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The Desert Project Soil Monograph

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THE DESERT PROJECT SOIL MONOGRAPH

Soils and Landscapes of a Desert Region Astride the Rio Grande Valley Near Las Cruces, New Mexico

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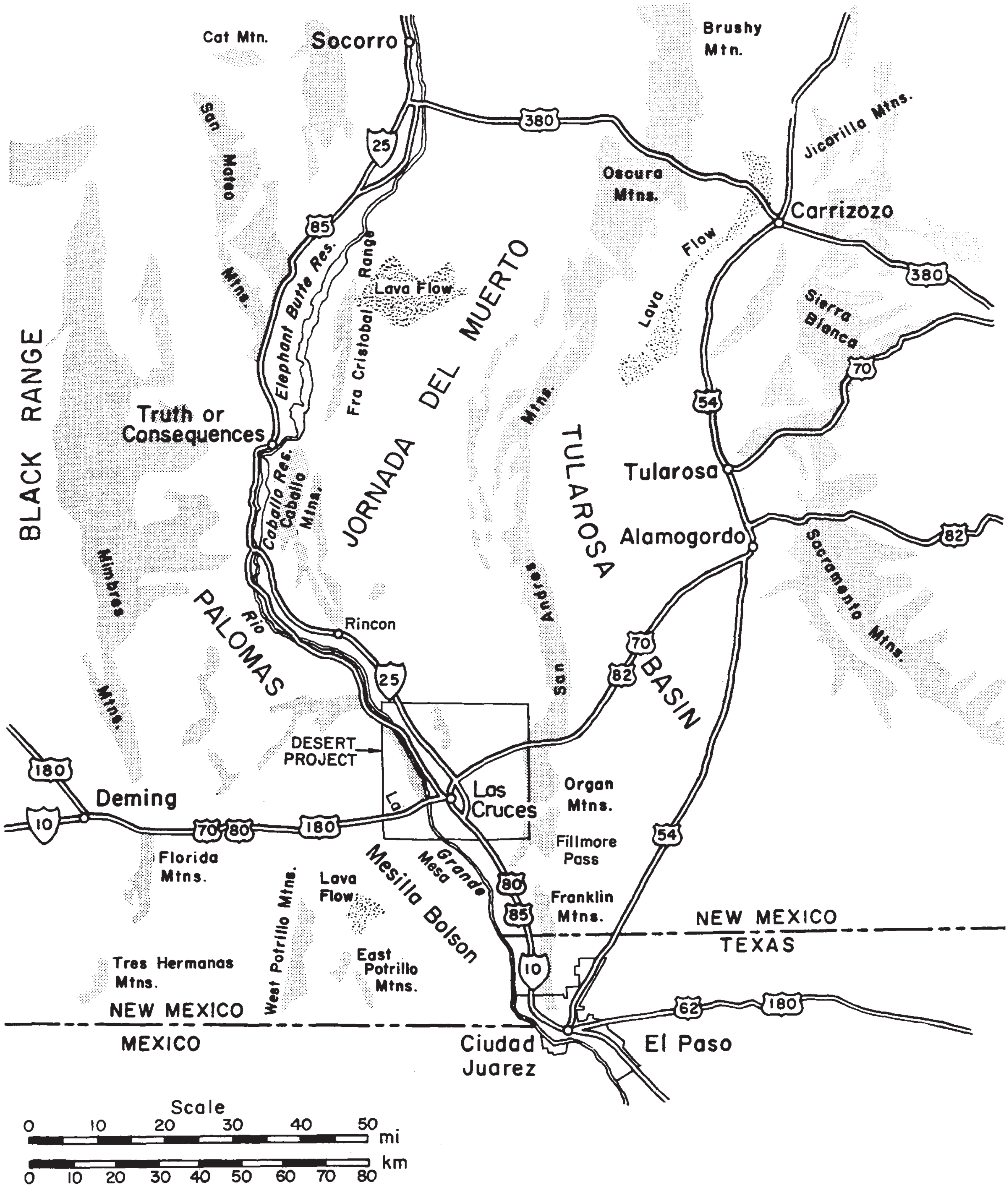
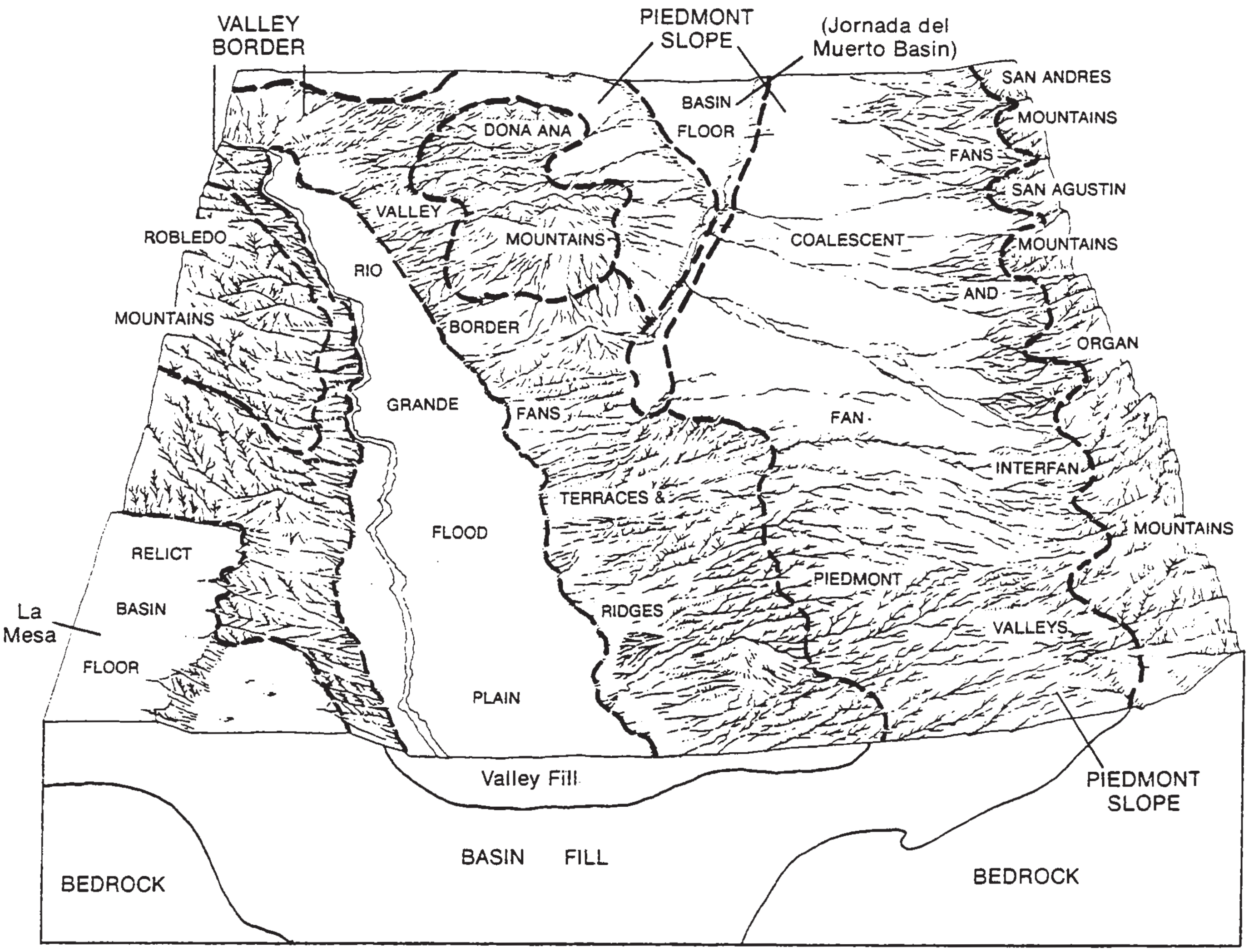


Frontispiece.--Location of the Desert Project.



Some of the landforms in the Desert Soil-Geomorphology Project, southern New Mexico. The Rio Grande flood plain is about 5 miles (8 km) wide at the cross section.

FOREWORD

The Soil-Geomorphology Project in the Las Cruces, New Mexico area was started in August 1957. The purpose of the project was to study the relationship between soils and geomorphology in an arid and semiarid environment. The fundamental premise was that once the relationship was understood in the Las Cruces area it could be extrapolated to other areas of similar climate and geology. Soil scientists making surveys in similar areas could use the principles developed at Las Cruces as an aid in increasing the speed, quality, and accuracy of soil surveys. Although the project had many practical applications, it must be emphasized that the study was designed as a basic research project. Because the emphasis was on the relationship between soil and geomorphology, the soil maps contained in this monograph have a distinct geomorphic bias. They are not the kind of maps that are produced in a standard soil survey because they have been developed for different purposes. This monograph is a very detailed report of the soil investigations, and the soil data are interpreted from a detailed knowledge of the pedon's geomorphic history.

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CONTENTS

OTHER STUDIES

"Other Studies" consist of field and/or laboratory studies conducted in some of the mapping units, and summary discussions at pertinent places.

1. PREFACE AND ACKNOWLEDGMENTS

In August, 1957, the Desert Soil-Geomorphology Project, informally termed "the Desert Project", was started by Soil Survey Investigations, Soil Conservation Service, in Dona Ana County, New Mexico. Although the study has been mainly concerned with arid-land soils with an average annual precipitation of 20 to 25 cm, it also encompasses parts of adjacent, semiarid mountains. The study was terminated in June 1972.

Results of the work have been disseminated in two general ways--by publication in technical journals and by numerous field study tours. Size of the groups taken on tours of the study area ranged from several to more than one hundred. Manuscripts concerning the study are listed in the bibliography section. Three reports concern the project as a whole after its completion. This report is about the soils and their relation to the landscape. Another concerns the geology and geomorphology (J. W. Hawley, in preparation). The third is intended primarily for use in the field (Gile, Hawley and Grossman, in preparation).

We thank Guy D. Smith, under whose general supervision these investigations were conducted, for advice and assistance from 1957 to 1972. Acknowledgment is made to R. V. Ruhe who, with Guy Smith, made arrangements for establishing the Desert Project, for geomorphic and administrative assistance from 1957 to 1965. Acknowledgment is also made to F. F. Peterson for work on geomorphic surfaces and soils from 1960 to 1962. We thank J. W. Hawley for geomorphic work since 1962, and for highly capable administrative assistance that facilitated all aspects of the study. Since 1972 Klaus W. Flach provided assistance and advice on administrative matters and on publication of this report.

We also thank Warren Lynn, for studies on clay mineralogy; John Cady, for mineralogical studies; L. T. Alexander, for suggestions on C-14 and dust studies; R. C. Vanden Heuvel, who first identified sepiolite in soils of the area; J. L. Gardner and K. A. Valentine, who identified many of the plants in the study area; and F. E. Houghton, who helped prepare the discussion of the present climate. A. B. Cox and Jeff Isaacks, ranchers in the vicinity of Las Cruces, generously allowed access to their lands for the study of soils. Thanks are extended to J. Melvin Williams, Arvad Cline, Victor Link, William Johnson, and Klaus Flach for their work on correlation of Desert Project soils. The late Billy Seay also contributed to the correlation work, with thoughtful discussions at various times during the latter part of the study. Dellon Cox discovered the two charcoal horizons at the Shalam Colony radiocarbon site. Most of the cross sections were prepared by Mark Gower, and most of the block diagrams were prepared by Sam Horn. Ken Gaskins and W. H. Harris provided valuable drafting assistance and advice in preparation of many of the figures.

The pedological laboratory data (Appendix) were obtained by the Lincoln Soil Survey Laboratory, Lincoln, Nebraska. Many of the samples could not be run in standard fashion but required special procedures. We thank Robert H. Jordan for supervision of the analyses, and data assembly; Dean C. McMurtry for chemical analyses and maintenance of the sample file; Leo G. Shields for his interest, suggestions and maintenance of high standards in the particle size analyses determinations; Robert L. Juve for supervision of the chemical analyses and for his own careful chemical determinations, in particular his contributions to the analyses of the small dust samples; Gerald Post for determinations of the calcium-magnesium ratios of carbonate; and John L. Millet for his overall assistance in the early formulative stages of the analytical work.

Acknowledgment is made to New Mexico State University, Las Cruces, for their generous assistance in providing office space and laboratory facilities. We thank the Agronomy Department, NMSU, and Arden Baltensperger, head of the department for most of the duration of the study, for their excellent cooperation and support. Some of the Desert Project studies were carried out on the Jornada Experimental Range, part of which is located in the Desert Project area. We thank Carlton Herbel and Fred Ares, Agricultural Research Service, for their cooperation and assistance throughout.

Parts of this report were written at Texas Tech University at Lubbock. Thanks are extended to them for housing and facilities during this period. Major assistance in preparing this report was provided by the Technical Service Center in Fort Worth, Texas. We greatly appreciate the outstanding support of William L. Vaught, formerly Director of the Center, and J. Vernon Martin, present Director. We extend our thanks to LeRoy Daugherty and Frank Carlisle for reviewing the manuscript.

Special acknowledgment is made to Mrs. Mona Rudisill, Mrs. Louise Lee, Miss Joan Hearne, Mrs. Alice Borden, Miss Nancy Armour, Mrs. Connie Miller and Mrs. Dora Gile for typing and assembling various sections of the manuscript.

2. SUMMARY

Location and purpose. This report presents a study of soils and landscapes in a 400-square mile area astride the Rio Grande Valley in the Basin and Range country of southern New Mexico. The area lies mainly in an arid region with precipitation of about 20 cm annually, and also encompasses parts of adjacent mountain ranges that are semiarid. The study was undertaken to learn about the morphology, genesis, and distribution of desert soils and their relation to the landscape, and to assist in understanding and mapping soils in similar arid regions elsewhere.

Soil parent materials. Alluvium is the major parent material; bedrock and eolian material are less common. The alluviums were derived primarily from rhyolite; monzonite; sedimentary rocks (mostly calcareous); and ancient river alluvium of mixed lithology, but usually without carbonate. In general there is a decrease in median weight diameter from the steep mountain fronts to the gentler slopes of the coalescent fan-piedmont. There are also prominent lateral variations related to the position of streams that deposited the alluvium; fragments in the main channel zones are coarser than in areas away from these zones. Holocene alluvium tends to be finer than late-Pleistocene alluvium. Monzonitic alluvium has a lower median weight diameter than rhyolitic alluvium because the monzonite comminutes readily during weathering and transport. Gravelly rhyolitic and monzonitic alluviums have appreciable very coarse and coarse sand and a minimum in medium sand. The ancient river sediments are very low in silt and very fine sand. On slopes of about 2 percent or less the alluvium from calcareous sedimentary rocks has less gravel and sand, and more silt and clay than the others.

Soils and soil-geomorphic relations. A soil map was made of the project area at a scale of 1:15,840. This was later supplemented by large-scale (1:7920) maps of selected areas. Soils of four orders are present (table 1). Aridisols are dominant in the arid zone except for the Rio Grande Valley, which is dominated by Entisols. Mollisols occur in places in the semiarid zone. Geomorphic surfaces were found to be useful in the studies of soils, because they provide a chronological framework for the soils, and also serve as a common thread that makes the soil patterns easier to understand and hence to map. A stepped sequence of geomorphic surfaces occurs in places along the valley border and the mountain fronts. Soils of the stepped sequences increase in development (of silicate clay and/or carbonate horizons) with increasing age and elevation of the steps. Soil-geomorphic relations are less evident on the coalescent fan-piedmont because of an intricate pattern of soil burial; and young soils may be above or at the same elevation as adjacent, much older soils. Soil morphology was found to be useful in unravelling the soil and landscape history of these complex areas. If the morphological range of soils on a given surface has been determined, soils may be used to identify geomorphic surfaces. Buried soils were found to be an integral part of the soil and geomorphic history. Many buried soils emerge at the land surface and their stratigraphic position can indicate the character and degree of pedogenesis at different times of landscape development.

Causes of soil differences and boundaries. Common causes for differences in the soils are differences in climate, soil age, parent materials, landscape dissection, soil moisture and faunal activity. In some places, soil boundaries are well marked by topographic features, e.g., terraces, scarps, and fans. Other boundaries have no expression at the land surface. Several changes in soil morphology occur as the mountains are approached. At stable sites and in low-carbonate parent materials, a surficial noncalcareous zone and a reddish brown Bt horizon thicken mountainward. The Bt horizon is underlain by a carbonate horizon, the top of which deepens mountainward. Toward the mountains organic carbon increases and color darkens in upper horizons. Thick, dark A horizons have formed in many soils of the mountains.

Soil age was found to be a major factor affecting the soils because of its great range--from fresh parent materials to mid-Pleistocene. Differences in soil age were caused by deposition of new parent materials in some places but not in others, and by erosion that penetrated to fresh parent materials. Particularly prominent changes in soil morphology and classification occur across the boundary between soils of Holocene and Pleistocene age.

Other boundaries are caused by changes in parent materials. High-carbonate parent materials prevent development of the argillic horizon and cause taxonomic differences at the level of suborder or order. Change in content of coarse fragments can cause category changes ranging from soil family to great group. In dissected terrains a change from Argids to Orthids has been caused by slow, long-continued soil truncation associated with the dissection. Soil fauna have obliterated argillic horizons by mixing A and B horizons in some places but not in others, causing a boundary between Argids and Orthids.

Differences in moisture movement in the past have caused soil differences resulting in change from Haplargids to Paleargids. During Pleistocene pluvials, soil moisture moved deeply into reddish brown pipes (preventing carbonate accumulation) but not in adjacent petrocalcic horizons. Typic Haplargids occur in the pipes whereas Petrocalcic Paleargids occur adjacent to the pipes.

Table 1. Soil orders, suborders, and great groups in the study area.

Order	Suborder	Great Group
Aridisols	Orthids	Camborthids
		Calciorthids
		Paleorthids
	Argids	Haplargids
		Paleargids
Entisols	Psamments	Torripsamments
	Orthents	Torriorthents
	Fluvents	Torrifluvents
Mollisols	Ustolls	Haplustolls
		Argiustolls
		Calciustolls
		Paleustolls
Vertisols	Torrerts	Torrerts

C-14 dating of buried charcoal. The discovery and subsequent dating of buried charcoal were major factors in the soil chronology. The dates range from 1100 to 7300 yr B. P. The charcoal was found both along the valley border in the arid part of the study area and along the mountain front where the climate is semiarid, thus establishing chronological control for Holocene soils and landscapes in both climates. The charcoal dates also enabled distinction between soils of Holocene age and soils of Pleistocene age. A generalized soil chronology is given in table 2. Horizons of carbonate and silicate clay accumulation in Holocene soils are thinner than in soils of Pleistocene age. This difference is attributed to the greater effective moisture of Pleistocene pluvials. The chronology also established approximate times and conditions required for the development of the diagnostic cambic, argillic, calcic, and petrocalcic horizons in the study area (table 2).

Atmospheric additions. Prominent horizons of calcium carbonate occur in soils formed in parent materials with little or no calcium and in locations where ground water could not have been a calcium source. Dust was considered a possible source because dust storms are common in the dry spring season. Dry dust was collected in a wide variety of physiographic positions and parent materials for 10 years. The dust traps were marble-filled trays at heights of 90 cm and 30 cm. The average yearly catch at 90 cm was 23 g/m^2. Clay content ranged from 20 to 40 percent and was negatively correlated with size of the catch. Organic carbon ranged from 3 to 7 percent, greatly exceeding that in surface horizons of nearby soils. $CaCO_3$ equivalent ranged from 0.2 to 1.1 $g/m^2/yr$. The sum of carbonate and water soluble calcium expressed as $CaCO_3$ equivalent ranged from 0.35 to 1.3 $g/m^2/yr$. This compares to an estimated $CaCO_3$ equivalent of 1.5$g/m^2/yr$ for calcium in the precipitation. Precipitation is therefore apparently more important than dry dust as a source of calcium for authigenic carbonate. The volume of carbonate was calculated and related to soil age for a number of soils formed in noncalcareous parent materials. The computed rate of carbonate accumulation and the current rate of carbonate accumulation based on atmospheric additions of calcium are in reasonable agreement.

Soil temperature and moisture. High temperatures in a surficial zone restrict root and faunal activity in the uppermost few cm. This commonly leads to low organic carbon and somewhat higher bulk densities in this surficial zone.

Much of the precipitation falls in 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 important because surficial horizons of sandy texture have most rapid infiltration rates during rainfalls of high intensity. This results in a greater number of moist days in deeper horizons. Soils with fine-textured B horizons, if wetted by precipitation only, have a markedly lower number of moist days. Soil structure and microrelief can substantially modify the effect of texture; surficial horizons with platy structure tend to "seal" when wetted and markedly reduce infiltration. At other sites the depth of moisture infiltration is considerably increased by cracks, holes and small depressions in the soil surface. Landscape position is significant since it determines whether the soil is subject

Table 2. The chronology for soils and diagnostic horizons in an arid region of southern New Mexico[1/].

		Low-carbonate parent materials[2/]		High-carbonate parent materials	
Soil age		Great Group and Diagnostic Horizon[3/]		Great Group and Diagnostic Horizon	
		Low-gravel materials[4/]	High-gravel materials	Low-gravel materials	High-gravel materials
	HOLOCENE	Torripsamments Torrifluvents Torriorthents	Torriorthents	Torrifluvents Torriorthents	Torrifluvents Torriorthents
			Camborthids; Cambic horizon		
Late		Camborthids; Cambic horizon	Haplargids; Argillic horizon		
Mid		Haplargids; Argillic horizon			
				Torrifluvents Torriorthents	Torrifluvents Torriorthents
				Calciorthids; Calcic horizon	Calciorthids; Calcic horizon
Early(?)					
7500 Years B. P.					
Latest	PLEISTOCENE	Haplargids; Calcic horizon	Haplargids; Calcic horizon		
Late		Haplargids	Paleargids; Petrocalcic horizon		Paleorthids; Petrocalcic horizon
Mid		Paleargids; Petrocalcic horizon		Paleorthids; Petrocalcic horizon	

1/ Soils are on stable sites that show little or no evidence of soil truncation.
2/ "Low" designates materials with less than about 2 percent $CaCO_3$ equivalent; "high" designates materials with more than about 15 percent $CaCO_3$ equivalent.
3/ "Low" designates materials with less than 20 percent rock fragments by volume; "high" designates materials with more than about 50 percent rock fragments by volume.
4/ Diagnostic horizons underlined.

to runoff or run-in. Run-in can increase the number of moist days up to 2-fold. The moisture relations are less complex where runoff is low and run-in is not a factor. In such situations the most favorable moisture conditions occur in soils and landscapes with the following characteristics: (1) level or nearly level areas that show little or no evidence of erosion, (2) a thin surficial horizon, about 5-10 cm thick, with sand or loamy sand texture to maximize infiltration, and (3) a slightly finer-textured horizon (e.g., 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. Indurated horizons can also be helpful in slowing or preventing downward penetration of moisture.

Surficial features and processes. The monzonite comminutes readily and surfaces tend to have few coarse fragments except along the mountain front. Rhyolite does not comminute easily and surfaces tend to have more coarse fragments. Except for the mountain front, piedmont slopes dominated by limestone commonly have few coarse fragments. Soil surfaces of basin floors commonly have few or no coarse fragments. In some areas coarse fragments have concentrated as a result of landscape dissection and soil truncation. On stable surfaces "desert varnish," or stain, occurs on coarse fragments other than limestone. The varnish is commonly black on that part of the pebble above the land surface. A reddish brown, red, or yellowish red color marks the part of a pebble that has been below the surface of soils with argillic horizons. The A horizons of soils in the arid part of the study area are commonly light-colored, thin, and vesicular.

Alternating barren and grassy strips are common in places on the lower piedmont slopes and basin floor. The strips are well expressed only in finer textures such as loam, sandy clay loam, or clay loam. They range from several to many m wide and are approximately on the contour. The boundary between the strips is often abrupt and marked by erosion of the thin A horizon that is present in the grassy strips. The harder, less pervious B horizon is usually at or very near the surface in the barren strips. There is considerable runoff from the barren onto the grassy strips and much greater penetration of moisture in the latter. Loss of moisture from the barren strips tends to keep them barren and gain of moisture in the grassy strips tends to keep them grassy. The strips may have been started by overgrazing.

Coppice dunes are by far the most extensive eolian deposit. They are sandy and have formed where upper horizons of adjacent soils were coarse-textured and had little or no gravel. The dunes consist of stratified materials that show no evidence of modification except for the occasional displacement of strata by soil fauna or roots. Land survey notes and present conditions indicate that most or all of the dunes are less than 100 years old and that a drastic change in vegetation (from grass to shrub) took place within the last 100 years. The coppice dunes may be divided into two main kinds according to their color. One kind has 5YR hue and the other, 10YR hue. Each kind occurs only where the underlying and adjacent soils have the same hue as the dune. Size of sand in the dune is very similar to that of upper horizons of soils beneath the dunes. These factors indicate that the dune materials were derived from upper horizons of adjacent soils.

Organic carbon accumulation. Variations in organic carbon of upper horizons are related primarily to vegetation, orographic influence, landscape position in terms of runoff and run-in, and texture. Except for some soils of the basin floors and drainageways, organic carbon in upper horizons generally increases towards the mountains in soils of all ages. Landscape position and runoff are important factors affecting organic carbon in the gentle slopes of desert areas between the mountain ranges. Soils in drainageways and basin floors tend to have more grass and more organic carbon than do adjacent soils on slight topographic highs. An elevation difference of only a few cm can be important in concentrating water. This can cause differences in vegetation and content of organic carbon. Very gravelly horizons contain relatively high organic carbon when expressed as a percentage of the fine-earth compared to adjacent horizons with little or no gravel because of the diluent effect of coarse fragments. However, the amounts of organic carbon on a volume basis are about the same. Petrocalcic horizons at shallow depths tend to concentrate roots and increase organic carbon. Clay content is also important since a soil with more clay usually has more organic carbon.

Carbonate accumulation. Horizons of carbonate accumulation are very common and in many soils are by far the most prominent horizon. Carbonate horizons considered to be of pedogenic origin in the arid part of the study area have the following characteristics. They parallel the soil surface; their upper boundaries commonly occur within about 10 to 50 cm of the soil surface; they have distinctive morphologies that show lateral continuity and that differ markedly from morphologies of overlying and underlying horizons; they occur between horizons containing relatively little carbonate; they occur in sediments of various compositions and textures, and their development is related to time. Carbonate horizons develop in two morphogenetic sequences, one in high-gravel materials and the other in low-gravel materials. The sequences have been ordered in stages I to IV and are summarized as follows. In the low-gravel sequence of carbonate accumulation, stage I horizons have scattered grain coatings or carbonate filaments; stage II horizons consist of carbonate nodules separated by low-carbonate material; stage III horizons are carbonate-impregnated virtually throughout, and are plugged with carbonate in the last part of the stage; and in stage IV an indurated laminar horizon consisting primarily of carbonate has formed atop the plugged horizon. In the gravelly sequence, stage I horizons have thin, partial, or complete carbonate coatings on pebbles; stage II horizons have thicker carbonate coatings and some fillings in interstices between the coatings. Stage III and IV horizons are similar to their analogues in low-gravel sequence except for the pebbles.

A new master horizon, the K horizon, was introduced to meet a need for suitable horizon designations. Carbonate in K horizons is essentially continuous throughout, and the morphology is largely determined by the carbonate. Stage III and IV carbonate horizons, above, are K horizons. Radiocarbon dating of authigenic carbonate was undertaken to assist in establishing the soil chronology and to relate carbonate morphology to carbonate ages. The C-14 ages added supporting evidence to the genetic interpretation noted earlier, concerning the development of the plugged and laminar horizons.

Carbonate C-14 ages are useful to corroborate relative ages of Holocene soils and soils of late-Pleistocene age. In older soils the carbonate C-14 age is much less than the soil age. The assemblage of dates indicates exchange with environmental C-14 subsequent to accumulation of the carbonate.

Silicate clay accumulation. Reddish brown or red horizons of silicate clay accumulation are prominent in many of the soils. Illuviation plays an important role in the genesis of these horizons. They are Bt horizons; most qualify as argillic horizons. The Bt horizons have a characteristic fabric in which distinct coatings of oriented clay occur on sand grains and on pebbles if they are present. This fabric has since been found to be characteristic of many Bt horizons in both arid and semi-arid regions. The coatings are particularly well expressed in sandy loam argillic horizons, in which nearly all of the clay in the horizon occurs as oriented coatings. Clay skins, an important marker of clay illuviation in many soils, do not occur on ped surfaces in soils at the present land surface except in pipes of overthickened argillic horizons in soils of Pleistocene age. Prominent argillic horizons occur only in soils that formed primarily during the Pleistocene, and hence are largely relict.

Many of the older soils lack argillic horizons. They have been truncated in many areas. In some soils, argillic horizons have been engulfed and masked by prominent carbonate accumulations. In other soils, argillic horizons have been mixed by soil biota. Argillic horizons do not occur in soils containing abundant fragments of highly calcareous rocks, even in soils of late-Pleistocene age.

Mineralogy. Quartz, feldspar, and microcrystalline grains consisting primarily of feldspar are the dominent minerals in the sand and silt, commonly with quartz comprising less than half of the total. Weathering is slight. Kaolinite and mica are present in the clays of all soil materials examined. Abundant, well-ordered montmorillonite occurs in and below K2 horizons of soils developed in alluvium from igneous rocks. All other horizons and materials contain only small or moderate amounts of poorly ordered montmorillonite.

3. PRESERVATION OF STUDY SITES

The Desert Project area is typical of many arid regions in terms of terrain, parent materials, range in age of soils, and general climatic history. Because of these similarities, results of the research may be extrapolated to other arid regions. Thus it is useful to preserve as much as possible of the project area as a study and training ground. A publication in preparation (Gile, Hawley, and Grossman) contains a four-day study tour of many of the detailed study sites. At each site there are soil and geomorphic maps, laboratory data, and a discussion of the soils, landscapes, and the soil and geomorphic history.

Some of the detailed study sites have already been obliterated by construction. Others are on private land. A substantial number, however, are in the public domain. It would be desirable if these sites and a portion of the adjacent soils and landscapes could be preserved so that each could be viewed in its natural setting. In a cooperative agreement with the Bureau of Land Management, two and one-half (2 1/2) acres at each study site have been set aside for this purpose. Other study sites are within the Jornada Experimental Range and will be preserved as a part of the Experimental Range.

Permanent bronze markers were installed at sites that appear to have reasonable chances for preservation. Markers were installed for the following sampled pedons (these pedons have been keyed to year of sampling, as below, as a shorthand method for reference to them):

1959	1960	1961	1965	1966	1967	1968	1969	1970
59-1	60-10	61-1	65-1	66-2	67-1	68-2	69-8	70-1
59-2	60-17	61-2	65-2	66-5	67-3	68-3		70-5
59-4	60-21	61-3	65-3	66-6	67-5	68-4		70-6
59-6		61-4	65-5	66-7	67-6	68-5		70-7
59-7		61-5	65-6	66-9		68-6		70-8
59-10		61-7	65-7	66-16		68-7		
59-16						68-9		

4. LOCATION OF INFORMATION

The table of contents locates major subjects. The general index in the last part of the book locates a large number of items. Location of information about particular segments of the work is given in table 3.

Table 3. Location of indexes.

Index no.	Title of index	Page
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3.	Location and page number of detailed soil maps.	714
4.	Location of sampled pedons on soil maps and in the data and description section, by year of sampling1/	715
5.	Location of mapping units in text and in soil maps, by mapping unit	716
6.	Location of sampled pedons in data and description section, by series.	759
7.	General	978

1/ See page 716a for the location (on soil maps) of pedons described but not analyzed. These pedons are designated numerically (e.g., P-2) and location of their descriptions in the text is given in Index 1. Soil descriptions at the soil moisture sites (section 51) are in section 209.

INDEX 1. DATA; SOIL DESCRIPTIONS; AND PHOTOGRAPHS, BY CLASSIFICATION[1/]

Classification[2/]	Pedon no.	Page: Laboratory data: Summary table	Complete data	Description	Photograph
ARIDISOLS					
Typic Haplargids					
loamy-skeletal					
Pinaleno	60-9	65, 132, 136, 193, 195, 213	814	815	
	66-16	65, 117, 132, 133, 137, 168	914	915	179
	67-4	65, 85, 117, 132, 213, 434	922	923	427, 428
	67-5	65, 117, 132, 137, 168	924	925	181
sandy					
Onite, sandy subsoil variant	59-5	168, 213	768	769	
	68-3	65, 213, 217, 455	932	933	456
coarse-loamy					
Onite	62-3	132, 168, 211, 213, 540	868	869	173
	70-5	132, 209, 211, 217, 460a	952	953	460, 461
	70-6	132, 168, 211, 217, 460a	954	955	461
Onite	P-1			464	465
Onite, buried soil variant	P-2			974	
Onite, calcic variant	66-1	132, 137, 336, 574	884	885	335, 337
Onite, deep petrocalcic phase	61-8	65, 117, 132, 168, 213, 217, 388	860	861	381, 407
	72-1	117, 211, 217, 388	962	963	
	72-2	117, 211, 217, 388	964	965	
Onite gravelly variant	61-5	85, 132, 168, 213, 217, 574	852	853	494
Onite, thin solum variant	68-5	213, 455	936	937	456
Sonoita	60-8	132, 193, 195, 209, 213, 486	812	813	
	72-3	117, 211, 217, 388	966	967	
Sonoita	P-3			370	371, 372
SND-1	59-12	132, 357	782	783	
fine-loamy					
Berino	60-7	132, 168, 193, 211, 213, 548	808	809	175, 461, 531
	60-13	65, 132, 211, 213, 540	822	823	
	68-9	121, 132, 168, 211, 213, 217, 455	944	945	122, 123
	70-7	132, 136, 168, 209, 211, 217, 460a	956	957	
Bucklebar	59-7	132, 168, 211, 213, 540, 541	772	773	
	60-22	132, 137, 168, 211	840	841	
	66-8	132, 548	898	899	547
	68-2	132, 136, 217, 388	930	931	391
	68-4	65, 132, 168, 211, 217, 455	934	935	458
	68-8	132, 414	942	943	419
Bucklebar, overburden variant	59-8	65, 132, 137, 168, 213, 540	774	775	
Bucklebar, gravelly variant					
Dona Ana	60-6	132, 137, 168, 211, 548	806	807	549
	61-4	132, 137, 168, 213, 217, 574	850	851	569
	65-5	132, 211	878	879	564
	68-6	132, 168, 217, 690	938	939	692
Dona Ana, deep petrocalcic phase	65-7	65, 132, 168, 211, 222	882	883	
Hap	P-4			551	552
Tres Hermanos	P-5			496	
SND-2	59-9	357	776	777	
fine					
Bucklebar, clayey subsoil variant					
SND-3	67-6	121	926	927	124

1/ All soils are thermic and have mixed mineralogy unless otherwise stated.
2/ See table 3a for an alphabetical listing of soil series, variants and phases.

