Field Moisture Regimes and Morphology of Some Arid-Land Soils in New Mexico[1]

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ABSTRACT

This paper relates soil moisture in an arid region of southern New Mexico to precipitation, soil morphology, landscape position, and runoff. Matric potential of soil water on arid rangeland was determined from 1960-1970 with gypsum electrical resistance blocks using an ohmmeter. Soil texture, landscape position, and microrelief had a significant effect on soil moisture. Soil water potential at the 25-cm depth was between 0 and −15 bars an average of 40 days in a fine Haplargid that did not receive run-in, and an average of 212 days in a coarse-loamy Paleargid. With run-in, the fine Haplargid had an average of 82 days when the soil water was between 0 and −15 bars. In another fine Haplargid, there was an average of 166 days when the soil water was between 0 and −15 bars at the 25-cm depth, and 204 days at the 60-cm depth. At this site the depth of water infiltration was considerably increased by small depressions and cracks leading into the soil. Where runoff is not a factor, moisture conditions most favorable for plants were found in areas with the following characteristics: (i) a level or nearly level landscape that is stable and shows little or no evidence of erosion, (ii) a thin, coarse-textured horizon at the surface for maximum infiltration of moisture, and (iii) a finer textured horizon and/or an indurated horizon at favorable depths to capture the moisture and prevent its movement to greater depths where it would be unavailable for plant use.

INTRODUCTION

Soil moisture, as well as other climatic features, has been recognized as an important factor in soil genesis and classification. Certain soils occur only in specific climatic zones. The water status of soil continually affects soil properties through its influence on weathering, soil development, friability, and permeability (Slatyer, 1967). It is also an important factor in erosion of some soils (Russell, 1959). In *Soil Taxonomy* (Soil Survey Staff, 1973), the

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[1] Cooperative investigations of the Agricultural Research Service, U. S. Department of Agriculture; Soil Survey Investigations, Soil Conservation Service, U. S. Department of Agriculture; and the Agricultural Experiment Station, New Mexico State University, Las Cruces, New Mexico. Journal Article 396, New Mexico Agricultural Experiment Station.

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system of soil classification adopted by the National Cooperative Soil Survey, soil moisture characteristics are used as differentiating criteria.

Soil moisture and precipitation data have been collected at a number of sites in an arid region of southern New Mexico. The effects of precipitation on soil moisture depend on such factors as (i) soil characteristics (e.g., structure and texture), (ii) position on the landscape, (iii) amount and intensity of precipitation event, (iv) plant cover, and (v) soil moisture status at time of storm.

There is very little information in the literature concerning field measurement of soil moisture on arid rangelands. Winkworth (1970) studied the soil water regime of an arid grassland [*Eragrostis eriopoda* Benth.] in central Australia. During a 2-year period, there were six significant periods of soil water recharge followed by withdrawal of soil moisture to an average soil water potential of −120 bars. Shreve (1934) demonstrated the relationship between the amount and intensity of rainfall and the periodicity of soil moisture near Tucson, Arizona. Kincaid, Gardner, and Schreiber (1964) compared soil moisture on a grass-covered drainage area of noncalcareous soil and on a shrub-covered drainage area of calcareous soil in southeastern Arizona. Moisture depletion at the 15-cm depth was more rapid in the grassland area indicating greater evapotranspiration. Moisture withdrawal from the 45-cm depth was about the same on the two areas. Cumulative infiltration increased with surface gravel. Houston (1968) compared seasonal soil moisture accumulation and depletion for different soils on heavily and lightly grazed semiarid rangelands in Montana.

MATERIALS AND METHODS

This study was conducted on the Jornada Experimental Range near Las Cruces, New Mexico (Fig. 1). The mountain ranges are steep and rocky. Large alluvial fans occur at the mouths of major canyons along the mountain fronts. Arroyos occur between the fans and cross them in places. The arroyos are dry, except when runoff occurs from precipitation on areas upslope. Downslope the fans merge into a broad, coalescent fan-piedmont with a slope of 2 to 3%. Slopes gradually decrease to about 0.5% at toeslopes of the fan-piedmont along the margins of the basin floor. Relief in the basin floor ranges from level to gently undulating, and there are scattered playas (see Fig. 2 for the location of the study sites and the general topography of the area). Table 1 gives the soils, landscapes, and geomorphic surfaces of the various sites.

The average annual precipitation is 22 cm; an average of 13 cm occurs during July to September. Most winter moisture comes from low-intensity rains or occasionally from snow. Most summer rainfall occurs as localized thunderstorms of high intensity. The precipitation is highly variable from time to time and place to place. Springs are usually dry and windy. The average annual evaporation from a Weather Bureau pan is 225 cm. The

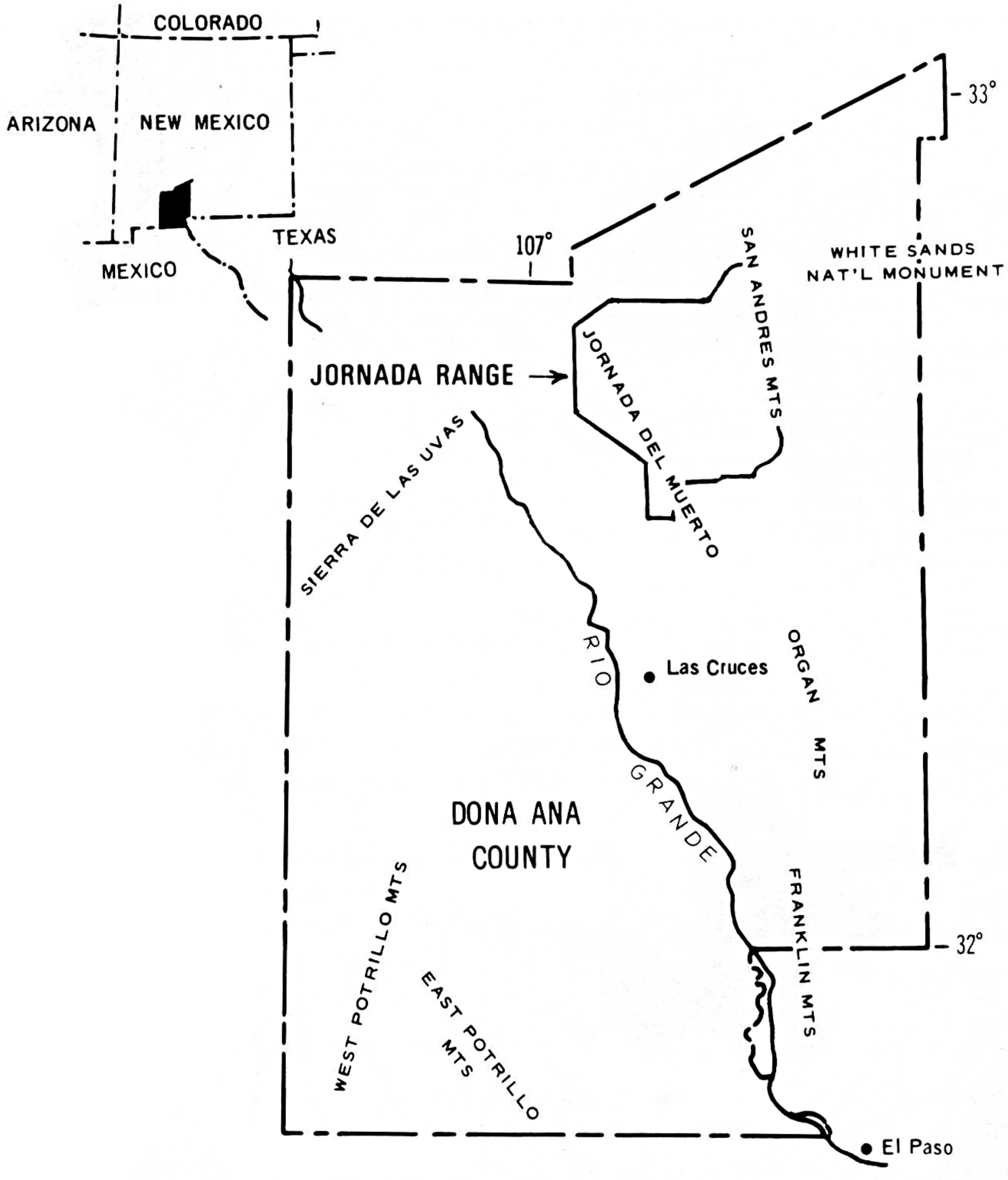

Figure 1. Location of the study area in southern New Mexico.

average temperature is 4C in January and 26C in July. The average annual precipitation for 1961–70 was 22 cm, or the same as the long-time average.

Vegetation data were collected at the end of the summer growing season in close proximity to the soil moisture station. Perennial grasses were clipped at ground level; old growth was separated from the production of the current year and the old growth was discarded; and the herbage was air-dried and weighed.

Soil parent materials in the basin floor are sandy sediments of the ancestral Rio Grande, the fluvial facies of the Camp Rice Formation (Strain, 1966; El Paso Geological Society, 1970). In places, the fluvial sediments have been moved by wind. Sediments of the alluvial fan-piedmont adjacent to the basin floor were derived from the San Andres and Dona Ana Moun-

