.00	3.87	16.56	23.17	5.41
0.25	4.12	20.68	28.94	5.76
0.50	5.28	25.96	36.32	7.39
0.75	4.82	30.78	43.07	6.74
1.00	8.63	39.41	55.14	12.07
1.25	6.70	46.11	64.52	9.37
1.50	5.62	51.73	72.38	7.86
1.75	5.72	57.45	80.38	8.00
2.00	3.52	60.97	85.31	4.93
2.25	1.98	62.95	88.08	2.77
2.50	1.54	64.49	90.23	2.15
2.75	0.89	65.38	91.48	1.25
3.00	0.54	65.92	92.23	0.76
3.25	0.24	66.16	92.57	0.34
3.50	0.15	66.31	92.78	0.21
3.75	0.15	66.46	92.99	0.21
4.00	0.10	66.56	93.13	0.14
Pan	4.91	71.47	100.00	6.87

Locality 2 Unit 3-4A Remarks Fluvio-deltaic

Mo 1.750 Md 1.500 Mz 1.500 Si 0.520 Ski 0.07 Kg 1.43

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	0.08	0.08	0.13	0.13
-0.50	0.12	0.20	0.33	0.20
-0.25	0.16	0.36	0.59	0.26
0.00	0.25	0.61	1.00	0.41
0.25	0.37	0.98	1.60	0.61
0.50	0.81	1.79	2.93	1.33
0.75	1.25	3.04	4.97	2.05
1.00	4.76	7.80	12.76	7.79
1.25	8.75	16.55	27.08	14.32
1.50	12.13	28.68	46.93	19.85
1.75	15.76	44.44	72.72	25.79
2.00	8.25	52.59	86.06	13.50
2.25	3.37	56.06	91.74	5.51
2.50	2.46	58.52	95.76	4.03
2.75	1.09	59.61	97.55	1.78
3.00	0.67	60.28	98.64	1.10
3.25	0.25	60.53	99.05	0.41
3.50	0.13	60.66	99.26	0.21
3.75	0.11	60.77	99.44	0.18
4.00	0.07	60.84	99.56	0.11
Pan	0.27	61.11	100.00	0.44

Locality 2 Unit 3-4B Remarks Fluvio-deltaic

Mo 2.500 Md 2.500 Mz 2.500 Si 0.550 Ski 0.13 Kg 1.30

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00
-0.25	0.01	0.01	0.02	0.02
0.00	0.02	0.03	0.06	0.04
0.25	0.01	0.04	0.08	0.02
0.50	0.02	0.06	0.12	0.04
0.75	0.03	0.09	0.18	0.06
1.00	0.09	0.18	0.36	0.18
1.25	0.09	0.27	0.54	0.18
1.50	0.37	0.64	1.28	0.74
1.75	1.75	2.39	4.79	3.50
2.00	4.57	6.96	13.94	9.15
2.25	5.69	12.65	25.33	11.39
2.50	10.43	23.08	46.22	20.89
2.75	9.38	32.46	65.00	18.78
3.00	8.27	40.73	81.56	16.56
3.25	3.53	44.26	88.63	7.07
3.50	2.11	46.37	92.85	4.23
3.75	1.54	47.91	95.94	3.08
4.00	0.66	48.57	97.26	1.32
Pan	1.37	49.94	100.00	2.74

Locality 2 Unit 3-4C Remarks Fluvio-deltaic

Mo 2.500 Md 2.000 Mz 2.00 Si 0.790 Ski -0.05 Kg 1.13

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	0.22	0.22	0.43	0.43
-0.50	0.22	0.44	0.86	0.43
-0.25	0.29	0.73	1.43	0.57
0.00	0.34	1.07	2.10	0.67
0.25	0.43	1.50	2.94	0.84
0.50	0.67	2.17	4.25	1.31
0.75	0.92	3.09	6.05	1.80
1.00	1.95	5.04	9.87	3.82
1.25	2.43	7.47	14.63	4.76
1.50	3.22	10.69	20.94	6.31
1.75	5.38	16.07	31.48	10.54
2.00	7.43	23.50	46.03	14.55
2.25	6.93	30.43	59.61	13.57
2.50	8.47	38.90	76.20	16.59
2.75	5.20	44.10	86.39	10.19
3.00	2.84	46.94	91.95	5.56
3.25	1.29	48.23	94.48	2.53
3.50	0.87	49.10	96.18	1.70
3.75	0.70	49.80	97.55	1.37
4.00	0.37	50.17	98.28	0.72
Pan	0.88	51.05	100.00	1.72

Locality 3 Unit 1 Remarks Lacustrine

Mo 1.750 Md 1.000 Mz 0.850 Si 0.910 Ski -0.17 Kg 1.04

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.42	2.42	3.81	3.81
-0.50	3.19	5.61	8.82	5.02
-0.25	3.22	8.83	13.89	5.06
0.00	3.32	12.15	19.11	5.22
0.25	3.06	15.21	23.92	4.81
0.50	4.28	19.49	30.65	6.73
0.75	3.93	23.42	36.84	6.18
1.00	7.86	31.28	49.20	12.36
1.25	7.95	39.23	61.70	12.50
1.50	8.01	47.24	74.30	12.60
1.75	8.31	55.55	87.37	13.07
2.00	3.35	58.90	92.64	5.27
2.25	1.14	60.04	94.43	1.79
2.50	0.80	60.84	95.69	1.26
2.75	0.50	61.34	96.48	0.79
3.00	0.42	61.76	97.14	0.66
3.25	0.26	62.02	97.55	0.41
3.50	0.21	62.23	97.88	0.33
3.75	0.25	62.48	98.27	0.39
4.00	0.16	62.64	98.52	0.25
Pan	0.94	63.58	100.00	1.48