INDEX 1. DATA; SOIL DESCRIPTIONS; AND PHOTOGRAPHS, BY CLASSIFICATION, cont.

INDEX 1. DATA; SOIL DESCRIPTIONS; AND PHOTOGRAPHS, BY CLASSIFICATION, cont.

Classification	Pedon no.	Page: Laboratory data: Summary table	Complete data	Description	Photograph
coarse-loamy					
Algerita	61-2	65, 132, 136, 189, 217, 690	846	847	190, 693
Algerita	P-17,P-18			558, 683	559, 684, 696
Algerita, partially indurated variant	61-1	132, 168, 217, 690	844	845	694
Jal (carbonatic)	65-6	132, 137, 222	880	881	587
Whitlock	60-2	132, 168, 189, 193, 217, 336	796	797	338
fine-loamy					
Algerita, deep gypsum phase	P-19			973	
Ustollic Calciorthids					
loamy-skeletal					
Polar					
fine-loamy					
Reagan, light subsoil variant	66-7	65, 136, 211, 666a	896	897	580
fine-silty					
Reagan	60-14	65, 132, 136, 193, 211, 523	824	825	519
	60-17	132, 136, 211, 217, 666a	830	831	669, 670
	65-1	132, 137, 211, 510	870	871	513
	66-6	65, 211, 666a	894	895	667
	68-7	132, 136, 211	940	941	660
Reagan	P-20			972	
Typic Camborthids					
sandy-skeletal					
Vado, sandy-skeletal variant	P-21			309	312
loamy-skeletal					
Vado	60-4	65, 193, 195	800	801	
coarse-loamy					
Agustin					
Pajarito	61-9	168, 292	862	863	288
	67-3	65, 137, 168, 449	920	921	446
fine-loamy					
Adelino	P-22			394	395
fine-silty					
Mimbres, overwash phase	66-14	292	910	911	287
Typic Paleorthids					
loamy-skeletal, shallow					
Delnorte	P-23,P-24			317, 600	318, 321
Tencee (carbonatic)	P-25			399	400, 401
Tencee (carbonatic)	62-1	137, 161	866	867	
sandy, shallow					
Tonuco					
loamy, shallow					
Simona	59-11	137, 193	780	781	
	60-10	65, 136, 207, 316a	816	817	
Upton (carbonatic)	66-5	137, 161, 189, 585	892	893	341
Ustollic Paleorthids					
loamy-skeletal, shallow					
Monterosa	61-10	137, 316a	864	865	
	66-2	65, 137, 316a	886	887	360
	67-2			919	164
Monterosa, carbonatic variant	P-26			618	
loamy, shallow					
Conger	60-20	85	836	837	
ENTISOLS					
SND-6					
Typic Torrifluvents					
sandy-skeletal					
Vinton, sandy-skeletal variant					

INDEX 1. DATA; SOIL DESCRIPTIONS; AND PHOTOGRAPHS, BY CLASSIFICATION, cont.

Classification	Pedon no.	Page: Laboratory data: Summary table	Page: Laboratory data: Complete data	Page: Description	Page: Photograph
loamy-skeletal					
Anthony, loamy-skeletal variant	65-2	65, 510	872	873	509
sandy					
Vinton	59-4	65, 193, 195, 212	766	767	
	67-1		916	917	
coarse-loamy					
Anthony	65-3	65, 510	874	875	501
	65-4	65, 510	876	877	
Gila					
Pintura, thin variant					
fine-silty					
Glendale	60-15	65, 121, 193, 211, 217, 523	826	827	517
Typic Torriorthents					
sandy-skeletal					
Arizo	60-3	65, 136	798	799	
	61-6	132	854	855	
Arizo	P-27			258	259
Dalian, sandy-skeletal variant (carbonatic)					
Kokan	P-28			350	
loamy-skeletal					
Canutio	66-3	132, 137	888	889	
Dalian (carbonatic)	66-4	132, 137, 283	890	891	279
sandy					
Yturbide	P-29			273	274
SND-7	59-3	65, 136, 212, 484	764	765	
coarse-loamy					
Canutio, loamy subsoil variant	P-30, P-31			471, 968	472
fine-loamy					
SND-8					
Typic Torripsamments					
Bluepoint	59-10	65, 132, 168, 193, 212, 266	778	779	263
	59-17	132, 193, 212, 266	792	793	269
Bluepoint	P-32			270	271
Pintura	66-11	65, 126, 132, 193	904	905	129
	66-13	85, 193	908	909	
	68-1	126, 132	928	929	127
Pintura	P-33			380	382, 392, 393
MOLLISOLS					
Aridic Argiustolls					
loamy-skeletal					
Earp	P-34			436	
Nolam, mollic variant					
coarse-loamy					
SND-9					
Pachic Argiustolls					
clayey-skeletal					
Limpia					
Petrocalcic Calciustolls					
loamy-skeletal, shallow					
Boracho	P-35			637	638, 639
Boracho, carbonatic variant	P-36			622	623
loamy, shallow					
Kimbrough					

INDEX 1. DATA; SOIL DESCRIPTIONS; AND PHOTOGRAPHS, BY CLASSIFICATION, cont.

Table 3a. Classification of soil series, variants, and phases[1/]

Series, variant, or phase	Classification
Adelino	Typic Camborthids, fine-loamy, mixed
Agustin	Typic Camborthids, coarse-loamy, mixed
Aladdin	Torriorthentic Haplustolls, coarse-loamy, mixed
Aladdin, calcareous variant	Pachic Haplustolls, coarse-loamy, mixed (calcareous)
Algerita	Typic Calciorthids, coarse-loamy, mixed
Algerita, deep gypsum phase	Typic Calciorthids, fine-loamy, mixed
Algerita, partially indurated variant	Typic Calciorthids, coarse-loamy, mixed
Anthony	Typic Torrifluvents, coarse-loamy, mixed (calcareous)
Anthony, loamy-skeletal variant	Typic Torrifluvents, loamy-skeletal, mixed (calcareous)
Arizo	Typic Torriorthents, sandy-skeletal, mixed
Berino	Typic Haplargids, fine-loamy, mixed
Berino, Ustollic variant	Ustollic Haplargids, fine-loamy, mixed
Bluepoint	Typic Torripsamments, mixed
Boracho	Petrocalcic Calciustolls, loamy-skeletal, mixed, shallow
Boracho, carbonatic variant	Petrocalcic Calciustolls, loamy-skeletal, carbonatic, shallow
Bucklebar	Typic Haplargids, fine-loamy, mixed
Bucklebar, clayey subsoil variant	Typic Haplargids, fine, mixed
Bucklebar, gravelly variant	Typic Haplargids, fine-loamy, mixed
Bucklebar, overburden variant	Typic Haplargids, fine-loamy, mixed
Cacique	Petrocalcic Paleargids, fine-loamy, mixed
Caliza	Typic Calciorthids, sandy-skeletal, mixed
Canutio	Typic Torriorthents, loamy-skeletal, mixed (calcareous)
Canutio, loamy subsoil variant	Typic Torriorthents, coarse-loamy, mixed (calcareous)
Caralampi	Ustollic Haplargids, loamy-skeletal, mixed
Casito	Petrocalcic Ustollic Paleargids, loamy-skeletal, mixed, shallow
Conger	Ustollic Paleorthids, loamy, mixed, shallow
Coxwell, shallow variant	Ustollic Haplargids, loamy-skeletal, mixed
Cruces	Petrocalcic Paleargids, loamy, mixed, shallow
Cruces, loamy-skeletal variant	Petrocalcic Paleargids, loamy-skeletal, mixed, shallow
Dalby, taxadjunct	Typic Torrerts, very-fine, mixed
Dalian	Typic Torriorthents, loamy-skeletal, carbonatic
Dalian, sandy-skeletal variant	Typic Torriorthents, sandy-skeletal, carbonatic

1/ Classification is according to Soil Taxonomy (Soil Survey Staff, in press). All soils are thermic. All series are established except Tonuco and Rilloso.

Table 3a. Classification of soil series, variants, and phases, cont.

Series, variant, or phase	Classification
Delnorte	Typic Paleorthids, loamy-skeletal, mixed, shallow
Dona Ana	Typic Haplargids, fine-loamy, mixed
Dona Ana, deep petrocalcic phase	Typic Haplargids, fine-loamy, mixed
Earp	Aridic Argiustolls, loamy-skeletal, mixed
Gila	Typic Torrifluvents, coarse-loamy, mixed
Glendale	Typic Torrifluvents, fine-silty, mixed (calcareous)
Hap	Typic Haplargids, fine-loamy, mixed
Hathaway	Aridic Calciustolls, loamy-skeletal, mixed
Hawkeye	Torriorthentic Haplustolls, sandy, mixed
Headquarters	Ustollic Haplargids, fine-loamy, mixed
Headquarters, clayey subsoil variant	Ustollic Haplargids, fine, mixed
Hueco	Petrocalcic Paleargids, coarse-loamy, mixed
Jal	Typic Calciorthids, coarse-loamy, carbonatic
Kimbrough	Petrocalcic Calciustolls, loamy, mixed, shallow
Kokan	Typic Torriorthents, sandy-skeletal, mixed
Limpia	Pachic Argiustolls, clayey-skeletal, mixed
Mimbres, overwash phase	Typic Camborthids, fine-silty, mixed
Monterosa	Ustollic Paleorthids, loamy-skeletal, mixed, shallow
Monterosa, carbonatic variant	Ustollic Paleorthids, loamy-skeletal, carbonatic, shallow
Nickel	Typic Calciorthids, loamy-skeletal, mixed
Nolam	Ustollic Haplargids, loamy-skeletal, mixed
Nolam, mollic variant	Aridic Argiustolls, loamy-skeletal, mixed
Onite	Typic Haplargids, coarse-loamy, mixed
Onite, buried soil variant	Typic Haplargids, coarse-loamy, mixed
Onite, calcic variant	Typic Haplargids, coarse-loamy, mixed
Onite, deep petrocalcic phase	Typic Haplargids, coarse-loamy, mixed
Onite, gravelly variant	Typic Haplargids, coarse-loamy, mixed
Onite, sandy subsoil variant	Typic Haplargids, sandy, mixed
Onite, thin solum variant	Typic Haplargids, coarse-loamy, mixed
Pajarito	Typic Camborthids, coarse-loamy, mixed
Pinaleno	Typic Haplargids, loamy-skeletal, mixed
Pintura	Typic Torripsamments, mixed
Pintura, thin variant	Typic Torrifluvents, coarse-loamy, mixed
Polar	Ustollic Calciorthids, loamy-skeletal, mixed
Reagan	Ustollic Calciorthids, fine-silty, mixed
Reagan, light subsoil variant	Ustollic Calciorthids, fine-loamy, mixed

Table 3a. Classification of soil series, variants, and phases, cont.

Series, variant, or phase	Classification
Rilloso	Typic Calciorthids, sandy, mixed
Rilloso, Ustollic variant	Ustollic Haplargids, sandy, mixed
Santo Tomas	Pachic Haplustolls, loamy-skeletal, mixed
Santo Tomas, calcareous variant	Pachic Haplustolls, loamy-skeletal, mixed
Santo Tomas, overburden variant	Pachic Haplustolls, loamy-skeletal, mixed
Santo Tomas, Torriorthentic variant	Torriorthentic Haplustolls, loamy-skeletal, mixed
Simona	Typic Paleorthids, loamy, mixed, shallow
SND-1	Typic Haplargids, coarse-loamy, mixed
SND-2	Typic Haplargids, fine-loamy, mixed
SND-3	Typic Haplargids, fine, mixed
SND-4	Ustollic Haplargids, fine-loamy, mixed
SND-5	Petrocalcic Paleargids, fine, mixed
SND-6	Entisols
SND-7	Typic Torriorthents, sandy, mixed
SND-8	Typic Torriorthents, fine-loamy, mixed
SND-9	Aridic Argiustolls, coarse-loamy, mixed
Sonoita	Typic Haplargids, coarse-loamy, mixed
Stellar	Ustollic Haplargids, fine, mixed
Stellar, overflow phase	Ustollic Haplargids, fine, mixed
Stellar, wedgy subsoil variant	Ustollic Haplargids, fine, mixed
Tencee	Typic Paleorthids, loamy-skeletal, carbonatic, shallow
Terino	Petrocalcic Ustollic Paleargids, loamy-skeletal, mixed, shallow
Terino, moderately deep variant	Petrocalcic Ustollic Paleargids, loamy-skeletal, mixed
Terino, mollic variant	Petrocalcic Paleustolls, loamy-skeletal, mixed, shallow
Terino, mollic, moderately deep variant	Petrocalcic Paleustolls, loamy-skeletal, mixed
Terino, thick solum variant	Petrocalcic Ustollic Paleargids, clayey-skeletal, mixed
Tonuco	Typic Paleorthids, sandy, mixed, shallow
Tres Hermanos	Typic Haplargids, fine-loamy, mixed
Upton	Typic Paleorthids, loamy, carbonatic, shallow
Vado	Typic Camborthids, loamy-skeletal, mixed
Vado, sandy-skeletal variant	Typic Camborthids, sandy-skeletal, mixed
Vinton	Typic Torrifluvents, sandy, mixed
Vinton, sandy-skeletal variant	Typic Torrifluvents, sandy-skeletal, mixed
Weiser	Typic Calciorthids, loamy-skeletal, carbonatic
Whitlock	Typic Calciorthids, coarse-loamy, mixed
Yturbide	Typic Torriorthents, sandy, mixed

5. HISTORY

The earliest men believed to have been in the Desert Project area (see p. ii) date from about 10,000 years ago. Numerous charcoal accumulations, the oldest of which is 7,300 years old, have been found along the Rio Grande Valley and the mountain fronts in the Desert Project. At least some of these charcoal accumulations appear to be hearthsites.

A number of early Spanish explorers followed the Rio Grande northward from Mexico. Two of the earliest expeditions were led by Agustin Rodriguez in 1581, and by Antonio de Espejo in 1583. In 1598 Don Juan de Onate led the first party of colonists and blazed a trail across a vast stretch of desert known as the Jornada del Muerto. At Fort Selden the route left the Rio Grande Valley and ascended to the broad plain of the Jornada del Muerto. Travel was easier on this smooth plain than along the Rio Grande north of Fort Selden. In the latter area, mountains are very close to the river, slopes are steep, and ambushes by the Indians were common. The new Jornada route was named the "El Camino Real" or the "King's Highway." A photograph of the trail is in Gardner (1951).

However, the Jornada del Muerto offered its own perils. Keyes (1905) made the following comments concerning it:

> Of all the basin plains of southwestern United States the Jornada del Muerto, in south-central New Mexico, is, in many ways, one of the most remarkable....For three hundred and fifty years after the Spanish invasion the Jornada lay in the beaten path of travel from Mexico northward. For 100 miles the famous El Paso and Santa Fe trail crossed its desert sands. In view of the horrors inspired by the trip across it from the time of Coronado to the advent of the railroad the Spaniards who ventured within its borders might well be pardoned for calling it the "Journey of Death." The long white line of bleached bones of man and horse, which not so very long ago marked the trail, amply attested the fitness of the title.

Keyes then quotes Wallace (1888) as describing the Jornada "in very somber though highly fanciful terms":

> Near the southern boundary of New Mexico the Spanish explorers were opposed by a barrier of all on earth most to be dreaded -- a shadeless, waterless plateau, nearly 100 miles long, from 5 to 30 miles wide, resembling the steppes of northern Asia....
>
> The portion I speak of appears to have served its time, worn out, been dispeopled, and forgotten. The grass is low and mossy, with a perishing look -- the shrubs, soapweed, and bony cactus writhing like some grisly skeleton; the very stones are like the scoria of a furnace. You vainly look for the flight of a bird, such as cheered the eyes of Thalaba in the desert;

> no bee nor fly hums in the empty air; and, save the lizard (the genius of desolation) and horn frog, there is no breath of living thing....
>
> The spot I am trying to describe is the battle ground of the elements. In winter it is made fearful by raging storms of wind and snow. There men and animals have been frozen to death, their bodies left the lawful prey of the mountain wolf. From the primeval years the Apache has harried the hungry waste, hunting for scalps; and, besides the savagest of savages, it is now the favorite skulking place of outlaws, an asylum for fugitives escaping justice in old Mexico and Texas.
>
> In our times many a party cut off and many a traveler murdered makes good the name it bears, given by the first white men who dared its perils, Jornada del Muerto -- "Journey of Death".

Fountain (1885), the Commissioner of Immigration for Dona Ana County, writing about the same area, stated: "Between these ranges are great plains, from twenty to sixty miles wide, treeless and almost waterless, but covered with a growth of rich, nutritious grass, that affords pasturage for stock at all seasons of the year."

6. TOWNS AND FORTS

The principal towns in the study area are Las Cruces, Mesilla, Dona Ana, and Organ. Fountain had the following comments about these towns in 1885:

> Las Cruces. The most important town in Dona Ana County is Las Cruces, the business center and seat of government, a town of 3000 inhabitants pleasantly situated in the richest portion of the Mesilla valley on the Atchison, Topeka and Santa Fe railroad 43 miles north of El Paso, Texas. The valley of the Rio Grande for several miles north of here and south to the Texas line is considered the finest growing section of New Mexico; the gardens of Las Cruces and the neighboring town of Mesilla are justly famed for their splendid fruit which in size and flavor is unrivalled by any grown in the Eastern States.
>
> Mesilla. A town of about 1500 inhabitants in the heart of the Mesilla valley, two miles from the Las Cruces railroad depot is the second town in the valley in point of population. A line of hacks make trips twice a day between this town and Las Cruces. The town of Mesilla is famous for its magnificent orchards and vineyards. It is laid out in regular streets which are shaded by large cottonwood and other trees, a catholic church and convent of the Sisters of Mercy comprise the public buildings. Some of the finest residences in the Mesilla Valley are situated in the town of Mesilla. Wine and fruit growing are the principal industries, the orchards and vineyards of this town have a national reputation.

Organ. A mining town with a population of about 400 is situated on the western slope of the Organ Mountains about 16 miles east of Las Cruces. This town is in the center of a rich and well developed mining district and promises to increase in wealth and importance. There are smelting works here with a capacity of 40 tons per day; this capacity will shortly be doubled. There is communication with Las Cruces by stage coach twice each day.

Dona Ana. This town is situate(d) in the Mesilla valley on the Dona Ana colony grant; population about 750, mostly native. Wine and fruit-growing are the most important industries. The close proximity of this town to the Organ mountain mines give it a prospective importance, it being the nearest railroad point; having all other facilities, it is more than probable that the works for the reduction of the ores of the Memphis and other mines in its vicinity will be erected here, in which event it will assume an importance second to no other town in the valley. The best quality of bottom land, under cultivation, with water privilege, adapted to the cultivation of the grape, fruits, and onions, can be purchased in the vicinity of Dona Ana in tracts of from 50 to 100 acres at $10 per acre, with good title.

Las Cruces, the largest center of population in the study area, had its beginning in 1848 according to Bloom (1903):

In 1848, the present site of Las Cruces was surveyed off by an Army officer, Chapman by name. Hon. Nestor Armijo, of Las Cruces, told me of having passed down the valley into Mexico in that year, and saw the men at work. In 1849 he returned to his home in the northern end of the Territory, and states that there were houses and people living in them.

The name, Las Cruces, comes from the Spanish, "The Crosses"; it was given to the settlement because of a fearful tragedy which had occurred years before, and to Hon. S. G. Bean I am indebted for the following description.

"In 1840, a party of forty Mexicans were on a journey from New Mexico to the state of Chihuahua with a train of pack-mules on a trading expedition, as it was the custom every year to make these trips for the purpose of exchanging commodities.

"At the point where the town of Las Cruces now stands there was a fearful mesquite jungle;" (More probably toward the north end of town, near the present site of the Alameda Sanitarium, and Fletcher's old ranch) "where the Indians, who held high carnival in the wilderness of this valley, waited the coming of the unsuspecting party. They made the onslaught from ambush, and it was a 'Custer Massacre', as not one of the forty Mexicans were left to tell the bloody tale.

"At the time there were no telegraph lines to wire the appalling news to kindred and friends, but they received notice by some means, and kind friends came and paid their last respects to the dead. Every spot of ground was marked where each bloody corpse was found by two boards nailed as the symbols of the holy cross. These crosses were standing here when I first came to the Territory in 1846."

In 1852 Las Cruces was made the county seat of Dona Ana County. In 1881 a railroad was located in Las Cruces, leading to increased growth. In 1940 its population was 8385, but the White Sands Missile Range was started soon after this. Many of the personnel at the Range live in Las Cruces, and in 1970 its population was 37,857.

The well-known Butterfield trail passed through the study area. Bloom (1903) describes its beginning:

> 1857 saw the establishing of the great Overland Mail line from Southwest Missouri to San Francisco, Cal. It was a great enterprise, established in co-operation with the Government and promoted and managed by an eastern man by the name of Butterfield; this level-headed man did his work well, and in honor of his good work the stage system was called the "Butterfield Route."...
>
> As the old Concord coach, with its mail and passengers swung into the Mesilla Valley, the road came from Texas up through the bottoms, on the east side of the Rio Grande to Fort Fillmore; here mail was exchanged, and the road led on up the river for about three miles - or about midway between Fort Fillmore and Mesilla Park - then after fording, met and followed the wagon road into La Mesilla. At this place was located the Home Station and Headquarters of the Route....
>
> After a stoppage to exchange mail, etc., the route continued its way up the valley to the town of Picacho, and from there made an angle westward to "Rough and Ready" station, which lay twenty miles from the Rio Grande. From this point the road ran on an almost straight line to San Francisco.

San Agustin Pass was and is one of the major east-west routes from the Tularosa Basin to Las Cruces and adjacent towns in the Rio Grande Valley. It is one of the few passes through the Organ-San Andres mountain chain. A number of old roads fan out from the pass to various points in the valley and are still visible. Depending upon the destination, the various roads headed towards Dona Ana; parts of Las Cruces; and north into the Jornada del Muerto. Many of the roads are partly gullied, providing excellent exposures of the soils in many places. The town of Organ is located just west of the pass and was responsible for some of the travel.

New Mexico State University is located in the southern part of the study area. The University was founded in 1888 as Las Cruces College. In 1889 it was established as a land grant college by an act of the Legislative Assembly of New Mexico in accordance with provisions of the Morrill Act, and named the New Mexico College of Agriculture and Mechanic Arts. In 1960 the name was changed to New Mexico State University.

Two forts were established to protect the early settlers. Fort Selden is located in the northern part of the study area (see p. 35). The fort was named for Col. Henry R. Selden of the First New Mexico Infantry. The fort was garrisoned from 1865 to 1877 and from 1880 to 1891 (Milton, 1971). Four years after the fort was established an attempt was made to close it. In 1870 Rep. W. T. Rynerson, in asking that the fort be retained, listed the following incidents in 1869 (Milton, 1971):

January 30	- Indians stole 40 yoke of oxen at San Augustine.
February 10	- Indians stole a herd of cattle from Captain Hines at Selden.
February 15	- Mail carrier horse killed at Cooper Peak.
March 3	- Ox killed on Selden reservation. Attempted capture of wood train at Selden.
March 4	- Shot cow belonging to Ft. O'Connor. Cut ferry cable at Selden.
April 27	- Killed 3 men at San Augustine.
December 10	- 10 head of mules and 7 horses stolen at Dona Ana.

Fort Fillmore, in the southern part of the study area, was named in honor of President Millard Fillmore. Fort Fillmore was garrisoned from 1851 to 1861.

7. THE RIO GRANDE

Before the Elephant Butte Dam was built in 1914, the Rio Grande flooded many times. In the summer of 1884, five railroad engines were lost due to floods in which the tracks were washed out by the Rio Grande. Bloom (1903) states:

> The Rio Bravo del Norte was the old Spanish for the poor excuse of a river we now call the Rio Grande. Who, learning first of this river from the maps does not imagine it a great noble stream, and very important? It has been important, however, for it was never dry in the three summer months early in the history of our valley, and over its shifting, restless banks has hung national arbitration more than once. Hon. Horace Stephenson remembers knowing of the river being completely dry in 1837; all the people gathered to see the sight, and the children to play in its dry sands. Never-the-less the other times the water came in terrible floods; banks could scarcely check the volume of water, and everything had to be ferried across almost the year around. At several places down the valley there were ferry stations, and many of the people owned private boats....
>
> The following are the facts agreed upon by my pioneer informants: the great Mesilla ditch head tapping the river had weakened its bank on the west side, and each spring when the freshets of water came from the melting ice at the north, the natives had to turn out in great numbers to stand guard over the ditch head, and strengthen the bank as best they could.

> When the Rebellion came to occupy the people with other dangers, the river was uncared for as in former years, and some time one May night, the great spring rise broke the limits and flooded the country. This went on for two or three years, each year water came over and after lying, became unhealthful, so causing that dreadful epidemic of chills and fever and malaria for which the valley was noted for years, even yet, unfortunately, though the cause and effect have been eradicated these many years.
>
> In the spring rise of 1865, the volume of water was so enormous that it took everything before it and made a mad dash down the valley along the hills on the west - a short cut, which left the town of La Mesilla high and dry upon the opposite bank about a mile away. The valley is described as one vast sheet of water from edge of Las Cruces to the hills on the west, with the site of La Mesilla a strip of island. It is said that for years the river actually ran into this bend, keeping the water high and almost deadly to inhabitants....
>
> In 1884-85 the river again caused a great deal of trouble in the country below. Big floods descended and the waters covered miles upon miles of hitherto high and dry land....

The present channel of the Rio Grande is controlled by levees.

8. LIVESTOCK AND VEGETATION

Buffington and Herbel (1965) present a detailed history of livestock use on the Jornada. The number of cattle greatly increased on the Jornada plain in the 1880s. A herd estimated at 20,000 cattle, under the Bar Cross brand, grazed an area of about 1800 square miles. The Bar Cross outfit had control over most of what is now the Jornada Experimental Range. In 1912 the Jornada Range Reserve was established and the area was fenced. From May 1915 to May 1916 the average number of stock on the Jornada Range was 4632 head on about 192,000 acres. This number was gradually reduced to only 1006 animal units for the period 1941-1947.

By using land office notes and records of the Experimental Range, Buffington and Herbel prepared maps showing the increase in shrubs from 1858 to 1963 (fig. 1). They state: "In 1858 the Jornada Experimental Range was a great expanse of grass with only isolated spots of mesquite.... Since 1858 the grass cover has decreased tremendously...vast areas having sandy soil are now dominated by mesquite sand dunes." This increase in shrubs and decrease in grassland were caused by large numbers of cattle. Livestock can disseminate mesquite seed since it passes through their digestive tracts without damage. Seed dispersal, accompanied by heavy grazing and periodic droughts, appeared to be the major factor affecting the rapid increase in shrubs (Buffington and Herbel, 1965).

Similar relations were found in the southern part of the study area by York and Dick-Peddie (1969) who stated, "The appearance of the grazing industry is the only factor which coincides with the time of this spectacular change (from grass to shrub)."

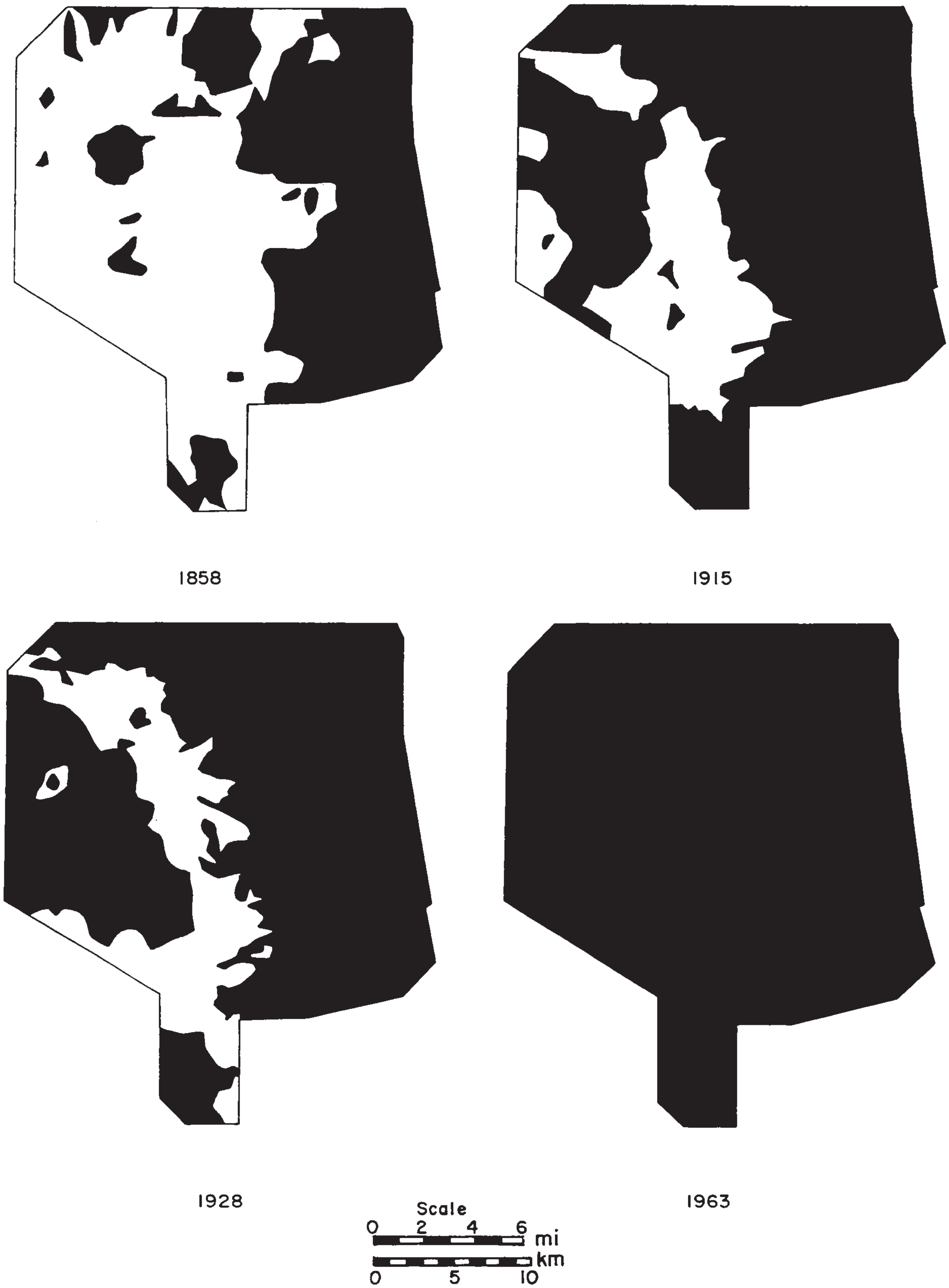


Figure 1. Encroachment of brush (mesquite, tarbush and/or creosotebush) on the Jornada Experimental Range in 1858, 1915, 1928 and 1963 (after Buffington and Herbel, 1965).

9. CLIMATE

10. PRESENT CLIMATE

Two general kinds of climate occur in the study area. The climate is arid (Thornthwaite, 1948) in desert areas along the Rio Grande Valley and in the closed basin north of Highway 70. The climate of the San Andres and Organ Mountains (the highest mountains) is considered to be semiarid. For purposes of this report the boundary to the semiarid zone of these mountains is considered to be about 5000 ft (1524 m). There is an increase in vegetative density at about this point; and the characteristic vegetation of higher elevations (such as blue grama) also first appear at about this elevation. At stable sites, A horizons are notably thicker and darker above 5000 ft. Distinct increases in depths of wetting occur above this elevation. This is indicated by depth of leaching in stable Holocene soils (section 66). Precipitation at 5000 ft is thought to be about 25 to 30 cm annually, based on estimates from data at Ropes Springs, Boyd's Ranch and the Jornada Experimental Range. These differences in climate make it possible to study the effects of climatic change on soils of the same age.