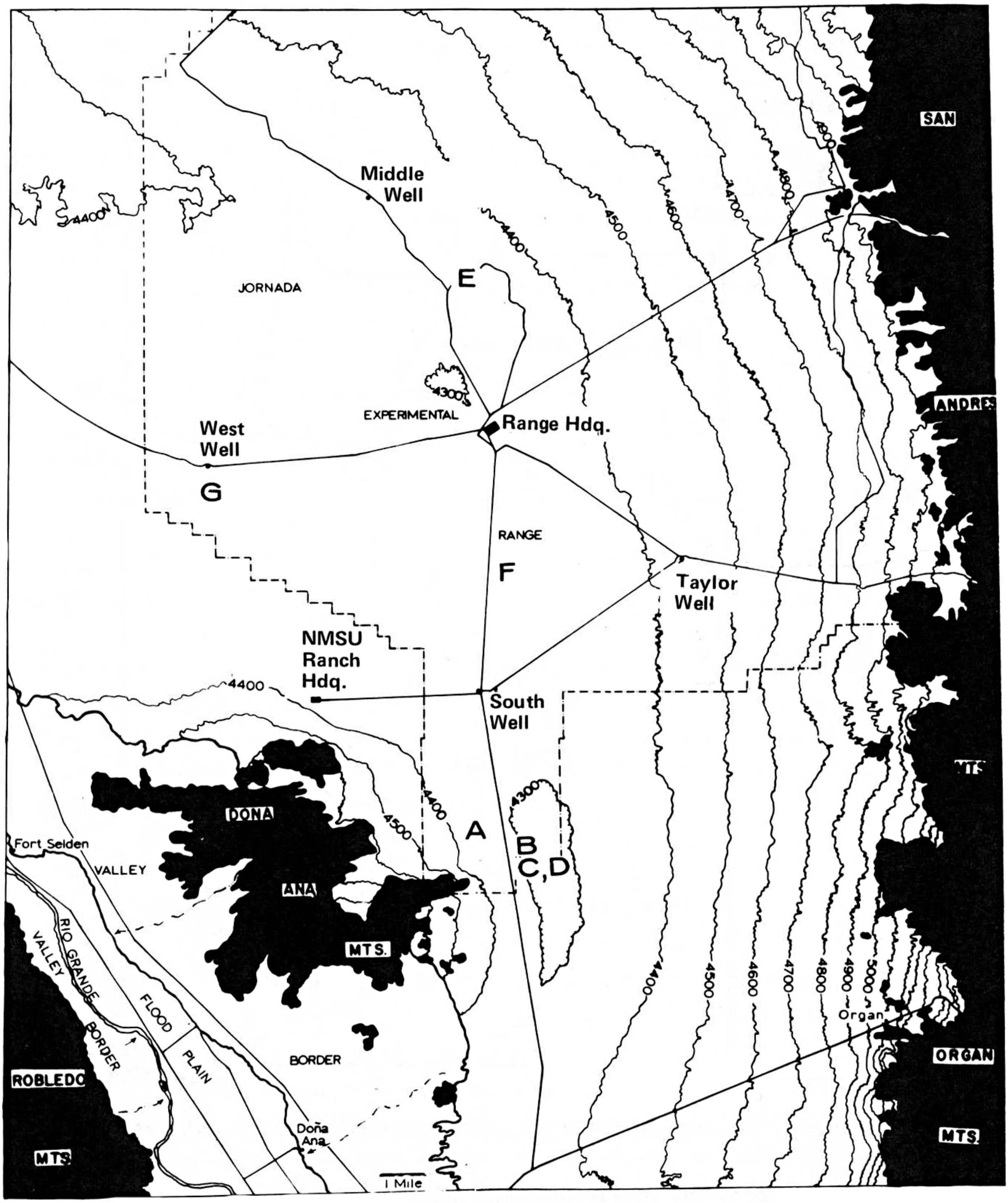

Figure 2. Topographic map of the Jornada Experimental Range showing the location of study sites A-G. Dashed lines indicate the approximate boundary of the Experimental Range.

tains in the area of the Experimental Range. Sedimentary rocks, including limestone, are dominant in the San Andres Mountains (Kottlowski et al., 1956). The Dona Ana Mountains contain a variety of igneous rocks, primarily monzonite, rhyolite, andesite, and latite, with a small area of sedimentary rocks (Kottlowski, 1960). In addition to the alluvial sediments, atmospheric additions of calcium and clay form an important part of the parent materials particularly in older soils. These atmospheric additions

Table 1. Some characteristics of soils and landscapes of the study area.

Site*	Soil series, variant or phase	Classification	Landscape position and slope	Geomorphic surface and age
A	Canutio, coarse-loamy variant	Typic Torriorthent, coarse-loamy, mixed, thermic	Fan-piedmont slope 2%	Organ, Holocene
B	Stellar, wedgy subsoil variant	Ustollic Haplargid, fine, mixed, thermic	Fan-piedmont toeslopes slope 0.5%	Jornada II, late-Pleistocene
C	Stellar	Ustollic Haplargid, fine, mixed, thermic	Basin floor nearly level	Jornada I, late mid-Pleistocene
D	Reakor†	Ustollic Calciorthid, fine-silty, mixed, thermic	Basin floor nearly level	Petts Tank, late-Pleistocene
E	Algerita†, deep gypsum phase	Typic Calciorthid, fine-loamy, mixed, thermic	Playa, level	Alluvium in floor of playa (latest Pleistocene-Holocene?)‡
F	Onite, buried soil variant	Typic Haplargid, coarse-loamy, mixed, thermic	Basin floor nearly level	Apparent eolian accumulation (Holocene?) on La Mesa surface (mid-Pleistocene)‡
G	Hueco†	Petrocalcic Paleargid, coarse-loamy, mixed, thermic	Basin floor nearly level	La Mesa, mid-Pleistocene

* Cf. Fig. 2.

† Tentative series.

‡ Details of the stratigraphy and chronology are not known in this part of the Experimental Range and assigned chronology must be considered tentative.

come from both the dry dustfall and the precipitation (Gile, Hawley, & Grossman, 1970). The top of the zone of ground-water saturation in basin-fill deposits of the study area commonly ranges from about 90 to 125 m (King et al., 1971).

Most of the Experimental Range is located north of the Desert Soil-Geomorphology Project where detailed soil-geomorphic studies have been conducted (see Gile et al., 1970 for a summary discussion and bibliography of some of this work). However, some of the conclusions from the Desert Project studies may be extrapolated to the Experimental Range.

Soil Moisture

Gypsum electrical resistance blocks were placed at several locations at varying depths depending on the soil depth. The soil moisture stations were located within a livestock exclosure. Moisture potential measurements were recorded with an ohmmeter 2 or 3 times a week when there was moisture during the summer. They were recorded monthly during the remainder of the year when there were fewer changes in moisture status. The blocks were calibrated in light- and medium-textured soils. They gave similar readings at the same moisture potential for the two soils. All of the blocks were tested and only those with similar response curves were used. The calibration and use of gypsum blocks has been discussed by Taylor, Evans, and Kemper (1961). The blocks used in this study were purchased from Taylor. Slatyer (1967) and Kramer (1969) are two of the recent authors who discuss use of gypsum-impregnated blocks to measure matric potential of soil water.

At sites *C, D,* and *E*, soil moisture was measured both inside and outside a sheet metal cylinder. The cylinder was 3 m in diameter and was buried

15 cm in the soil. The soil moisture units inside the cylinder provided estimates of moisture due to precipitation. Those outside the cylinder provided estimates of moisture due to precipitation plus run-in.

Soil temperatures were also recorded at several depths at several locations at about the same time as moisture was recorded. All of the resistance readings were adjusted to 15.6C. Precipitation was recorded at each study site in a standard U. S. Weather Bureau rain gauge.

For purposes of this study, daily precipitation of less than 0.63 cm was omitted from consideration. Examination of soil moisture data at the 10-cm depth (and consideration of the high rate of evaporation) showed that light amounts of precipitation seldom affected soil moisture at that depth. Bailey found that individual precipitation events of 1.3 cm or less during the summer were ineffective on some of the same sandy soils used in this study (O. F. Bailey, 1967. Water availability and grass root distribution in selected soils. M.S. Thesis. New Mexico State University, Las Cruces.).

The number of days when the moisture potential was between 0 and −15 bars at each depth was determined for each year. This was correlated with the annual precipitation (omitting daily amounts of less than 0.63 cm). A regression equation was computed for each depth that had a significant correlation (0.05 level).

Soil Morphology

The soils around the blocks were examined in detail with an auger, without disturbance of the blocks themselves, to determine the character of the soils in which the gypsum blocks were embedded. A pit was then dug in a similar soil, usually at a distance of only several meters away from the actual site of moisture measurement. The soils were described and then classified (Soil Survey Staff, 1973). Soil texture, type of structure, and dry consistence are summarized in Tables 2–5. Full descriptions are given in the Appendix along with notes about classification of the soils. Although no laboratory data are available at the actual sites of moisture measurement, a number of soils sampled in the Desert Project are similar. This information has been considered in the classification and genetic discussion of the soils at the moisture stations.

Two of the most prominent horizons in soils of this arid region are horizons of silicate clay and carbonate accumulation. Smith and Buol (1968) concluded that illuviation of silicate clay had occurred in certain semiarid soils that they studied in Arizona. In southern New Mexico, coatings of oriented clay on sand grains are typical of these horizons of silicate clay accumulation (Gile & Grossman, 1968). These oriented coatings are most strongly expressed in the horizon of maximum silicate clay. The correspondence of these factors is taken as evidence that oriented clay coatings on sand grains may be used as a marker of clay illuviation. Reference is made to these clay coatings in soil descriptions given in the Appendix. Morphogenetic relationships also indicate that carbonate in horizons of carbonate accumulation in soils of the region is predominantly to wholly of illuvial origin (Gile, Peterson, & Grossman, 1966).

Morphological features of Holocene soils are helpful in estimating common depths of present wetting because the morphology of such soils cannot be attributed to periods of more effective moisture during the Pleistocene (Gile, 1970). These morphological features may then be used in an assessment of Holocene processes of pedogenesis in soils that developed in part during a Pleistocene pluvial. Hence, the soil moisture data of this study which have been measured in soils of widely variable ages (from Holocene to mid-Pleistocene) provide quantitative information concerning amounts, depths, and times of wetting associated with the development of these morphological features.

Soil horizon terminology follows the *Supplement to the Soil Survey Manual* (Soil Survey Staff, 1962) except for the following: (i) Arabic instead of Roman numerals are prefixed to the master horizon designations to indicate lithologic discontinuities; (ii) wedge-shaped structural aggregates are designated wedges (Soil Survey Staff, 1973); (iii) horizons showing structural development in the B position are designated B; (iv) the K horizon nomenclature (Gile et al., 1965, 1970) is used to designate horizons of prominent carbonate accumulation; and (v) the C horizon is reserved for horizons that show little or no evidence of pedogenesis.

RESULTS AND DISCUSSION

Data are presented for certain soils of three general landscape positions: (i) a basin floor and an adjacent fan-piedmont that contributes water to the basin floor, (ii) a playa that receives some run-in water from long drainageways leading to adjacent mountains, and (iii) a broad, nearly level basin floor with good infiltration, only localized runoff, and no run-in from adjacent slopes.

Basin Floor, With Run-in, and Adjacent Fan-Piedmont

The landscape of this area (sites *A, B, C,* and *D,* Fig. 2) consists of a nearly level basin floor and an adjacent alluvial fan-piedmont. The study area on the fan-piedmont has 0.5–2% slopes that contribute water to the basin floor following rainfalls of high intensity. Sites *A* and *B* (Fig. 2) are on the fan-piedmont; sites *C* and *D* are on the basin floor.

SITE A

Vegetation records (1858 and 1915) and photographs (about 1920) indicate that this site was dominated at that time by black grama [*Bouteloua eriopoda*

(Torr.) Torr.] (Buffington & Herbel, 1965). The area is now dominated by creosotebush [*Larrea tridentata* (DC.) Coville]. With this shift in vegetation, there has been some erosion in the general area, and scattered small drainageways occur in the vicinity. The soil moisture units are located in a relatively stable area between the drainageways. The slope is 2%.

Examination of the soil adjacent to the moisture blocks indicates that they are embedded in a Typic Torriorthent, coarse-loamy, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil (Canutio, coarse-loamy variant) near the moisture blocks are given in Table 2. The soil has formed in fan-piedmont sediments derived from monzonite, andesite, and rhyolite. This soil is on the Organ surface of Holocene age (Ruhe, 1967; Hawley & Kottlowski, 1969) and is less than 5,000 years old (Gile et al., 1970).

The average annual precipitation (excluding daily amounts of less than 0.63 cm) during 1960-70 was 20.8 cm (Table 2). The number of annual precipitation events associated with the total ranged from 7 to 25. During that period, soil moisture was recorded at depths of 10, 25, 40, 60, and 90 cm. The average number of days per year when the soil moisture potential was between 0 and −15 bars ranged from 129.9 days at the 10-cm depth to only 6.6 days at the 90-cm depth. During a wet year, 1961, there were 251 days when the moisture potential was between 0 and −15 bars at the 25-cm depth as follows: 1 January-18 May, 17-30 July, 17 August-28 September, and 20 November-26 December. At the 40-cm depth, no moisture between 0 and −15 bars was recorded for 5 of the 11 years. At the 90-cm depth, it was 9 out of the 11 years. Only the number of days with soil moisture at the 10- and 60-cm depths was significantly correlated to annual precipitation, probably because there is considerable runoff from the area.