Locality 4 Unit 3(A) Remarks Lacustrine, Longshore bar

Mo 1.00 Md 1.250 Mz 1.330 Si 1.58 Ski 0.178 Kg 0.77

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.73	2.73	4.90	4.90
-0.50	2.75	5.48	9.83	4.93
-0.25	2.46	7.94	14.24	4.41
0.00	2.37	10.31	18.49	4.25
0.25	2.68	12.99	23.30	4.81
0.50	3.43	16.42	29.45	6.15
0.75	2.70	19.12	34.30	4.84
1.00	5.41	24.53	44.00	9.70
1.25	3.79	28.32	50.80	6.80
1.50	3.13	31.45	56.41	5.61
1.75	3.35	34.80	62.42	6.01
2.00	2.84	37.64	67.52	5.09
2.25	2.23	39.87	71.52	4.00
2.50	2.73	42.60	76.41	4.90
2.75	2.99	45.59	81.78	5.36
3.00	2.01	47.60	85.38	3.61
3.25	0.96	48.56	87.10	1.72
3.50	0.92	49.48	88.75	1.65
3.75	1.03	50.51	90.60	1.85
4.00	0.61	51.12	91.70	1.09
Pan	4.63	55.75	100.00	8.30

Locality 4 Unit 3(B) Remarks Lacustrine, Longshore bar

Mo 1.000 Md 1.000 Mz 1.250 Si N.C. Ski N.C. Kg N.C.

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.37	2.37	3.32	3.32
-0.50	2.95	5.32	7.45	4.13
-0.25	2.66	7.98	11.18	3.73
0.00	4.42	12.40	17.37	6.19
0.25	4.64	17.04	23.88	6.50
0.50	5.57	22.61	31.68	7.80
0.75	6.80	29.41	41.21	9.53
1.00	9.62	39.03	54.69	13.48
1.25	7.00	46.03	64.49	9.81
1.50	5.12	51.15	71.67	7.17
1.75	4.14	55.29	77.47	5.80
2.00	2.13	57.42	80.45	2.98
2.25	1.13	58.55	82.04	1.58
2.50	0.63	59.18	82.92	0.88
2.75	0.53	59.71	83.66	0.74
3.00	0.38	60.09	84.20	0.53
3.25	0.25	60.34	84.55	0.35
3.50	0.34	60.68	85.02	0.48
3.75	0.88	61.56	86.25	1.23
4.00	0.97	62.53	87.61	1.36
Pan	8.84	71.37	100.00	12.39

Locality 4 Unit 4 Remarks Lacustrine

Mo 1.000 Md 0.750 Mz 0.670 Si 0.970 Ski 0.00 Kg 1.15

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.14	2.14	3.27	3.27
-0.50	3.13	5.27	8.04	4.78
-0.25	3.80	9.07	13.84	5.80
0.00	5.61	14.68	22.40	8.56
0.25	5.99	20.67	31.54	9.14
0.50	6.39	27.06	41.29	9.75
0.75	5.83	32.89	50.19	8.90
1.00	10.02	42.91	65.48	15.29
1.25	6.98	49.89	76.13	10.65
1.50	4.45	54.34	82.92	6.79
1.75	3.36	57.70	88.05	5.13
2.00	1.96	59.66	91.04	2.99
2.25	1.15	60.81	92.80	1.75
2.50	0.96	61.77	94.26	1.46
2.75	0.59	62.36	95.16	0.90
3.00	0.58	62.94	96.05	0.89
3.25	0.40	63.34	96.66	0.61
3.50	0.43	63.77	97.31	0.66
3.75	0.61	64.38	98.25	0.93
4.00	0.35	64.73	98.78	0.53
Pan	0.80	65.53	100.00	1.22

Locality 4 Unit 6 Remarks Lacustrine, Beach

Mo 1.000 Md 0.750 Mz 0.750 Si N.C. Ski N.C. Kg N.C.

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	3.07	3.07	4.88	4.88
-0.50	3.07	6.14	9.76	4.88
-0.25	2.88	9.02	14.34	4.58
0.00	3.73	12.75	20.28	5.93
0.25	4.22	16.97	26.99	6.71
0.50	5.54	22.51	35.80	8.81
0.75	5.21	27.72	44.08	8.29
1.00	9.79	37.51	59.63	15.57
1.25	6.87	44.38	70.58	10.93
1.50	4.58	48.96	77.86	7.28
1.75	3.13	52.09	82.84	4.98
2.00	1.40	53.49	85.07	2.23
2.25	0.68	54.17	86.15	1.08
2.50	0.47	54.64	86.90	0.75
2.75	0.32	54.96	87.40	0.51
3.00	0.26	55.22	87.82	0.41
3.25	0.21	55.43	88.15	0.33
3.50	0.24	55.67	88.53	0.38
3.75	0.45	56.12	89.25	0.72
4.00	0.33	56.45	89.77	0.52
Pan	6.43	62.88	100.00	10.22

Locality 7 Unit 1 Remarks Lacustrine

Mo 0.000 Md 0.000 Mz 0.420 Si 1.480 Ski 0.59 Kg 1.84

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	7.24	7.24	10.82	10.82
-0.50	8.00	15.24	22.77	11.95
-0.25	7.70	22.94	34.28	11.51
0.00	8.73	31.67	47.33	13.05
0.25	8.37	40.04	59.83	12.51
0.50	6.54	46.58	69.61	9.77
0.75	3.29	49.87	74.52	4.92
1.00	3.89	53.76	80.33	5.81
1.25	1.18	54.94	82.10	1.76
1.50	0.59	55.53	82.98	0.88
1.75	0.48	56.01	83.70	0.72
2.00	0.40	56.41	84.29	0.60
2.25	0.28	56.69	84.71	0.42
2.50	0.13	56.82	84.91	0.19
2.75	0.29	57.11	85.34	0.43
3.00	0.49	57.60	86.07	0.73
3.25	0.54	58.14	86.88	0.81
3.50	0.72	58.86	87.96	1.08
3.75	1.25	60.11	89.82	1.87
4.00	0.98	61.09	91.29	1.46
Pan	5.83	66.92	100.00	8.71