Precipitation patterns in the study area are controlled mainly by its inland location and by the north-south orientation of the mountain ranges. In summer, moist air from the Gulf of Mexico dominates the region. Surface heating and lifting of the moist Gulf air as it moves upslope causes thundershowers that are usually short but commonly intense. Nearly all the precipitation is rain. Prolonged rains are not common. In winter, general eastward circulation of moist air from the Pacific Ocean is dominant. It snows an average of two years out of three, but the snow seldom covers the ground for two consecutive days.

Precipitation in the valley at University Park is slightly more than 8 in (20 cm) annually (table 4). These values are similar to those of Fort Fillmore, just south of University Park, and Fort Selden to the north. In the closed basin area north of Highway 70, precipitation is nearly 9 in (23 cm, Jornada Experimental Range, table 4). More than half of the moisture falls during July, August, and September. The yearly precipitation at University Park ranges from 3.4 in (9 cm) in 1970 to 19.6 in (50 cm) in 1941. The 6.5 in (16 cm) rain that fell in a 24-hour period on August 29-30, 1935, was one of the heaviest 24-hour rainfalls recorded in New Mexico.

Precipitation over the 10-year period from 1948 to 1957 for Boyd's Ranch and for University Park are summarized in table 5. Precipitation in the mountains is nearly double that in the valley. Maximum precipitation occurs in the summer in both the mountains and the valley. Both stations show a slight secondary maximum in the winter.

Average annual temperature at University Park is 60^{o} and the daily temperature range generally exceeds 30^{o}. Summer temperatures in the desert are warm (table 6). Daytime readings reach 90^{o} or higher during an average 101 days a year. Winters are mild. The average daily minimum in January (the coolest month) is 25^{o}; the average daily winter maximum is 57^{o}. The lowest recorded temperature to date is -10^{o}, on January 11, 1962. The desert areas normally experience about 75 to 80 percent of the sunshine possible each day.

Table 4. Precipitation (in inches) at several stations along the valley border[1]

Station and years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Ft. Fillmore (1852-1860)	.07	.49	.17	.11	.16	.45	1.80	1.60	1.48	.54	.71	.10	7.68 (19)
Ft. Selden (1866-1876)	.30	.22	.18	.13	.18	.59	1.99	1.91	1.32	.54	.25	.54	8.17 (21)
University Park (1892-1970)	.36	.42	.37	.20	.30	.59	1.49	1.72	1.22	.70	.45	.50	8.32 (21)
Jornada Exp. Range (1914-1966)	.46	.37	.33	.20	.38	.49	1.75	1.68	1.45	.91	.40	.57	8.94 (23)

1/ Data from Weather Station, University Park. Values are in inches except for cm in parentheses, annual column.

Table 5. Comparison of precipitation (in inches) at University Park (elevation 3881 feet, in the Rio Grande Valley)1/ and Boyd's Ranch (elevation 6200 feet, in the Organ Mts.)2/

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						University Park							
1948	.18	1.43	.16	.07	.04	.86	.07	.46	.39	.37	0	1.13	5.16
1949	1.85	.46	.07	.06	.79	.15	1.14	.73	2.37	.88	T	.51	9.01
1950	.11	.48	T	T	.06	.25	2.41	.51	1.14	.38	0	0	5.34
1951	.31	.38	.16	.42	.02	0	1.47	.96	0	.74	.08	.51	5.05
1952	T	.72	.71	.56	.16	1.07	1.11	1.22	.37	0	.19	.12	6.23
1953	0	.68	.41	.03	T	.28	1.31	.33	T	.57	T	.20	3.81
1954	.07	.30	.10	0	.82	.26	.72	1.34	.96	1.25	0	T	5.82
1955	.66	0	.39	0	.15	.08	3.17	.59	.01	2.10	.11	T	7.26
1956	.18	1.04	0	.02	T	.52	.86	1.35	.09	.28	T	.44	4.78
1957	.32	1.48	.53	.02	.34	T	.81	2.66	.50	1.82	.85	T	9.33
Average	.37	.70	.25	.12	.24	.35	1.31	1.02	.58	.84	.12	.29	6.18 (16)
						Boyd's Ranch							
1948	2.50	.85	0	.32	1.01	1.85	.90	2.18	.88	.30	0	0	10.79
1949	1.50	1.49	0	.32	1.00	.30	3.76	.94	1.68	1.62	0	1.20	13.81
1950	.35	1.50	0	0	.11	0	8.43	.85	1.29	.49	0	0	13.02
1951	.75	.55	.43	1.04	0	0	.77	1.65	.30	1.05	.74	.43	7.71
1952	.34	1.12	.90	.67	1.73	1.67	2.07	2.88	.38	0	.59	.60	12.95
1953	0	1.31	.16	.65	.04	.58	3.63	.61	.30	.90	0	.56	8.74
1954	.29	0	.08	0	.60	.32	2.95	1.64	2.89	1.90	0	0	10.67
1955	1.45	0	1.28	0	.06	.22	4.67	1.67	0	5.76	.20	0	15.31
1956	.58	.12	0	0	.03	.73	2.43	2.67	.38	.08	0	.60	7.62
1957	.44	1.28	.80	.35	.31	0	3.29	2.02	.19	4.66	.95	0	14.29
Average	.82	.82	.37	.34	.49	.57	3.29	1.71	.83	1.68	.25	.34	11.49 (29)

1/ Weather Bureau. Climatological Summary. Las Cruces, N. M. U. S. Dept. of Commerce, Albuquerque, N. M. Values are in inches except for cm in parenthesis, average column.

2/ R. E. Boyd. Personal communication.

Table 6. Daily temperature data (degrees F.) and evaporation at University Park, New Mexico.[1/]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Air temperature (1898-1960)													
Average	41.5	45.7	51.6	59.1	67.1	76.5	79.4	77.6	71.0	61.2	48.9	41.6	60.1
Average daily minimum	25.5	29.1	34.4	41.6	49.2	59.0	65.1	63.6	56.2	44.2	31.2	26.1	43.8
Lowest	-8	2	12	20	27	36	42	44	30	22	5	1	-8
Average daily maximum	57.4	62.2	68.7	76.6	85.0	93.9	93.6	91.6	86.8	77.5	65.5	57.1	76.3
Highest	78	86	90	94	103	107	109	103	102	93	83	78	109
Average evaporation (1930-1960)													Total
	3.0	4.4	7.8	10.3	12.6	13.8	12.5	10.7	8.7	6.2	4.0	2.7	96.7 (246)

1/ Weather Bureau. 1965. Decennial census of the United States climate. Climatic summary of the United States. U. S. Department of Commerce, Washington, D. C. Evaporation values in inches except for cm in parenthesis, annual column.

* * *

Table 7. Wind records at University Park, New Mexico, 1914-1967[1/]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Speed, average mph	5.3	6.2	7.3	7.6	6.9	6.4	6.0	5.1	5.1	4.7	4.7	4.9	5.9
Prevailing direction	N	NW	W	W	W	SE	SE	SE	SE	SE	N	N	SE

1/ Personal communication, F. E. Houghton.

At University Park the average humidity is somewhat less than 50 percent for the year. The humidity ranges from about 60 percent in the early morning to less than 30 percent during warmer hours of spring and early summer. Evaporation from a free-water surface, as recorded in an evaporation pan, averages about 97 in (246 cm) a year (table 6), which is more than ten times the average precipitation. Evaporation is greatest during late spring and summer. Maximum evaporation occurs during the time of maximum precipitation (tables 4, 6). This would tend to dry out the soil rapidly between rains. Effectiveness of the precipitation would therefore tend to be less in the arid zone than in areas that have similar amounts of precipitation, but are cooler, or that receive most of their precipitation in the winter.

Wind speed is important because surficial materials are susceptible to blowing in dry climates. Dust storms are most common during the spring months. Winds are highest during March and April, when they average 7.3 and 7.6 mph respectively as compared to a yearly average of 5.9 (table 7).

Hourly wind speeds during the dusty season show far greater contrast than the monthly averages. Windiest periods occur in the afternoons. In March, for example, winds at El Paso Airport Station at 2:00 PM were 25 mph or more for 15 percent of the time, as compared to only one percent for August and September at the same time of day (table 8). High winds and the dry spring season combine for maximum blowing of dust. Wind direction is variable during the year, but in the spring is dominantly from the west (table 7).

11. PAST CLIMATES WITH GREATER EFFECTIVE MOISTURE

Many of the soils in the area are very old and range up to mid-Pleistocene in age. If past climates were different from the present one, they could have affected the soils. There is evidence of climatic change since mid-Pleistocene. The stepped sequence of geomorphic surfaces along the Rio Grande Valley may reflect climatic changes. Kottlowski (1958a) states "The sediments suggest that the Rio Grande's chief role near El Paso . . . has been that of downcutting, fluvial beds being deposited by the local tributaries. Conversely, during the semiarid cycle of the last several thousand years, aggradation has dominated the flood plain; this supports the theory that the waning periods of glaciation (when glacial debris choked the lessening amount of meltwater) and the interglacial stages (relatively dry) were characterized by aggradation in Mesilla and El Paso Valleys, and the glacial stages resulted in lowering of valley floors, leaving the interglacial flood plains as terrace remnants."

Fossil snail faunas indicate significant lowering of certain life zones at times of glaciation in the past (Metcalf, 1967).

Sierra Blanca is about 90 miles northeast of the study area. Smith and Ray (1941) and Richmond (1963) report late-Pleistocene glaciation in the area of Sierra Blanca peak. No glacier now exists in that area.

The Tularosa Basin is about 25 miles east of the Rio Grande at Las Cruces and lies just east of the Organ and San Andres Mountains (frontispiece). Kottlowski (1958b) states: "The 280 square miles of dunes and other parts of the Tularosa Basin below 4,000 feet are underlain by bedded gypsum 5-25 feet thick--deposits of Lake Otero named by Herrick (1904). This Pleistocene lake was a series of salinas, probably of maximum extent during last glacial-pluvial and then contemporaneous with Lake Estancia and other basinal lakes."

Table 8. Percentage frequency wind speed 13-24 mph, and 25 mph and over, monthly, El Paso, Texas. Period of record: 1951-1960[1/]

Hour of Day	MPH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	13-24	24	30	32	35	37	33	30	25	21	23	21	21
	25-over	5	9	7	7	2	3	1	2	1	1	4	4
02	13-24	25	30	30	33	33	33	23	26	18	22	23	24
	25-over	5	8	9	7	2	4	2	1	1	*	4	4
03	13-24	29	29	29	33	26	28	21	25	18	21	25	24
	25-over	3	6	8	4	1	3	2	1	*	0	2	3
04	13-24	25	28	29	30	22	23	19	22	21	18	29	28
	25-over	4	5	6	3	1	2	2	*	0	*	2	2
05	13-24	26	30	29	27	24	23	20	23	16	19	24	28
	25-over	4	4	5	3	1	1	*	*	0	0	3	2
06	13-24	27	29	29	28	23	21	19	18	15	17	24	30
	25-over	2	4	4	3	2	1	0	0	*	0	3	3
07	13-24	30	29	27	31	26	22	19	20	16	21	27	26
	25-over	2	3	3	3	*	1	0	*	0	1	2	4
08	13-24	23	29	32	31	32	25	19	20	19	22	28	23
	25-over	3	4	4	5	1	1	*	0	1	1	2	4
09	13-24	26	29	36	37	40	31	21	19	21	27	28	23
	25-over	2	5	7	8	2	1	*	*	2	2	2	4
10	13-24	29	31	36	41	44	31	19	22	26	30	30	25
	25-over	4	6	11	8	4	2	*	0	1	2	3	3
11	13-24	32	33	37	43	45	33	25	23	25	34	32	28
	25-over	5	7	12	9	5	1	*	0	1	2	5	4
12	13-24	31	33	41	44	50	36	26	20	29	36	32	28
	25-over	7	9	13	12	3	*	0	0	*	3	4	5
13	13-24	38	36	46	49	53	38	29	24	31	39	32	28
	25-over	6	12	12	12	5	3	1	*	1	3	4	5
14	13-24	37	39	45	50	51	38	29	29	33	43	33	33
	25-over	6	13	15	14	9	3	2	1	1	4	3	7
15	13-24	36	42	46	52	51	43	31	34	34	39	34	32
	25-over	7	12	16	14	8	3	3	2	1	4	4	6
16	13-24	32	42	46	49	49	45	39	39	36	43	33	25
	25-over	6	11	17	17	9	4	4	3	1	4	4	5
17	13-24	27	34	43	47	50	46	48	39	37	35	26	24
	25-over	6	11	16	20	13	5	5	2	3	3	4	6
18	13-24	24	33	38	47	43	48	50	38	34	30	23	25
	25-over	7	10	12	14	11	6	4	1	1	3	6	5
19	13-24	25	30	33	43	43	41	40	34	34	30	27	27
	25-over	7	11	16	15	11	7	3	2	1	4	4	5
20	13-24	26	27	38	42	51	47	38	39	34	32	26	27
	25-over	5	11	13	15	8	5	6	2	1	2	6	4
21	13-24	27	27	37	41	52	48	42	36	32	25	23	27
	25-over	5	10	11	10	7	6	5	1	2	2	4	3
22	13-24	26	27	34	39	44	47	41	36	27	21	24	25
	25-over	5	9	10	11	8	7	2	1	1	2	3	4
23	13-24	26	27	31	37	40	42	34	29	23	21	24	26
	25-over	5	10	10	9	6	5	2	4	1	1	4	3
M	13-24	26	29	29	38	36	37	30	25	20	19	23	24
	25-over	3	10	10	8	5	4	2	2	2	2	4	4
Avg	13-24	28	31	36	40	40	36	30	28	26	28	27	26
	25-over	5	8	10	10	5	3	2	1	1	2	4	4

1/ Weather Bureau. 1964. The Climate of Texas and adjacent Gulf waters. U. S. Dept. of Commerce, Washington, D. C.

* Less than .5%.

Northward 150 miles is the Estancia Valley, once occupied by former Lake Estancia (Meinzer, 1911) with a maximum area of 450 square miles. The San Augustin plains are located about 125 miles northwest of the study area; during late-Pleistocene this basin was occupied by Lake San Augustin, with a maximum area of 255 square miles (Foreman et al., 1959). Westward about 100 to 125 miles Schwennesen (1918) described features of former lakes in the Animas, San Luis, and Playas Valleys. About 75 miles south of the study area, Sayre and Livingston (1945) cite ancient shorelines of lakes in northern Mexico, indicating that the lakes were formerly much larger than at present.

Relatively small, intermittent lakes or playas are all that now exist in the basins discussed above. The hydrologic regimens necessary to maintain permanent lakes in central and southern New Mexico have been considered (Meinzer, 1922; Leopold, 1951; Antevs, 1954; Snyder and Langbein, 1962). Their consensus is that the Pleistocene pluvial climates differed from the present climate in having heavier precipitation and lower temperatures. Galloway (1970) believes that there was no glacial pluvial and that the climate during the full-glacial period (23,000 to 19,000 B.P.) was cold and dry. He believes that the Pleistocene lakes formed because of greatly reduced evaporation, which he estimates to be about half of today's. Even if precipitation were not greater during the full-glacial climate than today, more moisture would have been available for leaching because of the reduced evaporation.

There is also evidence for a climatic change within the study area itself. A small playa (Isaacks' Lake playa) occurs in the closed basin between the Dona Ana and San Andres Mountains. While there are no distinct beach ridges suggesting a formerly higher stand of water in the playa, northward there are gypsiferous beds that may reflect a former lake. Pedologic evidence shows deeper horizons of silicate clay and carbonate accumulations in soils that started their development in late-Pleistocene than are developing now, indicating times of more effective moisture in the Pleistocene (section 78).

The evidence indicates that the present climate provides less effective moisture than the Pleistocene pluvial climates. Holocene soils developed primarily during a climate similar to the present, whereas soils of Pleistocene age developed in part during Pleistocene pluvials, which were times of more effective moisture.

12. FAUNA

Fauna of representative parts of the study area are given in tables 9 and 10. Kangaroo rats are the most common rodent. Ground squirrels, cottontail rabbits, jackrabbits, gophers and various types of rats and mice are also common. The most abundant predatory mammals are coyotes, bobcats and skunks. Badgers and foxes are present in fewer numbers. Owls, hawks, eagles, jays, quail, and roadrunners are among the most common birds. Deer are present in the Dona Ana, San Andres and Organ Mountains, Antelope occur in the basin floor north of Highway 70. The western spadefoot is the most common amphibian. Horned toads, bull snakes, and diamondback and prairie rattlesnakes are also common. Lizards are the most abundant vertebrate. Ants and termites are common in a number of soils. Termites are particularly important in some soils because they have mixed upper horizons, obliterating the argillic horizon (section 85).

Table 9. Fauna on the NMSU Ranch[1/]

Scientific name	Common name
Mammalian predators	
Canis latrans	Coyotes
Lynx rufus	Bobcats
Mephitis mephitis	Skunks, striped
Taxidea taxus	Badgers
Urocyon cinereoargenteus	Foxes, gray
Vulpes macrotis	Foxes, desert
Predatory birds	
Aquila chrysaetos	Eagles, golden
Buteo jamaicensis	Hawks, red-tailed
Buteo swainsoni	Hawks, Swainson's
Circus cyaneus	Hawks, marsh
Rabbits	
Lepus californicus	Jackrabbits, black-tailed
Sylvilagus auduboni	Cottontails, desert
Rattlesnakes	
Crotalus atrox	Rattlesnakes, diamondback
Crotalus viridis	Rattlesnakes, prairie
Rodents	
Citellus spilosoma	Squirrels, spotted ground
Dipodomys merriami	Rats, Merriam's kangaroo
Dipodomys ordi	Rats, Ord's kangaroo
Dipodomys spectabilis	Rats, bannertail kangaroo
Neotoma albigula	Rats, white-throated wood
Neotoma micropus	Rats, southern plains wood
Onychomys leucogaster	Mice, grasshopper
Perognathus flavus	Mice, silky pocket
Perognathus penicillatus	Mice, desert pocket
Peromyscus maniculatus	Mice, white-footed
Reithrodontomys megalotis	Mice, harvest
Sigmodon hispidus	Rats, cotton

1/ After Wood (1969).

Table 10 . Amphibians and reptiles of the Jornada Experimental Range[1/]

Scientific name	Common name
Lizards	
Cnemidophorus perplexus, Baird and Girard	Lizard
Cnemidophorus tessellatus tessellatus, Say	Lizard, desert whiptail
Crotaphytus collaris baileyi	Lizard, Bailey's collared
Crotaphytus wislizenii, Baird and Girard	Lizard, leopard
Eumeces obsoletus, Baird and Girard	Skink, Sonoran
Holbrookia maculata approximans, Baird	Lizard
Sceloporus consobrinus consobrinus, Baird and Girard	Lizard
Uta ornata ornata, Baird and Girard	Lizard
Uta stansburiana stejnegeri, Schmidt	Lizard
Salamanders	
Ambystoma tigrinum, Green	Salamander, tiger
Snakes	
Coluber flagellum, subsp.	Snake, whip
Coluber taeniatus, subsp., Hallowell	Racer, western striped
Crotalus atrox atrox, Baird and Girard	Rattlesnake, desert diamond
Crotalus confluentus confluentus, Say	Rattlesnake, prairie
Crotalus molossus, Baird and Girard	Rattlesnake, black-tailed
Heterodon nasicus, Baird and Girard	Snake, hog-nose, western
Pituophis sayi affinis, Hallowell	Snake, western bull
Tantilla nigriceps, Kennicott	Tantilla, Sonoran
Thamnophis sirtalis parietalis, Say	Garter snake, prairie
Toads	
Bufo cognatus, Say	Toad, Great Plains
Bufo debilis, Girard	Toad, dwarf
Bufo punctatus, Baird and Girard	Toad, spotted
Phrynosoma cornutum, Harlan	Horned toad, Texas
Phrynosoma modestum, Girard	Horned toad, round-tailed
Scaphiopus couchii, Baird	Spadefoot, Sonoran
Scaphiopus hammondii, Baird	Spadefoot, western

1/ After Little and Keller (1937)

Wood (1969) lists the fauna in table 9 in his study on the New Mexico state University Ranch, in and north of the Dona Ana Mountains. The most common amphibians and reptiles on the Jornada Experimental Range according to Little and Keller (1937) are given in table 10. Some of these are also discussed by van Denburg (1924).

13. FLORA

Names of plants observed in the study area are given in tables 11 and 12. Shrubs are dominant in the arid part of the study area and are mostly creosotebush, mesquite, tarbush, Mormon tea, ocotillo, snakeweed whitethorn, ratany, mariola, four-wing saltbush, prickly pear, *Yucca elata* and *Yucca baccata*. Desert willow, brickellbush, Apache plume, burro brush, sumac and mesquite are common in arroyos. Most of the shrubs listed above also occur at higher elevations (5000-6000 ft) along with catclaw, century plant, mountain lilac, indigo bush, sotol, turpentine bush, cholla, barrel cactus, juniper, squawbush, and a few pinon at highest elevations. In the arid zone, grasses occur only in scattered areas where moisture conditions are favorable (section 51) and are mainly three-awn, tobosa, burro grass, fluffgrass, black grama, bush muhly and dropseed. These grasses also occur at elevations above about 5000 ft where sideoats grama and blue grama are found. Vegetation of various soils is given in the mapping unit descriptions (sections 128 *et seq*.).

14. MAJOR PHYSIOGRAPHIC FEATURES

The study area is located in Mexican Highlands section of the Basin and Range province of southern New Mexico (Thornbury, 1965). The area (figs. 1a,2) is about 400 square mi in size. It includes parts of north-south trending mountain ranges; broad, intervening basins; and the valley of the Rio Grande (except for the flood plain). This kind of physiography is extensive in the Southwestern United States.

The Organ and San Andres Mountains occur along the eastern border of the area (fig. 2). The Organ Mountains are the highest range, with many peaks over 8000 ft (2440 m); highest is Organ Needle with an elevation of 9012 ft (2749 m). The Dona Ana and Robledo Mountains are smaller ranges in the central and western part of the area respectively; highest peaks are between 5500 ft and 6000 ft (1677 and 1830 m). Elevation of the Rio Grande flood plain in the southern part of the area is about 3900 ft (1188 m).

The basins have two major landscape components: basin floor and piedmont slope. The piedmont slope, which extends from the mountains to the basin floor and valley border, is composed of individual alluvial fans along the mountain fronts and a coalescent fan-piedmont downslope.

Table 11. Scientific and common names of grasses and forbs.

Scientific Name	Common Name	Scientific Name	Common Name
Perennial Grasses			
Aristida divaricata	Three-awn	Muhlenbergia emersleyi	Bullgrass
Aristida pansa	Three-awn	Muhlenbergia porteri	Bush muhly
Bouteloua curtipendula	Sideoats grama	Panicum obtusum	Vine mesquite
Bouteloua eriopoda	Black grama	Scleropogon brevifolius	Burro grass
Bouteloua gracilis	Blue grama	Setaria macrostachya	Bristlegrass
Bouteloua hirsuta	Hairy grama	Sporobolus airoides	Alkali sacaton
Enneapogon Desvauxii	Spike pappusgrass	Sporobolus cryptandrus	Sand dropseed
Eragrostis sp.	Lovegrass	Sporobolus flexuosus	Mesa dropseed
Hilaria mutica	Tobosa grass	Stipa eminens	Needle grass
Leptochloa dubia	Sprangletop	Trichachne californica	Cottontop
Annual Grasses			
Aristida adscensionis	Three-awn	Tridens muticus	Slim tridens
Bouteloua barbata	Six weeks grama	Tridens pulchellus	Fluffgrass
Forbs			
Allionia incarnata	Trailing-four-o'clock	Pectis angustifolia	Fetid marigold
Astragalus allochrous	Milkvetch	Perezia nana	Desert holly
Athysanus pusillus	Mustard	Phacelia sp.	Scorpion weed
Bahia sp.	Wild Chrysanthemum	Salsola kali	Russian thistle
Baileya pleniradiata	Desert-marigold	Verbena sp.	Vervain
Dithyrea Wislizeni	Spectacle-pod	Verbesina encelioides	Golden crown-beard
Eriogonum Abertianum	Desert buckwheat		

Table 12. Scientific and common names of shrubs and trees.

Scientific Name	Common Name	Scientific Name	Common Name
Acacia constricta	Whitethorn	*Gutierrezia sarothrae*	Snakeweed
Acacia Greggi	Catclaw	*Haplopappus laricifolius*	Turpentine bush
Agave palmeri	Century plant	*Helianthus ciliaris*	Blueweed
Artemesia filifolia	Sand sage	*Holacantha Emoryi*	Crucifixion thorn
Atriplex canescens	Four-wing saltbush	*Hymenoclea monogyra*	Burro brush
Bacharis pteronoides	Yerba de pasmo	*Juniperus monosperma*	Juniper
Brickellia laciniata	Brickellbush	*Koeberlinia spinosa*	Crucifixion thorn
Ceanothus Greggii	Mountain lilac	*Krameria parvifolia*	Ratany
Celtis reticulata	Desert hackberry	*Larrea tridentata*	Creosotebush
Croton corymbulosus	Croton	*Lippia Wrightii*	
Chilopsis linearis	Desert willow	*Lycium Berlandieri*	Desert thorn
Coldenia canescens		*Nolina microcarpa*	Beargrass
Condalia lycioides	Buckthorn	*Opuntia spp.*	Cholla, prickly pear
Condalia spathulata	Mexican crucillo	*Parthenium incanum*	Mariola
Dalea formosa	Indigo bush	*Pinus edulis*	Pinon
Dalea scoparia	Broomdalea	*Prosopis juliflora*	Mesquite
Dasylirion Wheeleri	Sotol	*Quercus sp.*	Oak
Echinocactus Wislizenii	Barrel cactus	*Rhus microphylla*	Sumac
Ephredra Torreyana	Mormon tea	*Rhus trilobata*	Squawbush
Ephedra trifurca	Mexican tea	*Senecio filifolius*	Threadleaf groundsel
Eurotia lanata		*Yucca baccata*	Yucca
Fallugia paradoxa	Apache plume	*Yucca elata*	Yucca
Flourensia cernua	Tarbush	*Zinnia pumila*	Desert zinnia
Fouquieria splendens	Ocotillo		

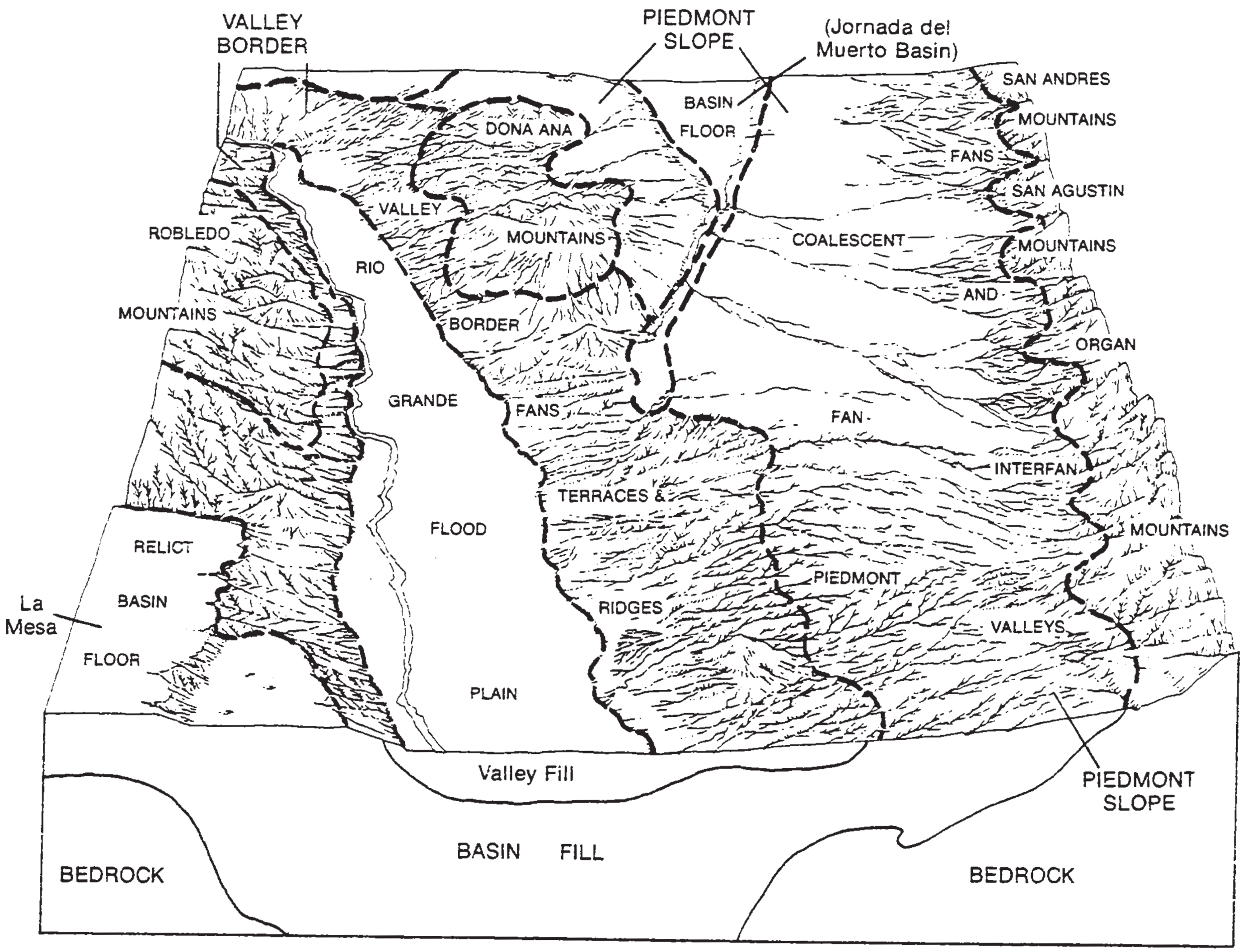


Figure 1a. Some of the landforms of the Desert Project.

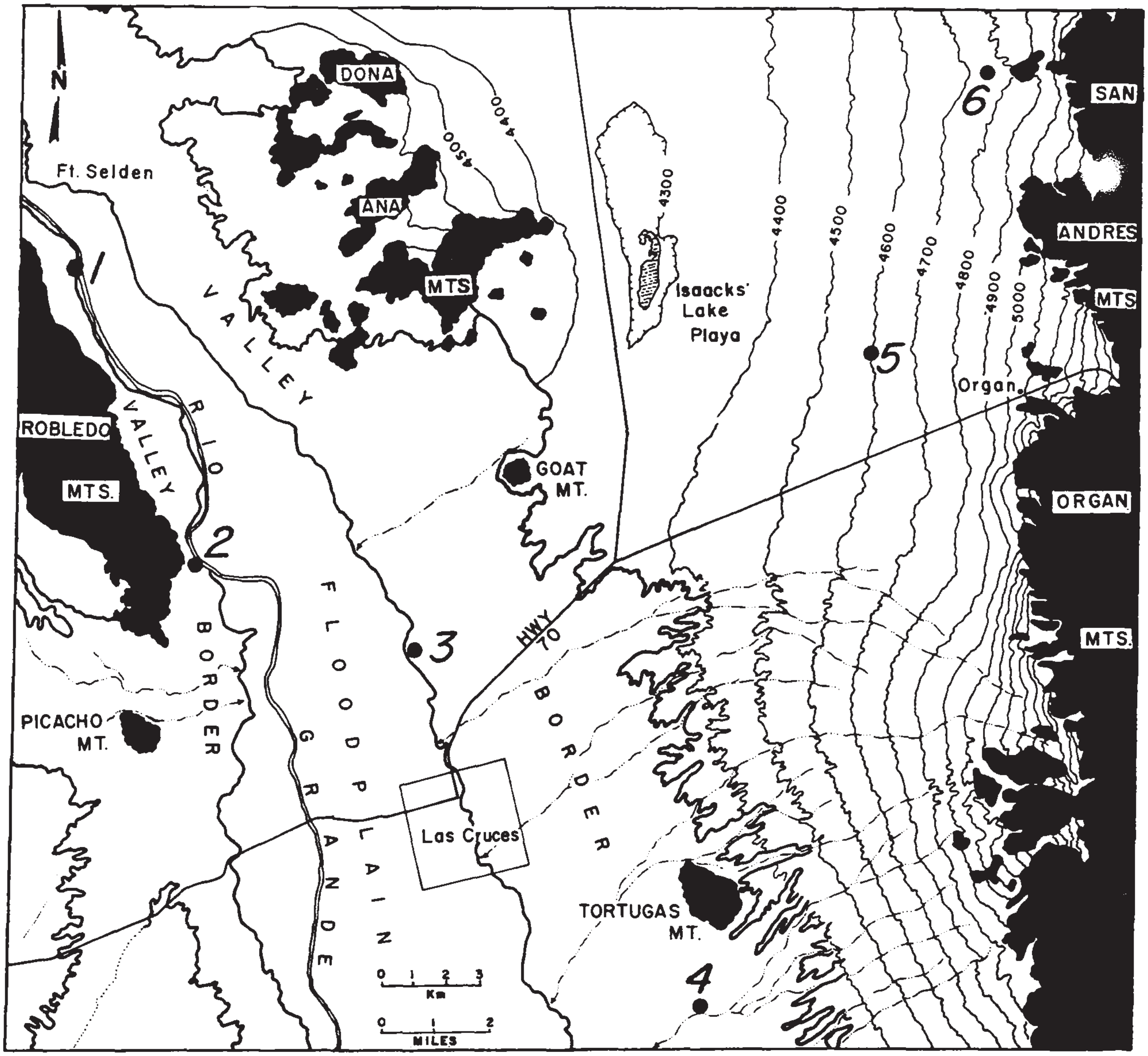


Figure 2. The Desert Project. Radiocarbon sites indicated as: 1 = Altimira; 2 = Shalam Colony; 3 = Chandler Tank Arroyo; 4 = Fillmore Arroyo; 5 = Isaacks; 6 = Gardner Spring. See table 13 for C14 dates. Contour lines are in feet.