Since this soil (to a depth of 67 cm, see Site A, Appendix) is less than 5,000 years old, it must have formed in a climate similar to the present one. The moisture data show that the noncalcareous B horizon is wetted most frequently, while the 2C1ca horizon is wetted somewhat less frequently. The moisture data, soil morphology, and soil age indicate that silicate clay is slowly accumulating in the B horizon and carbonate in the Cca horizon.

SITE B

The second site on the fan-piedmont occurs on the toeslopes at the edge of the basin floor. The slope is about 0.5%. While fan-toeslopes, such as this site, may contribute some runoff water to the basin floor from a high-intensity storm, they also receive considerable run-in from the adjacent steeper slopes such as those at site A. There are no distinct drainageways at this site but there is a microrelief, a few decimeters wide, caused by small depressions. The vegetation is a dense stand of tobosa [*Hilaria mutica* (Buckl.) Benth.]. Average annual production for 1958-61 was 3,000 kg/ha (Herbel, 1963). For 1960-66, it was 2,344 kg/ha. Clipping on this site was discontinued following 1966.

The soil moisture units are placed in an Ustollic Haplargid, fine, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil (Stellar, wedgy subsoil variant) near the moisture blocks are given in Table 2. The soil has formed in fan-piedmont sediments derived from monzonite, rhyolite, andesite, and latite, and is on the Jornada II surface of late-Pleistocene age (Gile & Hawley, 1968).

The average annual precipitation during 1960-70 was 19.8 cm (Table 2). During that period, soil moisture was recorded in two replications at depths of 10, 25, 40, 60, 90, and 120 cm. Soil moisture potential between 0 and −15 bars was recorded at an annual average of 166.5 days at the 25-cm depth and 203.9 days at the 60-cm depth. There were 46 days in 1960, 7 July-2 August and 14 August-3 September, when the moisture potential

Table 2. Precipitation, soil moisture, and soil morphology at Sites A and B, on the fan-piedmont adjacent to the basin floor.

Soil moisture and precipitation	Site A	Site B
Precipitation (cm)[*]		
Mean	20.8	19.8
Range	10.5-32.5	8.0-32.0
Soil moisture (days)[†] at stated depths		
10 cm		
Mean	129.9	172.1
Range	29-227	59-280
r[‡]	0.61	0.52
Regression[§]	19.3+5.3X	--
25 cm		
Mean	107.7	166.5
Range	1-251	46-285
r	0.54	0.16
Regression	--	--
40 cm		
Mean	60.8	191.1
Range	0-304	63-301
r	0.56	0.21
Regression	--	--
60 cm		
Mean	58.5	203.9
Range	0-224	51-356
r	0.67	0.25
Regression	-107.6+8.0X	--
90 cm		
Mean	6.6	175.5
Range	0-41	0-321
r	0.52	0.31
Regression	--	--
120 cm		
Mean	--	187.5
Range		0-365
r		0.26
Regression		--

Soil morphology (in part)[¶]			
Site A		Site B	
Typic Torriorthent, coarse-loamy, mixed, thermic		Ustollic Haplargid, fine, mixed, thermic	
Horizon and depth, cm	Morphology[¶]	Horizon and depth, cm	Morphology[¶]
A2, 0-4	Fine sandy loam, platy, crumb, soft, loose	A2, 0-7	Loam, crumb, blocky, slightly hard
B, 4-20	Gravelly sandy loam, massive, slightly hard	B1t, 7-15	Clay loam, blocky, very hard
2C1ca, 20-33	Very gravelly sandy loam, massive, soft	B21t, 15-43	Clay, blocky, extremely hard
3C2ca, 33-52	Gravelly sandy loam, blocky, slightly hard	B22t, 43-75	Clay, wedgy, platy, extremely hard
3C3ca 52-67	Gravelly sandy loam, massive, soft	K & B, 75-90	Clay, blocky, very hard
3Btcab, 67-80	Gravelly sandy clay loam, blocky, slightly hard	K2, 90-112	Silty clay loam, blocky, hard
4K&Ccab, 80-102	Gravelly sandy loam, massive, slightly hard	Bcacs, 112-133	Clay loam, blocky, hard
5Btcab2, 102-123	Gravelly sandy clay loam, blocky, hard	B1tcacsb, 133-152	Clay loam, blocky, hard
		B2tcacsb, 152-163	Clay loam, blocky, hard

[*] Annual precipitation excluding daily amounts of less than 0.63 cm.

[†] Days per year with the moisture potential between 0 and -15 bars.

[‡] Simple correlation between annual precipitation and days of moisture at each depth.

[§] Regression equations for those locations and depths having significant correlations (0.05 level). (Y = number of days of soil moisture at that depth and X = annual precipitation.)

[¶] Dominant texture, type of structure, and dry consistence for the stated horizons and depths. See sites A and B, Appendix, for full description.

was between 0 and −15 bars at the 25-cm depth. During 1962, there was moisture at the 25-cm depth for 285 days: 1 January–27 May, 20 July 29 August, and 26 September–30 December. There was only 1 year when no moisture was recorded at the 90- and 120-cm depths. There was no significant correlation of soil moisture at any depth with precipitation at this location, probably because a variable amount of the soil moisture is attributable to run-in water.

Upper horizons of this soil are quite high in clay which should cause slow infiltration of moisture from the surface. For this reason, the depth of moisture penetration (Table 2) might seem surprising at first glance. The microrelief and soil morphology suggest an explanation for the relatively deep and frequent wetting of this soil. A network of small circular and linear depressions occurs just upslope from the moisture station. One of the linear depressions is about 5 m long, 20–30 cm deep, and 50–75 cm wide; it occurs along the contour and should catch moisture moving downslope. This linear depression has branches 3–5 m long, one of which leads directly towards the moisture blocks and ends only about 1 m away from the blocks. In places, small tubes[3] extend from the depressions into the Bt horizon. The Bt horizon itself, described during a dry time, should transmit water rapidly at the onset of rainfall or run-in because of the numerous cracks between the plates, wedges, and blocks. These relationships indicate that the depressions, the tubes in the soil surface, and the cracks in the Bt horizon could cause lower horizons to be moistened quite rapidly and to depths greater than if wetting were accomplished only by downward movement through the matrix of the overlying horizons.

Soil morphology provides additional supporting evidence that the soil is wetted deeply in this way. The Stellar, wedgy subsoil variant is strongly calcareous throughout. Adjacent Argids only a few meters away, on the same surface, of the same age, and without the depressions, have Bt horizons that are noncalcareous in their upper parts and that lack the wedges and plates. This indicates that carbonates are being quite evenly leached by downward movement of water in the adjacent Argids, but not in the Argids with plates and wedges. These relationships also indicate considerable differences in depths of moisture penetration in soils that are only a few meters apart.

SITE C

Both this site and site D occur on the relatively level basin floor, although run-in water from the adjacent slopes does not stand on the area but drains slowly to a playa about 2 km south of these sites. The vegetation on this site is also tobosa, but in a somewhat sparser stand than at the previous location. Average annual production for 1960–70 was 1,055 kg/ha; during 1960–66 it was 755 kg/ha. The latter was only 32% of the production obtained at the previous site for the same period.

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[3] A term used to designate holes (in this case about 5 to 15 cm in diameter) descending into the soil.

The soil moisture units are placed in an Ustollic Haplargid, fine, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil (Stellar) near the moisture blocks are given in Table 3a. The soil has formed in basin floor sediments derived from monozonite, rhyolite, and andesite, and is on the Jornada I surface of late mid-Pleistocene age.

The average annual precipitation during 1960–70 was 19.6 cm (Table 3b). During that period, soil moisture was recorded in two replications at depths of 10, 25, 40, 60, 90, and 120 cm at site C, both inside and outside a metal cylinder. The soil moisture potential was between 0 and −15 bars for 48–53 days at the 40- through 120-cm depths for the 1960–70 period outside the metal cylinder. It was 82 and 134 days for the 25- and 10-cm depths, respectively. At the 25-cm depth outside the cylinder, no moisture between 0 and −15 bars potential was recorded for 2 of the 11 years. There was moisture for 205 days at the 25-cm depth in 1962: 1 January–8 May, 20 July–12 August, and 28 September–24 November. No moisture was recorded for 7 of the 11 years at the 90- and 120-cm depths. Inside the cylinder, the soil moisture potential was between 0 and −15 bars for 92 days at the 10-cm depth and for 32–40 days for the remaining depths. At the 25-cm depth inside the cylinder, no moisture between 0 and −15 bars potential was recorded for 7 of the 11 years. A similar situation existed for all depths greater than 25 cm.

Comparing data inside and outside the cylinder, an average of 36% of the days with soil moisture was attributable to run-in. Comparing data from site B and site C (outside the cylinder), there was an average of 128–425% more days with soil moisture potential between 0 and −15 bars at site B for the various depths. Outside the cylinder at site C, the number of days with soil moisture at the 10- through 60-cm depths was significantly correlated with annual precipitation. Inside the cylinder, all correlation values were significant and higher than those obtained from soil moisture measurements outside the cylinder.

The soil surface, morphology, and moisture data indicate that present genetic processes of this soil differ from those of the soil at site B. The Haplargid at site B is moistened deeply by way of the depressions and small tubes leading to cracks in the Bt horizon. In contrast, the depressions and tubes are not present at site C, and moistening of this soil is accomplished by wetting through the soil matrix from the soil surface downward. The soil moisture decreases regularly from the top down, in contrast to the situation at site B. The regular occurrence of the noncalcareous A3 and B21t horizons and the underlying calcareous B22t horizon in the soil at site C reflects this regular pattern of soil moisture. The moisture data and morphology of this soil and of the soil of Holocene age at site A, together with morphological comparisons of soils of Holocene and Pleistocene age elsewhere in the Desert Project (Gile, 1970), indicate that silicate clay is probably slowly accumulating in the B21t horizon at the present time. Carbonate accumulation is restricted primarily to the middle and lower parts of the B horizon with lesser accumulation at underlying depths.

The calcareous state of the A2 horizon is a feature of many soils in this basin-floor position. The carbonate has apparently been emplaced by the moisture of carbonate-laden waters and by incorporation of carbonate in the dustfall. More carbonate has accumulated at the soil surface than can be moved down into the soil by present soil moisture.

The effect of run-in is substantial (Table 3). At the 25-cm depth, the days per year when soil moisture is at 0 to −15 bars with run-in is more than twice that without run-in. This extra moisture may be critically important in keeping the A3 and B21t horizons noncalcareous.

However, available soil moisture at all depths, both with and without run-in, is less frequent than for the Paleargid at site G to be discussed later. This is attributed to the considerably greater percentage of clay and silt associated with the smooth-topped plates in the A2 horizon. Such horizons have a tendency to "seal" when wetted (Gile et al., 1970).

SITE D

This site is about 75 m from site C. The major species on this site is burrograss [*Scleropogon brevifolius* Phil.]. Average annual production for 1960–70 was 651 kg/ha or about 62% of the production obtained at site C.

The soil moisture blocks are in a Ustollic Calciorthid, fine-silty, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil

Table 3a. Soil morphology at Sites C and D in the basin floor.