Locality 7 Unit 2(A) Remarks Lacustrine

Mo 0.50Ø Md 1.00Ø Mz 1.25Ø Si 1.53Ø Ski 0.25 Kg 1.11

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	3.24	3.24	5.33	5.33
-0.50	3.44	6.68	10.99	5.66
-0.25	3.68	10.36	17.04	6.05
0.00	4.15	14.51	23.87	6.83
0.25	4.59	19.10	31.41	7.55
0.50	5.59	24.69	40.61	9.19
0.75	3.82	28.51	46.89	6.28
1.00	5.82	34.33	56.46	9.57
1.25	3.80	38.13	62.71	6.25
1.50	3.12	41.25	67.85	5.13
1.75	3.32	44.57	73.31	5.46
2.00	2.49	47.06	77.40	4.10
2.25	1.29	48.35	79.52	2.12
2.50	0.73	49.08	80.72	1.20
2.75	1.06	50.14	82.47	1.74
3.00	1.85	51.99	85.51	3.04
3.25	1.60	53.59	88.14	2.63
3.50	1.45	55.04	90.53	2.38
3.75	1.55	56.59	93.08	2.55
4.00	0.96	57.55	94.65	1.58
Pan	3.25	60.80	100.00	5.35

Locality 7 Unit 2(B) Remarks Lacustrine

Mo 1.750 Md 1.000 Mz 1.000 Si 1.380 Ski 0.15 Kg 1.37

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.91	2.91	4.95	4.95
-0.50	3.12	6.03	10.26	5.31
-0.25	3.22	9.25	15.74	5.48
0.00	3.29	12.54	21.33	5.60
0.25	3.11	15.65	26.62	5.29
0.50	3.95	19.60	33.34	6.72
0.75	3.25	22.85	38.87	5.58
1.00	4.90	27.75	47.21	8.34
1.25	4.21	31.96	54.37	7.16
1.50	4.38	36.34	61.82	7.45
1.75	6.02	42.36	72.07	10.24
2.00	4.37	46.73	79.50	7.43
2.25	2.18	48.91	83.21	3.71
2.50	1.36	50.27	85.52	2.31
2.75	1.26	51.53	87.67	2.14
3.00	1.40	52.93	90.05	2.38
3.25	0.82	53.75	91.44	1.40
3.50	0.57	54.32	92.41	0.96
3.75	0.61	54.93	93.45	1.04
4.00	0.42	55.35	94.16	0.71
Pan	3.43	58.78	100.00	5.84

Locality 7 Unit 3 Remarks Lacustrine

Mo 1.000 Md 1.130 Mz 1.080 Si 1.540 Ski 0.16 Kg 1.32

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.68	2.68	4.52	4.52
-0.50	3.33	6.01	10.13	5.61
-0.25	3.20	9.21	15.52	5.39
0.00	3.22	12.43	20.95	5.43
0.25	3.20	15.63	26.34	5.39
0.50	4.06	19.69	33.18	6.84
0.75	3.26	22.95	38.68	5.49
1.00	5.17	28.12	47.39	8.71
1.25	4.24	32.36	54.53	7.15
1.50	4.36	36.72	61.88	7.35
1.75	5.16	41.88	70.58	8.70
2.00	4.00	45.88	77.32	6.74
2.25	2.06	47.94	80.79	3.47
2.50	1.48	49.42	83.28	2.49
2.75	1.28	50.70	85.44	2.16
3.00	1.24	51.94	87.53	2.09
3.25	0.78	52.72	88.84	1.31
3.50	0.66	53.38	89.96	1.11
3.75	0.79	54.17	91.29	1.33
4.00	0.52	54.69	92.16	0.88
Pan	4.65	59.34	100.00	7.84

Locality 15 Unit --- Remarks Lacustrine

Mo 1.250 Md 1.120 Mz 1.080 Si 0.240 Ski 0.007 Kg 0.81

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	0.01	0.01	0.015	0.015
-0.50	0.04	0.05	0.074	0.06
-0.25	0.05	0.10	0.149	0.07
0.00	0.06	0.16	0.238	0.09
0.25	0.21	0.37	0.551	0.31
0.50	0.93	1.30	1.94	1.38
0.75	2.26	3.56	5.30	3.36
1.00	12.57	16.13	24.01	18.71
1.25	22.26	38.39	57.14	33.13
1.50	19.27	57.66	85.83	28.68
1.75	8.42	66.08	98.36	12.53
2.00	0.80	66.88	99.55	1.19
2.25	0.12	67.00	99.73	0.18
2.50	0.06	67.06	99.82	0.09
2.75	0.03	67.09	99.86	0.04
3.00	0.02	67.11	99.90	0.03
3.25	0.01	67.12	99.91	0.015
3.50	0.01	67.13	99.93	0.015
3.75	0.01	67.14	99.94	0.015
4.00	0.01	67.15	99.96	0.015
Pan	0.03	67.18	100.00	0.04

Locality 17 Unit lower Remarks Lacustrine, Longshore bar

Mo 1.000 Md 1.000 Mz 0.920 Si 0.930 Ski -0.11 Kg 1.33

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	1.71	1.71	3.03	3.03
-0.50	2.24	3.95	7.01	3.97
-0.25	2.14	6.09	10.80	3.80
0.00	2.54	8.63	15.31	4.51
0.25	2.64	11.27	19.99	4.68
0.50	3.80	15.07	26.73	6.74
0.75	3.57	18.64	33.07	6.33
1.00	7.42	26.06	46.23	13.16
1.25	7.18	33.24	58.97	12.74
1.50	7.11	40.35	71.58	12.61
1.75	7.01	47.36	84.02	12.44
2.00	3.46	50.82	90.15	6.14
2.25	1.58	52.40	92.96	2.80
2.50	1.58	53.98	95.76	2.80
2.75	0.94	54.92	97.43	1.67
3.00	0.70	55.62	98.67	1.24
3.25	0.30	55.92	99.20	0.53
3.50	0.16	56.08	99.49	0.28
3.75	0.10	56.18	99.66	0.18
4.00	0.05	56.23	99.75	0.09
Pan	0.14	56.37	100.00	0.25