15. BURIED CHARCOAL

Radiocarbon dating of buried charcoal establishes a maximum date for overlying sediments and soils. Such charcoal is thus a useful stratigraphic tool for dating deposits and studying the relation of soil development to time. Buried charcoal has been dated at a number of localities in the project (fig. 2). Information about the charcoal dates is given in table 13.

The charcoal dates enable a distinction between soils of Holocene age and soils of Pleistocene age. Different national groups mostly favor 10,500 to 10,000 yr B. P. as the boundary (Fairbridge, 1968). In the study area a boundary of about 7500 yr B. P. seems to fit best.

Table 13. Radiocarbon ages of buried charcoal in Fillmore and Organ alluviums

Alluvium, site, and section where discussed	Depth	Age	Lab No.
	cm	yr B.P.1/	
Fillmore alluvium			
Fillmore Arroyo (129)	112-132	2620 ± 200	W-819
Shalam Colony (131)	96-104	2850 ± 120	I-294
	234-242	4910 ± 225	I-295
Altimira	102-112	3960 ± 150	I-2736
Chandler Tank Arroyo	201	7340 ± 285	I-4282
Organ alluvium			
Gardner Spring (162)			
III	130-140	1130 ± 90	I-292
II	51-81	2120 ± 110	I-290
	80-99	2220 ± 95	I-2225
I	127-152	4570 ± 120	I-1795
	229-249	4640 ± 180	I-291
	231-257	4700 ± 225	I-1794
	152	4960 ± 130	I-1740
	260	6400 ± 110	I-4281
Isaacks (157)	43-53	4035 ± 115	I-2902
	99-107	4200 ± 105	I-4282

1/ B.P. = Before Present. Present = 1950 for purposes of C14 studies.

16. GEOMORPHIC SURFACES

Table 14 shows the fourteen geomorphic surfaces and one general landscape unit distinguished in the study area (Ruhe, 1964, 1967; Hawley, 1965; Hawley and Kottlowski, 1969). The surfaces occur on all parts of the landscape--alluvial fans, coalescent fan-piedmonts, basin floors, terraces, ridges, and arroyo channels. The terminology of Hawley and Kottlowski (1969) has been followed in designating materials associated with the surface by the geomorphic surface name (e. g., Fillmore alluvium).

The geomorphic surfaces were found to be useful in studies of soils because they serve as a chronological framework, and provide a common thread that makes the soil patterns easier to understand. Most geomorphic surfaces in the study area are extensive; and their surficial sediments, in which the soils have formed, can range widely in mineralogy, texture, and climatic occurrence. Many kinds of soils can therefore occur on a single geomorphic surface; for example, 10 soil mapping units occur on the Organ surface. However, a common feature to the various soils of a given surface is the degree of soil development, taking into account effects of changes in parent materials and climate (sections 34, 46). Thus soil morphology can supply important evidence for the identification of geomorphic surfaces (section 155).

The distinction between geomorphic surfaces is commonly most apparent between the surfaces of Holocene and Pleistocene age. This is because of the predictable position and exclusively surficial location of the Holocene deposits, and prominent morphological differences between Holocene soils and soils of Pleistocene age. This distinction is less apparent between some of the older surfaces. This is particularly the case where geomorphic surfaces (and their soils) of widely variable ages are at about the same elevation.

A distinction is made between a constructional surface and a structural bench. The term, constructional, is "said of a landform that owes its general character to the processes of upbuilding, such as accumulation by deposition" (Glossary of Geology, 1972). Constructional geomorphic surfaces form the major portion of the stable older land surface remnants along the Rio Grande Valley. Such surfaces were formed as a result of continued accumulation of alluvium, followed by a halt in deposition and the start of soil formation. Stabilization of the Picacho surface, for example, must have occurred and soil formation must have started at about the same general period of time during late-Pleistocene. Structural benches form by erosion instead of deposition. They have ridge crests with accordant elevations, and form on erosion-resistant gravel units (see section 143).

<u>Relative</u> ages of soils may be determined from the chronological arrangement of the geomorphic surfaces. For example, in the stepped sequence of stable surfaces along the Rio Grande Valley, both the surfaces and their associated soils usually become progressively older with increasing elevation of the steps. <u>Absolute</u> ages of soils are usually difficult to determine. Approximate ages may be established if materials in favorable stratigraphic positions can be dated. Radiocarbon ages of buried charcoal are very useful, since age of the buried charcoal establishes a maximum age for horizons above it. Fairly precise maximum ages have been determined for many Holocene soils. However, charcoal has not been found associated with soils and parent materials of Pleistocene

Table 14. Estimated age, landform, and materials associated with geomorphic surfaces and their soils.

Geomorphic surface	Physiographic location and soil age, years B.P. or epoch[1/]	Landform and material
	The valley border	
Arroyo channels	Historical	Arroyo; alluvium
(Coppice dunes)[2/]	Historical	Dune; eolian sediments
Fillmore	100 to 4000	Fan, ridge remnant, terrace; alluvium; colluvium
Leasburg	Earliest Holocene-latest Pleistocene	Fan, ridge remnant, terrace; alluvium
Fort Selden	(Fillmore or Leasburg, undifferentiated)	Fan, ridge remnant, terrace; alluvium; colluvium
Picacho	Late-Pleistocene	Fan, ridge remnant, terrace; alluvium; colluvium
Tortugas	Late- to mid-Pleistocene	Fan, ridge remnant, terrace; alluvium; colluvium
Jornada I[3/]	Late mid-Pleistocene	Fan-piedmont, ridge; alluvium remnant
La Mesa[3/]	Early mid-Pleistocene	Basin floor; alluvium
	The piedmont slope	
Arroyo channels	Historical	Arroyo; alluvium
(Coppice dunes)[2/]	Historical	Dune; eolian sediments
Whitebottom[4/]	Historical	Small fan, drainageway; alluvium
Organ	100 to 7500	Fan, fan-piedmont, terrace, draingeway, valley fill, ridge; alluvium; colluvium
III	100 (?) to 1100	Gully fill at Gardner Spring
II	1100 to 2100	Valley fill and terrace at Gardner Spring
I	2200 to 7500	Valley fill at Gardner Spring, extensive elsewhere in landforms noted for Organ
Isaacks' Ranch	Earliest Holocene-latest Pleistocene	Fan, drainageway, ridge; alluvium
Jornada II	Late-Pleistocene	Fan, fan-piedmont, terrace, ridge; alluvium; colluvium
Jornada I	Late mid-Pleistocene	Fan, fan-piedmont, ridge remnant, terrace
Jornada	(Jornada I or Jornada II, undifferentiated)	As for Jornada I and II
Dona Ana	Mid-Pleistocene	Fan, ridge remnant; alluvium
	Basin floor north of Highway #70	
Lake Tank	Present to mid-Pleistocene	Playa; alluvium, lacustrine
Petts Tank	Late-Pleistocene	Basin floor; alluvium (lacustrine in part?)
Jornada I	Late mid-Pleistocene	Basin floor; alluvium
La Mesa	Mid-Pleistocene	Basin floor; alluvium
Jornada I-La Mesa	(Jornada I or La Mesa, undifferentiated)	Basin floor; alluvium
	- - - - - - - -	
Mountain slopes and summits (undifferentiated)		

1/ The age of geomorphic surface and its soils is considered to be the same. On a constructional surface, for example, all would date from the approximate time that sedimentation stopped and soil development started.

2/ Coppice dunes have not been formally designated a geomorphic surface, but are considered separately here because of their extent and significance to soils of the area.

3/ The Jornada I and La Mesa surfaces are not formally considered a part of the valley border. They are included here because they form part of a stepped sequence with the valley border surfaces.

4/ **The Whitebottom surface is recognized in the silty, highly calcareous sediments northeast of Isaacks' Lake Playa. Associated sediments are generally only a few cm thick.**

age in the study area. Inorganic carbon has been dated from carbonate horizons of some soils of late-Pleistocene as well as Holocene age (section 89) but does not provide an absolute time measure. Vertebrate paleontology (Ruhe, 1962; Strain, 1966; Hawley et al., 1969) has placed a general mid-Pleistocene time for the maximum age of the soils of La Mesa. Potassium-argon dating of Quaternary basalts on the soils of La Mesa surface show that the basalts are no older than about 0.3 million yr (Hoffer, 1971). Paleomagnetic studies and dating of volcanic ash are in progress and may provide information concerning more precise ages for soils that began their development in the Pleistocene. See Hawley (Hawley, John W. In preparation. Quaternary geology and geomorphology of the Las Cruces area, Southern New Mexico), for more details on the chronology.

17. LANDSCAPE DISSECTION

Landscape dissection is a common feature adjacent to river valleys. Dissection also occurs on old, high fans along mountain fronts not tributary to valleys, but the process is most prominent adjacent to many valleys because of their depth. Dissection significantly affects soils since soil erosion associated with the dissection removes upper horizons in highly variable degree (table 15; sections 135, 145 are examples).

Regional dissection has been caused by long-continued downcutting of the Rio Grande. Arroyos extend headward from the flood plain and are separated by ridges along the valley border. The arroyos are particularly large towards the Organ Mountains because of the extensive watershed. Areas next to the valley have been affected most; the effects of dissection become progressively less upslope. Dissection and associated soil erosion can cause soil category changes ranging from series to order. Figure 4 shows changes at the order and suborder level (see sections 138 and 140 for further discussion).

Five classes of dissection have been defined (figs. 3 to 5; table 15). The classes are related to relatively small parts of the landscape, such as ridges, drainageways and saddles, to focus the effect on soil horizons. Soil change ranges from none in undissected (class 1) areas to the truncation of all major horizons in severely dissected (class 5) areas. All classes of dissection are generally not present in any one area. For example, dissection similar to that shown in figure 3 occurs on the east side of the valley, north and south of Tortugas Mountain. Class 1 does not occur in that area but classes 2 to 5 do.

Table 15. Classes of landscape dissection in the study area.

Character of landscape and soils

Class 1. These areas may be level (as in a basin floor) or sloping (as on a fan-piedmont) but they are marked by the absence of incised drains and by the preservation of essentially all soil horizons. All diagnostic horizons are present and soil classification has not been changed by dissection and associated soil truncation.

Class 2. These areas are dissected by drains a few cm to 1 m or more deep, but areas between the drains are level transversely. Diagnostic soil horizons have been truncated only in the drains. Classification of soils between the drains has not been changed by truncation associated with the dissection. Intervals between drains commonly range from about 50 to 200 m.

Class 3. Essentially no part between the drains is level transversely; ridge crests are rounded. In the arid part of the study area, argillic horizons (if present in adjacent undissected sites) have commonly been truncated or carbonate-engulfed although a few "islands" of soils with argillic horizons may remain. Other diagnostic horizons (calcic or petrocalcic horizons) are still present. These areas are usually characterized by slight ridges, but the ridges are not deeply dissected or steep except along their margins.

Class 4. Ridges are prominent. Major genetic horizons - the calcic or petrocalcic horizons - are still preserved on ridge crests. Slope of ridge sides commonly ranges from 10 to 40 percent. On soils and landscapes older than late-Pleistocene, calcic or petrocalcic horizons also may be present on ridge sides that slope less than about 20 percent. Saddles (formed by joining of drainageways in ridge sides) in ridge crests are not present or are very sparse, and a consistent longitudinal slope usually occurs along the ridge crests.

Class 5. Saddles are common in ridge crests; the original ridge crests have been largely or wholly obliterated. Slope of ridge sides usually ranges from 20 to 50 percent. Calcic or petrocalcic horizons occur only in scattered, best-preserved places along the ridge crests. There is no consistent longitudinal slope along ridge crests because of the numerous saddles. Substantial downwearing of former ridge crests has occurred in most advanced stages and soils of both ridge crests and ridge sides are Entisols.

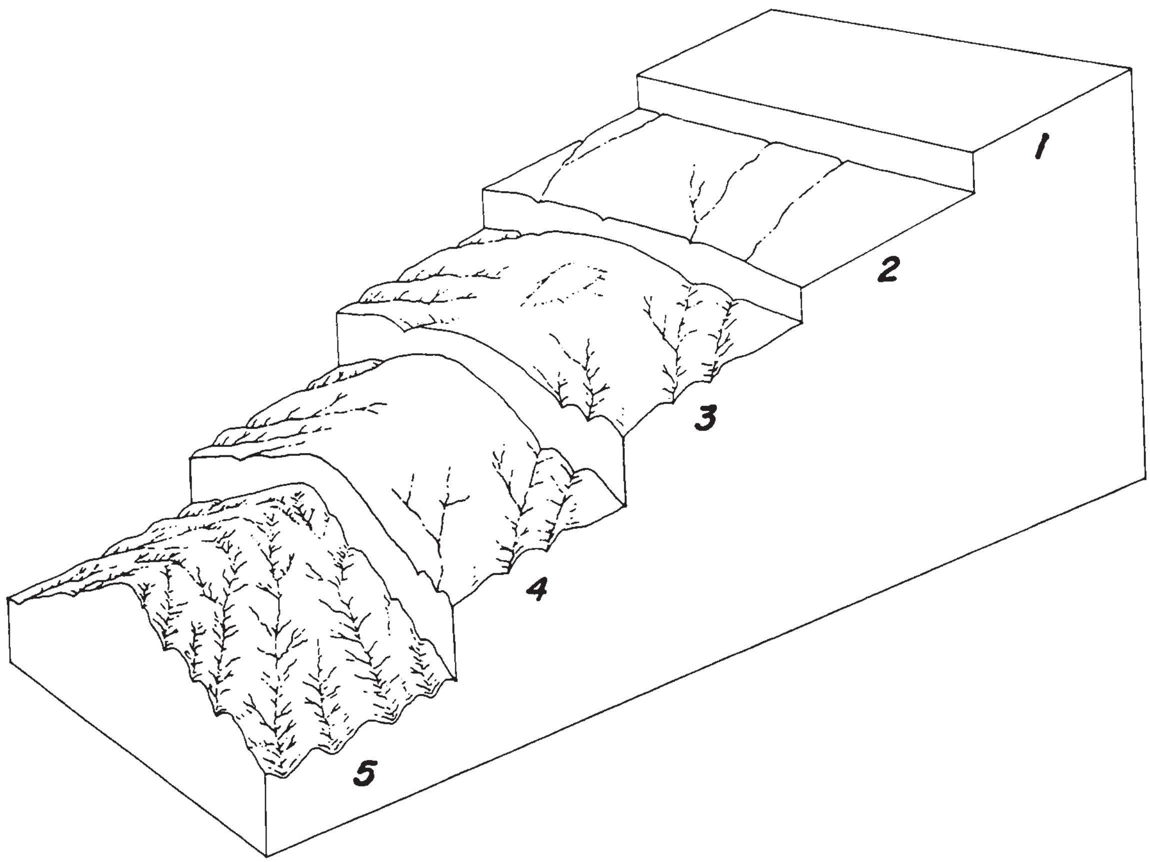


Figure 3. Generalized diagram showing classes of landscape dissection along and near the valley border.

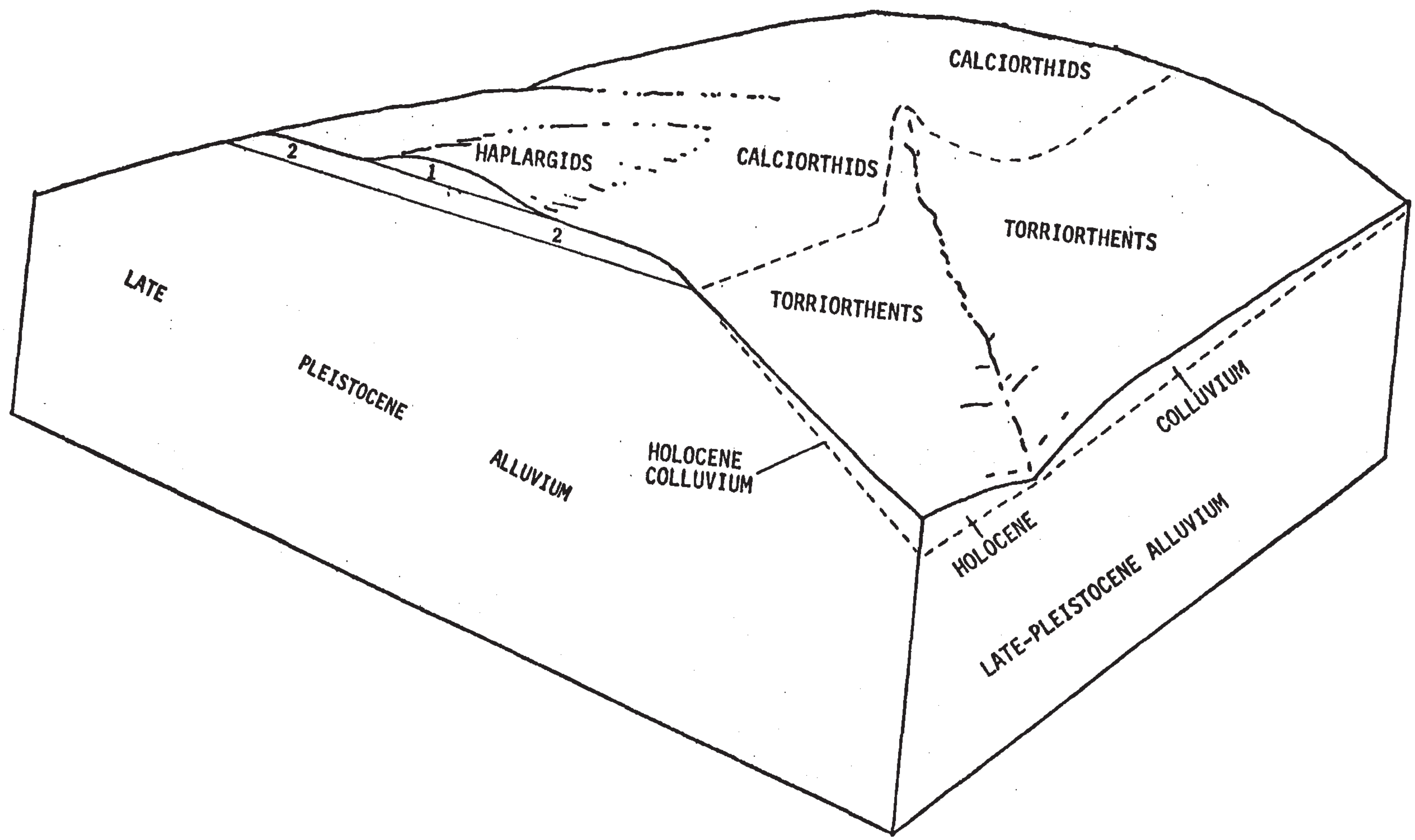


Figure 4. Class 3 dissection (fig. 3) on a Picacho fan remnant near University Park. The diagram shows boundaries between suborders, and relation of the boundaries to the dissection pattern. Argids occur in small islands (ridge crests that are level or nearly level transversely) that have been only slightly affected by the dissection. Orthids occur where the argillic horizon has been truncated and/or carbonate-engulfed (on rounded ridge crests, and in and adjacent to drainageways). Orthents occur on ridge sides where the diagnostic calcic horizon has been truncated.

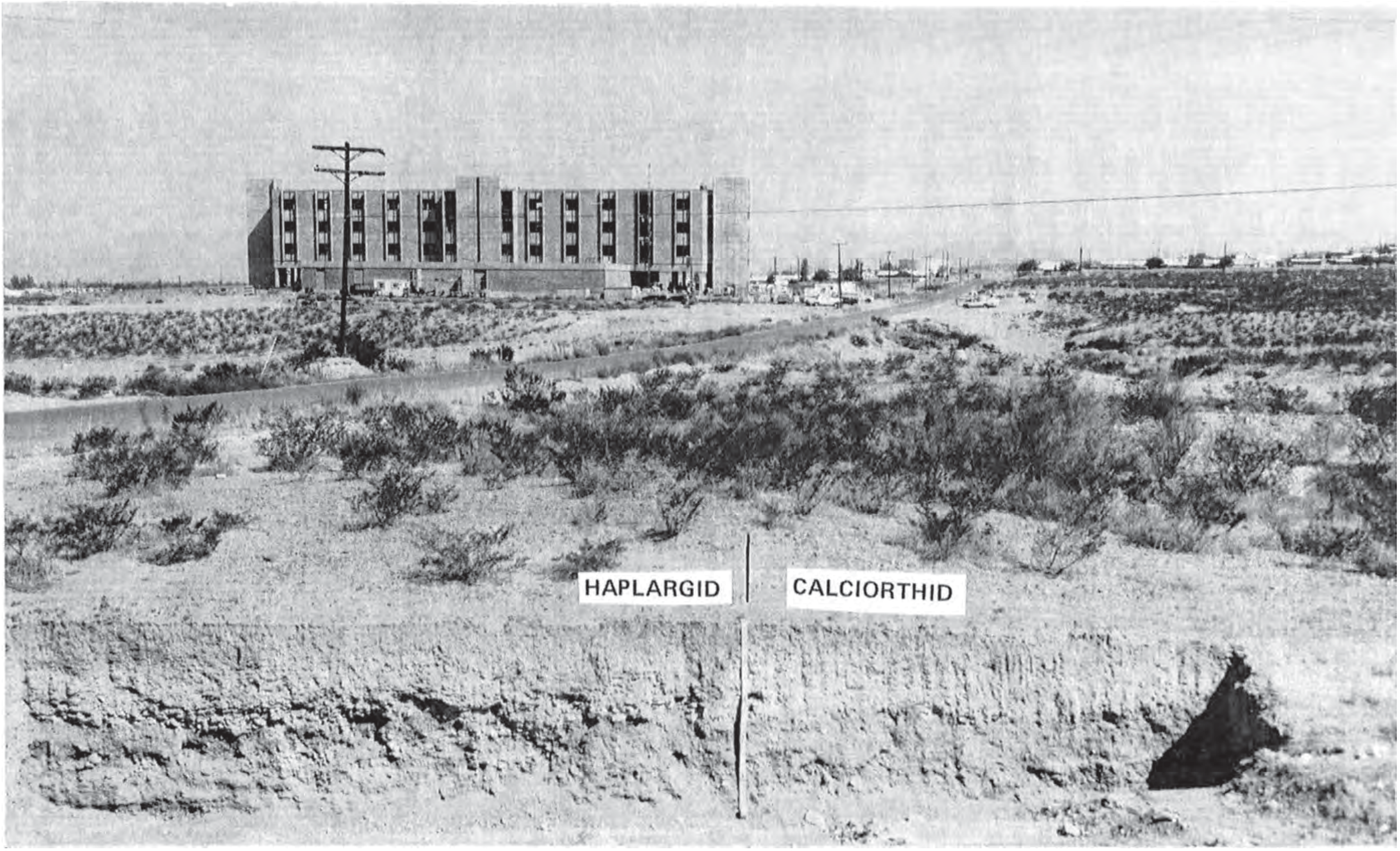


Figure 5. The boundary between Haplargids and Calciorthids on the Picacho remnant east of University Park. The tape marks the boundary between the Haplargid (left, best-preserved part) and the Calciorthid (right, which has been strongly eroded). Thus erosion associated with landscape dissection has resulted in the obliteration of the argillic horizon, changing the soil from a Haplargid to a Calciorthid (see also sections 138 and 140).

18. TAXONOMY FOR THE PROJECT AREA

There are six categories in Soil Taxonomy (Soil Survey Staff, 1975). They are order, suborder, great group, subgroup, family, and series. The first four of these and their diagnostic features for the project area are given in table 16. The various diagnostic features are discussed in the following sections.

19. SOIL MOISTURE REGIME

The soils have aridic (torric) moisture regimes. These moisture regimes are the same but are used in different categories (order and great group), and apply to a soil depth termed the soil moisture control section. This control section lies approximately between depths of 10 and 30 cm if the particle-size class is fine-loamy, coarse-silty, fine-silty, or clayey; between 20 and 60 cm if the particle-size class is coarse-loamy; and between 30 and 90 cm if the particle-size class is sandy.

In most years, the moisture control section in the aridic (torric) moisture regime is (Soil Survey Staff, 1975).

1. Dry in all parts more than half the time (cumulative) that the temperature at a depth of 50 cm is above 5°C; and
2. 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.

Some Aridisols are even drier. For example, Petrocalcic Paleargids "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."

20. DIAGNOSTIC HORIZONS

Only summary statements concerning diagnostic horizons are presented here. Full definitions may be found in Soil Taxonomy (Soil Survey Staff, 1975). Six diagnostic horizons are important in the classification of soils in this area. Two of these -- the mollic epipedon and the ochric epipedon -- are surface horizons. The other four (the cambic, argillic, calcic, and petrocalcic horizons) are subsurface horizons.

The mollic epipedon occurs only in the semiarid part of the area and has at least 0.6 percent organic carbon; values (moist) and chromas are 3 or less. Thickness requirements vary depending on other horizons present, but in the soils to be observed the mollic epipedon must be at least 25 cm thick. Ochric epipedons are too light in color, too thin, and/or have too little organic carbon for mollic epipedons.

Table 16. Soil orders, suborders, great groups, subgroups, and diagnostic features in the study area[1/]

Order	Suborder + Diagnostic feature	Great Group + Diagnostic feature	Subgroup + Diagnostic Feature[6/]
Aridisols	Orthids	Camborthids Cambic horizon	Typic Camborthids
		Calciorthids[3/] Calcic horizon	Typic Calciorthids
			Ustollic Calciorthids Organic C + s/c ratio
		Paleorthids[2/] Petrocalcic horizon	Typic Paleorthids
			Ustollic Paleorthids Organic C + s/c ratio
	Argids Argillic horizon	Haplargids[3/]	Typic Haplargids
			Ustollic Haplargids Organic C + s/c ratio
		Paleargids Petrocalcic horizon	Typic Paleargids
			Petrocalcic Ustollic Paleargids Organic C + s/c ratio
Entisols	Psamments sandy particle-size class[4/] in all subhorizons and have <35% (by volume) of rock fragments in all subhorizons[5/]	Torripsamments Torric moisture regime	Typic Torripsamments
	Orthents loamy or finer particle-size class[4/] or ≥35%, by volume, of rock fragments in some subhorizons[5/]	Torriorthents Torric moisture regime	Typic Torriorthents
	Fluvents organic carbon decreases irregularly with depth and/or is more than 0.2% at 125 cm depth	Torrifluvents Torric moisture regime	Typic Torrifluvents
Mollisols mollic epipedon	Ustolls Ustic moisture regime	Haplustolls	Pachic Haplustolls Mollic ep. >50 cm thick
			Torriorthentic Haplustolls Lack cambic horizon
		Argiustolls Argillic horizon	Aridic Argiustolls
		Calciustolls Petrocalcic horizon	Petrocalcic Calciustolls
		Paleustolls Petrocalcic horizon	Petrocalcic Paleustolls Argillic horizon
Vertisols After the upper 18 cm have been mixed, have 30% or more clay in all horizons to a depth of 50 cm or more; at some period in most years have cracks that are open to the surface, and are at least 1 cm wide at a depth of 50 cm; at some depth between 25 cm and 1 m there are slickensides close enough to intersect.	Torrerts	Torrerts	Typic Torrerts

1/ Diagnostic feature (s) underlined.
2/ A cambic horizon may be present in these soils but is not diagnostic.
3/ A calcic horizon may be present. It is commonly used as a series separator in Haplargids.
4/ Between 25 and 100 cm depth.
5/ After the upper 18 cm have been mixed.
6/ Diagnostic for other than Typic subgroups.

The cambic horizon is an altered horizon with texture of loamy very fine sand or finer, and has its base at least 25 cm below the surface. Most or all of the rock structure (e.g., sedimentary strata) has been obliterated. If carbonates are in the parent materials, dustfall and/or precipitation, the cambic horizon must also have evidence of redistribution of carbonates (as indicated by an underlying ca horizon) with the carbonate maxima below 25 cm. If no carbonates have been supplied from these sources, the cambic horizon is identified by the presence of soil structure and the absence of rock structure. In Camborthids of this area, the most common type of cambic horizon is reddish brown and has evidence of illuvial clay, but not enough clay increase for an argillic horizon.

The argillic horizon contains illuvial silicate clay. If the eluvial horizon has not been truncated, the increase in clay to the argillic horizon is as follows:

Clay content of eluvial horizon	Minimum clay increase required for an argillic horizon
pct	pct or ratio
< 15	3
15-40	ratio of 1.2 or more
> 40	8

Various kinds of evidences for clay illuviation are required in different situations. In this arid region, the pertinent evidence is at least 1% of oriented clay as viewed in thin section. Most argillic horizons in the area easily meet this requirement.

There is a wide range of expression of the argillic horizon (silicate clay section). The reddish brown or red Bt material ranges from 0 to 100 percent by volume in horizons. If the horizon contains about 10 percent or more of this Bt material, the horizon is considered an argillic horizon in this study.

The calcic horizon is a horizon of secondary carbonate enrichment. It is at least 15 cm thick and has a calcium carbonate equivalent content of 15% or more unless the particle size class is sandy, sandy-skeletal, coarse-loamy, or loamy-skeletal with less than 18% clay. In these cases the 15% requirement for $CaCO_3$ equivalent is waived and the calcic horizon must have at least 5% (by volume) more soft powdery secondary $CaCO_3$ than an underlying horizon; it must also be at least 15 cm thick and have an upper boundary within 1 m of the surface of the soil.

The petrocalcic horizon is cemented by carbonates. Dry fragments do not slake in water. It is indurated and cannot be penetrated by spade or auger when dry. It is massive or platy, very hard or extremely hard when dry, and very firm or extremely firm when moist. Hydraulic conductivity is moderately slow to very slow. Accessory silica may be present but not enough for a duripan. Laminar horizons are commonly at the surface but are not required.

21. ORGANIC CARBON AND SAND/CLAY RATIOS

Aridisols are dominant in the desert areas between the mountains and Mollisols occur in places along the mountain fronts. Intergrades between these two orders would therefore be expected. Such intergrades do occur and are designated Ustollic. Their identification is based on the amount of organic carbon relative to sand/clay ratios. The example below illustrates (Soil Survey Staff, 1975):

Typic Haplargids are the Haplargids that (a - d omitted)

e. have a weighted average percentage of organic carbon in the upper 40 cm that is <0.6 percent if the weighted average ratio of sand to clay in the soil above that depth is 1.0 or less, or is less than one-seventh percent if the ratio is 13 or more, or have intermediate percentage of organic carbon if the ratio of sand to clay is between 1 and 13; or have a weighted average percentage of organic carbon in the soil to a depth of 18 cm that is not as much as one-fifth more than the values just stated if there is a lithic or paralithic contact at a depth <40 cm but >18 cm;

(f, g omitted.)

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

Ustollic Haplargids are like the Typic except for e with or without h. They have a mean annual soil temperature of 8° C or higher and an aridic moisture regime that borders on an ustic regime. They are not recognized if a petrocalcic horizon is shallower than 18 cm.

22. FAMILY DIFFERENTIAE

Properties diagnostic for the soil family in the project area are particle size, mineralogy, depth and soil temperature. Classes of particle size are given in table 17.

Two mineralogy classes are found in soils of the project area, mixed and carbonatic. In the carbonatic class, materials in the control section have more than 40 percent by weight of carbonates (expressed as $CaCO_3$) plus gypsum, and the carbonates are greater than 65 percent of the sum of carbonates and gypsum. The determinant size fraction is either the less than 2 mm material, or the less than 20 mm material, whichever has the higher percentage of carbonates plus gypsum. Soils with mixed mineralogy have less than 40 percent of any one mineral other than quartz or feldspars.

Soils that have a petrocalcic horizon at a depth less than 50 cm are in shallow families.

Measurements of soil temperature (section 47) have shown that all soils are within the thermic temperature class; mean annual soil temperatures are between 15° C to 22° C (59° F to 72° F).

Table 17. The particle-size classes and their definitions. 1/

Class	Definition
1. Fragmental	Stones, cobbles, gravel, and very coarse sand particles; too little fine earth to fill interstices > 1 mm in diameter.
2. Sandy-skeletal	Rock fragments 2 mm or coarser make up 35 percent or more by volume; enough fine earth to fill interstices > 1 mm; the fraction < 2 mm is sandy as defined for particle-size class 5.
3. Loamy-skeletal	Rock fragments make up 35 percent or more by volume; enough fine earth to fill interstices > 1 mm; the fraction < 2 mm is loamy as defined for particle-size class 6.
4. Clayey-skeletal	Rock fragments make up 35 percent or more by volume; enough fine earth to fill interstices > 1 mm; the fraction finer than 2 mm is clayey as defined for particle-size class 7.
5. Sandy	The texture of the fine earth is sand or loamy sand but not loamy very fine sand or very fine sand; rock fragments make up < 35 percent by volume.
6. Loamy	The texture of the fine earth is loamy very fine sand, very fine sand, or finer, but the amount of clay 2/ is < 35 percent; rock fragments are < 35 percent by volume.
a. Coarse-loamy	By weight, 15 percent or more of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; < 18 percent clay in the fine-earth fraction.
b. Fine-loamy	By weight, 15 percent or more of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; 18 through 34 percent clay in the fine-earth fraction (< 30 percent in Vertisols).
c. Coarse-silty	By weight, < 15 percent of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; < 18 percent clay in the fine-earth fraction.
d. Fine-silty	By weight, < 15 percent of the particles are fine sand (diameter 0.25 to 0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; 18 through 34 percent clay in the fine-earth fraction (< 30 percent in Vertisols).
7. Clayey	The fine earth contains 35 percent or more clay by weight, and rock fragments are < 35 percent by volume.
a. Fine	A clayey particle-size class for soils having 35 through 59 percent clay in the fine-earth fraction (30 through 59 percent for Vertisols).
b. Very-fine	A clayey particle-size class for soils having 60 percent or more clay in the fine-earth fraction.