Soil morphology (in part)*			
Site C		Site D	
Ustollic Haplargid, fine, mixed, thermic		Ustollic Calciorthid, fine-silty, mixed, thermic	
Horizon and depth, cm	Morphology*	Horizon and depth, cm	Morphology*
A2, 0–5	Clay loam, platy, slightly hard	A, 0–4	Clay loam, platy, slightly hard
A3, 5–9	Clay loam, blocky, hard	A3, 4–10	Silty clay loam, blocky, very hard
B21t, 9–23	Clay, prismatic, blocky, very hard	B1, 10–26	Clay loam, blocky, slightly hard
B22t, 23–44	Clay loam, prismatic, blocky, very hard	B21ca, 26–53	Silty clay loam, prismatic, blocky, hard
B23tca, 44–67	Clay, prismatic, blocky, very hard	B22ca, 53–79	Clay loam, prismatic, blocky, hard
B24tca, 67–87	Clay, prismatic, blocky, very hard	K & B, 79–95	Clay loam, blocky, slightly hard
K & Bt, 87–118	Clay loam, blocky, hard	B2tcab, 95–122	Sandy clay loam, prismatic, blocky, hard
K21, 118–134	Clay loam, platy, hard		

* Dominant texture, type of structure, and dry consistence for the stated horizons and depths. See sites C and D, Appendix, for full descriptions.

(Reakor) near the moisture blocks are given in Table 3a. The soil has formed in basin floor sediments derived primarily from sedimentary rocks such as limestone, siltstone, sandstone, and shale with lesser amounts derived from igneous rocks. This soil occurs on the Petts Tank surface (Hawley & Gile, 1966).

During 1960-70, soil moisture was recorded in two replications at the same depths as sites B and C, both inside and outside a sheet metal cylinder. Soil moisture potential between 0 and −15 bars ranged from 114.9 days at

Table 3b. Precipitation and soil moisture at sites C and D in the basin floor.

	Soil moisture and precipitation			
	Site C*	Site C†	Site D*	Site D†
Precipitation (cm)‡				
Mean	19.6	19.6	19.6	19.6
Range	11.8-32.0	11.8-32.0	11.8-32.0	11.8-32.0
Soil moisture (days)§ at stated depths				
10 cm				
Mean	134.4	91.8	114.9	78.2
Range	33-205	18-172	46-192	0-175
r¶	0.65	0.79	0.88	0.78
Regression**	23.8+5.7X	-29.6+6.2X	-7.9+6.3X	-49.6+6.5X
25 cm				
Mean	82.4	40.4	69.6	45.3
Range	0-205	0-179	0-165	0-162
r	0.80	0.83	0.82	0.87
Regression	-103.7+9.5X	-114.5+7.9X	-81.8+7.7X	-113.4+8.1X
40 cm				
Mean	51.3	32.7	47.2	28.3
Range	0-185	0-186	0-172	0-173
r	0.71	0.72	0.67	0.70
Regression	-74.5+6.4X	-100.4+6.8X	-69.1+5.9X	-96.1+6.4X
60 cm				
Mean	48.0	33.1	49.7	29.0
Range	0-193	0-182	0-181	0-174
r	0.66	0.72	0.51	0.70
Regression	-83.0+6.7X	-99.3+6.8X	--	-96.1+6.4X
90 cm				
Mean	52.6	32.8	34.5	27.3
Range	0-196	0-181	0-181	0-155
r	0.50	0.71	0.68	0.69
Regression	--	-99.0+6.7X	-93.4+6.5X	-96.1+6.4X
120 cm				
Mean	51.7	37.5	38.0	27.3
Range	0-176	0-203	0-181	0-155
r	0.42	0.66	0.67	0.69
Regression	--	-91.6+6.6X	-91.9+6.6X	-96.1+6.4X

* Soil moisture due to precipitation plus run-in.

† Soil moisture due to precipitation only.

‡ Annual precipitation excluding daily amounts of less than 0.63 cm. Because of the proximity of sites C and D, precipitation was recorded only at site C.

§ Days per year with the moisture potential between 0 and -15 bars.

¶ Simple correlation between annual precipitation and days of moisture at each depth.

** Regression equations for those locations and depths having significant correlations (0.05 level).

the 10-cm depth at site D to 34.5 days at the 90-cm depth outside the cylinder (Table 3b). At the 25-cm depth outside the cylinder, no moisture between 0 and −15 bars potential was recorded for 2 of the 11 years. During the wettest year, 1967, at the 25-cm depth, moisture was recorded 3–29 July and 14 August–31 December. No moisture was recorded for 8 of the 11 years at the 90- and 120-cm depths. Inside the cylinder, the soil moisture potential was between 0 and −15 bars for 78.2 days at the 10-cm depth and for 27.3 days at the 90- and 120-cm depths. There was 1 year when no moisture between 0 and −15 bars was recorded at the 10-cm depth. It was 6 years at the 25-cm depth and 9 years for all the remaining depths. Over all sampling depths, there were about 33% more days with moisture between 0 and −15 bars outside the cylinder or due to run-in. Virtually all correlations between days with soil moisture and precipitation were significant.

This soil has formed in high-carbonate parent materials as noted earlier. Studies of a similar soil not far from this site indicate that some carbonate originally in the parent materials still is present in upper horizons (Gile et al., 1970). Present moisture is clearly insufficient to remove carbonate from upper horizons. Further, this soil was formed in part during a Pleistocene pluvial when there was more effective moisture than now. The relationships indicate that even greater amounts of effective moisture of a pluvial was insufficient to remove the carbonate from upper horizons. As with the Haplargid at site C, the increased days of moisture due to run-in are considerable.

Playa

SITE E

This site is in a small playa at the end of a drainageway that begins on the slopes of the San Andres Mountains. The playa is flooded about twice every 3 years. The vegetation on this site is a mixed stand of tobosa and burrograss. Separate yield estimates were obtained for the relatively unmixed patches of each species. Average annual production of tobosa for 1960–70 was 1,291 kg/ha. Burrograss yields for the same period were 637 kg/ha. The yields at this site are more variable than those reported for sites B, C, and D.

The soil moisture blocks are embedded in a Typic Calciorthid, fine-loamy, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil (Algerita, deep gypsum phase) near the moisture blocks are given in Table 4. The soil has apparently formed primarily in alluvium resting on gypsum of lacustrine origin. While the alluvium has not been studied in detail, it apparently was originally derived from rocks of the San Andres Mountains to the east—limestone, sandstone, siltstone, and shale, with lesser amounts of igneous rocks. The alluvium is thickest in the lowest part of the playa, as at this site. At other parts of the playa, gypsum is nearer the surface or at the surface.

Table 4. Precipitation, soil moisture, and soil morphology at Site E, in the playa.

Soil moisture and precipitation		
	Site E[†]	Site E[‡]
Precipitation (cm)[§]		
Mean	18.8	18.8
Range	8.9-31.1	8.9-31.1
Soil moisture (days)[¶] at stated depth		
10 cm		
Mean	124.0	112.7
Range	32-211	36-176
r[**]	0.50	0.45
Regression[††]	--	--
25 cm		
Mean	81.2	71.5
Range	0-227	0-190
r	0.46	0.46
Regression	--	--
40 cm		
Mean	45.6	38.1
Range	0-168	0-146
r	0.50	0.62
Regression	--	-40.2+4.2X
60 cm		
Mean	6.8	1.9
Range	0-30	0-21
r	0.72	-0.21
Regression	-14.5+1.1X	--
90 cm		
Mean	0	0
Range		
r		
Regression		
120 cm		
Mean	0	0
Range		
r		
Regression		

Soil morphology (in part)[*]	
Site E	
Typic Calciorthid, fine-loamy, mixed, thermic	
Horizon and depth, cm	Morphology[*]
C, 0-3	Fine sandy loam, single grain, loose
A1, 3-12	Fine sandy loam, massive, platy, hard
B11, 12-31	Clay loam, prismatic, blocky, very hard
B12, 31-50	Sandy clay loam, prismatic, blocky, very hard
B21ca, 50-65	Silty clay loam, prismatic, blocky, slightly hard
B22ca, 65-90	Silty clay loam, prismatic, blocky, slightly hard
B23ca, 90-112	Silty clay loam, prismatic, blocky, hard
2C1ca, 112-120	Loam, prismatic, blocky, slightly hard
2C2ca, 120-138	Sandy loam, massive, very hard

[*] Dominant texture, type of structure, and dry consistence for the stated horizons and depths. See Site E, Appendix, for full description.

[†] Soil moisture due to precipitation plus run-in.

[‡] Soil moisture due to precipitation only.

[§] Annual precipitation excluding daily amounts of less than 0.63 cm.

[¶] Days per year with the moisture potential between 0 and -15 bars.

[**] Simple correlation between annual precipitation and days of moisture at each depth.

[††] Regression equations for those locations and depths having significant correlations (0.05 level). (Y = number of days of soil moisture at that depth, and X = annual precipitation.)

The average annual precipitation during 1960–70 was 18.8 cm (Table 4). During that period, soil moisture was recorded on an area with a mixed stand of tobosa and burrograss in two replications at depths of 10, 25, 40, 60, 90, and 120 cm, both inside and outside a sheet metal cylinder. During the 11-year period, no moisture between 0 and −15 bars potential was recorded at the 90- and 120-cm depths. In 1959, there were 31 days with moisture between those levels at those depths. Soil moisture was recorded for an average of 124.0 days at the 10-cm depth and 6.8 days at the 60-cm depth outside the cylinder. At the 25-cm depth outside the cylinder, no moisture between 0 and −15 bars potential was recorded for 4 of the 11 years. There was moisture for 227 days at the 25-cm depth in 1962: 1 January–29 April, 28 July–17 August, 3 October–3 December, and 29–31 December. No moisture was recorded for 8 of 11 years at the 60-cm depth. Inside the cylinder, the soil moisture potential was between 0 and −15 bars for 112.7 days at the 10-cm depth and 1.9 days at the 60-cm depth.

Over all depths with moisture, there was an average of about 8 days each year when soil moisture could be attributed to run-in. This is considerably lower than for sites B, C, and D. This is attributed to the fact that the local watershed is much less than at sites B, C, and D. Also, observations indicate that water from the mountains and intervening areas does not often reach the playa in large amounts. The days with soil moisture at only one depth in each, outside and inside the cylinder, were significantly related to precipitation.

The moisture data show that the A1 and B11 horizons are moistened most frequently. However, these horizons are still strongly calcareous. This is probably due in part to the highly calcareous nature of the parent materials.

Judging from morphology and soil moisture relations at sites A, C, and D, carbonate is slowly accumulating at the present time in the soil at site E, primarily in the upper part of the B horizon. No evidence of illuviation of silicate clay was observed in the soil at site E.

Basin Floor Without Run-in

This part of the basin has a level to gently rolling topography. Water movement following high intensity rainfall is very localized because the landscape is level or nearly level; there is no run-in; and upper horizons are relatively coarse in texture.

SITE F

This site is on a very slight slope. The area is subject to wind erosion and the surface has small hummocks. This area had a good cover of black grama prior to the great drouth of 1951–56 (Herbel, Ares, & Wright, 1972). By the end of that drouth, black grama cover was reduced to 1% of the predrouth average and it has not increased since that time. The present vegetation is a relatively sparse stand of mesa dropseed [*Sporobolus flexuosus* (Thurb.) Rydb.] and a variety of forbs and annual grasses under certain weather conditions. Average annual production of perennial grasses for 1960–70 was 23 kg/ha.