Locality AF Unit Chl Remarks Ephemeral stream channel

Mo 1.000 Md 0.750 Mz 0.790 Si 0.910 Ski -0.11 Kg 1.02

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	3.27	3.27	5.63	5.63
-0.50	2.50	5.77	9.93	4.30
-0.25	3.25	9.02	15.53	5.60
0.00	4.15	13.17	22.68	7.15
0.25	3.71	16.88	29.06	6.39
0.50	5.27	22.15	38.14	9.07
0.75	4.94	27.09	46.64	8.51
1.00	8.06	35.15	60.52	13.88
1.25	6.10	41.25	71.02	10.50
1.50	5.07	46.32	79.75	8.73
1.75	4.58	50.9	87.64	7.89
2.00	2.54	53.44	92.01	4.37
2.25	1.14	54.58	93.97	1.96
2.50	1.18	55.76	96.01	2.03
2.75	0.69	56.45	97.19	1.19
3.00	0.57	57.02	98.17	0.98
3.25	0.25	57.27	98.61	0.43
3.50	0.17	57.44	98.90	0.29
3.75	0.21	57.65	99.26	0.36
4.00	0.11	57.76	99.45	0.19
Pan	0.32	58.08	100.00	0.55

Locality AF Unit Ch2 Remarks Ephemeral stream channel

Mo 1.000 Md 0.500 Mz 0.500 Si 0.990 Ski 0.04 Kg 0.89

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	6.54	6.54	9.53	9.53
-0.50	6.20	12.74	18.57	9.04
-0.25	5.59	18.33	26.71	8.15
0.00	6.35	24.68	35.97	9.25
0.25	4.74	29.42	42.87	6.91
0.50	6.11	35.53	51.78	8.90
0.75	5.20	40.73	59.36	7.58
1.00	7.43	48.16	70.18	10.83
1.25	5.32	53.48	77.94	7.75
1.50	4.13	57.61	83.96	6.02
1.75	4.00	61.61	89.78	5.83
2.00	2.51	64.12	93.44	3.66
2.25	1.27	65.39	95.29	1.85
2.50	1.05	66.44	96.82	1.53
2.75	0.65	67.09	97.77	0.95
3.00	0.50	67.59	98.50	0.73
3.25	0.22	67.81	98.82	0.32
3.50	0.19	68.00	99.10	0.28
3.75	0.19	68.19	99.37	0.28
4.00	0.12	68.31	99.55	0.17
Pan	0.31	68.62	100.00	0.45

Locality AF Unit ChBl Remarks Ephemeral stream channel

Mo 1.000 Md 0.750 Mz 0.790 Si 1.160 Ski 0.13 Kg 1.02

Phi Class	Raw Wt.	Cum. Wt.	Cum. %	Indiv. %
-1.00	0.00	0.00	0.00	0.00
-0.75	2.83	2.83	5.09	5.09
-0.50	3.72	6.55	11.77	6.69
-0.25	4.12	10.67	19.18	7.41
0.00	4.48	15.15	27.23	8.05
0.25	3.51	18.66	33.54	6.31
0.50	5.07	23.73	42.66	9.11
0.75	4.22	27.95	50.24	7.59
1.00	5.77	33.72	60.61	10.37
1.25	4.16	37.88	68.09	7.48
1.50	3.61	41.49	74.58	6.49
1.75	3.51	45.00	80.89	6.31
2.00	2.40	47.40	85.21	4.31
2.25	1.40	48.80	87.72	2.52
2.50	1.49	50.29	90.40	2.69
2.75	1.23	51.52	92.61	2.21
3.00	1.20	52.72	94.77	2.16
3.25	0.60	53.32	95.85	1.08
3.50	0.15	53.47	96.12	0.27
3.75	0.51	53.98	97.03	0.92
4.00	0.31	54.29	97.59	0.56
Pan	1.34	55.63	100.00	2.41

Appendix III

Soil Profiles

Soil profiles from five soil pits and two natural exposures are presented. Terminology and format of presentation are essentially those of the U.S. Soil Conservation Service. Soil Survey Staff (1975) discusses diagnostic surface and subsurface horizons, master horizons and layers, and taxonomy. Locations of profile sites are shown on Plate I.

Procedure of Soil Sample Analysis

Samples from horizons described in soil pits were analyzed for sand, silt, and clay percentages in order to apply accurately soil textural names and to identify argillic horizons. Samples from strongly calcareous horizons were not subjected to particle-size analysis owing to difficulty of treatment.

Each sample was prepared for particle-size analysis by light crushing to break down natural soil agregates. The crushed material was sieved on a 10-mesh sieve (2 mm opening) to obtain the fine earth fraction. From this, approximately 40 grams were separated which in turn were divided into two splits weighing approximately 20 grams each. The two splits were placed in separate beakers, dryed overnight at 100 - 110°C and weighed to 0.0001 gram on a Mettler balance. Care was taken to weigh samples immediately upon removal from the oven since clays begin to absorb air moisture when the temperature falls below 100°C. After weighing, samples were placed in clean beakers. Twenty milliliters of sodium hexametaphosphate (Calgon) solution at concentration of 50g/liter H_2O were added to each and the beakers then filled with distilled H_2O to the 200 or 250 ml. mark. The samples were allowed to stand overnight and were checked the following day for signs of flocculation.

If no flocculation occurred, the samples were wet-sieved on a 270 mesh sieve (0.053 mm opening). The sand held on the screen was transferred to a pre-weighed 50 ml beaker, dryed in the oven, and weighed while hot. The solution containing the silt and clay fractions was transferred to a 1000 ml graduated cylinder, diluted with distilled H_2O to exactly 100 ml, stirred thoroughly, and allowed to settle for 30 minutes. The depth of the silt-clay interface at the end of this time is given below for three temperatures.

T°C	Depth (cm)
24°	2.72
25°	2.77
26°	2.84

A 20 ml aliquot was withdrawn from the top 2 cm of the solution and drained into a pre-weighed 30 ml beaker. The pipette was washed with a few milliliters of distilled H_2O and the wash allowed to drain into the beaker with the aliquot. This was oven-dryed for 24 hours and weighed to 0.0001 g while still hot.