1/ Soil Survey Staff (1972).

2/ Carbonates of clay size are not considered to be clay but are treated as silt in all particle-size classes. If the ratio of 15-bar water to clay is 0.6 or more in half or more of the control section, for this purpose the percentage of clay is considered to 2.5 times the percentage of 15-bar water.

23. THE FAMILY CONTROL SECTION

Names of particle-size and mineralogy classes are not applied to indurated horizons or layers, but to specified horizons or to materials between given depth limits defined in terms of either the distance below the surface of the mineral soil or the upper boundary of a specified horizon. The vertical section so defined is called the control section. Definitions of the control section for determination of the particle-size classes are arranged as a key.1/

A. The control section extends from the surface to a lithic or paralithic contact, or to a petrocalcic horizon if any of these are within a depth of 36 cm.

B. In other soils that do not have an argillic horizon or a natric horizon:

1. The control section extends from the base of the Ap horizon or from a depth of 25 cm, whichever is greater, to a lithic or paralithic contact, or petrocalcic horizon if any of these are within a depth of 1 m.

2. Otherwise the control section extends from a depth of 25 cm to a depth of 1 m.

C. In great groups of Aridisols and Mollisols that have an argillic horizon that has (a) a lower boundary deeper than 25 cm (see E) and (b) an upper boundary shallower than 1 m:

1. If there is no petrocalcic horizon between the top of the argillic horizon and a depth of 1 m, the control section is the whole argillic horizon if it is less than 50 cm thick or the upper 50 cm of the argillic horizon if it is greater than 50 cm thick.

2. If there is a petrocalcic horizon below an argillic horizon, the control section extends from the top of the argillic horizon, excluding any part incorporated in an Ap horizon, to the top of the petrocalcic horizon, or the upper 50 cm of the argillic horizon, whichever of these is less.

D. In great groups of Aridisols and Mollisols that have an argillic horizon with its upper boundary at a depth greater than 1 m, the control section extends from a depth of 25 cm to a depth of 1 m.

E. In other soils in which the lower boundary of the argillic horizon is shallower than 25 cm, that is, they have a ca horizon in which there is soft powdery lime, or have a calcic or other named diagnostic horizon that has its upper boundary within 25 cm of the surface, or have rock structure dominant within that depth, the control section extends from the top of the argillic horizon or the base of an Ap horizon, whichever is shallower, to a lithic or paralithic contact, a petrocalcic horizon, or to a depth of 1 m, whichever is shallowest.

1/ Only the parts that apply to soils of the project area are listed. See Soil Taxonomy for a complete list.

24. BURIED SOILS

Buried soils are common in the project area and observations elsewhere indicate that they also are extensive in other desert regions. The buried soils vary considerably in thickness and in the depth at which they occur. Buried soils considered in classification of soils at the land surface have been defined as follows (Soil Survey Staff, 1975):

> A soil is considered to be a buried soil if there is a surface mantle of new material that is 50 cm or more thick, or if there is a surface mantle between 30 and 50 cm thick and the thickness of the mantle is at least half that of the named diagnostic horizons that are preserved in the buried soil. A mantle that is <30 cm thick is not considered in the taxonomy but, if important to the use of the soil, is considered in establishing a phase. The soil that we classify in places where a mantle is present, therefore, has its upper boundary at the surface or < 50 cm below the surface, depending on the thickness of its horizons.
>
> A surface mantle of new material as defined here is largely unaltered. It is usually finely stratified and overlies a horizon sequence that can be clearly identified as the solum of a buried soil in at least part of the pedon, as defined in the following chapter. The recognition of a surface mantle should not be based solely on studies of associated soils.

If the mantle is 30 to 50 cm thick and lacks diagnostic horizons, the mantle only is classified (as an Entisol since it lacks diagnostic horizons) if it is half or more the thickness of the diagnostic horizons of the buried soil. If the mantle is more than 50 cm thick and lacks diagnostic horizons, classification is based on the mantle, which again is classified as an Entisol because diagnostic horizons are absent.

Psamments must have sandy particle size in all subhorizons to a depth of one m. Soils with 50 to 100 cm of new sandy materials over buried horizons with finer texture are Torrifluvents because the buried upper horizons cause irregular decrease in organic carbon.

25. APPLICATION OF THE DIAGNOSTIC HORIZONS

Some of the horizons are diagnostic at more than one categorical level. The argillic horizon, for example, is diagnostic at the level of both order (Aridisols vs Entisols) and suborder (Argids vs Orthids). Some horizons are diagnostic only if other diagnostic horizons are absent. For example, an Aridisol with both cambic and petrocalcic horizons is a Paleorthid instead of a Camborthid. This is because the petrocalcic horizon, which is diagnostic for the Paleorthids, is considered to be the more important of the two horizons.

The calcic horizon is diagnostic for the Calciorthids and the petrocalcic horizon is diagnostic for the Paleorthids in Aridisols that lack argillic horizons. In Aridisols the petrocalcic horizon is diagnostic only if the upper boundary occurs within a depth of one m. The argillic horizon is diagnostic for the Haplargids whether or not a calcic horizon is present. Soils with argillic horizons and petrocalcic horizons are Paleargids.

The calcic and petrocalcic horizons may be related to the stages of carbonate accumulation (section 68). Stage III horizons contain enough carbonate for calcic horizons, and some stage II horizons qualify as calcic horizons. Horizons in late stage I of carbonate accumulation (horizons with common carbonate filaments, for example) usually qualify as calcic horizons if the parent materials contain abundant calcium carbonate. Minimum expression of the petrocalcic horizon corresponds to late stage III of carbonate accumulation, in which the horizon of accumulation is plugged with accumulated carbonate. Nearly all petrocalcic horizons are in stage IV of carbonate accumulation. Soils with petrocalcic horizons are designated as "pale" great groups or as petrocalcic subgroups depending on the great group involved.

Soils are Camborthids if they have a cambic horizon and lack a calcic, petrocalcic, or argillic horizon, or if they have a calcic horizon but are noncalcareous in some horizon after the soil has been mixed to a depth of 18 cm. The latter condition does not occur in this area, for by the time a calcic horizon has formed, if a horizon above it is noncalcareous, then a distinct argillic horizon is present. Other soils without diagnostic horizons have altered horizons that are too thin or too coarse-textured to qualify as cambic horizons. Although some of these horizons are quite distinct (e.g., see pedon 59-10, Appendix) the soils are Entisols since they do not have diagnostic horizons required for the Aridisols. Thus Entisols constitute a significant portion of the developmental scale in soils of the region. They are classified as Psamments, Orthents, or Fluvents depending on amount of sand, gravel, or organic carbon. Entisols occur in steeper, younger, less stable areas along the valley border, and in high-carbonate parent materials of Holocene age.

Mollisols have mollic epipedons. In Mollisols of this area, soils are Haplustolls if they lack argillic horizons and petrocalcic horizons. Argiustolls have argillic horizons. Paleustolls of this area have argillic horizons and petrocalcic horizons. Calciustolls lack argillic horizons and have petrocalcic horizons.

26. SERIES DIFFERENTIAE

In this book, statements concerning soils of given series pertain only to soils of that series as they occur in the study area. Several families in the study area have more than one series. Differentiae for these series are given in table 18.

Three soils do not fall within the range of characteristics of established series but are placed in the Dalby, Jal, and Yturbide series as follows. The Dalby series is a member of the fine, montmorillonitic, thermic family of Typic Torrerts. In the study area, a typical pedon (60-16) of the playa soils concerned has mixed mineralogy, and clay content of the 25 to 100 cm control section averages about 65 percent (Appendix). The soil is considered to be a taxadjunct to the Dalby series and is classified as a Typic Torrert, very fine, mixed, thermic.

The Jal series is a member of the fine-loamy, carbonatic, thermic family of Typic Calciorthids. A typical pedon (65-6) of the soils concerned is well within the coarse-loamy family by laboratory analyses (Appendix). This is the case for many Calciorthids with strong carbonate accumulation and developed in materials containing abundant sand, because the carbonate accumulation has diluted the parent materials; when carbonate clay is treated as silt, silicate clay for the 25 to 100 cm control section averages less than 18 percent. Laboratory analyses are not available for the Jal pedon at the type location, and it also may be coarse-loamy. The soil concerned is designated Jal and classified as a Typic Calciorthid, coarse-loamy, carbonatic, thermic.

The Yturbide series is a member of the mixed, thermic family of Typic Torripsamments. Psamments must have less than 35 percent (by volume) of rock fragments in all subhorizons. Average gravel content of Yturbide soils must range from 15 to 35 percent, by volume, but the Yturbide series was proposed before formulation of the criterion involving the amount of gravel for the Orthent-Psamment distinction. It is thought that Yturbide soils would generally contain

Table 18. Series differentiae for soils in the study area.

Series	Series differentiae
Typic Torrifluvents, coarse-loamy	
Anthony	Occurs on slopes of 0 to 5 percent.
Pintura, thin var.	Occurs on dunes with slopes more than 5 percent.
Typic Torripsamments	
Bluepoint	Has 10 percent or more of silt plus clay in the control section; at least one subhorizon in the control section is calcareous.
Pintura	No restriction on silt plus clay; noncalcareous throughout or at most is calcareous only in a few spots.
Typic Torriorthents, sandy-skeletal	
Arizo	Occurs on slopes less than about 10 percent.
Kokan	Occurs on slopes ranging from about 10 to 60 percent.
Typic Haplargids, coarse-loamy	
Onite	Combined thickness of A and B horizons totals 25 to 75 cm.
Sonoita	Combined thickness of A and B horizons totals more than 75 cm.
Typic Haplargids, fine-loamy	
Bucklebar	Lacks calcic horizon within 1 meter depth.
Berino	Has calcic horizon within 1 meter; does not have macroscopic carbonate in all subhorizons of the Bt horizon.
Dona Ana	Has calcic horizon within 1 meter; has macroscopic carbonate in all subhorizons of the Bt horizon.
Hap	Has calcic horizon within 1 meter; averages 15 to 35 percent by volume of coarse fragments in the control section.
Tres Hermanos	Has calcic horizon within 1 meter; has some macroscopic carbonate in all subhorizons of the Bt horizon; averages 15 to 35 percent coarse fragments in the control section.
Petrocalcic Ustollic Paleargids, loamy-skeletal	
Terino	Does not have macroscopic carbonate in all subhorizons of the Bt horizon.
Casito	Has some macroscopic carbonate in all subhorizons of the Bt horizon.
Ustollic Haplargids, loamy-skeletal	
Caralampi	Lacks a calcic horizon within 1 meter.
Nolam	Has a calcic horizon within 1 meter.
Typic Camborthids, coarse-loamy	
Pajarito	Averages less than 15 percent by volume of coarse fragments in the control section.
Agustin	Averages from 15 to 35 percent by volume of coarse fragments in the control section.
Typic Calciorthids, coarse-loamy	
Algerita	Control section averages 10 to 20 percent carbonate clay, and is dominantly sandy clay loam or clay loam.1/
Whitlock	Control section averages less than 10 percent carbonate clay, and is dominantly coarser than sandy clay loam.

1/ Algerita soils have thicker calcic horizons than do Whitlock soils. Most Algerita soils are much older than Whitlock soils, occurring on La Mesa surface and on Jornada I and II surfaces (the latter in high-carbonate materials). Whitlock soils occur mostly on the valley-border Picacho surface.

too much gravel for the Psamments; since they average 15 to 35 percent gravel, some subhorizon would likely contain more than 35 percent. Also, these gravelly and very gravelly sands were excluded from Psamments because they are much less subject to blowing and drifting than nongravelly sands, and provide a better support for wheeled vehicles (Soil Survey Staff, 1975). For these reasons, it is thought that the soils concerned are best classified as Orthents rather than Psamments, and the soils designated Yturbide are classified as Typic Torriorthents, sandy, mixed, thermic.

27. HORIZON DESIGNATIONS AND CONVENTIONS

Parts of this volume were prepared at different times and do not reflect conventions presently in use. Thus lithologic discontinuities (Soil Survey Staff, 1962) are indicated by Roman numerals in some cases and by arabic numbers in others.

Intermediate colors are estimated. For example, the designation 9YR indicates that the hue is between 7.5YR and 10YR, but is closer to 10YR than 7.5YR.

Definitions and designations for soil horizons follow the 1962 Supplement to the Soil Survey Manual except as noted below. Master genetic horizons are designated A, B, and K. The C horizon designates horizons that are largely or wholly not genetic soil horizons, except for hard bedrock which is designated R.

28. A HORIZONS

A1 horizon. The A horizons of desert and mountain soils differ markedly in the study area. The A horizons of mountain soils are dark, contain distinct amounts of organic carbon, and qualify as A1 horizons as defined in the 1962 Supplement. Those with color values darker than 5.5 when dry and 3.5 when moist are designated A1 horizons. Some of these horizons are thick enough and have sufficient organic carbon to qualify as mollic epipedons.

In contrast, desert soils at low elevations between the mountain ranges have light-colored A horizons. Some of these are A2 horizons. Others do not qualify either as A1 or A2 horizons and are designated A.

A2 horizon. In A2 horizons "...the feature emphasized is the loss of clay, iron or aluminum" (Soil Survey Staff, 1962).

A horizon. Horizons that do not qualify as either A1 or A2 are designated A. There are two kinds of these: (1) Light colored horizons, high in organic carbon, that occur in soils formed in high-carbonate parent materials. Textures are commonly loam, clay loam or silt loam. (2) A mixed-appearing horizon that may have been caused by trampling of cattle. Textures are usually a light sandy loam, loamy sand or sand.

29. B HORIZONS

B horizon. This notation designates two kinds of horizons that do not qualify as B (Soil Survey Staff, 1962). Both kinds of horizons show marked alteration of the parent materials, and the designation of C horizon does not, therefore, seem appropriate. These are: (1) Horizons that have distinct structural development, but that lack evidence of the formation of silicate clay or liberation of oxides. Such horizons (commonly termed "structural B" horizons) are most common in soils developed in highly calcareous parent materials. (2) Horizons between the thin A horizon and the horizon of maximum carbonate accumulation that fail to qualify as K1 horizons, defined later. Fine strata are absent, and the horizons have been mixed by roots and soil fauna. In older soils, particularly, there has been a high degree of alteration since deposition of the parent materials and the start of soil formation; and the underlying K horizons indicate abundant carbonate redistribution.

Bt horizon. B horizons that contain illuvial silicate clay are designated Bt. The Bt notation is not restricted to the argillic horizon but also designates B horizons that do not have enough clay increase to qualify as argillic horizons. Some of these Bt horizons qualify as cambic horizons but in the study area most are either too thick or too coarse-textured for a cambic horizon.

The transitional B1 and B3 horizons are defined simply on the relative strength of morphological development.

B1 - A transitional horizon between the A horizon and the B2 horizon. The B1 horizon has weaker development than the B2 horizon and is present in most, but not all B horizons.

B2 - The most strongly expressed part of the B horizon. In Bt horizons, for example, the B2t would be the subhorizon of maximum clay content

B3 - A transitional horizon between the B2 horizon and a horizon beneath B3. The B3 horizon has weaker development than the B2 horizon, and is not present in all B horizons.

30. K HORIZONS

The K horizon nomenclature was proposed (Gile et al., 1965) to meet a need for notation and nomenclature for prominent horizons of pedogenic carbonate. These horizons are considered C horizons in many places and are designated Cca. Studies in the Southwest and in other parts of the world have shown that extensive areas of the earth's surface are occupied by soils with prominent horizons of pedogenic carbonate. Others have recognized the pedogenetic significance of these horizons, and in some areas they are designated B horizons. While such designation is better than Cca, the unusual character and extent of these horizons support their designation as a separate master horizon. Major factors favoring K, instead of B for these horizons are as follows. (1) Carbonate content ranges widely--from about 0.1 to nearly 100 percent. (2) The great range of morphological types is virtually unmatched in soils of this extent. (3) The authigenic nature of pedogenic carbonate is unique for it can be shown that essentially all of it must have accumulated since deposition of the alluvial or eolian parent materials. This contrasts with horizons such as the Bt horizon, in which some of the clay is usually present when soil development starts; and the specific identification of the amount and disposition of authigenic vs allogenic clay is usually impossible. In contrast, pedogenic carbonate is readily identified because of the prominent morphological difference between authigenic carbonate and the material in which it accumulates. (4) Prominent horizons of pedogenic carbonate have transitional subhorizons that are most readily denoted by the K nomenclature. These transitional horizons are difficult to show with B horizon nomenclature if overlying B horizons are present, as they usually are. (5) We need to consider the effectiveness with which we can convey concepts of soil horizons both to students and to scientists in other fields. Inclusion of all the morphological variety of K horizons in a Bca would tend to confuse, as does the Cca horizon. Adding the K horizon to our small assemblage of master horizons should increase our ability to transmit ideas about these and associated horizons.

The K horizon is defined on the basis of approximate volumes of a diagnostic fabric termed K-fabric. In K-fabric, authigenic carbonate occurs as an essentially continuous medium. The carbonate coats or engulfs, and commonly separates and cements skeletal pebbles, sand, and silt grains. Materials with K-fabric display a variety of macroscopic forms, such as laminar, nodular, cylindroidal, massive, blocky, and platy.

The K horizon contains 90 percent or more by volume of K-fabric in its most prominent subhorizon (K2), and 50 percent or more of K-fabric in upper and lower transitional horizons (K1 and K3).

The K1 horizon is transitional to an A or B horizon from an underlying K2 or K2m horizon and contains 50 percent or more of K-fabric. The K1 horizon may be transitional because of less hardness, less continuous induration, or a lesser volume of K-fabric than in the K2 horizon. Some K1 horizons consist of discrete, somewhat loose nodules or plates overlying a continuously indurated K2m horizon.

The K2 horizon is the most prominent, hardest, and whitest part of the K horizon and generally contains most of the authigenic carbonate. The K2 contains 90 percent or more of K-fabric. The K2 can be massive, blocky, platy, nodular, or cylindroidal, and is commonly composed of two or more of these macroscopic forms. Indurated K2 horizons are designated K2m. A distinctive subhorizon, the laminar horizon, occurs at the top of most K2m horizons. The laminar horizon is composed primarily of laminar carbonate with a small amount of included sand, silt, clay and organic matter. In some K2m horizons, several laminar horizons occur and in places are separated by nonlaminar, carbonate-cemented material.

The K3 horizon is transitional from a K2 or K2m horizon to an underlying Cca horizon, C horizon, paleosol, or bedrock, and contains 50 percent or more of K-fabric. The K3 horizon contains less carbonate, a smaller volume of K-fabric, or is not as hard or as light colored as the overlying K2 horizon. The K3 horizon is not continuously indurated, but can contain indurated nodules or agglomerations of skeletal grains. In the K3 horizon, carbonate content and volume of K-fabric commonly decrease with increasing depth. K3 horizons occur in most soils with K2 horizons.

The K & B and K & C notations designate horizons that contain 50 to 90 percent of K-fabric and that occur in soils lacking horizons with 90 percent or more of K-fabric.

As a whole, K horizons are usually prominent, light-colored horizons, many of which are white throughout. Consistence ranges from soft to extremely hard. Many K horizons are indurated. Where bedrock is shallow, the K horizon may occur as a thin, light-colored horizon that rests on bedrock.

Macroscopic carbonate accumulations in soil horizons that fail to meet the requirements for a K horizon are noted by the ca suffix.

31. C HORIZONS

In some areas the C horizon groups both prominent pedogenic horizons and materials unaltered by pedogenesis into one master horizon. There are vast volumes of the latter material and from this standpoint alone a separate designation for it would be useful. As used in this study, the notation C designates horizons other than bedrock, and consisting largely or wholly of material not identifiable as a genetic soil horizon. Small amounts of pedogenic material are included in some instances. For example, the designation "Cca" includes horizons with small amounts of pedogenic carbonate but fabric of the C horizon is readily identified and has been little altered by pedogenic processes.

The C horizon may be meters thick, and may or may not be overlain by genetic horizons. Thin youthful deposits that do not qualify as other horizons defined above, and overlying genetic horizons are also designated C. As a convention, the suffix, b, indicating buried horizons, is not used unless the surficial deposit of C horizon material is at least 25 cm thick.

32. R HORIZONS

The notation R designates consolidated bedrock. This designation does not include bedrock material that can be dug out with a shovel or pick. This kind of softer bedrock is designated B or C, depending on the morphology.

33. LABORATORY METHODS

The pedon descriptions follow the Soil Survey Manual (Soil Survey Staff, 1951) and its 1962 Supplement (Soil Survey Staff, 1962) except for the use of the K horizon nomenclature and other practices discussed previously. Conventions for reporting the data largely follow those given in the compendium of laboratory methods of the Federal soil survey laboratories (Soil Conservation Service, 1972). Column headings in the data sheets contain index numbers to the description of the methods in this publication.

Unless otherwise indicated the analyses reported are for the less than 2mm and carbonate is retained in the sample. Particle-size distribution commonly is reported for samples after removal of the carbonate with pH 5 NaOAc buffer (referred to as carbonate-free sample). For 1962 and earlier samples, organic carbon, nitrogen, cation exchange capacity, and extractable iron were made on the carbonate-free sample and the values calculated on a carbonate-containing basis, assuming the carbonate was a diluent.

Some horizons contain allogenic coarse fragments cemented by authigenic carbonate. For such horizons, subsamples weighing several kilograms were treated to remove carbonate (methods 1B3; Soil Conservation Service, 1972). The coarse fragments were then separated from the less than 2 mm by sieving. A second subsample of the field sample was ground for the determination of carbonate. This carbonate value for the whole-ground sample was computed to a base free of coarse fragments, using the coarse fragment percentage in the subsample treated to remove carbonate (methods 1B4; Soil Conservation Service, 1972). Exposure to the pH 5 NaOAc buffer for up to nine weeks did not affect any of the standard characterization determinations or the clay mineralogy as determined by X-ray analysis.

Pretreatment with NaOH as part of the particle size analyses was employed for all 1960 and subsequent samples, plus samples from upper horizons of selected pedons sampled in 1959. After the removal of organic matter with hydrogen pyroxide, the standard 10 gram sample was allowed to stand overnight in 200 ml of 0.1N NaOH solution. This treatment consistently increased the clay percentage of surface horizons by 10 to 15 percent relative, and also increased the values of some subsurface horizons. The increase was restricted to soils sufficiently old to have diagnostic subsurface horizons. Samples for fine clay were similarly treated.

The weight proportion of carbonate and noncarbonate sand, silt, and clay have been calculated for pedons with either over 10 percent coarse fragments, or over 10 percent authigenic carbonate from 0 to 100 cm. Values are only reported if estimates inclusive of the full range in size of coarse fragments are available and if the carbonate is largely authigenic.

Volume of coarse fragments is reported if information is available for the full range of coarse fragment size. Commonly these volume percentages combine weight determinations for the less than 75 mm and volume estimates for the greater than 75 mm; 2.7 g/cc is the assumed particle density of the coarse fragments. Bulk densities of the fine-earth fabric for this calculation commonly are estimated and not measured.

The amounts (in kilograms) of organic carbon and authigenic carbonate accumulation are reported for volumes of soil with a land surface area of one square m (method 6A). The depth for the carbonate calculations were selected to encompass carbonate associated with pedogenesis of the soil at the land surface. An initial (before pedogenesis started) carbonate content of 1 percent for the fine earth is assumed, and the amount accumulated is calculated as the algebraic sum. Data for C horizons of sampled pedons indicate that for some pedons the initial carbonate content was below 1 percent and in a few instances probably exceed 1 percent. Analyses of two samples of fresh monzonite arroyo alluvium from different locations yielded, respectively, a trace (less than 0.4 percent) and 1 percent, suggesting that 1 percent is reasonable. A few soils with upper horizons very low or free of carbonate and a weak bulge have negative values for carbonate accumulation. The negative values do not necessarily indicate that the pedon has had a net loss of carbonate, but rather that the percentage of carbonate assumed present initially is too high.

34. PARENT MATERIALS

Alluvium is the major parent material; bedrock and eolian materials are less extensive. Eolian sediments occur primarily as coppice dunes. Most or all of these dunes are apparently less than about 100 yr old (section 62). Bedrock is a parent material only in the mountains and in scattered outliers near the mountains. Most bedrock areas are dominated by outcrops of extremely hard bedrock in which soils are not apparent.

Bedrock in the mountains is important because it is the ultimate source of the piedmont-slope deposits below. The approximate distribution of general types of bedrock is shown on the soil maps. Detailed information concerning the character and distribution of the bedrock may be found in Dunham (1935); Kottlowski (1960); Ruhe (1967); and Hawley (in preparation).

Large areas are available in which soils of various ages formed on a single parent sediment can be compared. Sediments of several extensive piedmont-slope areas were derived mainly from a single type of rock such as rhyolite. Extensive areas of soils have also formed in noncalcareous sandy sediments of the ancestral Rio Grande.

The weathering relations between the soils and their parent materials are complicated because the parent materials of many soils contained sediments eroded from older soils upslope. These earlier cycles of soil development would have taken place at higher elevations than a given soil and in some instances under higher precipitation. Transport and possible prior weathering may have reduced easily weathered components such as books of biotite.

In general there is a decrease in particle size from the mountain fronts to the gentler slopes of the alluvial-fan piedmont. However, there are exceptions to this because of lateral variations in particle size at any given position on the slope. These variations are due to differences in position with respect to the streams that deposited the alluvium; coarser fragments occur in the main channel zones than in areas away from these zones. At a given distance on the piedmont slope from the mountain front, late-Pleistocene fan sediments commonly have a greater proportion of coarse fragments. Energy for transport during periods in the Pleistocene apparently exceeded that during the Holocene.

35. RHYOLITIC BEDROCK AND ALLUVIUM

The Organ Mountains south of Fillmore Canyon are almost entirely composed of rhyolite. Smaller areas of rhyolite also occur in the San Andres, Dona Ana and Robledo Mountains. Analyses of Soledad rhyolite (the major type in the Organ Mountains) and the average of 102 rhyolites are given in table 19. The CaO content of Soledad rhyolite is much lower than the average; the FeO content is higher. Dunham made the following comments on mineralogy of Soledad rhyolite (Dunham, 1935, page 58):

Table 19. Analyses of rhyolites[1/]

Compound	I Soledad rhyolite Soledad Canyon	II Average of 102 rhyolites (Daly)
SiO_2	73.30	72.77
TiO_2	0.28	0.29
Al_2O_3	12.82	13.33
Fe_2O_3	1.42	1.40
FeO	1.94	1.02
MnO	0.00	0.07
MgO	0.22	0.38
CaO	0.16	1.38
Na_2O	4.24	3.34
K_2O	5.26	4.58
H_2O-	0.00	
H_2O+	0.24	1.50
CO_2	0.00	
P_2O_5	0.00	
S	0.09	
BaO	0.02	
	99.99	

Norm of Soledad rhyolite

qu		27.36
or		31.14
ab		35.63
an		0.28
di	$CaO.SiO_2$	0.23
	$MgO.SiO_2$	0.07
	$FeO.SiO_2$	0.18
hy	$MgO.SiO_2$	0.43
	$FeO.SiO_2$	1.48
il		0.61
mag		2.09
		99.50

1/ /After Dunham (1935). The source of the average of 102 rhyolites is given by Dunham as: Daly, R. A., Igneous rocks and the depths of the earth: New York, 1933, p.9.

> The structure is porphyritic, the phenocrysts being cream-colored feldspars up to 3 mm in length....The phenocrysts consist of an alkali feldspar, antiperthite. The ground mass...probably consists of quartz, alkali feldspars and occasional flakes of biotite.

The rhyolite bedrock is extremely hard and dense. Areas of distinct soils in the bedrock have been observed only in a few places. Slight accumulations of clay and carbonate locally occur along fracture planes in the bedrock.

Rhyolite is an extensive rock in the southern Organ Mountains and consequently rhyolitic alluvium is also extensive. Rhyolite resists comminution and alluvium derived from it tends to be gravelly or very gravelly. Figure 6 shows a typical particle-size cumulative curve. For slopes of about 3 percent and greater, most soils tend to be skeletal. At 2 percent slope there are marked facies changes in many places from very gravelly to low-gravel materials. The median weight diameters (table 20) do not decrease regularly with decrease in elevation. Field observations do indicate that there is a decrease in median weight diameters. The lateral variability is, however, too large for regular decrease to be expressed in the pedons sampled for soil characterization. Figure 7 contains a cumulative curve for the fine-earth of typical rhyolitic alluvium. The material is high in very coarse and coarse sand (2 to 0.5 mm) and has relatively little medium sand (0.5 to 0.25 mm).

36. MONZONITIC BEDROCK AND ALLUVIUM

The northern part of the Organ Mountains consist primarily of two kinds of monzonite (phase II and III, Dunham, 1935). Chemical analyses of these two monzonites are presented in table 21; mineral composition (modes) are in table 22. Concerning mineralogy of the monzonite, Dunham writes:

Phase II, quartz-monzonite (p. 71):

> The quartz-monzonite is a buff or reddish granular rock composed largely of feldspars averaging about 7 mm in length. The plagioclase can be recognized readily in the hand specimen by its conspicuous zoning, which is especially well revealed on weathered surfaces where the inner zones tend to decompose more readily than the outer zones. Quartz, although an important constituent, can be seen with the unaided eye only very seldom. Biotite is occasionally present, and rarely there is little hornblende....In thin section, the minerals found are perthite, oligoclase, quartz, biotite and accessory minerals, in order of decreasing abundance. Hornblende is occasionally found.

Phase III, Quartz-bearing monzonite (p. 73):

> The rock is coarse-grained and contains alkali feldspar crystals exceeding 20 mm in length. The average grain, is however, distinctly finer and seems to be about 10 mm. In the hand specimen, feldspars, hornblende, biotite, and titanite can be recognized; quartz, though present, is not at all conspicuous and a lens is

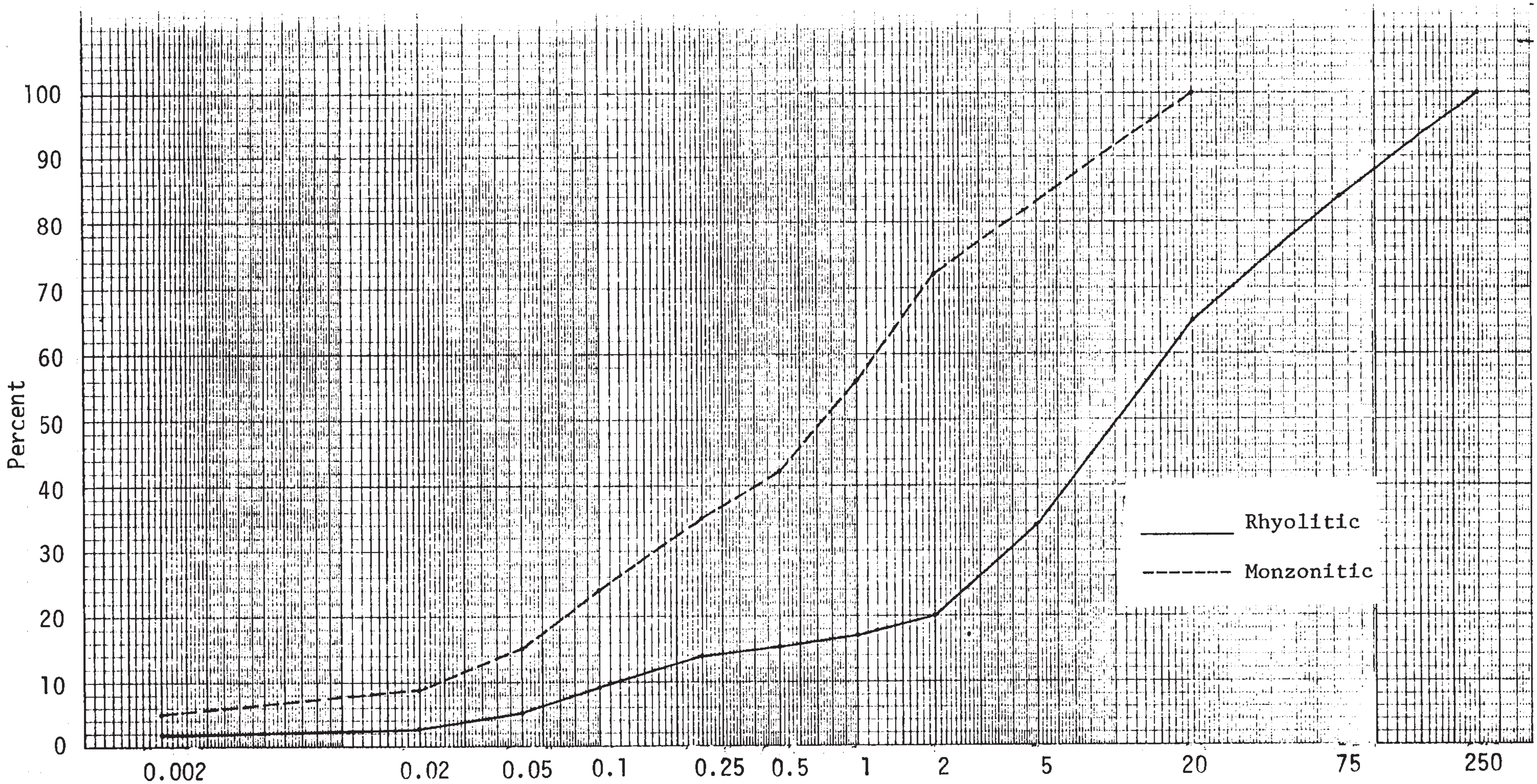


Figure 6. Cumulative particle-size curves for pedons of Holocene age developed in rhyolite alluvium (pedon 66-16) and in monzonite alluvium (pedon 59-2).