Table 5. Precipitation, soil moisture, and soil morphology at Sites F and G, in the basin floor.

Soil moisture and precipitation		
	Site F	Site G†
Precipitation (cm)‡		
Mean	19.3	18.9
Range	10.8-29.8	11.5-34.9
Soil moisture (days)§ at stated depths		
10 cm		
Mean	192.0	193.9
Range	97-301	64-321
r¶	0.51	0.51
Regression**	--	--
25 cm		
Mean	173.5	212.2
Range	62-318	99-336
r	0.58	0.64
Regression	--	81.4+6.9X
40 cm		
Mean	121.9	158.5
Range	0-312	32-333
r	0.63	0.67
Regression	-80.2+10.5X	-8.2+8.8X
60 cm		
Mean	90.2	116.8
Range	0-319	0-350
r	0.44	0.70
Regression	--	-107.7+11.9X
90 cm		
Mean	18.7	96.5
Range	0-179	0-278
r	0.32	0.71
Regression	--	-114.9+11.2X

Soil morphology (in part)*			
Site F		Site G	
Typic Haplargid, coarse-loamy, mixed, thermic		Petrocalcic Paleargid, coarse-loamy, mixed, thermic	
Horizon and depth, cm	Morphology*	Horizon and depth, cm	Morphology*
B2t, 0-18	Fine sandy loam, blocky, slightly hard	C, 0-5	Sand, loose, soft, single grain, massive
B31t, 18-34	Fine sandy loam, massive, slightly hard	A2, 5-10	Fine sandy loam, massive, soft
B32t, 34-44	Loamy sand, massive, soft	B1t, 10-23	Fine sandy loam, massive, slightly hard
B1tcab, 44-60	Sandy loam, prismatic, blocky, hard	B21t, 23-36	Fine sandy loam, massive, slightly hard
B21tcab, 60-76	Sandy clay loam, prismatic, blocky, hard	B22tca, 36-46	Fine sandy loam, massive, slightly hard
B22tcab, 76-90	Sandy clay loam, prismatic, blocky, hard	B3ca, 46-71	Sandy loam, blocky, slightly hard
B23tcab, 90-103	Sandy clay loam, prismatic, blocky, hard	K1, 71-79	Very gravelly sandy loam, crumb, loose
K2b, 103-126	Sandy clay loam, blocky, very hard	K2m, 79-90	Carbonate-cemented material, massive, extremely hard

* Dominant texture, type of structure, and dry consistence for the stated horizons and depths. See Sites F and G, Appendix, for full descriptions.

† On site G, soil moisture units were placed at depths of 10, 25, 40, 53, and 68 cm instead of 10, 25, 40, 60, and 90 cm.

‡ Annual precipitation excluding daily amounts of less than 0.63 cm.

§ Days per year with the moisture potential between 0 and -15 bars.

¶ Simple correlation between annual precipitation and days of moisture at each depth.

** Regression equations for those locations and depths having significant correlations (0.05 level). (Y = number of days of soil moisture at that depth and X = annual precipitation.)

The soil moisture blocks are in a Typic Haplargid, coarse-loamy, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil (Onite, buried soil variant) are given in Table 5. The soil at the land surface has apparently formed in a sandy eolian deposit considerably younger than the buried horizon below.

The average annual precipitation during 1960-70 was 19.3 cm (Table 5). During that period, soil moisture was recorded in three replications at depths of 10, 25, 40, 60, and 90 cm. The average number of days per year when the soil moisture potential was between 0 and −15 bars ranged from 192.0 at the 10-cm depth to 18.7 at the 90-cm depth. There were 62 days in 1967 (4–31 July, 21–25 August, and 29 September–30 October) when there was moisture at the 25-cm depth. During 1962, there was moisture for 318 days: 1 January–25 June, 4 July–20 August, and 28 September–30 December. At the 40-cm depth, no moisture between 0 and −15 bars was recorded for 3 of the 11 years. At the 90-cm depth, it was 8 of the 11 years. Only the number of days with soil moisture at the 40-cm depth was significantly correlated to annual precipitation. It was noted that moisture from individual precipitation events was more diffuse throughout the profile than in Site G. This has apparently contributed to greater drouth damage on this site than the shallower site G (Herbel et al., 1972).

The soil moisture at this site is considerably greater than in the soil at site E despite the fact that this soil receives virtually no run-in. This is because of the considerable difference in texture, upper horizons of this soil being much less clayey and having greater infiltration rates. This soil is noncalcareous to a depth of 44 cm and is moistened fairly frequently to that depth.

The soil at the land surface has apparently been recently truncated since the Bt horizon is at the surface. However, morphology, moisture data, and comparisons with similar soils of known age indicate that silicate clay is very slowly accumulating in the B2t and B3t horizons, and that carbonate is accumulating in the B1tcab horizon.

SITE G

There is less wind erosion evident at this site than at site F. Both areas are nearly level. There was also less drouth damage at this site than at site F. The major species on the area is black grama with scattered plants of mesa dropseed and soaptree yucca [*Yucca elata* Engelm.]. Average annual production of perennial grasses for 1960–70 was 346 kg/ha.

The soil moisture blocks are in a Petrocalcic Paleargid, coarse-loamy, mixed, thermic. The texture, type of structure, and dry consistence of a similar soil (Hueco) near the moisture blocks are given in Table 5. The soils have formed in sandy sediments of the Camp Rice Formation (fluvial facies).

The average annual precipitation during 1961–70 was 18.9 cm (Table 5). During that period, soil moisture was recorded at depths of 10, 25, 40, 53, and 68 cm. The average number of days when the soil moisture potential was between 0 and −15 bars ranged from 212.2 at the 25-cm depth to 96.5 at the 68-cm depth. During the driest year, 1965, there was moisture at the 25-cm depth 1 March–27 April and 20 September–1 November. There was moisture at the 25-cm depth for the entire year in 1961, except 11 June–10 July. At the 53-cm depth, no moisture between 0 and −15 bars potential was recorded for 3 of the 10 years. At the 68-cm depth, it was 5 of the 10 years. There was considerably more moisture at this site than at site F particularly at the deeper depth.

The soil moisture data are similar to those at site F in upper horizons, but the soil moisture increases considerably in lower horizons. The difference is partly attributed to the greater thicknesses of coarser-textured horizons that occur above the clay maximum in this soil. Infiltration rate should be relatively rapid in the uppermost two horizons, a sand and light fine sandy loam.

Another prominent difference of this soil, as compared to the one at site F, is the presence of the petrocalcic horizon at 68 cm. In general, any discontinuity, whether a change from more permeable to less permeable material with depth or the existence of relatively impermeable material within the profile, increases the water retained by the soil. At site G, the petrocalcic horizon at about the 68-cm depth holds the soil moisture at depths favorable for plant use. Further, the soil water is stored longer because the texture of the surface soil is fairly coarse. There is less loss of soil water through evaporation from soils with sandy surfaces than from soils with finer textures at the surface because of considerably reduced capillary movement of water in the coarser-textured horizons.

A large pipe (cf. Gile et al., 1966, for diagram and discussion of one of the pipes in these ancient soils of La Mesa surface) was found near the moisture blocks with an auger. The pipe extends to depths greater than 125 cm. The soil in the pipe has a fine sandy loam Bt horizon at about the same depth as the described soil. The grama grass was well developed; there appeared to be little or no difference in the vegetation of soils in the pipe and soils adjacent to the pipe.

Bailey studied infiltration and water movement on the Jornada Experimental Range on soils similar to those at sites F and G (O. F. Bailey. 1967. Water availability and grass root distribution in selected soils. M.S. Thesis. New Mexico State Univ., Las Cruces). He simulated rainfall in amounts of 1.3, 2.5, and 3.8 cm. Most of the applied water was retained in the upper two horizons of the soils studied. There was less moisture in the upper two horizons on the deeper soils, such as at site F, than the shallower soils, such as at site G, after each of the simulated rains. Apparently, the soil water is more diffused throughout the profile in the soil at site F than the shallower soil at site G.

Relation of the Soil Moisture Data to the New U. S. System of Soil Classification

The moisture data presented above are of interest from the standpoint of soil classification because criteria involving soil moisture are used in the new U. S. system of classification (Soil Survey Staff, 1973). Moreover, the data are from an arid region where very little information of this kind is available. In the classification system, *soil moisture regimes* are defined in terms of a *soil moisture control section* as discussed in the following sections.

SOIL MOISTURE CONTROL SECTION AND THE SOIL MOISTURE REGIME

The following information concerning the soil moisture criteria is quoted below since it is still in the process of publication (Soil Survey Staff, 1973).

> The intent in defining the soil moisture control section is to facilitate the estimation of soil moisture regimes from climatic data. The upper boundary of this control section is the depth to which the dry(tension > 15 bars, but not air dry) soil will be moistened by 2.5 cm (1 inch) of water within 24 hours. Its lower boundary is the depth to which the dry soil will be moistened by 7.5 cm (3 inches) of water within 48 hours. These depths are exclusive of the depth of moistening along any cracks or animal burrows that are open to the surface.
>
> If 7.5 cm of water moistens the soil to a lithic, petroferric, or paralithic contact or to a petrocalcic horizon or a duripan, the upper boundary of the rock or of the cemented horizon is the lower boundary of the soil moisture control section. If 2.5 cm of water moistens the soil to one of these contacts or horizons, the soil moisture control section is the lithic contact itself, the paralithic contact, or the upper boundary of the cemented horizon. The control section of the latter soil is moist if the upper boundary of the rock or the cemented horizon has a thin film of water. If the upper boundary is dry, the control section is dry.
>
> As a rough guide to the limits, the soil moisture control section lies approximately between 10 and 30 cm (4 and 12 inches) if the particle-size class is fine-loamy, coarse-silty, fine-silty, or clayey. . . .The control section extends approximately from a depth of 20 cm to a depth of 60 cm (8 to 24 inches) if the particle-size class is coarse-loamy, and from 30 to 90 cm (12 to 35 inches) if the particle-size class is sandy. Obviously, coarse fragments deepen these limits to the extent that the fragments do not absorb and release water. In addition to the particle-size class, differences in structure, differences in pore size distribution, and other factors that influence movement and retention of water in the soil also affect the limits of the soil moisture control section.
>
> The soil moisture regime, as the term is used here, refers to the presence or absence either of groundwater or of water held at a tension of less than 15 bars in the soil or in specific horizons by periods of the year. Water held at a tension of 15 bars or more is not available to keep most mesophytic plants alive. The availability of water also is affected by dissolved salts. A soil may be saturated with water that is too salty to be available for most plants, but it would seem better to call such a soil salty rather than dry. Consequently, we consider a horizon to be dry when the moisture tension is 15 bars or more. If water is held at a tension of less than 15 bars but more than zero, we consider the horizon to be moist.
>
> *Aridic and Torric* (L. *aridus*, dry, and L. *torridus,* hot and dry) moisture regimes. These terms are used for the same moisture regime, but in different categories of the taxonomy.
>
> In the aridic (torric) moisture regime, the moisture control section in most years is
>
> a. Dry in all parts more than half the time (cumulative) that the soil temperature at a depth of 50 cm is above 5°C; and

> b. Never moist in some or all parts for as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8°C.

The area of this study has been placed within the aridic and torric moisture regimes defined above.