Weights of the sand fraction and clay aliquot were obtained by subtracting the weights of weighing beakers. The calculated weight of dispersant (0.02 g) was subtracted from the clay aliquot and the corrected weight multiplied by 50 to obtain the weight of clay in the solution. The weight of silt was obtained indirectly by subtracting the weight of sand-plus-clay from the original sample weight. Percentages of each separate were then calculated.

After both 20-gram splits from a sample of a horizon had been analyzed, the results were compared. If, for each separate (i.e., sand, silt, clay) of a given sample, the difference between percentages obtained in the two analyses of the sample was less than 4.0%, the two were averaged to obtain the sand, silt, clay percentages of the horizon. If the difference between percentages obtained in the two analyses was greater than 4.0% for even one of the separates, other 20-gram splits were analyzed until two analyses were obtained in which all separates were within the 4.0%. Hence, the value given for each fraction may be regarded as having a maximum experimental error of ±2.00%. Exceptions were made for two samples in which the percent difference for a separate was less than 4.1%.

Profile No. 1

Location: North of stock tank, NE1/4 SE1/4 SW1/4 Sec. 36, T23S, R21W.

Physiographic Setting: East facing slope just below crest of lowest shoreline ridge at toe of alluvial fan.

Parent Material: Lacustrine sand and gravel derived from andesite, latite, and rhyolite.

Classification: Typic Camborthid.

A1	0 - 4 cm (0 - 1.5 in.). Pale brown to brown (10YR 5.5/3) sandy loam, dark grayish brown (10YR 4/2) when moist; weak, medium platy structure; soft (dry), slightly sticky and slightly plastic (wet); noncalcareous; abrupt, smooth boundary; 2.5 - 4 cm (1 - 1.5 in.) thick.
B1	4 - 25 cm (1.5 - 10 in.). Pale brown (10YR 6/3) loamy sand, very dark grayish brown (10YR 3/2) when moist; massive; soft (dry), very friable (moist), slightly sticky and nonplastic (wet); noncalcareous; abrupt, smooth boundary; 15 - 30.5 cm (6 - 12 in.) thick.
B2t	25 - 64 cm (10 - 25 in.). Dark grayish brown (10YR 4/2) sandy loam, very dark grayish brown (10YR 3/2) when moist; massive; slightly hard (dry), very friable (moist), slightly sticky and nonplastic (wet); noncalcareous; few clay coatings on coarse sand grains; clear to gradual, wavy boundary; 33 - 40.5 cm (13 - 16 in.) thick.
C1ca	64 - 107 cm (25 - 42 in.). Light brownish gray (10YR 6/2) sand, dark grayish brown (10YR 4/2) when moist; massive to single grain; soft (dry), loose (moist), nonsticky and nonplastic (wet); calcareous with thin, continuous to discontinuous, carbonate coatings on grains and pebbles; gradual, irregular boundary; 41 - 43 cm (16 - 17 in.) thick.
C2ca	107 - 135 cm (42 - 53 in.). Light brownish gray (10YR 6/2) gravelly sand; single grain; loose (dry), loose (moist), nonsticky and nonplastic (wet); calcareous with thin, continuous to discontinuous, carbonate coatings on grains; boundary not exposed.

Textural Analyses for Profile No. 1

I. Fine Earth Fraction (size limits in mm)

Horizon	Depth (cm)	% Sand (2.0-.05)	% Silt (.05-.002)	% Clay (.002)	Color (dry)
A11	0 - 4	72.41	22.84	4.75	10YR 5.5/3
B1	4 - 25	75.76	18.30	5.86	10YR 6/3
B2t	25 - 64	76.48	15.50	8.01	10YR 4/2
C1ca	64 - 107	89.05	7.50	3.46*	10YR 6/2
C2ca	107 - 135	96.32	2.83	0.85*	10YR 6/2

*includes carbonate

II. Sand Separate (size limits in mm)

Horizon	% V.Coarse 2.00-1.00	% Coarse 1.00-0.50	% Medium 0.50-0.25	% Fine 0.25-0.10	% V.Fine 0.10-0.05
A11	7.1	22.31	41.41	17.28	11.90
B1	12.35	30.15	37.75	12.62	7.14
B2t	23.34	33.25	32.04	7.62	3.75
C1ca	15.19	29.02	44.54	9.45	1.80
C2ca	15.37	31.68	44.34	8.14	0.47

Profile No. 2

Location: West of stock tank and south of road, SE1/4 SW1/4 SW1/4 Sec. 36, T23S, R21W.

Physiographic Setting: Crest of intermediate shoreline ridge at toe of alluvial fan.

Parent Material: Lacustrine sand and gravel derived from andesite, latite and rhyolite.

Classification: Typic Camborthid.

A1 0 - 5 cm (0 - 2 in.). Light yellowish brown (10YR 6/4) loamy sand, dark brown (10YR 3/3) when moist; massive, upper 0.6 to 1.0 cm having weak, medium platy structure; soft (dry), very friable (moist), nonsticky and nonplastic (wet); abrupt, wavy boundary; 2.5 - 8 cm (1 - 3 in.) thick.

B1 5 - 25 cm (2 - 10 in.). Pale brown (10YR 6/3.5) loamy sand, dark, brown (10YR 3/2.5) when moist; weak, very fine granular to massive; soft (dry), very friable (moist); nonsticky and nonplastic (wet); abrupt, irregular boundary; 18 - 28 cm (7 - 11 in.) thick.

B2t 25 - 56 cm (10 - 22 in.). Brown (10YR 5.5/3) gravelly loamy sand, dark brown (10YR 4/2.5) when moist; massive; soft (dry), very friable (moist), nonsticky and nonplastic (wet); thin, discontinuous clay skins on pebbles; abrupt, irregular boundary; 25 - 38 cm (10 - 15 in.) thick.