Table 20. Median weight diameters listed in descending order for different parent materials and ages.[1/]

Alluvium Source	Age and Geomorphic Surface	Pedon	Depth	Median Weight Diameter	Elevation	Slope
			cm	mm	ft	%
Rhyolite	Holocene					
	Organ	60-4	0-100	20	5000	7
	Organ	60-3	0-100	12	4750	4
	Fillmore	66-16	5-94	10	4350	2
	Organ	67-4	18-94	7	4750	4
	Organ	60-12	0-100	4	5700	7
	Late Pleistocene					
	Jornada II	59-15	43-145	30	4720	4
	Picacho	59-16	64-127	24	4330	2
	Picacho	59-13	48-132	23	4250	2
	Isaacks' Ranch	67-5	51-104	9	4600	3
	Mid-late Pleistocene					
	Jornada I	59-14	97-173	37	5600	8
	Jornada I	70-8	82-179	10	4500	3
	Jornada I	66-2	64-165	7	4370	2
	Jornada I	60-10	74-127	4	4450	2
Monzonite						
	Holocene					
	Organ	59-3	0-100	1	4900	4
	Organ	59-1	0-100	0.9	5500	8
	Organ	59-2	0-100	0.8	5125	5
	Organ	59-4	0-58	0.5	4735	3
	Organ	67-3	0-100	0.3	4600	2
	Organ[2/]	68-3	0-117	1	4310	
	Organ[2/]	68-4	0-130	0.06	4310	
	Organ[2/]	69-8	6-89	0.003	4310	
	Pleistocene					
	Jornada	60-9	84-152	250[3/]	5200	15
	Jornada II	60-13	86-114	0.6	4675	2
	Jornada II	59-8	155-178	0.1	4470	5/
Sedimentary Rocks						
	Holocene					
	Organ	60-15	0-100	0.03	4475	2
	Organ	60-14	0-100	0.02	4400	1
	Organ	66-7	0-51	0.01	4310	1
	Organ	66-6	0-64	0.005	4300	1
	Organ II[4/]	65-2	0-100	3	4760	
	Organ I [4/]	65-2	107-287	0.4	4760	
	Organ I [4/]	65-4	36-160	0.1	4725	
	Organ II[4/]	65-3	0-64	0.07	4760	
Mid-Pleistocene River Alluvium[6/]						
	Pleistocene					
		66-11	163-188	0.3		
		61-7	272-353	0.3		
		59-10	64-111	0.2		
		60-21	284-305	0.2		
		61-2	165-185	0.1		
		61-8	236-267	0.1		
		65-7	274-307	0.1		

1/ Carbonate-free soil material if carbonate authigenic.
2/ To illustrate lateral variation in the lower fan piedmont. Pedon 68-3 along axis of deposition; pedons 68-4, 69-8 progressively farther from axis.
3/ Somewhat larger median weight diameter below this zone.
4/ To illustrate lateral variation near mountain front.
5/ Buried surface.
6/ Elevations are similar.

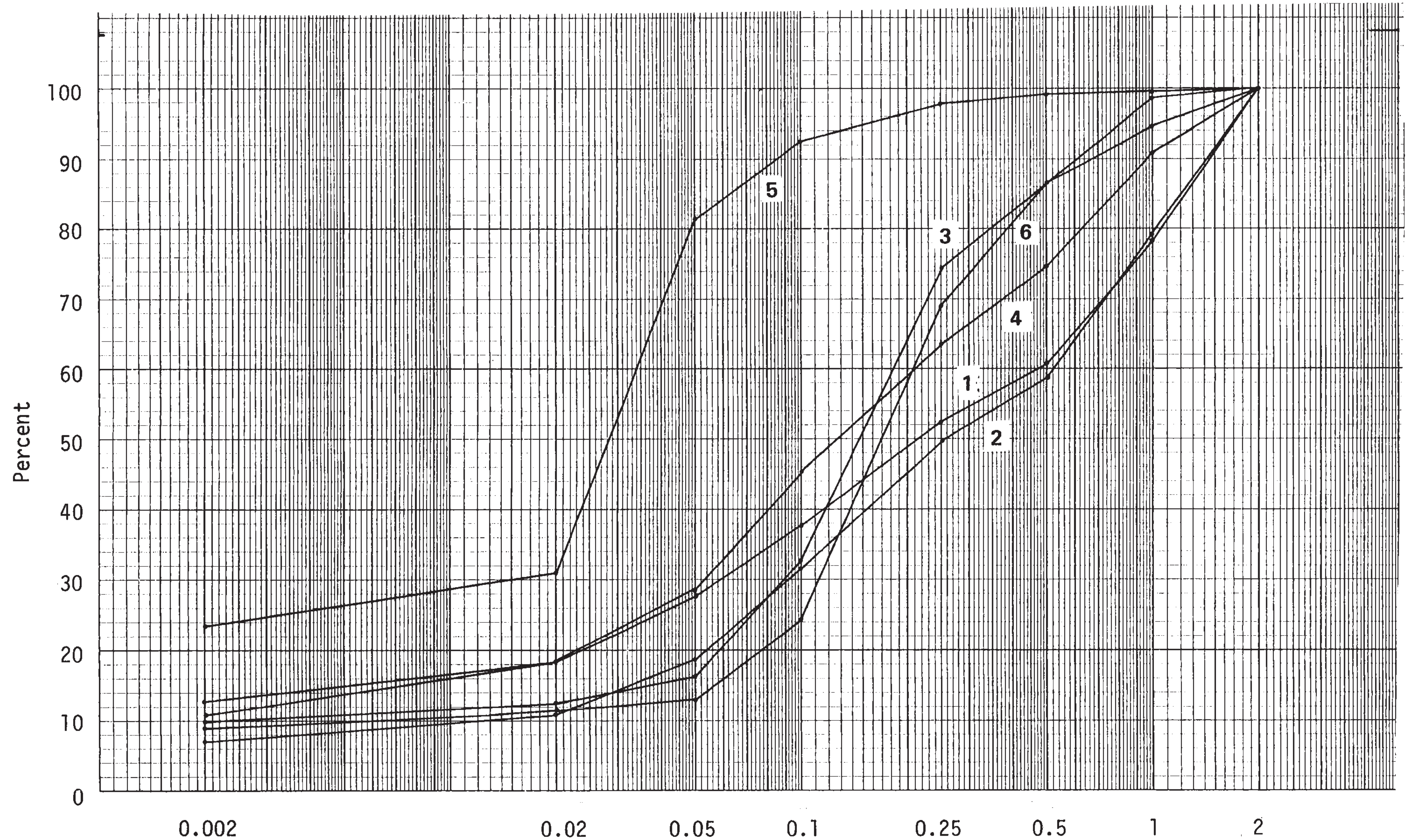


Figure 7. Cumulative particle size curves for < 2 mm material of major alluviums. The materials are: 1 = gravelly rhyolite; 2 = gravelly monzonite; 3 = nongravelly monzonite; 4 = gravelly alluvium from sedimentary rocks; 5 = nongravelly alluvium from sedimentary rocks; 6 = Camp Rice.

Table 21. Analyses of monzonite, Organ Mountains (after Dunham, 1935).

Compound	Phase II (1278) Quartz-monzonite East of Hayner Mine	Phase III Quartz-bearing monzonite 500 feet south of Merrimac Mine
SiO_2	68.92	61.12
TiO_2	0.47	1.30
Al_2O_3	15.50	15.78
Fe_2O_3	1.08	2.69
FeO	1.65	3.15
MnO	0.03	0.09
MgO	0.76	1.90
CaO	1.04	3.95
Na_2O	4.72	4.14
K_2O	5.17	4.48
H_2O-	0.00	0.32
H_2O+	0.36	0.56
CO_2	0.03	0.22
P_2O_5	0.03	0.45
ZrO_2	nd	0.04
S	0.02	0.05
BaO	0.06	0.07
SrO	nd	0.04
	99.82	100.35

NORMS

qu		17.52	10.14
or		30.58	26.69
ab		39.82	35.11
an		5.56	11.12
di	$CaO.SiO_2$		2.44
	$MgO.SiO_2$		1.70
	$FeO.SiO_2$		0.53
hy	$MgO.SiO_2$	1.90	3.00
	$FeO.SiO_2$	1.45	0.92
il		0.91	2.43
mag		1.62	3.94
ap		0.17	1.10
		99.63	98.12

Table 22. Mineral compositions (modes) of phase II and phase III monzonite (from Dunham, 1935)

Name and Locality	Weight Percentages						
	Oligoclase	Perthite	Pyroxenes	Hornblende	Biotite	Quartz	Titanite Apatite Magnetite
Phase II, Baylor Pass	36	45		2		17	1
Phase II, East of Hayner Mine	34	52				14	
Phase II, Texas Canyon	30	46		4		19	1
Phase III, Quickstrike	39	44		8		7	2

> usually needed to see it. In thin section the plagioclase proved to have properties identical with the oligoclase in the two preceding phases....The alkali feldspar, which is again perthitic, predominates over the oligoclase....Green pleochroic hornblende and brown biotite are universally present. Quartz occurs in small but varying amounts.

Soils have formed in the monzonite because of numerous joints, which are much more closely spaced than joints in the rhyolite and limestones. Water readily infiltrates along the joints and horizons of clay and carbonate accumulation have formed. Distinct soils have formed in monzonite in the vicinity of San Agustin Pass and on a broad pediment west of the Pass (section 160).

An extensive area of piedmont-slope sediments derived from monzonite occurs west of the northern part of the Organ Mountains. The monzonite comminutes rather easily in weathering and transport. Consequently, the soils are low in gravel except for steeper slopes.

Median weight diameter of Holocene alluvium generally decreases slightly downslope (table 20). Materials of main channel zones at lower elevations, however, can be substantially coarser than materials at higher elevations as shown by pedon 68-3 in table 20. Similarly, pedons 68-3, 68-4 and 69-8 also illustrate that materials at the same elevation can differ markedly in size. Median weight diameter of Pleistocene alluvium shows a substantial decrease with elevation (table 20).

Fine earth of gravelly monzonitic sediment has a similar size distribution to rhyolitic sediment (fig. 7). Monzonitic alluvium free of gravel has a high proportion of fine sand (0.1-0.25 mm), differing from its gravelly monzonitic counterpart and also from rhyolitic alluvium, and similar to alluvium deposited by the ancestral Rio Grande.

37. SEDIMENTARY ROCKS AND ALLUVIUM

Sedimentary rocks are dominant in the San Andres and Robledo Mountains. Small areas also occur in the Dona Ana Mountains and in places along the front of the Organ Mountains. Limestone and other calcareous rocks are the dominant component with variable amounts of igneous rocks, chert and quartzite. The Holocene alluvium tends to be free of gravel on slopes of about two percent or less. Pleistocene alluvium usually has some gravel even on slopes of one percent. Median weight diameters for Holocene alluvium tend to decrease with distance from the mountain front (table 20).

Holocene alluvium on the middle and lower slopes is high in silt and clay and has little sand except for a few places in the C horizon (curve 5, fig. 7). Along the mountain front, lateral variation in the particle-size distribution of the Holocene alluvium is large (table 20). Commonly the fine earth of gravelly sediments is lower in coarse and very coarse sand (2 to 0.5 mm) than gravelly monzonitic or rhyolitic alluviums (fig. 7).

38. RIVER ALLUVIUM OF MIXED LITHOLOGY

Mid-Pleistocene river alluvium (the fluvial facies of the Camp Rice Formation) underlies extensive areas of the basin floors. It is exposed to substantial depths in the upper slopes of the valley border south of the Robledo and Dona Ana Mountains. In those areas it crops out just below the outer valley-rim scarp as a gravelly, erosion-resistant unit, commonly not more than 10 to 15 m thick, above scores of meters of sandy sediments with little or no gravel. In most other places the sediments at the surface contain little or no gravel. River alluvium of late-Pleistocene age is exposed in places along the valley border between the Dona Ana and Robledo Mountains. The alluvium of late- and mid-Pleistocene age is informally designated "ancient river alluvium." The fine earth of the low-gravel alluvium tends to be high in fine sand (0.1 to 0.25 mm) and very low in silt (fig. 9).

39. SIGNIFICANCE OF CARBONATE AND COARSE FRAGMENTS

Carbonate content and the percentage of coarse fragments affects the accumulation of both silicate clay and authigenic carbonate. This in turn affects classification of the soils. General relations of these two factors to soils of various ages and terrains are summarized in table 23. which also indicates the approximate times for development of various diagnostic horizons under stated conditions.

Table 23. Relation of soil development and classification to carbonate and coarse fragments in the parent materials (arid zone) 1/

Soil age		Low-carbonate parent materials: Great group and diagnostic horizon 2/		Low-carbonate parent materials: Obliteration of the argillic horizon 3/		High-carbonate parent materials: Great group and diagnostic horizon	
		Low-gravel materials	High-gravel materials	Low-gravel materials	High-gravel materials	Low-gravel materials	High-gravel materials
Late	HOLOCENE	Torripsamments Torrifluvents Torriorthents Camborthids; Cambic Horizon	Torriorthents Camborthids; Cambic Horizon Haplargids; Argillic Horizon			Torrifluvents Torriorthents	Torrifluvents Torriorthents
Mid	HOLOCENE	Haplargids; Argillic Horizon				Calciorthids; Calcic Horizon	Calciorthids; Calcic Horizon
Early(?)	HOLOCENE						
7500 Years B.P.							
Latest	PLEISTOCENE	Haplargids; Calcic Horizon	Haplargids; Calcic Horizon				
Late	PLEISTOCENE		Paleargids; Petrocalcic Horizon	Calciorthids; Calcic Horizon	Paleorthids; Petrocalcic Horizon		Paleorthids; Petrocalcic Horizon
Late-mid	PLEISTOCENE						
Mid	PLEISTOCENE	Paleargids; Petrocalcic Horizon		Paleorthids; Petrocalcic Horizon			

1/ Soils are on stable sites that show little or no evidence of landscape dissection unless otherwise indicated (see footnote 3).

2/ Diagnostic horizons underlined.

3/ Where the argillic horizon has been obliterated by landscape dissection, carbonate engulfment, and/or faunal activity.

40. ATMOSPHERIC ADDITIONS

Prominent horizons of calcium carbonate occur in soils formed in parent materials very low in calcium. The atmosphere is a possible source of calcium. Brown (1956) in Texas; Gile et al. (1966) in New Mexico; and Gardner (1972) in Nevada have postulated an atmospheric source for the calcium of these horizons. Yaalon and Ganor (1973) present a review of dustfall as a source of calcium for calcium carbonate horizons. In the study area, dustfall during the dry spring season was caught and analyzed for as long as 11 years at 7 locations.

41. DRY DUST

42. Site descriptions

Location of the seven dust trap sites is shown in figure 8. Tables 24 and 25 describe the sites. Figures 9 to 11 are photographs of the sites.

43. Methods

The dust traps were left out during the dry, dusty season from February to June. They consisted of detachable pans filled flush to the top with commercial marbles about 1 cm in diameter. The pans were 30 cm square and 5 cm deep. They were constructed from 16-gauge galvanized iron and had folded edges and water-tight seams. All sharp edges were smoothed to avoid tearing a plastic lining. A threaded base plate was attached to the bottom of the pan so that it could be screwed onto or off a 5 cm pipe permanently mounted in concrete.

A double thickness of 10 mil vinyl sheeting was the most satisfactory lining. It covered the inside and most of the outside of the pans. Nylon tape fastened the sheeting tightly to the sides of the trap. The tape and the outside of the trap were painted for protection against the weather. The marbles were thoroughly washed with tap and distilled water before filling the pans level full. A piece of plastic sheeting was taped over the pans to prevent contamination during transport to the sites and return to the laboratory after they had been open during the dusty season.

As a first step for removing the dust, a small quantity of distilled water was poured over the marbles in the pan. The marbles were gently rolled and stirred in this water, then transferred to a container of distilled water and washed twice. All washings were combined in a beaker. Most of the dust remained in the wash water in the pan after the marbles were removed. Liquids and solids in the pan were transferred quantitatively to the beaker that contained the wash water from the marbles. The combined washings were reduced in volume by evaporation at 90° C, transferred to polyethylene bags mounted in large beakers, and brought to air dryness. The dust was then quantitatively removed, and gently crushed so all but resistant mineral grains would pass a 0.5 mm sieve.

Sample weights commonly were on the order of a gram, necessitating certain modifications in the standard analyses, which are discussed in footnotes to table 26.

To check whether corrosion of the commercial glass marbles contributed to

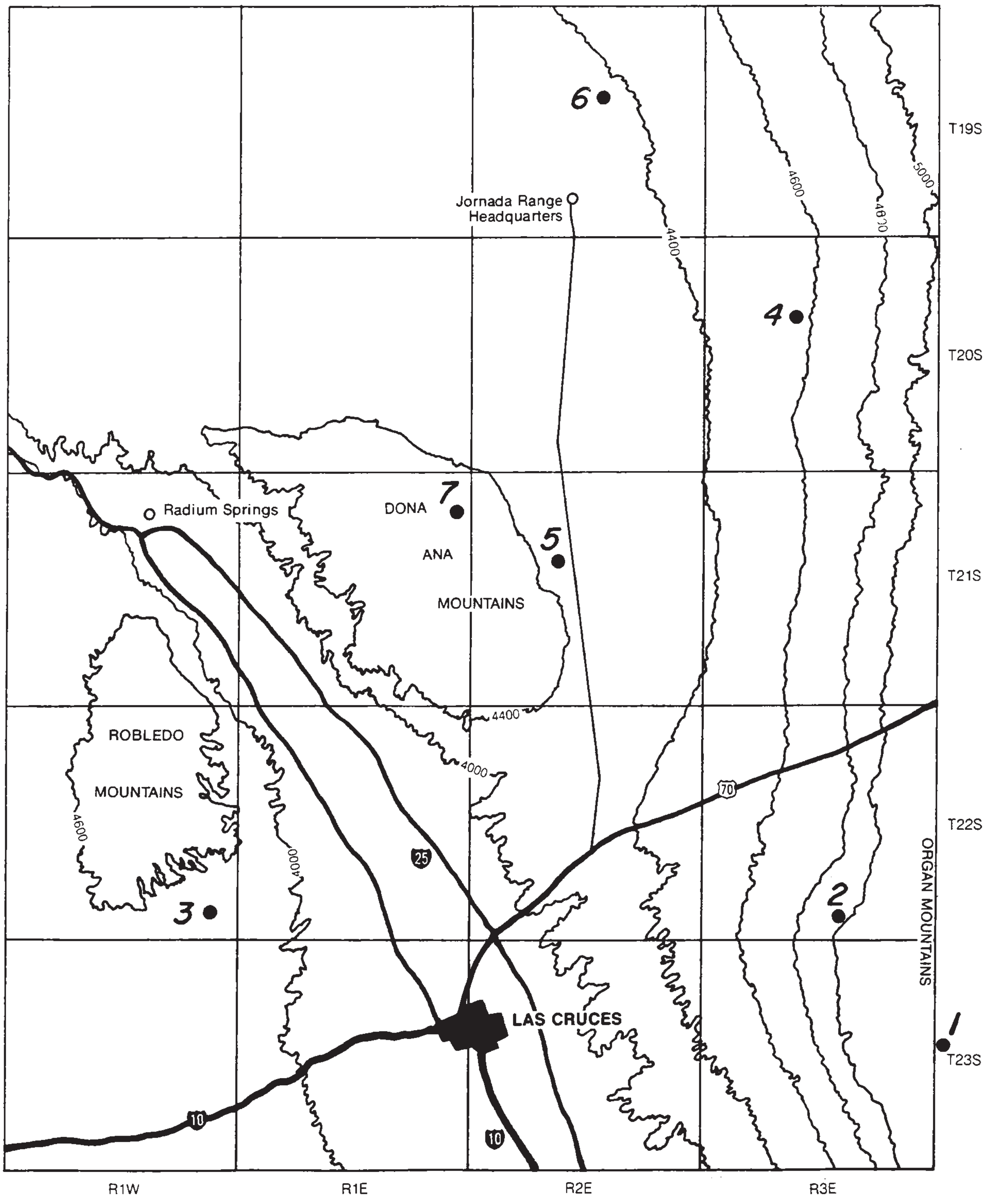


Figure 8. Location of dust traps.

Table 24. Some characteristics of dust trap sites 1-4.

Trap # and years of data[1]	Landscape position, location and elevation	Slope and aspect	Vegetation	Soil surface	Soil type[1] carbonates[2]	Lithology of soil parent materials
1 1962-1967	Alluvial fan near the divide in Soledad Canyon, Organ Mountains; in the NW 1/4 sec. 19, T23S, R4E. Elevation: 6200 feet, 1891 meters.	11% to the west.	Vegetation dominantly grasses, mainly clumps of black grama and sideoats grama; a scattering of trees (mostly cedar, a few pinon) ranging from about 2 to 6 m in height, and scattered cholla, prickly pear, snakeweed, oak.	Between vegetation the soil surface is 100% covered by closely packed, angular rhyolite fragments, mainly from 1/2 to 2 cm in diameter, a few up to 10 cm diameter.	Very gravelly sandy loam; noncalcareous.	Alluvial fan sediments derived from rhyolite.
2 1962-1972	Coalescent fan-piedmont, downslope from Organ Mountains; in the SE 1/4 sec. 34, T22S, R3E. Elevation: 5000 feet, 1525 meters.	4% to the west	Vegetation dominantly grasses, mostly black grama, with some 3-awn; few Mormon tea, snakeweed, mesquite.	30% covered by desert pavement of gravel, mainly rhyolite, ranging from about 1/2 to 3 cm in diameter, occasional cobble up to 20 cm diameter.	Very gravelly sandy loam; noncalcareous.	Fan-piedmont sediments derived primarily from rhyolite, with smaller amounts of monzonite and andesite.
3 1962-1972 3a[3] 1965-1972	Basin floor, west of the Rio Grande Valley; in the NW 1/4 sec. 23, T23S, R1W. Elevation: 4450 feet, 1357 meters.	Level	Good grass cover, mainly black grama, but with some dropseed and scattered snakeweed and mesquite.	No coarse fragments; soil surface is weakly crusted.	Sandy loam; noncalcareous.	Basin-floor sediments of mixed origin; mainly noncalcareous sand.
4 1962-1972	Coalescent fan-piedmont, downslope from San Andres Mountains, in the NW 1/4 sec. 14, T20S, R3E. Elevation: 4775 feet, 1446 meters.	3% to the west.	Scattered creosotebush and mesquite.	90% to 95% covered with closely packed desert pavement of mainly limestone and sandstone pebbles, most range from about 1/2 to 3 cm.	Very gravelly loam; calcareous throughout.	Fan-piedmont sediments derived mainly from limestone and sandstone.

1/ Average particle size of upper 15 cm.

2/ Effervescence with dilute HCl in the upper 15 cm.

3/ All traps are at 90 cm height except for trap 3a, which is at 30 cm height.

Table 25. Some characteristics of dust trap sites 5-7.

Trap # and years of data1/	Landscape position, location and elevation	Slope and aspect	Vegetation	Soil surface	Soil type1/ carbonate2/	Lithology of soil parent materials
5 1962-1972 5a3/ 1965-1972	Coalescent fan-piedmont, downslope from the Dona Ana Mountains, in the NW 1/4 sec. 16, T21S, R2E. Elevation: 4350 feet, 1327 meters.	2% to the east.	Scattered creosotebush, tarbush, Mormon tea, few mesquite, and Yucca elata, no grass except for a few clumps of bush muhly at base of some shrubs.	30% to 40% covered with rhyolite, andesite, and monzonite pebbles, most of which range from about 1/2 to 3 cm diameter, with occasional pebbles up to 6 cm diameter. This area actively eroding with drainageways spaced 7 to 10 m apart, ranging from 10 to 25 cm deep; sides are gently sloping. Traps are on edge of drainageway.	Gravelly sandy loam; noncalcareous in upper few cm, calcareous below.	Fan-piedmont sediments derived primarily from monzonite, rhyolite and andesite.
6 1962-1972	Lower part of coalescent fan-piedmont modified by wind action; downslope from the San Andres Mountains; in the NE 1/4 sec. 16, T19S, R2E. Elevation: 4370 feet, 1333 meters.	General slope 1% to the west, locally gently undulating due to wind action.	Numerous barren areas; scattered Mormon tea, mesquite and Yucca elata; a few clumps of dropseed.	Loose-appearing and sandy; no desert pavement; occasional dunes up to 1 m high and several m diameter.	Sand; noncalcareous.	Noncalcareous sand of eolian origin.
7 1962-1972	Coalescent fan-piedmont, downslope from the Dona Ana Mountains; in the NE 1/4 sec. 12, T21S, R1E. Elevation: 4525 feet, 1380 meters.	3% to the east.	Creosotebush, mesquite, few tarbush, barren between shrubs.	Scattering of coarse sand grains, mainly monzonite fragments on the surface; range from 5% to 30% of fine pebbles of monzonite and rhyolite. Small drainageways occur at intervals of 5 to 10 m, range from 5 to 10 cm deep and from 20 to 150 cm wide. Coarse sandy sediments occur in channels. Trap 7 occurs in a stable area between drainageways.	Sandy loam; calcareous throughout.	Fan-piedmont sediments derived primarily from monzonite, rhyolite and andesite.

1/ Average particle size of upper 15 cm.

2/ Effervescence with dilute HCl in the upper 15 cm or as otherwise indicated.

3/ All traps are at 90 cm height except for trap 5a, which is at 30 cm height.

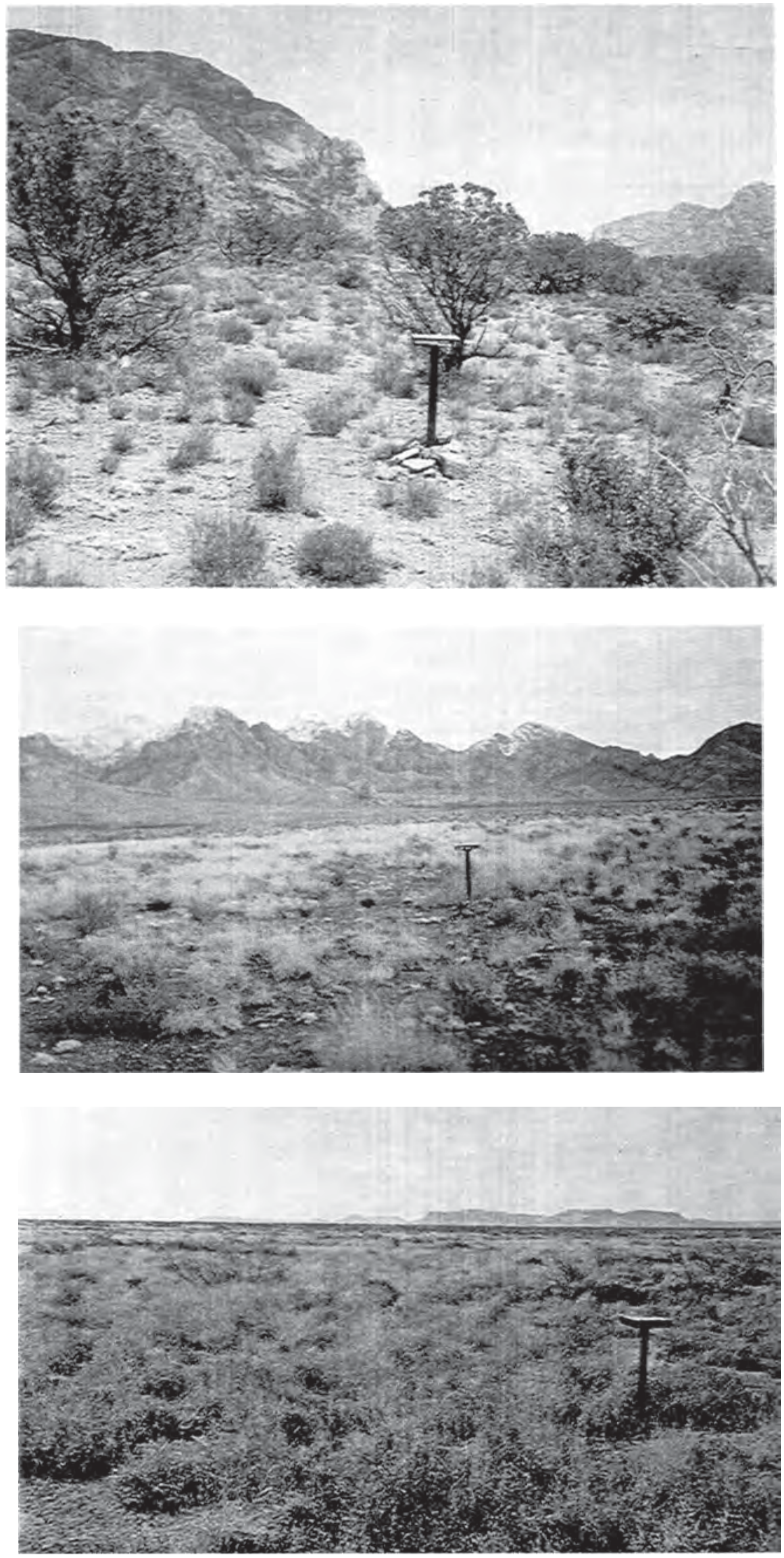


Figure 9. Photographs of sites, dust traps 1 (top), 2 (middle), and 3 (bottom).

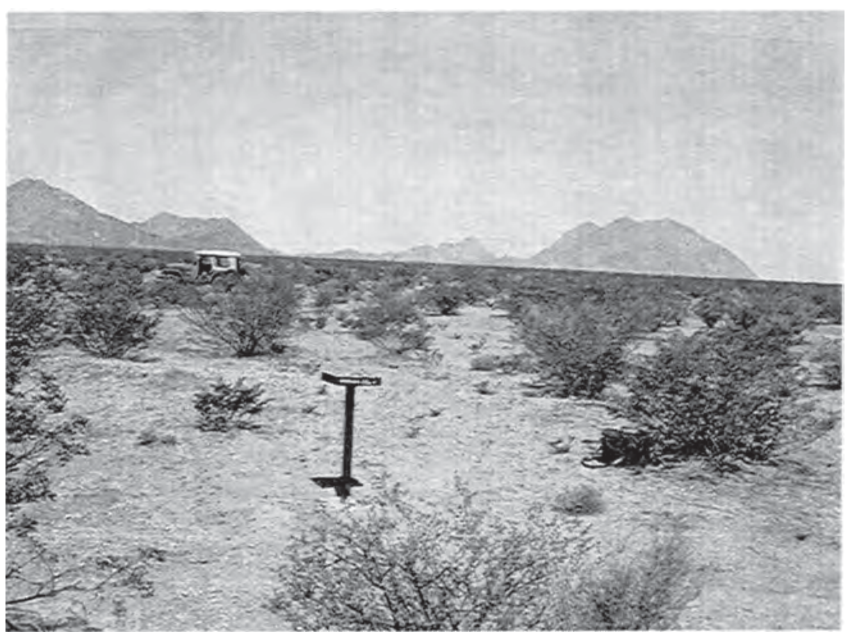
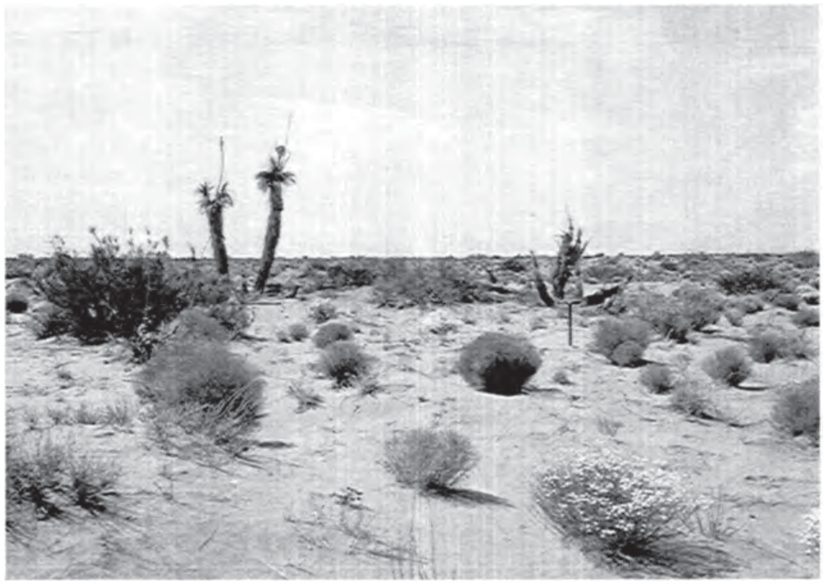


Figure 10. Photographs of sites, dust traps 4 (top) and 5 (bottom).