The moisture data in Tables 2–5 indicate that most of the soils easily meet the requirement "In most years there is no available water in any part of the moisture control section more than half the time (cumulative) that the soil temperature at 50 cm is above 5°C. . . ."

It appears that the Haplargid at site B may not meet the stated requirements, but this soil is excluded because depths cited in the definition of the moisture control section "are exclusive of the depth of moistening along any cracks or animal burrows that are open to the surface."

The Petrocalcic Paleargid at site G does exceed the time of moistening allowed in the definition. An examination of the soil moisture records from 1961–70 indicates that available moisture was present at 25 cm more than half the time in 7 of the 10 years. However, at 40 cm (Table 5) the moisture data meet the criteria for the aridic moisture regime.

Soil moisture criteria are also used at the subgroup level of classification for some soils. Again considering the Petrocalcic Paleargid at site G, the following information (Soil Survey Staff, 1973) that applies to Petrocalcic Paleargids is pertinent:

> f. are dry in all parts of the moisture control section more than three-fourths of the time (cumulative) that the soil temperature at 50-cm depth is 5°C or more.

As can be seen, the moisture control section of this soil, on an average basis, is moistened nearly three times as long as allowed under the stated definition. In the driest year, 1965, there was soil moisture between 0 and −15 bars potential for 99 days at 25 cm (Table 5). As discussed earlier, this site has no run-in but does have conditions for maximum infiltration and entrapment of moisture.

Another reason for the presence of soil moisture for a relatively long time in this soil is the precipitation that falls during some winters. Soil moisture from this precipitation tends to stay in the soil for a long time, commonly throughout the early spring season until plant growth begins.

SOIL MOISTURE AND THE USTOLLIC INTERGRADES

Aridisols in southern New Mexico are dominant in arid areas between the mountains, and Mollisols occur in places along the mountain fronts. Therefore, intergrades between these two soil orders would be expected. Such intergrades do occur and are designated as Ustollic subgroups (e.g., Ustollic Calciorthid). The identification of the Ustollic subgroups is based on the amount of organic carbon relative to sand-clay ratios (Soil Survey Staff, 1973). Ustollic intergrades occur both along the mountain fronts, closely associated with the Mollisols, and in the arid regions between the mountains.

Distribution of the Ustollic subgroups is presently under study. Indications are that they are quite readily predicted, particularly in soils that contain little or no gravel, such as the soils in this study.

Some of the arid-land soils between the mountain ranges (Fig. 2) actually contain more organic carbon than some Mollisols, but are not Mollisols because their upper horizons are too light-colored for a mollic epipedon. These soils are most common in landscape positions that receive extra moisture as runoff from areas upslope—in basin floors and broad drainageways. Also, in this area the Ustollic subgroups occur only in soils that contain fairly high amounts of clay, silt, or both. The Ustollic subgroups are well illustrated by the Stellar and Reakor soils (sites B, C, and D). The soil moisture data and analyses for similar soils indicate that some soils (e.g., the Paleargid at site G) are wetted fairly frequently in the moisture control section, but contain insufficient organic carbon because of their low clay content.

SOIL GROUPINGS BASED ON MOISTURE DIFFERENCES WITHIN THE ARIDISOLS

As noted earlier, there is considerable variation in soil moisture in the study area even in soils only several meters apart. Because of this variation, it may be feasible to make groupings at the series or phase level where needed for use of the soil. Some separations may be made on the basis of soil morphology, such as structural differences between the Haplargids at sites B and C. Soils similar in morphology and not otherwise separable may be separated on the basis of location in landscape positions subject to overflow (an overflow phase). On a regional basis, it may be feasible to separate some soils by differences in precipitation if other factors cannot be used.

CONCLUSIONS

Much of the precipitation in this arid region falls during torrential rainstorms and runoff rates are high on slopes. Soil texture, soil structure, landscape position, vegetative cover, and microrelief are also variable and can have a marked effect on soil moisture.

Soil texture is an important factor because surficial horizons of sandy texture should have most rapid infiltration rates during rainfalls of high intensity. This is shown by the data at site G. Conversely, low infiltration rates would be expected in soil horizons with high clay content, where wetting is accomplished by infiltration at the surface and not through tubes and cracks in the soil such as at site B. At the 25-cm depth, the fine Haplargid at site C (wetted by precipitation only) had less than one-fifth the days of moisture than the coarse-loamy Paleargid at site G. Platy structure of the A horizon is also important, particularly in the finer-textured soils as such horizons tend to "seal" when wetted.

Landscape position is also significant in determining the amount of moisture that enters the soil. Runoff from higher areas can markedly increase depths of wetting in topographic lows as shown by sites C, D, and E. Conversely, such runoff decreases moisture in the soils upslope.

Microrelief can greatly influence moisture infiltration. The microrelief at site B, together with the soil morphology, indicates that the depth of moisture infiltration has been considerably increased by small depressions and tubes in the soil surface and by cracks in soil horizons connected to the tubes. Conversely, absence of these features can greatly decrease depths of wetting in soils only a few meters away.

In stable areas where runoff is not a factor, most favorable moisture conditions occur in soils and landscapes that have the following characteristics: (i) level or nearly level areas of a stable landscape that show little or no evidence of erosion, (ii) a thin surficial horizon about 5–10 cm thick and coarse textured (sand or loamy sand) to allow maximum infiltration of moisture, and (iii) a slightly finer-textured horizon (e.g., medium or heavy sandy loam) a few decimeters thick just beneath the surficial horizon to capture most of the moisture that has penetrated and to prevent its movement to greater depths with consequent loss to the plant. Such horizons still have fairly rapid infiltration rates. Indurated horizons can also be helpful in slowing or preventing downward penetration of moisture.

Therefore, precipitation values alone can be misleading from the standpoint of the moisture that actually enters the soil. Clearly the factors discussed above must be considered in evaluating moisture of arid-land soils.

APPENDIX—Descriptions of Soils at Sites A–G

Site A

Soil Variant—Canutio, coarse-loamy variant.

Classification—Typic Torriorthent, coarse-loamy, mixed, thermic.

Soil Surface—About 50% covered with rhyolite and monzonite pebbles, most of which range from 1–2 cm in diameter, with a few up to 3 cm diameter.

A2 (0–4 cm)—Pinkish-gray (7.5YR 6/3, dry) or dark brown (7.5YR 4/3, moist) fine sandy loam, mainly weak fine platy structure and soft, with some parts a loose mass of soft fine crumbs; very few roots; noncalcareous; mildly alkaline; abrupt smooth boundary.

B (4–20 cm)—Light brown (7.5YR 5.5/4, dry) or dark brown (7.5YR 4/4, moist) gravelly sandy loam; massive, slightly hard, friable; very few roots; clay coatings on sand grains and pebbles; occasional very gravelly lenses up to about 5 cm thick and 40 cm long; effervesces weakly in the lower 2 cm of the horizon where scattered pebbles have carbonate coatings on their undersides, otherwise, noncalcareous; mildly alkaline; clear wavy boundary.

2C1ca (20–33 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 4.5/4, moist) very gravelly sandy loam; massive; soft, very friable; very few roots; thin carbonate coatings on pebbles; effervesces strongly; moderately alkaline; clear wavy boundary.

3C2ca (33-52 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 4.5/4, moist) gravelly sandy loam; weak medium subangular blocky structure; slightly hard, friable; very few roots; a few carbonate filaments; pebbles and sand grains thinly carbonate-coated; effervesces strongly; moderately alkaline; clear wavy boundary.

3C3ca (52-67 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 4.5/4, moist) gravelly light sandy loam; massive; soft, very friable; very few roots; thin, discontinuous carbonate coatings on pebbles and sand grains; several pockets and lenses of very gravelly materials ranging from 5-25 cm in diameter; in places the lower 1-2 cm is a fine gravelly loamy sand; effervesces strongly; moderately alkaline; abrupt and clear wavy boundary.

3Btcab (67-80 cm)—Reddish-brown (5YR 5/4, dry; 5YR 4/4, moist) gravelly light sandy clay loam; weak medium and fine subangular blocky structure; slightly hard, friable, very few fine roots; clay coatings on sand grains and pebbles; common carbonate filaments; pebbles thinly coated with carbonate; generally effervesces strongly, a few parts effervesce weakly; moderately alkaline; abrupt wavy boundary.

4K & Ccab (80-102 cm)—Dominantly pinkish-white (7.5YR 8/2, dry) or pink (7.5YR 8/4, moist) with lesser amounts of light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) gravelly to very gravelly sandy loam; massive; slightly hard and hard, friable, and firm; no roots; grains in light-colored volumes are separated by carbonate; grains in darker-colored material are usually in contact but do have a few thin discontinuous carbonate coatings; in places, texture is a gravelly sand in the lower 2 cm; effervesces strongly; moderately alkaline; abrupt smooth boundary.

5Btcab2 (102-123 cm)—Reddish-brown (5YR 5/4, dry; 5YR 4/4, moist) gravelly sandy clay loam; weak medium and fine subangular blocky structure; hard, friable, and firm; no roots; clay coatings on sand grains; common carbonate filaments and pebble coatings; effervesces strongly in most places, a few areas effervesce weakly or are noncalcareous; moderately alkaline; abrupt smooth boundary to underlying petrocalcic horizon.

Remarks—The increase in clay from A to B is too slight for an argillic horizon. The B horizon is too thin for a cambic horizon since the carbonate maximum starts at 20 cm (Soil Survey Staff, 1973). There is not enough carbonate for a calcic horizon. The soil may be a Torrifluvent, but analyses of similar horizons in similar positions indicate that both amounts and irregular decrease in organic carbon are questionable for a Fluvent. Therefore, the soil is considered to be a Torriorthent.

The soil from 0 to 67 cm has formed in Organ alluvium and is less than 5000 years old. The buried soil from 67 to 102 cm is considered to be of Isaacks' Ranch age (Gile et al., 1970) and is thought to have formed largely during latest Pleistocene. The second buried soil, below 102 cm and including the petrocalcic horizon, is considered to be of Jornada II age (Gile & Hawley, 1968) and must have formed entirely during late Pleistocene.

Site B

Soil Series—Stellar, wedgy subsoil variant.

Classification—Ustollic Haplargid, fine, mixed, thermic.

Soil Surface—There are scattered small depressions, commonly 20–30 cm deep and 10–40 cm in diameter, but in places linear and ranging up to several meters long. Tubes extend from some of the depressions into the Bt horizon.

A2 (0–7 cm)—Light gray (10YR 7/2, dry) or grayish-brown (10YR 4.5/2, moist) loam; weak fine and very fine crumb in upper part, weak medium subangular blocky and coarse platy below; slightly hard and hard, friable; common roots; effervesces strongly; moderately alkaline; abrupt smooth boundary.

B1t (7–15 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) heavy clay loam in upper part, clay in lower part; weak medium subangular blocky structure, very and extremely hard, firm; common roots; effervesces strongly; moderately alkaline; clear smooth boundary.

B21t (15–43 cm)—Brown (7.5YR 5/4, dry) or dark brown (7.5YR 4/4, moist) clay; moderate medium and coarse blocky structure; blocks separated by an irregular network of cracks up to 0.5 cm in diameter; this material easier to remove than that below; common roots; extremely hard, very firm; effervesces strongly; clear wavy boundary.