Cca 56 - 140 cm (22 - 55 in.). Light brownish gray (10YR 6/2) gravelly sand, dark grayish brown (10YR 4/2.5) when moist; single grain, becoming stratified near base; soft (dry), loose to very friable (moist), nonsticky and nonplastic (wet); calcareous in upper half; boundary not exposed.

Textural Analyses for Profile No. 2

I. Fine Earth Fraction (size limits in mm)

Horizon	Depth (cm)	% Sand (2.0-.05)	% Silt (.05-.002)	% Clay (.002)	Color (dry)
A11	0 - 5	76.11	19.59	4.30	10YR 6/5
B1	5 - 25	76.73	18.64	4.63	10YR 6/3.5
B2t	25 - 56	80.47	13.78	5.75	10YR 5.5/3
Cca	56 - 140	97.77	1.21	1.02*	10YR 6/2

*includes carbonate

II. Sand Separate (size limits in mm)

Horizon	% V.Coarse 2.00-1.00	% Coarse 1.00-0.50	% Medium 0.50-0.25	% Fine 0.25-0.10	% V.Fine 0.10-0.05
A11	7.07	22.21	34.62	22.18	13.92
B1	12.88	32.80	33.65	13.60	7.07
B2t	12.70	35.80	38.39	9.65	3.46
Cca	40.05	38.40	16.70	4.29	0.56

Profile No. 3

Location: West of stock tank and south of dirt road, SW1/4 SW1/4 SE1/4 SW1/4 Sec. 36, T23S, R21W.

Physiographic Setting: Swale between high and intermediate shoreline ridges at toe of alluvial fan.

Parent Material: Fine-grained alluvium.

Classification: Camborthid

A1 0 - 15 cm (0 - 6 in.). Brown to light brown (7.5YR 5.5/4) silty clay loam, brown to dark brown (7.5YR 4/3) when moist; massive, upper 1.0 cm weak, medium platy structure; slightly hard (dry), very friable (moist), sticky and plastic (wet); noncalcareous; abrupt, smooth boundary; 13 - 15 cm (5 - 6 in.) thick.

B2 15 - 38 cm (6 - 15 in.). Pale brown to light yellowish brown (10YR 6/3.5) silty clay loam, dark yellowish brown (10YR 3/4) when moist; moderate, medium subangular blocky structure; hard (dry), firm to very firm (moist), very sticky and plastic (wet); noncalcareous; gradual, smooth boundary; 23 - 25 cm (9 - 10 in.) thick.

B3b 38 - 71 cm (15 - 28 in.). Brown (10YR 5/3) silt loam, very dark grayish brown to dark brown (10YR 3/2.5) when moist; weak to moderate, very fine subangular blocky structure; slightly hard (dry), very sticky and plastic (wet); calcareous near base; clear, smooth boundary; 28 - 42 cm (11 - 13 in.) thick.

C 71 -107 cm (28 - 42 in.). Light brownish gray (10YR 6/2) sandy loam, dark grayish brown (10YR 4/2) when moist; massive; slightly hard (dry), slightly sticky and plastic (wet); calcareous; abrupt, smooth boundary; 30 - 36 cm (12 - 14 in.) thick.

IIBb 107 - 114 cm (42 - 45 in.). Reddish brown (5YR 5/4) loam, reddish brown (5YR 5/3) when moist; massive in limited exposure; slightly hard (dry), very friable to friable (moist), sticky and plastic (wet); calcareous; boundary not exposed.

Textural Analyses for Profile No.3

I. Fine Earth Fraction (size limits in mm)

Horizon	Depth(cm)	% Sand (2.0-.05)	% Silt (.05-.002)	% Clay (.002)	Color(dry)
A1	0 - 15	11.39	61.61	27.00	7.5YR 5.5/4
B2	15 - 38	9.03	57.67	33.30	10YR 6/3.5
B3b	38 - 71	22.34	62.96	14.70	10YR 5/3
C	71 - 107	60.65	25.31	14.04	10YR 6/2
IIBb	107 - 114	41.29	33.77	24.94	5YR 5/4

II. Sand Separate (size limits in mm)

Horizon	% V.Coarse 2.00-1.00	% Coarse 1.00-0.50	% Medium 0.50-0.25	% Fine 0.25-0.10	% V.Fine 0.10-0.05
A1	5.47	15.97	18.38	23.85	36.32
B2	9.92	19.83	17.36	19.83	33.06
B3b	28.40	27.39	17.82	15.14	11.25
C	15.13	24.87	23.09	24.58	12.33
IIBb	33.76	23.67	14.67	15.88	12.02

Profile No. 4

Location: West of tank and south of dirt road, SE1/4 SE1/4 SW1/4 SW1/4 Sec. 36, T23S. R21W.

Physiographic Setting: East facing slope below crest of high shoreline ridge on toe of alluvial fan.

Parent Material: Lacustrine sand and gravel derived from andesite, latite, and rhyolite.

Classification: Typic Haplargid.

A1 0 - 8 cm (0 - 3 in.). Very pale brown (10YR 7/3.5) sandy loam, dark brown (10YR 3.5/3) when moist; massive to weak, fine platy structure; soft (dry), very friable (moist), slightly sticky and slightly plastic (wet); noncalcareous; abrupt, smooth boundary; 8 cm (3 in.) thick.

B21t 8 - 41 cm (3 - 16 in.). Dark yellowish brown to yellowish brown (10YR 4.5/4) sandy clay loam, dark brown (10YR 3/3) when moist; weak, coarse prismatic structure to massive; slightly hard (dry), very friable (moist), sticky and plastic (wet); noncalcareous; clay skins on pebbles, and clay bridges between sand grains; gradual, smooth boundary; 33 cm (13 in.) thick.

C1 41 - 71 cm (16 - 28 in.). Pale brown (10YR 6.5/3) loamy sand, brown (10YR 4.5/3) when moist; single grain; loose (dry), loose (moist), nonsticky and nonplastic (wet); calcareous near base; abrupt, smooth boundary; 28 - 33 cm (11 - 13 in.) thick.