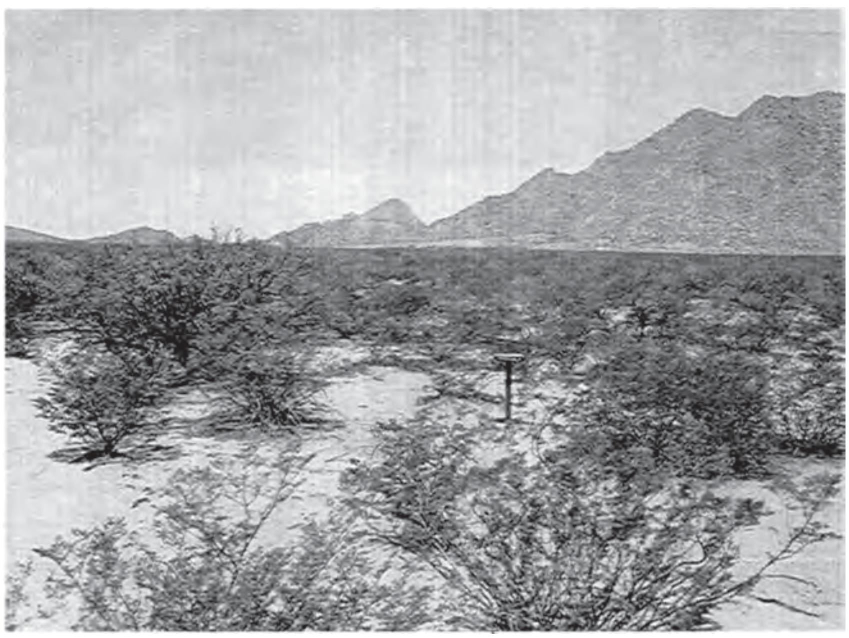


Figure 11. Photographs of sites, dust traps 6 (top) and 7 (bottom).

the extractable bases, lucite plexiglass spheres were used in place of the marbles for trap 5 in 1971 and 1972. Extractable calcium and magnesium were not lower than for 1970, when marbles were used, hence little or no calcium or magnesium seems to have leached from the marbles.

44. Results

The complete analyses by year are in tables 26 and 27, with a summarization in table 28. The average yearly catch for all of the traps at 90 cm height was 23 g/m^2, with a range among traps of 10 to 60 g/m^2. Yields for the traps at 30 cm were 2- and 5-fold higher, respectively, than the companion trap at 90 cm. These values at 90 cm are similar to those obtained by Smith et al. (1970) for central and eastern United States. The traps differ in the two studies. A liquid trap, such as that used by Smith et al. (1970) should retain practically all of the dust that drops into it. A surface of marbles, as employed in this study, probably would not retain all of the dust. Some of it could be blown away before moving down into the interstices. Other differences are that the dust catch for this project is for only a portion of the year; and since the traps are out during the dry spring season, they catch little of the dust carried to the earth by precipitation. The average yearly catch is equivalent to the deposition of one to two cm of dust in a thousand years. Very gravelly surfaces should tend to catch more dustfall than nongravelly ones; and high-gravel soils do show evidence of incorporation of silt and clay in the dustfall as well as the carbonate (section 56). Ancient low-gravel soils such as the soils of upper La Mesa (section 152) have very high amounts of carbonate but little silt and clay. In these areas some carbonate in the dustfall must have moved into the soil in solution, but most of the silt and clay was probably blown away in a later windstorm.

Amount of dust is related to landscape stability near the trap. Trap 6 yielded the most dust (table 28) and is in an undulating area of active wind erosion. Trap 5, which caught significantly more dust than trap 2, is in an area of actively eroding drainageways. In contrast, trap 2 is on a stable site with little evidence of erosion.

There is a significant difference in the amount of dust among years (table 29). Neither total air movement nor precipitation would appear to explain the difference (table 30). It may be due to brief periods of high winds that would not show up in the totals.

Clay content ranges from 20 to 40 percent. Some of the clay probably was transported as aggregates or coatings on larger grains, and not as discrete particles in the clay-size range (Gillette and Goodwin, 1974). The dust catch becomes coarser as the amount increases, with sand substituting for clay and silt. Clay percentage is therefore negatively correlated with weight of catch (table 31). Only a small portion exceeds 0.25 mm despite appreciable > 0.25 mm in some of the nearby soils (table 32). Particles larger than about 0.2 mm are not moved in suspension but rather by saltation (Bagnold, 1941). Apparently saltation has been a minor contributing process to the traps at 90 cm height.

Organic carbon ranges from 2.5 to 6.6 percent for the traps at 90 cm (table 28) and is negatively correlated with amount of dust. Other investigators have found appreciable organic matter in dust (Smith et al., 1970; Laprade,

Table 26. Characterization data for dust catch, traps 1 to 3a.

Trap and height	Year[1/]	Sample number	Weight	Particle-size distribution[2/] mm 2-0.25	0.25-0.1	0.1-0.05	0.05-0.002	< 0.002	Organic carbon 6A1a	Carbonate as $CaCO_3$[3/] 6E1c, 6E1f	Soluble bases[4/] Water Ca	Water Mg	pH 5 NH4OAc Ca	pH 5 NH4OAc Mg
			g	pct	pct	pct	pct	pct	pct	pct	←--------me/100g----------→			
1, 90 cm	1962	17935	1.45							tr				
	1963	19141	0.88	-	13	9	41	37	6.2	3				
	1964	20277	0.94	-	6	10	49	35	7.5	5				
	1965	20542	0.98	1	17	8	36	38	5.8	2.2				
	1966	66L542	1.52	2	14	9	42	33	3.4	2.4				
	1967	67L173	1.11	1	9	16	39	35	3.4	2.3				
2, 90 cm	1962	17936	1.54							tr				
	1963	19142	0.75	-	9	8	46	37		2				
	1964	20278	0.79	2	4	7	48	39	7.9	7				
	1965	20543	0.86	1	16	6	41	36	5.7	3.2				
	1966	66L543	1.33	2	14	6	42	36	4.1	3.9				
	1967	67L174	0.82	1	6	9	45	39	6.2	2.2				
	1968	68L268	0.44						12.0	1.5				
	1969	69L408	0.91						7.1	2.7				
	1970	70L1198	0.45						6.0	2.2	35.0	4.4	57.5	5.9
	1971	71L472	0.95						5.3	2.4	25.6	0.9	68.8	6.3
	1972	72L539	0.66						5.2	0.7	28.8	2.0	37.5	6.0
3, 90 cm	1962	17937	1.99						4.9	tr				
	1963	19143	1.14	-	14	9	41	36	5.9	2				
	1964	20279	2.30	1	11	10	34	44	4.0	2				
	1965	20544	1.54	2	25	5	31	37	3.9	0.8				
	1966	66L544	2.93	1	23	6	30	40	3.1	1.1				
	1967	67L175	2.51	1	13	13	33	40	3.5	0.4				
	1968	68L269	0.88						8.0	1.1				
	1969	69L409	1.26						4.5	3.0	41.8	2.9	76.9	5.1
	1970	70L1199	1.03						5.8	0.8	20.6	6.6	45.6	6.1
	1971	71L473	1.71						4.3	1.5	19.4	1.1	55.0	5.1
	1972	72L540	1.01						4.9	1.1	33.8	4.1	46.9	6.9
3a, 30 cm	1965	20545	2.28	7	40	7	23	23	2.6	1.3				
	1966	66L545	4.81	3	28	9	31	29	1.8	0.9				
	1967	67L176	8.24	7	28	21	23	21	1.6	tr(s)				
	1968	68L270	1.58						6.7	0.2				
	1969	69L410	2.49						2.9	1.4	19.3	1.4	45.0	3.8
	1970	70L1200	1.25						3.6	1.2	13.8	1.6	38.8	5.3
	1971	71L474	2.48						3.9	1.3	13.8	0.6	51.3	4.3
	1972	72L541	2.89						1.7	0.4	13.1	0.9	15.0	3.0

1/ Clay mineralogy was determined for dust in all traps for the years 1965 and 1966. By X-ray diffraction (method 7A2c) the clays are very similar. The clay contains small amounts of mica and kaolinite (ratio of 2 to 1) and small amounts of poorly ordered montmorillonite.

2/ Sand separated from silt plus clay after standard treatment to remove organic matter and disperse as in method 3A1. Clay removed from silt by successive centrifugation and decantation. Clay obtained by difference between initial weight of silt plus clay and weight of silt.

3/ 6E1c used 1962-1964. Trace (tr) means < 0.4% for method 6E1c. For method 6E1f, trace (tr) means < 0.04%. Tr(s) means effervesces when treated with acid but carbonate not detectable by method 6E1f. As a check on the carbonate determinations, the $CaCO_3$ equivalent of the calcium and magnesium extracted by pH5 NH_4OAc was compared to carbonate values determined by CO_2 evolution. Three milliequivalents were added to the measured calcium plus magnesium to correct for carbonate dissolved in the prior water extraction described in footnote 4. From this corrected sum an estimate of the exchangeable bases was subtracted, assuming 100 percent base saturation. The estimate was obtained by assuming 0.6 milliequivalent for each unit percent clay (using the average clay values for preceding years) and 2 milliequivalents for each unit percentage of organic carbon in excess of 10 percent of the clay. The t test value on the 23 pairs of comparisons of the computed and calculated $CaCO_3$ equivalent was 0.9534. The hypotheses is accepted that there is no difference between the two methods of determining the $CaCO_3$ equivalent. The extractable cation data therefore corroborate the measured carbonate values.

4/ A 0.2-gram sample was placed in a micro Buchner funnel (fritted disc) fitted with filter paper and filter pulp. A small amount of Celite was mixed with the sample and the stem was stoppered. One ml of distilled water was mixed with the sample and allowed to stand overnight. The sample was extracted with water the following morning and the made to 5 ml in a volumetric flask. The sample remaining in the funnel was mixed with 1 N NH_4OAc and volume made to 5 ml. Calcium and magnesium were determined by atomic absorption.

Table 27. Characterization data for dust catch, traps 4 to 7[1/].

Trap and height	Year	Sample number	Weight	Particle-size distribution mm 2-0.25	0.25-0.1	0.1-0.05	0.05-0.002	< 0.002	Organic carbon 6A1a	Carbonate as $CaCO_3$ 6E1c, 6E1f	Soluble Bases Water Ca	Water Mg	pH 5 NH_4OAc Ca	pH 5 NH_4OAc Mg
			g	pct	pct	pct	pct	pct	pct	pct	←me/100g			→
4,	1962	17939	2.27						3.5	5				
90	1963	19145	1.24	1	10	14	46	29	6.7	7				
cm	1964	20280	1.90	1	8	17	47	27	4.1	8				
	1965	20546	1.11	2	24	9	39	26	4.8	5.2				
	1966	66L546	2.66	1	17	11	42	29	3.2	6.7				
	1967	67L177	1.56	3	11	21	40	25	3.9	4.7				
	1968	68L271	0.82						8.0	5.3				
	1969	69L411	0.85						6.5	6.0				
	1970	70L1201	0.84						5.1	5.7	40.6	0.6	12.5	7.1
	1971	71L475	1.88						4.0	5.2	20.6	0.5	12.3	5.1
	1972	72L542	0.96						4.9	3.7	28.1	2.3	87.5	5.1
5,	1962	17940	2.50						3.7	1.4				
90	1963	19146	1.27	1	12	14	45	28	6.8	3				
cm	1964	20281	1.34	2	15	22	37	24	4.5	3				
	1965	20547	2.16	2	27	18	33	20	3.0	1.5				
	1966	66L547	4.13	2	27	17	35	19	2.5	1.8				
	1967	67L178	5.32	2	17	39	25	17	1.6	0.6				
	1968	68L272	3.79						2.7	0.1				
	1969	69L412	1.44						3.9	0.5	31.2	1.7	26.2	3.7
	1970	70L1202	1.62						3.5	1.2	17.5	1.9	33.1	4.1
	1971	71L476	1.80						3.1	1.8	17.5	1.2	56.9	4.3
	1972	72L543	1.49						3.0	1.7	25.0	2.0	46.3	5.1
5a,	1965	20548	9.23	7	40	21	19	13	1.1	0.6				
30	1966	66L548	14.61	4	38	24	20	14	1.1	0.7				
cm	1967	67L179	24.19	6	29	42	12	11	0.6	tr(s)				
	1968	68L273	22.35						0.8	tr				
	1969	69L413	5.69						1.5	0.2	6.4	0.7	13.1	1.9
	1970	70L1203	6.95						1.5	0.4	3.8	0.4	14.4	1.8
	1971	71L477	4.31						2.2	0.6	9.7	0.4	40.6	2.8
	1972	72L544	6.2						2.0	0.7	8.5	0.9	23.8	2.5
6,	1962	17941	8.48						2.8	tr				
90	1963	19147	2.49	4	24	20	30	22	4.3	3				
cm	1964	20282	13.96	3	27	30	19	21	1.0	2				
	1965	20549	3.48	4	32	15	27	22	2.2	2.1				
	1966	66L549	9.13	4	34	16	24	22	1.7	2.6				
	1967	67L180	5.22	4	18	25	29	24	1.9	2.3				
	1968	68L274	2.41						3.3	1.7				
	1969	69L414	2.46						2.7	1.3				
	1970	70L1204	3.91						2.2	1.6	13.8	1.0	57.5	4.4
	1971	71L478	4.99						3.0	1.1	12.5	0.7	50.0	3.0
	1972	72L545	3.41						2.6	1.3	12.3	0.8	43.1	2.9
7,	1962	17942	2.58						4.3	2				
90	1963	19148	1.27	4	7	16	49	24	5.4	4				
cm	1964	20283	1.47	2	9	22	41	25	4.2	5				
	1965	20550	1.42	4	24	13	39	20	4.7	2.4				
	1966	66L550	2.03	2	20	13	39	26	5.5	2.8				
	1967	67L181	1.60	3	12	23	37	25	3.3	1.2				
	1968	68L275	0.86						9.0	1.9				
	1969	69L415	0.91						5.2	1.3				
	1970	70L1205	0.98						5.0	2.6	31.9	2.9	66.9	6.9
	1971	71L479	1.86						3.8	2.2	13.1	1.0	68.1	4.8
	1972	72L546	1.41						4.5	1.2	16.9	1.4	38.1	5.3

1/ Footnotes as for table 26.

Table 28. Summarization of characterization data for the dust collected at seven locations in the project area.[1/]

Trap No.	Years	Weight	Particle-size distribution[2/] mm					Organic carbon		$CaCO_3$ Equivalent			
			2- 0.25	0.25- 0.1	0.1- 0.05	0.05- 0.002	< 0.002			Measured		Water soluble calcium[3/]	Sum
		$g/m^2/yr$	←Pct					→	$g/m^2/yr$	Pct	←$g/m^2/yr$		→
1	1962-67	12.4	1	12	10	41	36	5.3	0.57	2.6	0.30		
2	1962-72	9.3	1	10	7	45	37	6.6	0.54	2.6	0.25	0.096	0.35
3	1962-72	17.9	1	17	9	34	39	4.8	0.78	1.3	0.21	0.17	0.38
3a	1965-72	35.0	6	32	12	26	24	3.1	0.87	0.8	0.23	0.15	0.38
4	1962-72	15.7	2	14	14	43	27	5.0	0.71	5.7	1.1	0.16	1.3
5	1962-72	26.3	2	20	22	34	22	3.5	0.73	1.5	0.33	0.17	0.50
5a	1965-72	125.8	6	35	29	17	13	1.4	1.3	0.4	0.43	0.12	0.55
6	1962-72	58.6	4	27	21	26	22	2.5	1.2	1.8	1.1	0.22	1.3
7	1962-72	19.2	3	14	17	42	24	5.0	0.76	2.4	0.39	0.12	0.51

1/ See tables 26 and 27 for source data. The percentage values given are the average of the yearly values and are not weighted means adjusted for differences in amounts of dust from year to year. Unless otherwise indicated, the averages pertain to the years listed in the second column. The quantity values ($g/m^2/yr$) were obtained by averaging the yearly quantities; they are not the product of the average weights and percentages. The amounts for the 30 cm square pan were multiplied by 10.8 to obtain the values for 1 m^2. Traps at 90 cm height unless otherwise indicated.

2/ 3a, 5a, 1965-67; others, 1963-67.

3/ 1969-72 for traps 3, 3a, 5, 5a; others 1970-72. Measured calcium in the water extract was reduced by 3 me to correct for the contribution by carbonate to the water soluble calcium. This correction is based on an assumed carbonate solubility of about 1 me/l, approximately the solubility of calcite in water in equilibrium with atmospheric CO_2.

Table 29. Analysis of variance for the weight of dust by location and years for the 7 traps at 90 cm height.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F test
Location	5	17,488.0	3,497.6	**1/
Years	10	6,197.0	619.7	* 2/
Residual	50	12,785.3	255.7	
Total	65	36,470.3		

1/ Significant at 95% level.

2/ Significant at 90% level.

* * *

Table 30. Rank order of dust catch related to wind and precipitation.

Year	Average weight for all traps	Total wind Feb. - May1/	Total precipitation Feb. - May1/
	g/m^2	mi	mm
1969	14.0	8,107	18
1963	14.6	8,513	24
1970	15.8	7,819	25
1972	16.0	7,419	3
1968	16.5	8,533	57
1965	19.0	7,731	25
1971	23.7	9,227	4
1967	30.5	7,508	11
1962	34.7	8,256	16
1964	39.0	10,189	19
1966	39.8	8,072	26

1/ At University Park, N. M.

1957). The organic carbon percentages are several-fold higher than for surface horizons of the soils in the vicinity of the traps (table 32). Organic matter is closely associated with clay; the higher organic carbon may be in part related to clay content. Visual examination suggests that most of the organic matter is humified; the dust samples are relatively dark when moist. Water extracts from the dust samples are dark colored, attesting that a portion of the organic matter is soluble in water. Origin of the organic matter is not known. Vegetal remains on the soil surface may be a source. Organic matter is lighter than the mineral fraction and proportionately more should be transported by wind. Pollen and other sources of organic matter occur in the air.

Carbonate was measured directly on the dust samples (table 28). It was reported both as a percentage and as an amount, expressed as $g/m^2/yr$ (table 28). Trap 4 has a significantly higher carbonate percentage than the other traps (table 28), a reflection of the surrounding soils which have strongly calcareous surface horizons. Carbonate percentage and the amount of dust are negatively correlated (table 31). For the traps at 90 cm, the range in amount of carbonate is 0.2 to 1.1 $g/m^2/yr$. Omitting trap 4 (high carbonate related to strongly calcareous surface horizons) and trap 6 (large dust catch because of the local conditions), the range is only 0.2 to 0.4 $g/m^2/yr$. Traps 3 and 5, representative of fairly stable sites in the arid part of the study area, and trap 1, which occurs in the Organ Mountains, have similar amounts of carbonate.

Water soluble calcium expressed as $CaCO_3$ equivalent ranges from 0.1 to 0.2 $g/m^2/yr$ and shows no relationship to the amount of carbonate (table 28). The amounts exceed the solubility of calcite; salts more soluble than calcite must be present.

The measured carbonate plus the water soluble calcium expressed as $CaCO_3$ equivalent, termed "labile calcium," range from 0.35 to 1.3 $g/m^2/yr$ for all traps and 0.35-0.55 $g/m^2/yr$ if traps 4 and 6 are excluded. The traps at 30 and 90 cm have similar values, suggesting that the amounts at ground level would be similar to those for the traps.

Deposition of labile calcium by dust is relatively uniform over most of the project. Winds during the dusty season come from the west, roughly at right angles to the Rio Grande Valley. This wind transports dust containing labile calcium (mostly carbonate) eastward into the Organ Mountains where the parent rocks are noncalcareous, and in the case of Soledad rhyolite are very low in calcium. Movement of labile calcium in dust apparently has been an important agency for the dissemination of carbonate over the landscape for a long period of time. This is indicated by the increasing amount of carbonate with increasing age of soils in noncalcareous parent materials (section 76).

45. PRECIPITATION AND TOTAL ADDITIONS

Labile calcium in the dry dust is not the only source of calcium, which also occurs in the precipitation. From July 1955 to July 1956, monitoring of the ionic composition of precipitation (dust from between precipitation events excluded) for the continental United States indicated an average of about 3 mg/l of Ca^{++} in the precipitation of the project area (Junge and Werby, 1958). A similar study by Lodge _et al_. (1968) from 1960-1968 supports the estimate of

Table 31. Statistical analysis of the dust data for the 7 traps at 90 cm height.

Variable	Number observations	Mean	Standard deviation	Simple correlation coefficients with weight	Duncan multiple range test 1/
Weight (g/m^2)	72	23.0	22.9		2 1 4 7 3 5 6
Clay (%)	35	30	8	-0.440**	
Organic carbon (%)	69	4.6	1.9	-0.611**	
Carbonate (%)	72	2.5	1.8	-0.201*	3 5 6 7 1 2 4
Carbonate (g/m^2)	72	0.50	0.53	0.687**	3 2 1 5 7 4 6

1/ Numerals are the trap locations. Underlines connect locations for which there is not a significant difference at the 5 percent level.

* * *

Table 32. Selected characteristics of dust catch and surface horizons of soils similar to those near the traps.

Trap and pedon nos.	Horizon thickness	Particle-size distribution 2-0.25	0.25-0.1	0.1-0.05	0.05-0.002	< 0.002	Carbonate	Organic carbon
	cm	pct < 2 mm						
3 (trap)	--	1	17	9	34	39	1.3	4.8
3a (trap)	--	6	32	12	26	24	0.8	3.1
61-7	0-5	27	43	15	5	10	1/	0.25
66-12	0-3	21	49	14	4	9	tr(s)	ND
66-13 (dune)	0-25	5	51	31	5	8	tr(s)	0.45
2 (trap)	--	1	10	7	45	37	2.6	66
67-4	0-5	18	22	28	23	8	tr(s)	18
4 (trap)	--	2	14	14	43	27	5.7	5.0
60-20	0-5	10	17	30	28	16	17	0.54
5 (trap)	--	2	20	22	34	22	1.5	3.5
61-5	0-5	14	25	25	24	12	0.3	0.27

1/ Not determined; noncalcareous in field.

3 mg/l. From these figures, the Ca^{++} in the mean annual precipitation for the arid part of the study area, taken as 200 mm, would be sufficient to form about 1.5 $g/m^2/yr$ of carbonate or two to three times the carbonate from labile calcium in the dry dust.

Ionic calcium in the precipitation plus labile calcium in the dry dust would be sufficient to form about 2 kg/m^2 of carbonate per thousand years. Such an amount of authigenic soil carbonate assumes that all of the labile calcium in the dry dust and all of the precipitation infiltrate into the soil. These are very questionable assumptions. Most of the dust deposited on a soil (in contrast to the dust traps) probably is air-borne again. As evidence, the eolian additions to the soils are far less than the approximately 1 cm per kyr that would be predicted from the amounts of dust caught by the traps. Since most of the dust is deposited in the dry season, it probably is deposited and air-borne numerous times before being wetted. Some would be moved eastward into the mountains and beyond without being wetted. The total precipitation in the arid part of the study area under equilibrium conditions does have the capacity to dissolve an amount of carbonate 10 fold greater than that in the dry dust catch. But it is doubtful that much of this capacity is utilized.

All of the precipitation does not enter the soil. An appreciable portion runs off some soils and accumulates on other soils. Consequently, some soils have received less calcium than calculated from atmospheric sources and others more. Further complications arise because the history of the soil must be considered. Soils of Pleistocene age have developed partially during intervals in which atmospheric additions of calcium may have been far different.

The precipitation contains sodium, currently about 1 mg/l (Junge and Werby, 1958), and the principal anion is sulfate. A number of soils contain little exchangeable sodium and water soluble ions within the zone of carbonate accumulation. For these soils, occasional deep wettings would seem a necessary corollary of the hypothesis that the calcium came largely from the precipitation. Occasional deep wetting does occur at the present time in some soils (section 50), and deep wetting should have been much more frequent in pluvials. However, certain soils do show a distinct increase in exchangeable sodium with depth (section 95). The field relations of these soils suggest conditions in which sodium of atmospheric origin might be retained within soils of the study area (section 149).

46. SOIL CLIMATE

47. TEMPERATURE REGIME

Table 33 gives the soil temperature taken at monthly intervals at three elevations. The yearly average from the monthly determinations is 67° F at the two lower elevations and 66° F at the higher. This is within the range of 57° to 72° F for the thermic family (Soil Survey Staff, 1975).

Table 34 gives afternoon temperatures at various depths for two soils in coarse-loamy families. Temperatures near 100° F are common within the uppermost 10 cm. These high temperatures coupled with episodic extreme desiccation make the uppermost 10 to 20 cm a less favorable environment for plant roots and soil fauna than horizons below. Thus in many soils organic matter is lower in surficial horizons than in horizons beneath (section 63). Similarly, the loosening or bulking action of plant roots and soil fauna is usually greater below the surficial horizons. This leads to a common decrease in bulk density from the upper B horizon into the lower B horizon and upper K horizon, where root and faunal activity are greater, reflecting more favorable temperature and moisture relationships in these deeper horizons.

48. MOISTURE REGIME

This section discusses a model for infiltration of overflow or intense precipitation into soil initially at high tension but lacking cracks or holes that extend to the soil surface. Information is also presented on annual differences in soil moisture as determined by the highly episodic precipitation, and on differences in the number of moist days among sites located in the arid part of the study area.

49. Infiltration model

This section considers the moisture profile that theory predicts would be produced on rapid wetting of an initially dry soil that lacks large channels continuous to the soil surface. The discussion to follow closely parallels the presentation in Skaggs *et al*. (1970). According to the widely accepted model for water content distribution with depth as shown in figure 12, and based on the studies of Bodman and Colman (1943), there is a thin saturated zone immediately beneath the soil surface. Below this saturated zone, the water content decreases rapidly with depth over a short distance (transition zone), under which is the relatively thick transmission zone in which water content decreases slowly with depth. In the wetting zone at the base of the wetted depth, water content decreases rapidly with depth to produce the commonly observed wetting front. Mathematical solution by Philip (1957) of a flow equation provides a qualitative theoretical basis for all but the transition zone. Presence of the transition zone is attributed to the increase with depth near the soil surface in the amount of entrapped air. The reason for the increase is that with greater distance from the soil surface the air has progressively less chance to escape across the soil surface. The increase in entrapped air in turn leads to a decrease with depth in the water content at very low or zero tension.

Table 33. Monthly soil temperatures at three elevations during 1966.

	Month												
Elevation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
3900 ft,[2/] 1189 m	48	49	58	70	73	80	83	82	76	68	62	50	67
4500 ft,[3/] 1372 m	48	49	59	69	72	80	84	82	80	69	64	52	67
5500 ft,[3/] 1676 m	47	45	59	67	71	80	78	81	79	69	63	52	66

1/ Soil temperatures were taken about the middle of each month at the bottom of a 50 cm hole made with an auger 8 cm in diameter.

2/ Rio Grande flood plain northwest of Surplus City, Las Cruces, N. M.

3/ Eastward from Rio Grande valley along U. S. Highway 70.

Table 34. Soil temperature (^{o}F) of upper 30 cm for two coarse-loamy soils in the arid part of the study area1/.

Location and depth (cm)	Month, day and time in 1966						Month, day and time in 1972								
	7-7	7-19	8-3	8-15	8-29	9-13	1-1	2-3	3-1	4-4	5-2	5-31	6-23	7-6	7-21
Exclosure "A"2/	1425	1430	1230	1450	1315	1450	1400	1423	1430	1417	1520	1146	1102	1123	1136
3	99	99	89	99	99	84	49	41	63	73	73	73	73	84	78
8	101	99	89	99	84	84	49	38	49	67	72	67	72	84	77
13	100	92	87	87	81	82	48	36	56	65	70	70	81	81	81
18	95	87	87	81	75	70	51	39	55	64	70	70	81	75	70
23	90	85	85	78	73	73	46	38	54	67	63	63	85	78	73
30	87	82	82	76	70	70	47	39	61	61	65	70	82	82	70
Dona Ana Rain Gauge3/	1530	1425	1030	1525	1435	1400	1305	1347	1355	1342	1245	1306	1132	1157	1252
3	108	108	101	108	101	101	51	43	69	86	80	80	91	91	75
8	107	107	90	100	100	85	42	39	59	74	79	74	85	90	79
13	100	94	84	89	84	84	41	38	53	62	72	67	84	84	77
18	98	87	83	88	83	83	44	37	57	71	62	71	83	83	77
23	95	87	83	83	83	83	44	40	57	62	62	71	83	83	77
30	89	83	83	83	83	83	40	44	57	62	62	72	83	83	77

1/ Unpublished data, courtesy of Carlton Herbel, Agricultural Research Service.

2/ Soil similar to that at Site F of soil moisture study (section 54) and classified as a coarse-loamy Typic Haplargid. See Appendix for description.

3/ Soil similar to that at Site A of soil moisture study (section 52) and classified as a coarse-loamy Typic Torriorthent. See Appendix for description.

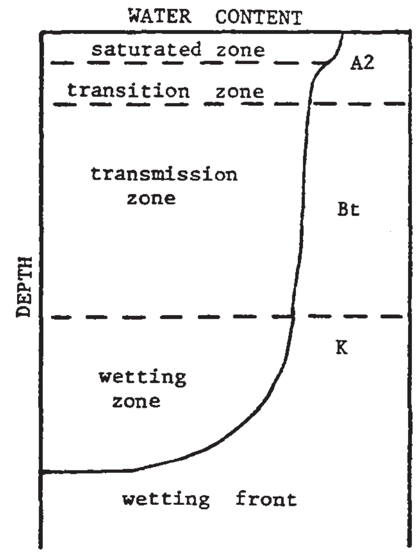


Figure 12. Water distribution in an initially dry, hypothetical Argid after sufficient water has entered to penetrate the zone of carbonate accumulation. Water content curve after Bodman and Coleman, 1943. Pedon lacks large vertical channels that extend to or very near the surface.

The model described pertains to a soil fabric in which water moves downward as a roughly horizontal front under the impetus of gravity and capillary attraction. There are other soils in which water moves downward under positive pressure in the large voids (cracks, root channels, and the like) to form salients of wetting ahead of the general front. At the extreme, the large voids extend to the surface, and free water at the soil surface moves directly down them. There are all gradations between highly frontal water movement that may obey the described scheme of wetting very closely, to soils in which the wetting is principally from the large voids that extend to the surface. Soils in which the water movement is frontal and the distribution is according to that depicted by Bodman and Colman (1943) have low so-called hydrodynamic dispersion (Rose, 1973); soils in which the wetting is from free water that moves down the large voids ahead of the wetting front have high hydrodynamic dispersion. Infiltrating precipitation is much more efficient as a leaching agent in soils with low hydrodynamic dispersion.

Coarse-textured soils have generally low hydrodynamic dispersion. For this reason, apart from low water holding capacity, a given volume of water that enters the soil should be highly efficient as a leaching agent. In contrast, a fine textured soil with strongly expressed prismatic structure, would have high hydrodynamic dispersion and a consequence the infiltrating water would be less efficient. Fine-textured soils with holes that extend to the surface in positions subject to run-in would have infiltrating water with a particularly low leaching efficiency (see site B, section 51).

The water state prior to wetting also determines the hydrodynamic dispersion and therefore the efficiency for leaching of an increment of downward moving water. If the horizon is at very low tension, additional water will move down the larger voids of the transmission zone. Such water exhibits relatively high hydrodynamic dispersion and low leaching efficiency (Miller et al., 1965) compared to water that moves under unsaturated flow down the same transmission zone when initially at higher tension. Climatic conditions for the project area (summer convectional precipitation) are conducive to the soil being dry prior to a wetting event; hence compared to more moist climates, the leaching efficiency of infiltrating water would be higher. A further implication is that leaching efficiency of the infiltrating water (assuming constant morphology and composition with depth) would tend to increase with depth, and be particularly high in the wetting zone (fig. 12). This may be a factor contributing to the fairly rapid increase of carbonate content at the upper boundary of the carbonate horizon of many soils.

50. Annual pattern

Figure 13 shows the moisture pattern for a single year, and the relation to precipitation. The soil is a coarse-loamy Paleargid at site G (see section 54). Precipitation events are common during the summer, and consequently despite the high evapotranspiration relative to precipitation, the soil is moist for a period in the summer. Computations from climate data based on long-term normals (figure 14) would not indicate the duration and extent of moistening during the summer. The discrepancy arises not only because computed evapotranspiration greatly exceeds that for the soil, but also because computations based on monthly normals over a long period miss the short periods for a particular year when precipitation does exceed evapotranspiration.

51. Field study

A study relating soil moisture to precipitation, soil morphology, landscape position and yield was conducted at the Jornada Experimental Range (fig. 15, table 35), most of which lies just north of the study area. Details of the study are given in Herbel and Gile (1973).

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 percent. Slopes gradually decrease to about 0.5 percent 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. Water tables are deep; 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).