B22t (43–75 cm)—Brown (7.5YR 5/4, dry) or dark brown (7.5YR 4/4, moist) clay; dominantly moderate coarse platy and wedgy, with some weak medium subangular blocky structure; plates and wedges nearly horizontal ranging from about 0.5–2 cm thick and up to 5 cm long; extremely hard, very firm; a few roots ranging from about 0.5–1 mm thick; slickensides on some ped faces; blocks, plates, and wedges tightly packed and difficult to remove with a hammer; a few vertical cracks ranging from < 0.5–1 mm in width extend into this horizon from the overlying horizon, and there are also cracks, commonly horizontal or nearly so, about 0.5 mm or less in width, between the structural units; effervesces strongly; moderately alkaline; clear smooth boundary.

K & B (75–90 cm)—Dominantly pink (7.5YR 8/4, dry) or light brown (7.5YR 6/4, moist) with lesser amounts of brown (7.5YR 5/4, dry) or dark brown (7.5YR 4/4, moist) clay; dominantly weak medium subangular and angular blocky, but both high-carbonate parts (light-colored) and low-carbonate parts (dark-colored) are usually arranged in roughly vertical strips ranging from 1–10 mm in diameter; a few wedges and plates, 1–2 cm thick and 2–4 cm long; very hard, firm; very few roots; a few carbonate filaments; a few hard carbonate nodules; harder than underlying horizons; effervesces strongly; moderately alkaline clear smooth boundary.

K2 (90-112 cm)—Dominantly pinkish-white (7.5YR 8/2, dry) or light brown (7.5YR 6/4, moist) with lesser amounts of light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) silty clay loam; weak medium subangular blocky structure; hard, firm; no roots; light-colored, high-carbonate zones occur in irregular masses between which are darker-colored zones lower in carbonate; few very fine tubular pores; effervesces strongly; moderately alkaline; clear wavy boundary.

Bcacs (112-133 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) heavy clay loam; compound weak medium prismatic and weak and moderate, fine and medium subangular blocky structure; hard, firm; no roots; few carbonate nodules, 1-5 mm in diameter; powdery, fine gypsum crystals on ped surfaces in a few places; common very fine tubular pores; moderately alkaline; effervesces strongly; clear wavy boundary.

B1tcacsb (133-152 cm)—Dominantly light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) with a few parts reddish-brown (5YR 5/4, dry; 5YR 4/4, moist) heavy clay loam; weak medium subangular blocky structure; hard, firm; no roots; a few powdery discontinuous gypsum coatings on ped faces; common fine and very fine tubular pores some of which are lined with reddish-brown material; effervesces strongly; moderately alkaline; clear wavy boundary.

B2tcacsb (152-163 cm)—Reddish-brown (5YR 5/4, dry; 5YR 4/4, moist) clay loam; weak fine and medium subangular blocky structure; hard, firm; no roots; black (Mn? Fe?) filamentary coatings on many ped faces; few gypsum filaments; a few carbonate filaments and nodules; many ped faces smooth and reflective; generally effervesces strongly, but a few parts noncalcareous; moderately alkaline.

Remarks—Some of the clay in the Bt horizon is thought to be of sedimentary origin, placed by movement of clay-laden water into the holes and along cracks in the Bt horizon when it is dry. However, this soil is considered to have an argillic horizon on the following evidence: (i) there is an increase in clay from A to B; (ii) although no thin sections were made of the B horizon, judging from thin sections of similar materials, the required amount of oriented clay is present; and (iii) the horizon may be traced laterally to soils of the same surface, of the same age, and only a few meters away that do have demonstrable argillic horizons and that lack the plates and wedges in the Bt horizon. Prior to development of the plates and wedges, the described soil is thought to have had an argillic horizon similar to that of the adjacent soils. Therefore, part of the clay in the present platy and wedgy horizon is considered to be of illuvial origin, placed earlier in the history of the soil.

Vertical cracks of the described width in the B21t horizon developed only after the pit had been open and the soil had dried for several days. The soil was fairly dry when the pit was dug in May 1971, with no effective rain since August 1970.

Site C

Soil Series—Stellar

Classification—Ustollic Haplargid, fine, mixed, thermic.

Soil Surface—The soil surface between grass clumps is cracked into smooth-topped polygons ranging from 1-5 cm in diameter. Cracks between polygons range from 0.5-1 mm in width. The topmost part of the polygons is readily removed and disengages as a plate ranging from about 2-8 mm in diameter. The soil surface as a whole is very smooth with virtually no microrelief.

A2 (0-5 cm)—Light gray (10YR 7/2, dry) or dark brown (10YR 4/3, moist) clay loam; weak fine and medium platy; slightly hard, very friable; few roots; few fine and very fine tubular pores; effervesces strongly; moderately alkaline; abrupt smooth boundary.

A3 (5-9 cm)—Light brown (7.5YR 6/3, dry) or dark brown (7.5YR 4/3, moist) clay loam; weak fine subangular blocky structure; hard, friable; common roots, about 1 mm in diameter; horizon becomes redder in lower part; generally noncalcareous, effervesces weakly in places; mildly alkaline; abrupt smooth boundary.

B21t (9-23 cm)—Reddish-brown (6YR 5/4, dry; 6YR 4/4, moist) clay; compound weak medium prismatic and weak medium and fine subangular blocky structure; very hard, firm; common roots, about 1 mm in diameter; sand grains coated with clay; noncalcareous; mildly alkaline; clear wavy boundary.

B22t (23-44 cm)—Reddish brown (6YR 5/4, dry; 6YR 4/4, moist) heavy clay loam; weak coarse prismatic, breaking to weak medium subangular blocky structure; very hard, firm; few roots, about 1 mm diameter; sand grains coated with clay; effervesces strongly; moderately alkaline; clear wavy boundary.

B23tca (44-67 cm)—Reddish brown (5YR 5/4, dry; 5YR 4/4, moist) clay; compound weak coarse prismatic and weak medium and coarse subangular blocky structure; very hard, firm; few roots, 0.5-1 mm in diameter; some ped faces have smooth, reflective faces; a few fine hard carbonate nodules ranging from 1-3 mm in diameter; sand grains coated with clay; effervesces strongly; moderately alkaline; clear smooth boundary.

B24tca (67-87 cm)—Reddish brown (5YR 5/4, dry; 5YR 4/4, moist) clay, with a few spots slightly redder; compound weak coarse prismatic and weak medium and coarse subangular blocky structure; very hard, firm; very few roots; sand grains coated with clay; a few fine carbonate nodules ranging from 1-5 mm in diameter; a few carbonate filaments; some ped surfaces have smooth reflective faces; effervesces strongly; moderately alkaline; clear smooth boundary.

K & Bt (87-118 cm)—About equal parts of high-carbonate material, pinkish white (7.5YR 8/2, dry) or light brown (7.5YR 7/4, moist) with parts whiter, and parts containing less carbonate, light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) and reddish brown (5YR 5/4, dry; 5YR 4/4, moist) clay loam; weak medium subangular blocky structure; dominantly hard, firm; very few roots; carbonate occurs as nodular and cylindroidal forms and as masses of irregular shape with consistence ranging from slightly to very hard; effervesces strongly; moderately alkaline; clear wavy boundary.

K21 (118–134 cm)—Dominantly pinkish white (7.5YR 8/2, dry), pink (7.5YR 7/4, moist), or light brown (7.5YR 6/4, moist) with lesser amount pink (7.5YR 7/4, dry), a few stainings of pink (5YR 8/4, dry) or reddish brown (5YR 5/4, dry) heavy clay loam; weak medium and coarse platy structure; hard, firm; no roots; effervesces strongly; moderately alkaline.

Remarks—Only the upper subhorizon of the thick K horizon is described here (see pages A-91 and 92, Gile et al., 1970 for description and laboratory data for the full thickness of a similar pedon).

Site D

Soil Series—Reakor

Classification—Ustollic Calciorthid, fine-silty, mixed, thermic.

Soil Surface—The surface is cracked into polygons ranging from about 1–3 cm in diameter. Most cracks between polygons are less than 0.5 mm wide. Fragments of loose drying platelets, 1–2 mm thick, occur on the surface around the grass clumps. Tops of polygons are easily removed as plates which range from about 2–8 mm thick. A few pebbles of mixed lithology occur near the moisture blocks. Most pebbles range from about 1–2 cm in diameter; a few range up to 4 cm in diameter. There is very little microrelief in the surface as a whole.

A (0–4 cm)—Light brownish-gray (10YR 6.5/2, dry) or dark brown (10YR 4.5/3, moist) clay loam; weak fine and medium platy structure; slightly hard; few and common roots; few very fine tubular pores; effervesces strongly; moderately alkaline; abrupt smooth boundary.

A3 (4–10 cm)—Light brownish-gray (10YR 6.5/2, dry) or dark brown (10YR 4/3, moist) silty clay loam; weak coarse subangular blocky structure; very hard, firm; few fine and very fine tubular pores; common roots; effervesces strongly; moderately alkaline; clear smooth boundary.

B1 (10–26 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) clay loam; weak fine and medium subangular blocky structure; slightly hard and hard, friable; common roots, 0.5–1 mm thick; few very fine tubular pores; effervesces strongly; moderately alkaline; clear wavy boundary.

B21ca (26–53 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 4.5/4, moist) silty clay loam; compound weak medium prismatic and weak fine and medium subangular blocky structure; hard, friable; few roots; few carbonate filaments; a few insect burrows, 0.5–1 cm diameter, most filled or partly filled with fine earth; effervesces strongly; moderately alkaline; clear wavy boundary.

B22ca (53-79 cm)—Light brown (7YR 5.5/4, dry; 7YR 4/4, moist) heavy clay loam; compound moderate medium prismatic and weak medium subangular blocky structure; hard, friable; few fine roots, about 0.5 mm in diameter; few fine and very fine tubular pores; effervesces strongly; moderately alkaline; clear smooth boundary.

K & B (79-95 cm)—Dominantly pink (7.5YR 7/4, dry; 7.5YR 5/4, moist) heavy clay loam, common carbonate nodules, very pale brown (10YR 9/3-7/3, dry); weak medium and fine subangular blocky structure; slightly hard and hard, friable; very few fine roots; moderately alkaline; effervesces strongly; clear wavy boundary.

B2tcab (95-122 cm)—Dominantly reddish brown (5YR 5/5 and 5YR 5/4, dry; 5YR 4/5 and 5YR 4/4, moist) with some parts light brown (7.5YR 6/4, dry) sandy clay loam; compound weak medium prismatic and weak fine and medium subangular blocky structure; hard, friable; no roots; sand grains in reddish brown parts stained with clay; common carbonate nodules and cylindroids, 0.5-2 cm diameter, ranging from slightly to very hard; reddish brown parts effervesce weakly, rest effervesce strongly; moderately alkaline; clear smooth boundary to underlying K2b horizon.

Remarks—The B2 horizon was not examined in thin section. However, judging from microscopic observations of similar horizons, it seems questionable that the 1% of oriented clay required for the argillic horizon (Soil Survey Staff, 1973) is present, and this soil is therefore considered to be a Calciorthid.

The buried soil rises to the west as the Stellar soil and is more deeply buried to the east (see Gile et al., 1970 for a discussion of the chronology and stratigraphy of soils of the basin floor in this area). The soil surface was described inside the exclosure containing the moisture blocks because of trampling by cattle outside the exclosure.

Site E

Soil Phase—Algerita, deep gypsum phase.

Classification—Typic Calciorthid, fine-loamy, mixed, thermic.