IIB22tb 71 - 81 cm (28 - 32 in.). Reddish brown to yellowish red (5YR 5/5) clay loam, yellowish brown (5YR 5/6) when moist; compound moderate to weak, medium prismatic structure and moderate, fine angular blocky structure; slightly hard (dry), very friable (moist), very sticky and plastic (wet); calcareous with carbonate coatings on pebbles and soft carbonate lining and filling root tubes and pores; clear, smooth boundary; 8 - 13 cm (3 - 5 in.) thick.

IIB23ca 81 - 104 cm (32 - 41 in.). Yellowish red (5YR 4.5/6) sandy clay loam, yellowish red (5YR 4/6) when moist; weak to moderate, coarse angular blocky structure, breaking to fine angular blocky structure; slightly hard (dry), friable (moist), very sticky and plastic (wet); calcareous with thin, discontinuous coatings of carbonate (5YR 8/1) on pebbles, fractures, and root tubes; boundary not exposed.

Textural Analyses for Profile No. 4

I. Fine Earth Fraction (size limits in mm)

Horizon	Depth (cm)	% Sand (2.0-.05)	% Silt (.05-.002)	% Clay (.002)	Color (dry)
A1	0-8	75.07	18.73	6.20	10YR 7/3.5
B21t	8-41	60.26	17.97	21.77	10YR 4.5/4
C	41-71	85.82	7.28	6.90	10YR 6.5/3
IIB22tb	71-81	22.83	42.86	34.31	5YR 5/5

II. Sand Separate (size limits in mm)

Horizon	% V.Coarse 2.00-1.00	% Coarse 1.00-0.50	% Medium 0.50-0.25	% Fine 0.25-0.10	% V.Fine 0.10-0.05
A1	6.11	20.94	37.15	20.15	15.65
B21t	13.94	32.53	38.01	9.61	5.91
C	19.60	29.14	43.43	6.16	1.67
IIB22tb	16.95	28.76	33.22	12.71	8.36

Profile No. 5

Location: West of stock tank and south of dirt road, SW1/4 SE1/4 SW1/4 SW1/4 Sec. 36, T23S, R21W.

Physiographic Setting: Fan surface upslope from high shoreline ridge.

Parent Material: Alluvium derived from andesite, latite,and rhyolite.

Classification: Typic Haplargid.

A1 0 - 5 cm (0 - 2 in.). Light brown (7.5YR 6/4) sandy loam, brown to dark brown (7.5YR 4/4) when moist; weak, medium platy structure; soft (dry), sticky and plastic (wet); noncalcareous; abrupt, smooth boundary; 2.5 - 6 cm (1 - 2.5 in.) thick.

B21 5 - 15 cm (2 - 6 in.). Reddish brown (5YR 4/4) loam, reddish brown (5YR 4/3) when moist; weak, fine angular blocky structure; slightly hard (dry), very sticky and plastic (wet); noncalcareous; abrupt, smooth boundary; 5 - 10 cm (2 - 4 in.) thick.

B22 15 - 36 cm (6 - 14 in.). Reddish brown (5YR 4/4) clay loam, reddish brown (5YR 4/3) when moist; moderate, medium angular blocky structure; slightly hard (dry), sticky and plastic (wet); noncalcareous; thin, discontinuous clay coatings on pebbles; abrupt, smooth boundary; 20 - 33 cm (8 - 13 in.) thick.

B23 36 - 48 cm (14 - 19 in.). Reddish brown (5YR 4/4) clay loam; reddish brown (5YR 4/3) when moist; compound moderate, fine prismatic and very fine angular blocky structure; hard (dry), very sticky and plastic (wet); noncalcareous; thin clay skins on ped faces and root pores; clear, discontinuous boundary; 0 - 15 cm (0 - 6 in.) thick.

C1ca 48 - 76 cm (19 - 30 in.). Brown (7.5YR 5/4) gravelly sandy clay loam, dark brown (7.5YR 4/4) when moist; massive; slightly hard (dry), very friable (moist), sticky and plastic (wet); calcareous, with thick continuous coatings (7.5YR 7/4) on pebbles, and local strong cementation; clear, smooth boundary; 28 cm (11 in.) thick.

C2ca 76 - 89 cm (30 - 35 in.). Pink (7.5YR 7.5/4) gravelly sandy loam, light brown (7.5YR 6/4) when moist; massive; very hard (dry), firm (moist), sticky and plastic (wet); calcareous, with thick, continuous coatings on pebbles and inter-pebble fillings; boundary not exposed.

Textural Analyses for Profile No. 5

I. Fine Earth Fraction (size limits in mm)

Horizon	Depth(cm)	% Sand (2.0-.05)	% Silt (.05-.002)	% Clay (.002)	Color(dry)
A1	0 - 5	60.73	30.16	9.11	7.5YR 6/4
B21	5 - 15	37.72	38.93	23.35	5YR 4/4
B22	15 - 36	34.33	34.12	31.55	5YR 4/4
B23	36 - 48	25.19	40.20	34.61	5YR 4/4
C1ca	48 - 76	-----	-----	-----	7.5YR 5/4
C2ca	76 - 89	-----	-----	-----	7.5YR 7.5/4

II. Sand Separate (size limits in mm)

Horizon	% V.Coarse 2.00-1.00	% Coarse 1.00-0.50	% Medium 0.50-0.25	% Fine 0.25-0.10	% V.Fine 0.10-0.05
A1	13.26	27.94	20.39	18.81	19.60
B21	18.66	29.07	18.66	16.81	16.81
B22	28.98	25.77	15.64	14.57	15.03
B23	19.56	24.33	17.97	18.47	19.66

Profile No. 6

Location: South bank of first arroyo north of dirt road leading to Robinson Windmill, NW1/4 SE1/4 NE1/4 SW1/4 Sec. 36, T23S, R21W.

Physiographic Setting: Crest of intermediate shoreline ridge on toe of alluvial fan.

Parent Material: Lacustrine sand and gravel derived from andesite, latite, and ryholite.

Classification: Typic (?) Camborthid.

A1 0 - 8 cm (0 - 3 in.). Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 3/2) when moist; massive; loose (dry), very friable (moist), slightly sticky and slightly plastic (wet); noncalcareous; abrupt, smooth boundary; 5 - 8 cm (2 - 3 in.) thick.

B21 8 - 28 cm (3 - 11 in.). Brown (10YR 5/3) gravelly sandy loam, very dark grayish brown (10YR 3/2) when moist; massive; soft (dry), very friable (moist), sticky and slightly plastic (wet); noncalcareous; some thin, discontinuous clay skins on pebbles and clay bridges between sand grains; gradual, smooth boundary; 20 - 28 cm (8 - 11 in.) thick.

B3 28 - 56 cm (11 - 22 in.). Brown (10YR 5/3) loamy sand, dark brown (10YR 3/3) when moist; single grain; loose (dry), loose to soft (moist), nonsticky and nonplastic (wet); noncalcareous; gradual, smooth boundary; 25 - 28 cm (10 - 11 in.) thick.

C1ca 56 - 89 cm (22 - 35 in.). Light gray (10YR 7/2) sand or loamy sand, light brownish gray (10YR 6/2.5) when moist; single grain; loose (dry), loose (moist), nonsticky and nonplastic (wet); calcareous, with thin discontinuous carbonate coatings on pebbles; clear, smooth boundary; 38 cm (15 in.) thick.

C2ca 89 - 107 cm (35 - 42 in.). Light yellowish brown (10YR 6/4) gravelly sand, yellowish brown (10YR 4.5/4) when moist; stratified; loose (dry), loose (moist), nonsticky and nonplastic (wet); noncalcareous; abrupt, smooth boundary; 13 - 18 cm (5 - 7 in.) thick.

IIB22b 107 - 122 cm (42 - 48 in.). Reddish brown (5YR 5.5/4) sandy clay, reddish brown (5YR 5/4) when moist; compound moderate, coarse prismatic and weak, fine prismatic structure, breaking to moderate, fine angular blocky structure; slightly hard (dry), very friable (moist), very sticky and plastic (wet); slightly calcareous; thick sand coatings, apparently from sandy horizon above, on faces of coarse prisms; clear, wavy boundary; 13 - 15 cm (5 - 6 in.) thick.

IIB23ca 122 - 145 cm (48 - 57 in.). Reddish brown (5YR 5/5) sandy clay; massive, in places moderate, coarse angular blocky structure; slightly hard (dry), very friable (moist), very sticky and plastic (wet); calcareous; clear, smooth boundary; 15 - 23 cm (6 - 9 in.) thick.

IIC3ca 145 - 201 cm (57 - 79 in.). Light reddish brown (5YR 6/4) gravelly sand, reddish brown (5YR 5/4) when moist; massive and stratified; slightly hard (dry), very friable (moist), nonsticky and nonplastic (wet); calcareous, with coatings (pink, 5YR 8/3) on pebbles and in inter-pebble fill; few mangans on pebbles; abrupt, smooth boundary; 46 - 56 cm (18 - 22 in.) thick.

IIBcab 201 - 224 cm (79 - 88 in.). Yellowish red (5YR 4/6) when moist; clay or silty clay; massive; very friable (moist), very sticky and very plastic (wet); common, coarse mottles and nodules of $CaCO_3$, pink to reddish yellow (7.5YR 8/5) when moist, boundary not exposed.

Profile No. 7

Location: Arroyo cut along east side of shoreline ridge SE1/4 NE1/4 NW1/4 NW1/4 Sec. 18, T24S, R19W.

Physiographic Setting: Flat ridge crest of lower shoreline ridge on toe of alluvial fan.

Parent Material: Lacustrine sand and gravel derived from granodiorite, basalt, andesite, pyroclastic volcanics, and rhyolite.

Classification: Typic Camborthid.

A1 0 - 5 cm (0 - 2 in.). Brown (10YR 5/3) sandy loam, very dark grayish brown (10YR 3/2) when moist; weak, very thin platy structure; soft (dry), very friable (moist), slightly sticky and nonplastic (wet); noncalcareous; abrupt, wavy boundary; 2.5 - 5 cm (1 - 2 in.) thick.

B21 5 - 13 cm (2 - 5 in.). Grayish brown to brown (10YR 5/2.5) sandy loam, dark brown (10YR 3.3) when moist; massive; soft (dry), very friable (moist), slightly sticky and nonplastic (wet); noncalcareous; clear, wavy boundary; 8 - 13 cm (3 - 5 in.) thick.

B22 13 - 30 cm (5 - 12 in.). Grayish brown to brown (10YR 4.5/2.5) gravelly sandy loam, very dark grayish brown to brown (10YR 3.2/5) when moist; massive; loose (dry), loose (moist), slightly sticky and slightly plastic (wet); calcareous in lower part; gradual, wavy boundary; 15 - 25 cm (6 - 10 in.) thick.

C1ca 30 - 178 cm (12 - 70 in.). Light brownish gray (10YR 5.5/2) sandy gravel and gravelly sand, dark brown (10YR 3.5/3) when moist; single grain, becoming crudely stratified toward base; loose (dry), loose (moist), nonsticky and nonplastic (wet); calcareous, with thin, discontinuous and continuous carbonate coatings on pebbles; abrupt, wavy boundary; 152 - 163 cm (60 - 64 in.) thick.

Appendix IV

Climate Data

Temperature, precipitation, and evaporation data are listed below for stations at Lordsburg and Las Cruces, New Mexico. Sources for the data are Maker and others (1970) and Maker and others (1971).

	Altitude m (ft)	Temperature °C(°F)		Precipitation cm(in)		Evaporation Class-A Pan cm(in)
		Mean Jan.	Mean July	Mean Annual	Yrs. of Record	
Lordsburg	1294 (4225)	6.1(43)	27.8(82)	24.8(9.8)	80	234(92)
Las Cruces	1183 (3881)	5.6(42)	26.1(79)	21.3(8.4)	103	246(97)

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