Soil Surface—Weakly crusted between grass clumps.

C (0-3 cm)—Light brown (8YR 6.5/4, dry) or brown (8YR 5/4, moist) light fine sandy loam; single grain; loose; no roots; effervesces strongly; moderately alkaline; abrupt smooth boundary.

A1 (3-12 cm)—Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) heavy fine sandy loam; massive and weak medium platy structure; hard, friable; few roots; common fine and medium tubular pores; effervesces strongly; moderately alkaline; abrupt smooth boundary.

B11 (12-31 cm)—Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) clay loam; compound weak coarse prismatic and weak medium subangular blocky structure; very hard, firm; few roots between grass clumps, common beneath clumps; few fine and medium tubular pores; a few insect burrows, 0.5–1 cm in diameter, some empty and some filled with fine earth; effervesces strongly, moderately alkaline; clear wavy boundary.

B12 (31–50 cm)—Pinkish-gray (7.5YR 6.5/3, dry) or brown (7.5YR 5/3, moist) light sandy clay loam; compound weak medium prismatic and weak medium subangular blocky structure; very hard, firm; very few roots; very few fine tubular pores; an occasional carbonate nodule, about 0.5 cm in diameter; effervesces strongly; moderately alkaline; clear wavy boundary.

B21ca (50–65 cm)—Pinkish-gray (7.5YR 7/3, dry) or brown (7.5YR 5/4, moist) silty clay loam; compound weak medium prismatic and weak fine and medium subangular blocky structure, slightly hard and hard, friable; very few roots; few very fine tubular pores; very few carbonate nodules ranging from 1–4 mm in diameter; effervesces strongly; moderately alkaline; clear wavy boundary.

B22ca (65–90 cm)—Pinkish-gray (7.5YR 7/3, dry) or brown (7.5YR 5/4, moist) silty clay loam; compound moderate fine and medium prismatic and weak fine and medium subangular blocky structure; slightly hard and hard, friable; no roots; few carbonate nodules ranging from about 1–4 mm in diameter; effervesces strongly; moderately alkaline; clear wavy boundary.

B23ca (90–112 cm)—Very pale brown (10YR 7/3, dry) or brown (10YR 5/3, moist) silty clay loam; compound moderate fine and medium prismatic and weak medium and fine subangular blocky structure; hard and slightly hard, friable; no roots; common very fine tubular pores; few carbonate nodules; effervesces strongly; moderately alkaline; clear wavy boundary.

2C1ca (112–120 cm)—White (10YR 9/2, dry) or light gray (10YR 7/2, moist) loam; compound weak medium prismatic and weak medium subangular blocky structure; slightly hard and hard, friable; no roots; common very fine tubular pores; carbonate occurs as scattered grain coatings; some fine-grained gypsum is present; this horizon is absent in places along the trench exposure; effervesces strongly; moderately alkaline; abrupt smooth boundary.

2C2ca (120–138 cm)—White (10YR 8/2, dry) or pale brown (10YR 6/3, moist) sandy loam; massive; very hard, firm; no roots; the material consists largely of fine-grained gypsum; one crack filling, nearly vertical, consists largely of gypsum and is about 1 mm thick; common very fine tubular pores; carbonate occurs as scattered faint patches and grain coatings; effervesces strongly; moderately alkaline.

Remarks—The stratigraphy and chronology of the materials in and adjacent to the playa are not known. Gypsum in the horizons from 112–138 cm is considered to be of geologic (lacustrine) origin instead of pedologic origin. The material from 0–112 cm is considered to be alluvium of latest Pleistocene or early to mid-Holocene age.

This soil is designated "Algerita, deep gypsum phase" to distinguish it from normal Algerita soils, which lack such gypsum deposits.

Site F

Soil Variant—Onite, buried soil variant.

Classification—Typic Haplargid, coarse-loamy, mixed, thermic.

Soil Surface—The surface is smooth and bare because of strong erosion by wind. Along the fences and around a few plants, there is an accumulation of sand, apparently of very recent origin.

B2t (0–18 cm)—Reddish-brown (5YR 5/5, dry; 5YR 4/5, moist) fine sandy loam; very weak medium subangular blocky structure; slightly hard, very friable; few roots; a few fine and very fine tubular pores; silicate clay coatings on sand grains; few termite tunnels; noncalcareous; mildly alkaline; clear wavy boundary.

B31t (18–34 cm)—Reddish-brown (5YR 5/5, dry; 5YR 4/5, moist) light fine sandy loam; massive; slightly hard, very friable; very few roots; clay coatings on sandy grains; a few termite tunnels; noncalcareous; mildly alkaline; clear wavy boundary.

B32t (34–44 cm)—Reddish-brown (5YR 5.5/4, dry; 5YR 4.5/4, moist) loamy sand; massive and single grain; soft and slightly hard, very friable and friable; very few roots; in places, tongues of sandy loam extend irregularly upward from the underlying horizon; generally noncalcareous, but effervesces weakly in a few spots; mildly alkaline; clear and abrupt, wavy and irregular boundary.

B1tcab (44–60 cm)—Reddish-brown (5YR 5.5/4, dry; 5YR 4.5/4, moist) heavy sandy loam; compound weak coarse prismatic and weak medium subangular blocky structure; hard, friable; very few roots; clay coatings on sand grains; few carbonate filaments; distinctly firmer and harder in place than the overlying horizon; commonly effervesces strongly, noncalcareous in a few places; moderately alkaline; clear wavy boundary.

B21tcab (60–76 cm)—Light reddish-brown (6YR 6/4, dry) or reddish-brown (6YR 4.5/4, moist) light sandy clay loam; compound weak coarse prismatic and weak medium and coarse subangular blocky structure; hard, friable; very few roots; a few volumes of yellowish red (5YR 5/6, dry; 5YR 4/6, moist); few dark insect burrow fillings, 0.5–1 cm in diameter; common carbonate filaments; few very fine tubular pores; clay coatings on some sand grains; most parts effervesce strongly, a few weakly; moderately alkaline; clear wavy boundary.

B22tcab (76–90 cm)—Dominantly light brown (7.5YR 6/5, dry) or brown (7.5YR 5/5, moist) light sandy clay loam; compound weak coarse prismatic and weak medium subangular blocky structure; hard and very hard, friable and firm; no roots; common carbonate nodules, white

(10YR 9/2, dry) or pink (10YR 8/4, moist); a few parts yellowish red (5YR 5/6, dry; 5YR 4/6, moist); few fine tubular pores; few carbonate filaments; sand grains in yellowish-red parts have clay coatings; few dark, fine-earth insect burrow fillings, 0.5–1 cm in diameter; most parts effervesce strongly, yellowish-red parts effervesce weakly; moderately alkaline; clear wavy boundary.

B23tcab (90–103 cm)—Dominantly reddish-brown (5YR 5.5/5, dry; 5YR 4.5/5, moist) with smaller amounts of light brown (7.5YR 6/5, dry) or brown (7.5YR 4/5, moist) light sandy clay loam; compound weak coarse prismatic and very weak medium subangular blocky structure; hard and very hard, friable and firm; no roots; a few carbonate nodules, white (7.5YR 9/2, dry) or pinkish-white (7.5YR 8/2, moist); clay coatings on sand grains in reddish-brown parts; few fine tubular pores; in places this horizon is absent and the B22tcab rests directly on the K2; most parts effervesce weakly, some parts noncalcareous; moderately alkaline; clear smooth boundary.

K2b (103–126 cm)—Pinkish-white (7.5YR 8/2, dry; 7.5YR 7/4, moist) sandy clay loam, a few parts light brown (7.5YR 6.5/4, dry) or brown (7.5YR 5.5/4, moist), and reddish-brown (5YR 5/4, dry, or 5YR 4/4, moist); weak medium and coarse subangular blocky structure; very hard, firm; few very fine tubular pores; sand grains separated by carbonate; grades to less carbonate with depth; no roots; moderately alkaline; effervesces strongly.

Remarks—Sediments from 0–44 cm are considered to be a deposit considerably younger than the materials below, and may mark a period of instability during the Holocene. The extent of this apparently younger deposit is not known. The lack of an A horizon, the Bt horizon at the surface, sand accumulations around shrubs, and sand piled along the exclosure fences—all indicate considerable wind erosion during recent years. This soil is designated "Onite, buried soil variant" because of the buried soil at shallow depths.

Site G

Soil Series—Hueco.

Classification—Petrocalcic Paleargid, coarse-loamy, mixed, thermic.

Soil Surface—A few indurated carbonate nodules, most less than 2 cm in diameter, are scattered over the surface.

C (0–5 cm)—Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) sand; loose and soft; single grain and massive; few roots; noncalcareous; mildly alkaline; abrupt smooth boundary.

A2 (5–10 cm)—Reddish-brown (6YR 5.5/4, dry; 6YR 4.5/4, moist) light fine sandy loam; massive; soft, very friable; very few roots; noncalcareous; mildly alkaline; abrupt smooth boundary.

B1t (10–23 cm)—Reddish-brown (5YR 5/4, dry; 5YR 4/4, moist) light fine sandy loam; massive; slightly hard, friable; very few roots; clay coatings on sand grains; few fine tubular pores; noncalcareous; mildly alkaline; clear wavy boundary.

B21t (23-36 cm)—Reddish-brown (5YR 5.5/4, dry; 5YR 4/4, moist) fine sandy loam; massive; slightly hard to hard, friable; harder in place than above; very few roots; clay coatings on sand grains; common fine and very fine tubular pores; noncalcareous; mildly alkaline; clear wavy boundary.

B22tca (36-46 cm)—Light reddish-brown (6YR 6/4, dry) or reddish-brown (6YR 5/4, moist) fine sandy loam; massive; slightly hard to hard, friable; very few roots; clay coatings on some sand grains; carbonate coatings on some grains, and a few carbonate filaments; few fine tubular pores; effervesces weakly and strongly; moderately alkaline; clear wavy boundary.

B3ca (46-71 cm)—Light brown (6YR 6.5/4, dry) or reddish-brown (6YR 4.5/4, moist) heavy sandy loam; very weak medium subangular blocky structure; generally slightly hard, with some parts hard, friable; no roots; common carbonate filaments and grain coatings; few fine tubular pores; effervesces strongly; moderately alkaline; abrupt wavy boundary.

K1 (71-79 cm)—Light reddish-brown (6YR 6/4, dry) reddish-brown (6YR 5/4, moist) very gravelly sandy loam; a loose mass of very fine crumbs between the indurated carbonate nodules that constitute the gravel; most nodules are less than 5 cm in diameter; nodules have pustulose surfaces; surfaces of nodules are stained reddish brown but interiors are commonly white (10YR 8/2, dry) or very pale brown (10YR 7/3, moist); effervesces strongly; moderately alkaline; abrupt wavy boundary.

K2m (79-90 cm)—Dominantly white (10YR 8/2, dry) or very pale brown (10YR 7/3, moist) carbonate-cemented material; massive; extremely hard, extremely firm; indurated; no roots; sand grains widely separated by carbonate; carbonate laminae occur discontinuously in upper part; effervesces strongly; moderately alkaline.

Remarks—Thickness of the petrocalcic horizon (the upper boundary of which is at 79 cm) is not known. However, based on exposures elsewhere, it is believed to grade through a transitional horizon with less carbonate into unconsolidated sand, possibly with some gravel, at a depth of several meters.

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