Gypsum electrical resistance blocks were placed at depths of 10, 25, 40, 60, 90 and 120 cm except for site G where the soil has a petrocalcic horizon. The soil moisture stations were located within a livestock exclosure. Moisture measurements were made with an ohmmeter two or three times a week when there was moisture during the summer. Measurements were made monthly during the remainder of the year when there were fewer changes in moisture.

At sites C and D, soil moisture was measured both inside and outside of 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. Units outside the cylinder provided estimates of moisture due to precipitation plus run-in. The number of days when the moisture potential was between 0 and -15 bars (referred to as moist days) at each depth was determined for each year.

Vegetation data were collected nearby the soil moisture station at the end of the summer growing season. 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.

To determine the character of the soils in which the gypsum blocks were

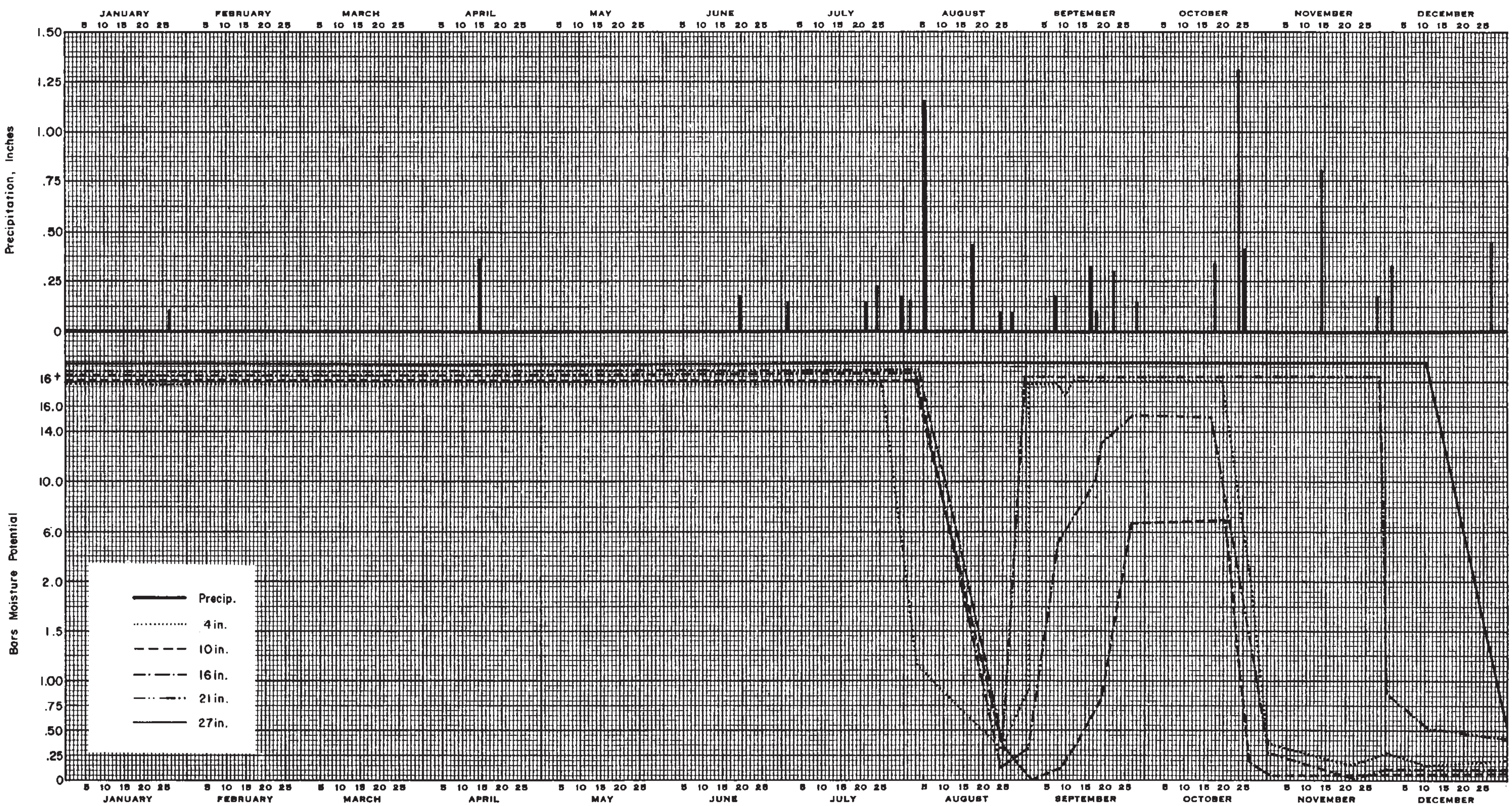


Figure 13. Soil moisture and precipitation for 1971 for the Petrocalcic Paleargid at site G, at depths of 4, 10, 16, 21 and 27 inches.

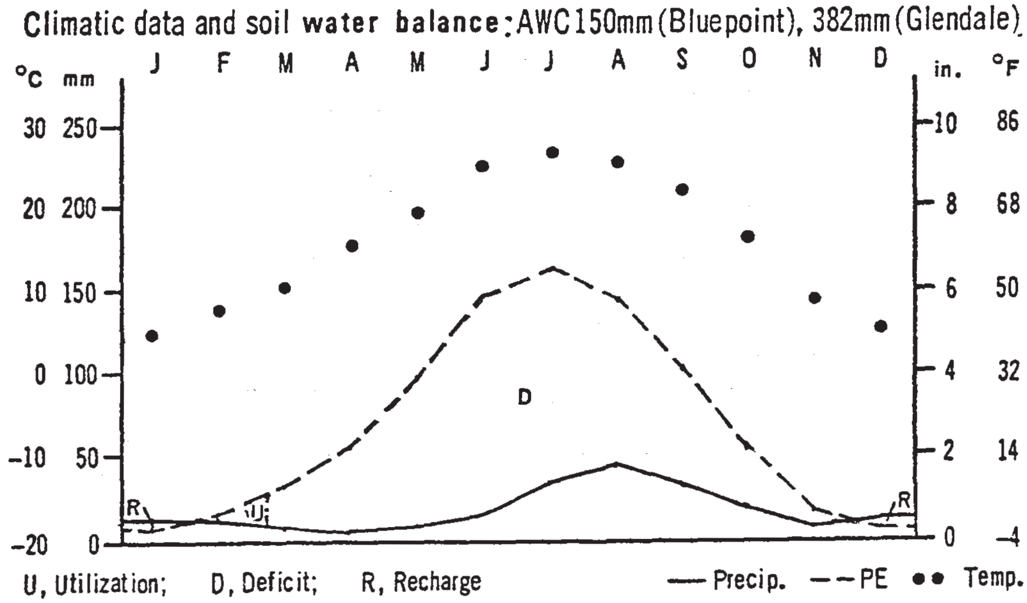


Figure 14. Climatic data and water balance for University Park, N. M., a graph based on long-term climatic normals. The following statements are made concerning such graphs in Soil Taxonomy (Soil Survey Staff, 1975):

> The area between the lines which join all the precipitation normals together and all the PE normals together indicates the status of soil moisture. Beginning with the point where precipitation becomes greater than PE, the area to the right marked "R", for "recharge", shows the amount of moisture stored in the soil profile. This area often extends to the extreme right of the diagram and from there is continued beginning at the extreme left. The amount of recharge is either limited to the available water capacity (AWC) of the soil, in which case a vertical line delimits the area to the right as "S", "surplus", or by the fact the PE again exceeds precipitation before AWC has been filled. Beginning with the point where PE exceeds precipitation, the area to the right marked "U", "utilization", shows the amount of PE necessary to remove the < 15-bar water. Excess PE, if any, prior to time recharge begins is called "D", "deficit", and is delimited by a vertical line.

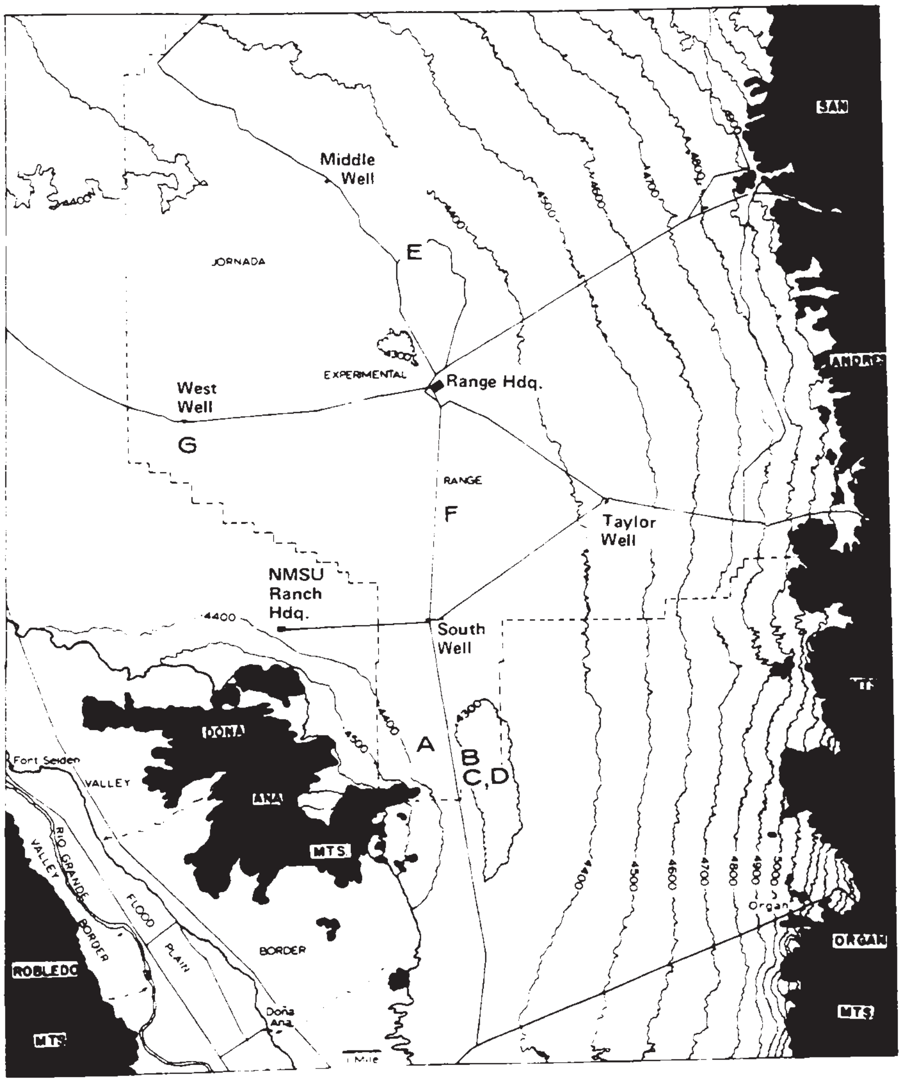


Figure 15. Topographic map of the Jornada Experimental Range showing the location of study sites A-G. Dashed lines indicate the approximate boundary of the Experimental Range.

Table 35. Some characteristics of the moisture study sites.

General physiographic situation of associated sites	Site[1/]	Landscape and slope of individual site	Soil series, variant or phase	Classification[2/]
Basin floor with run-in and adjacent fan-piedmont	A	Fan-piedmont, slope 2%	Canutio, coarse-loamy variant	Typic Torriorthent, coarse-loamy
	B	Fan-piedmont toeslopes, slope 0.5%	Stellar, wedgy subsoil variant	Ustollic Haplargid, fine
	C	Basin floor nearly level	Stellar	Ustollic Haplargid, fine
	D	Basin floor, nearly level	Reagan	Ustollic Calciorthid, fine-silty
Playa	E	Playa, level	Algerita, deep gypsum phase	Typic Calciorthid, fine-loamy
Basin floor without run-in	F	Basin floor nearly level	Onite, buried soil variant	Typic Haplargid, coarse-loamy
	G	Basin floor nearly level	Hueco	Petrocalcic Paleargid, coarse-loamy

1/ See figure 15.
2/ All soils are thermic and have mixed mineralogy.

embedded, the soils around the blocks were examined in detail with an auger, but without disturbing the blocks themselves. A pit was then dug in a similar soil, usually only several m away from the actual site of moisture measurement. The soils were described and then classified according to Soil Taxonomy (Soil Survey Staff, 1975). Tables 36 to 42 give soil texture, type of structure, dry consistence and whether or not the horizon is calcareous. Data are presented for certain soils of three general landscape positions: (1) a basin floor and an adjacent fan-piedmont that contributes water to the basin floor, (2) a playa that receives some run-in water from long drainageways leading to adjacent mountains, and (3) a broad, nearly level basin floor with good infiltration, only localized runoff, and no run-in from adjacent slopes.

Two moisture control sections are involved for the studied soils (Soil Survey Staff, 1975). The one for coarse-loamy soils extends from 20 to 60 cm; the one for fine-loamy, fine-silty, and clayey soils extends from 10 to 30 cm. The number of moist days differs in different parts of these control sections. The control section was divided into 10 cm sections and the 10 cm zone with the highest number of moist days was determined by graphical interpolation between the measured values.

52. BASIN FLOOR WITH RUN-IN, AND ADJACENT FAN-PIEDMONT

The landscape of this area (sites A, B, C, and D, fig. 10) consists of a nearly level basin floor and an adjacent alluvial fan-piedmont. The study area on the fan-piedmont has 1/2 to 2 percent slopes that contribute water to the basin floor following rainfalls of high intensity. Sites A and B (fig. 15) are on the fan-piedmont; sites C and D are on the basin floor.

SITE A

Table 36 gives information on the setting, soil moisture and soil morphology for the Torriorthent at Site A. Vegetation records (1858 and 1915) and photographs (about 1920) indicate that this site was dominated at that time by black grama. The area is now dominated by creosotebush. With this shift in vegetation there has been some erosion, and scattered small drainageways occur in the vicinity of the site.

The soil moisture units are located in a relatively stable area between the drainageways, and are emplaced in a coarse-loamy, Typic Torriorthent. The average number of moist days per year ranged from 130 days at the 10-cm depth to only 7 days at the 90-cm depth. During a wet year, 1961, there were 251 moist days at the 25-cm depth as follows: 1 January - 18 May, 17-30 July, 17 August - 28 September, and 20 November - 26 December. 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. The frequency of moist days decreases progressively with depth. The moisture control section is from 20 to 60 cm. The most moist 10 cm of this zone is moist for 108 days.

The soil (to a depth of 67 cm, see description in Appendix) is less than 5000 years old and must have formed in a climate similar to the present one. The moisture data (table 36) show that the noncalcareous B horizon is wetted most frequently and that the 2C1ca horizon is wetted somewhat less frequently.

Table 36 . Soil moisture, soil morphology and setting for a Typic Torriorthent at Site A.

Soil: Canutio, loamy subsoil variant

Classification: Typic Torriorthent, coarse-loamy, mixed, thermic

Mapping Unit: Anthony complex

Landscape position and parent material: Fan-piedmont sloping 2 percent; sediments from monzonite, rhyolite, andesite

Geomorphic surface and age: Organ, Holocene

Dominant vegetation: Creosotebush (Larrea tridentata)

Precipitation (cm)1/ 1960-1970: Mean 20.8; range 10.5 - 32.5

Horizon and depth, cm	Soil morphology (in part)2/	Soil moisture (days)3/ at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth	
A2, 0-4	Fine sandy loam, platy, crumb, soft, loose, noncalcareous	10 cm	129.9 29-227 0.61
B, 4-20	Gravelly sandy loam, massive, slightly hard, noncalcareous	25 cm	107.7 1-251 0.54
2C1ca, 20-33	Very gravelly sandy loam, massive, soft, calcareous	40 cm	60.8 0-304 0.56
3C2ca, 33-52	Gravelly sandy loam, blocky, slightly hard, calcareous	60 cm	58.5 0-224 0.67
3C3ca, 52-67	Gravelly sandy loam, massive, soft, calcareous		
3Btcab, 67-80	Gravelly sandy clay loam, blocky, slightly hard, calcareous	90 cm	6.6 0-41 0.52
4K & Ccab, 80-102	Gravelly sandy loam, massive, slightly hard, calcareous	20-30 cm4/	108
5Btcab2, 102-123	Gravelly sandy clay loam, blocky, hard, calcareous		

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and -15 bars.

4/ The 10 cm of the moisture control section (20 to 60 cm in these soils) that is moist for the longest cumulative time.

The moisture data, soil morphology, and the youthfulness of the soil indicate that silicate clay is slowly accumulating in the B horizon and carbonate in the Cca horizon at the present time.

SITE B

Table 37 gives information on the setting, soil moisture and soil morphology for the Haplargid at site B. This site is on toeslopes of the fan-piedmont, at the edge of the basin floor. While fan-toeslopes (such as this site) 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.

The soil moisture units are in a fine Ustollic Haplargid. The annual average number of moist days was 167 at the 25 cm depth and 204 days at the 60 cm depth. 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 of a variable amount of run-in water. The taxonomic moisture control section is from 10 to 30 cm. The most moist 10 cm of this zone is moist for 170 days, nearly enough to exclude the soil from Aridisols (this soil is excluded from the rule on moist days in any event, 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).

Upper horizons of this soil are quite high in clay. This should cause slow infiltration of moisture from the surface. For this reason, the depth of moisture penetration (table 37) might seem surprising at first glance. The micro-relief 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 to 30 cm deep, and 50 to 75 cm wide; it occurs along the contour and should catch moisture moving downslope. This linear depression has branches 3 to 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 holes 5 to 15 cm across 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. The combination of micro-relief, holes in the soil surface, and cracks in the Bt horizon must cause the lower horizons to be moistened quite rapidly, to depths greater than if wetting were accomplished only by downward movement through the matrix of the overlying horizons. The wedge shape of the structural units (table 37) is probably determined by the pattern of wetting from beneath as well as downward from the soil surface.

The carbonate distribution is additional evidence that the soil is wetted deeply in this way. The Stellar, wedgy subsoil variant is strongly calcareous throughout. Adjacent Argids only a few m 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 plates and wedges. 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

Table 37. Soil moisture, soil morphology and setting for an Ustollic Haplargid at Site B.

Soil : Stellar, wedgy subsoil variant

Classification: Ustollic Haplargid, fine, mixed, thermic

Mapping unit: Stellar clay loam, overflow

Landscape position and parent materials: Fan-piedmont toeslope with a slope of 1/2 percent; sediments from monzonite, rhyolite, andesite

Geomorphic surface and age: Jornada II; late-Pleistocene

Dominant vegetation: Tobosa (*Hilaria mutica*)

Average annual production: Tobosa 3,000 kg/ha 1958-61; 2,344 kg/ha 1960-66

Precipitation (cm)1/ 1960-1970: Mean 19.8; range 8.0-32.0

Horizon and depth, cm	Soil morphology (in part)2/	Soil moisture (days)3/ at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth	
A2, 0-7	Loam, crumb, blocky, slightly hard, calcareous	10 cm	172.1 59-280 0.52
B1t, 7-15	Clay loam, blocky, very hard, calcareous	25 cm	166.5 46-285 0.16
B21t, 15-43	Clay, blocky, extremely hard, calcareous	40 cm	191.1 63-301 0.21
B22t, 43-75	Clay, wedgy, platy, extremely hard, calcareous	60 cm	203.9 51-356 0.25
K & B, 75-90	Clay, blocky, very hard, calcareous	90 cm	175.5 0.321 0.31
K2, 90-112	Silty clay loam, blocky, hard, calcareous	120 cm	187.5 0-365 0.26
Bcacs, 112-133	Clay loam, blocky, hard, calcareous	12-22 cm4/	170
B1tcacsb, 133-152	Clay loam, blocky, hard, calcareous		
B2tcacsb, 152-163	Clay loam, blocky, hard, calcareous		

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and -15 bars.

4/ The 10 cm of the moisture control section (10 to 30 cm in these soils) that is moist for the longest cumulative time.

in soils that are only a few m apart.

The significance of the contribution of deeply penetrating run-in water is indicated by the relatively large number of moist days, the largest vegetal yield (by far) of the soils studied, and by the lack of significant correlation between moist days and precipitation (table 37).

SITE C

Table 38 gives information on the setting, soil moisture and soil morphology for the Ustollic Haplargid at site C. This site occurs on the basin floor, which is nearly level. Run-in water from the adjacent slopes drains slowly to a playa about 2 km south of these sites. The soil surface, morphology. and moisture data (tables 37, 38) indicate that present genetic processes of this soil differ from those of the soil at site B. The depressions and holes at site B are not present at site C; moistening of this soil is accomplished by wetting along a front from the soil surface downward. As evidence, the number of moist days decreases regularly from the top into the upper B2t horizon.

The most moist 10 cm of the 10 to 30 cm control section is moist for 109 days, far less than the 170 days for site B. The difference at greater depths is even greater. At 90 cm, site B is moist for 175 days whereas site C is moist for only 53 days. Comparing data inside and outside the cylinder, an average of 36 percent of the moist days was attributable to run-in.

Outside the cylinder, the number of moist days at the 10- through 60-cm depths was significantly correlated with annual precipitation. Inside the cylinder, all correlation values were significantly correlated with annual precipitation. Inside the cylinder, all correlation values were higher than those outside the cylinder.

However, available soil moisture at all depths, both with and without run-in, is less frequent than for the Paleargid at site G, discussed later. This is attributed to smooth-topped plates in the A2 horizon and to higher percentages of clay and silt. Such horizons have a tendency to "seal" when wetted (section 57).

The calcareous A2 horizon is common to many soils in this basin-floor position. The occurrence of noncalcareous A3 and B21t horizons and the underlying calcareous B22t horizon in the soil at site C reflects this frontal pattern of wetting. 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.

SITE D

Table 39 gives information on the setting, soil moisture and soil morphology for the Calciorthid at site D. This site is about 75 m from site C. Over all sampling depths, there are about 33 percent more moist days outside the cylinder, attributable to run-in. Nearly all correlations between days with soil moisture and precipitation were significant. The most moist 10 cm of the moisture control section is moist for 92 days, similar to the soil at site C and about half that for the soil at site B.

Table 38. Soil moisture, soil morphology and setting for an Ustollic Haplargid at Site C.

Soil: Stellar

Classification: Ustollic Haplargid, fine, mixed, thermic
Mapping Unit: Stellar clay loam, overflow
Landscape position and parent material: Nearly level basin-floor sediments from monzonite, rhyolite, andesite

Geomorphic surface and age: Jornada I; late mid-Pleistocene

Dominant vegetation: Tobosa (Hilaria mutica)

Average annual production: Tobosa 1,055 kg/ha 1960-70; 755 kg/ha 1960-66

Precipitation (cm)1/ 1960-1970: Mean 19.6; range 11.8-32.0

Horizon and depth, cm	Soil morphology (in part)2/	Soil moisture (days)3/ at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth	Includes run-in	Excludes run-in
A2, 0-5	Clay loam, platy, slightly hard, calcareous	10 cm	134.4 33-205 0.65	91.8 18-172 0.79
A3, 5-9	Clay loam, blocky, hard, noncalcareous	25 cm	82.4 0-205 0.80	40.4 0-179 0.83
B21t, 9-23	Clay, prismatic, blocky, very hard, noncalcareous	40 cm	51.3 0-185 0.71	32.7 0-186 0.72
B22t, 23-44	Clay loam, prismatic, blocky, very hard, calcareous	60 cm	48.0 0-193 0.66	33.1 0-182 0.72
B23tca, 44-67	Clay, prismatic, blocky, very hard, calcareous	90 cm	52.6 0-196 0.50	32.8 0-181 0.71
B24tca, 67-87	Clay, prismatic, blocky, very hard, calcareous	120 cm	51-7 0-176 0.42	37.5 0-203 0.66
K & Bt, 87-118	Clay loam, blocky, hard, calcareous	12-22 cm4/	109	
K21, 118-134	Clay loam, platy, hard, calcareous			

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and-15 bars.

4/ The 10 cm of the moisture control section (from 10 to 30 cm in these soils) that is moist for the longest cumulative time.

Table 39 . Soil moisture, soil morphology and setting for an Ustollic Calciorthid at Site D.

Soil: Reagan

Classification: Ustollic Calciorthid, fine-silty
Mapping Unit: Reagan clay loam
Landscape position and parent material: Nearly level basin-floor sediments from sedimentary rocks - limestone, sandstone and shale

Geomorphic surface and age: Petts Tank, late-Pleistocene

Dominant vegetation: Burrograss (Scleropogon brevifolius)

Average annual production, 1960-1970: Burrograss 651 kg/ha

Precipitation (cm)1/ 1960-1970: Mean 19.6; range 11.8-32.0

Horizon and depth, cm	Soil morphology (in part)2/	Soil moisture (days)3/ at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth.		
			Includes run-in	Excludes run-in
A, 0-4	Clay loam, platy, slightly hard, calcareous	10 cm	114.9 46-192 0.88	78.2 0-175 0.78
A3, 4-10	Silty clay loam, blocky, very hard, calcareous	25 cm	69.6 0-165 0.82	45.3 0-162 0.87
B1, 10-26	Clay loam, blocky, slightly hard, calcareous	40 cm	47.2 0-172 0.67	28.3 0-173 0.70
B21ca, 26-53	Silty clay loam, prismatic, blocky, hard, calcareous	60 cm	49.7 0-181 0.51	29.0 0-174 0.70
B22ca, 53-79	Clay loam, prismatic, blocky, hard, calcareous	90 cm	34.5 0-181 0.68	27.3 0-155 0.69
K & B, 79-95	Clay loam, blocky, slightly hard, calcareous	120 cm	38.0 0-181 0.67	27.3 0-155 0.69
B2tcab, 95-122	Sandy clay loam, prismatic, blocky, hard, calcareous	12-22 cm4/	92	

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and -15 bars.

4/ The 10 cm of the moisture control section (from 10 to 30 cm in these soils) that is moist for the longest cumulative time.

This soil has formed in high-carbonate parent materials (table 39). Studies of a similar soil (Reagan 60-17) not far from this site indicate that some carbonate originally in the parent materials still is present in upper horizons (section 191). Present moisture is clearly insufficient to remove carbonate from upper horizons. Further, since this soil was formed in part during a Pleistocene pluvial, not even the greater effective moisture of a pluvial was enough to remove the carbonate from upper horizons. As with the Haplargid at site C, the number of moist days due to run-in are considerable, but probably reduced because of "sealing" of the surface.

53. 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 area with the moisture blocks has run-in about twice every three years.

The soil moisture blocks are in a fine-loamy Typic Calciorthid. The soil has apparently formed primarily in alluvium resting on gypsum of lacustrine origin. 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. The moisture data (table 40) show that the A1 and B11 horizons are moistened most frequently. These horizons are still strongly calcareous; this is probably due in part to the highly calcareous 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.

Over all depths with moisture, there was an average of about 8 moist days each year attributable to run-in. This is considerably lower than for sites B, C and D, and is probably due to the smaller local watershed. Also, observations indicate that water from the mountains and intervening areas does not often reach the playa in large amounts. Moist days at only one depth outside and inside the cylinder were significantly related to precipitation. The most moist 10 cm of the moisture control section is moist for 104 days where run-in is included. This depth has zero moist days where run-in is excluded (table 40).

54. 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 the upper horizons are sandy.

SITE F

Table 41 gives information on the setting, soil moisture and soil morphology for the Haplargid at 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,

Table 40 . Soil moisture, soil morphology and setting for a Typic Calciorthid at Site E.

Soil: Algerita, deep gypsum phase

Classification: Typic Calciorthid, fine-loamy, mixed, thermic

Mapping unit: Not in Desert Project

Landscape position and parent material: Level playa sediments derived from mainly sedimentary rocks - limestone, sandstone and shale

Geomorphic surface and age (tentative): Floor of playa (latest Pleistocene-Holocene?)

Dominant vegetation: Tobosa (Hilaria mutica) and burrograss (Scleropogon brevifolius)

Average annual production, 1960-1970: Tobosa 1291 kg/ha; burrograss 637 kg/ha

Precipitation (cm)1/ 1960-1970: Mean 18.8; range 8.9-31.1

Horizon and depth, cm	Soil morphology (in part)2/	Soil moisture (days)3/ at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth.		
			Includes run-in	Excludes run-in
C, 0-3	Fine sandy loam, single grain, loose, calcareous	19 cm	124.0 32-211 0.50	112.7 36-176 0.45
A1, 3-12	Fine sandy loam, massive, platy, hard, calcareous	25 cm	81.2 0-227 0-46	71.5 0-190 0.46
B11, 12-31	Clay loam, prismatic, blocky, very hard, calcareous	40 cm	45.6 0-168 0-50	38.1 0-146 0.62
B12, 31-50	Sandy clay loam, prismatic, blocky, very hard, calcareous	60 cm	6.8 0-30 0.72	1.9 0-21 -0.21
B21ca, 50-65	Silty clay loam, prismatic, blocky, slightly hard, calcareous	90 cm	0	0
B22ca, 65-90	Silty clay loam, prismatic, blocky, slightly hard, calcareous	120 cm	0	
B23ca, 90-112	Silty clay loam, prismatic, blocky, hard, calcareous	12-22 cm4/	104	0
2C1ca, 112-120	Loam, prismatic, blocky, slightly hard, calcareous			
2C2ca, 120-138	Sandy loam, massive, very hard, calcareous			

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and -15 bars.

4/ The 10 cm of the moisture control section (from 10 to 30 cm in these soils) that is moist for the longest cumulative time.

Table 41. Soil moisture, soil morphology and setting for a Typic Haplargid at Site F.

Soil: Onite, buried soil variant

Classification: Typic Haplargid, coarse-loamy, mixed, thermic

Mapping unit: Not in Desert Project

Landscape position and parent material: Nearly level basin floor; sandy eolian deposit over basin-floor sediments of mixed origin

Geomorphic surface and age: Apparent eolian accumulation (Holocene?) on La Mesa surface (mid-Pleistocene).

Dominant vegetation: Sparse mesa dropseed (*Sporobolus flexuosus*)

Average annual production, 1960-1970: Perennial grasses, 23 kg/ha.

Precipitation (cm)1/ 1960-1970: Mean 19.3; range 10.8-29.8

Horizon and depth, cm	Soil morphology (in part)2/	Soil moisture (days)3/ at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth.	
B2t, 0-18	Fine sandy loam, blocky, slightly hard, noncalcareous	10 cm	192.0 97-301 0.51
B31t, 18-34	Fine sandy loam, massive, slightly hard, noncalcareous	25 cm	173.5 62-318 0.58
B32t, 34-44	Loamy sand, massive, soft	40 cm	121.9 0-312 0.63
B1tcab, 44-60	Sandy loam, prismatic, blocky, hard, calcareous	60 cm	90.2 0-319 0.44
B21tcab, 60-76	Sandy clay loam, prismatic, blocky, hard, calcareous	90 cm	18.7 0-179 0.32
B22tcab, 76-90	Sandy clay loam, prismatic, blocky, hard, calcareous	20-30 cm4/	174
B23tcab, 90-103	Sandy clay loam, prismatic, blocky, hard, calcareous		
K2b, 103-126	Sandy clay loam, blocky, very hard, calcareous		

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and-15 bars.

4/ The 10 cm of the moisture control section (which is 20 to 60 cm in these soils) that is moist for the longest cumulative time.

Ares and Wright, 1972). By the end of that drouth, black grama cover was reduced to one percent of the predrouth average and it has not increased since. Production of perennial grasses is very low (table 41).

The average annual number of moist days ranged from 192 at the 10 cm depth to 19 at the 90 cm depth. There were 318 moist days at 25 cm depth in 1962, and the most moist 10 cm of the moisture control section is moist for 174 days. This is nearly too moist for an Aridisol. The soil moisture at this site is considerably greater than in the soil at site E even though this soil receives essentially no run-in. This greater number of moist days is due to coarser texture, which leads to faster infiltration and less water required to bring the soil to the tension limit of moist.

Only the number of moist days at the 40 cm depth was significantly correlated with annual precipitation. 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 <u>et al</u>., 1972).

The soil at the land surface has formed in a sandy eolian deposit considerably younger than the buried horizons below, and has been truncated since the Bt horizon is at the surface. This soil is noncalcareous to a depth of 44 cm and is moistened fairly frequently to that depth. 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

Table 42 gives information on the setting, soil moisture and soil morphology for the Petrocalcic Paleargid at 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 average number of moist days ranged from 212 at the 25 cm depth to 97 at the 68 cm depth. There was moisture at the 25 cm depth for the entire year in 1961, except 11 June - 10 July. There was considerably more moisture at this site than at site F, particularly at the deeper depth. The most moist 10 cm of the moisture control section is moist for 212 days. This soil is too moist for the Petrocalcic Paleargids, which "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." (Soil Survey Staff, 1975).

The greater number of moist days (table 42) than at site F is partly attributed to the greater thicknesses of coarser-textured horizons that occur above the clay maximum in this soil. Infiltration rates should be relatively rapid in the uppermost two horizons, a sand and light fine sandy loam. Such coarse surface horizons act as a mulch, due to their low capacity to conduct water upward by capillarity. Also, the petrocalcic horizon (at 68 cm) retains water in the moisture control section, which extends to 60 cm, just above the petrocalcic horizon. 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,

Table 42. Soil moisture, soil morphology and setting for a Petrocalcic Paleargid at Site G.

Soil: Hueco

Classification: Petrocalcic Paleargid, coarse-loamy, mixed, thermic
Mapping unit: Not in Desert Project
Landscape position and parent material: Nearly level basin-floor sediments of mixed origin.

Geomorphic surface and age: La Mesa, mid-Pleistocene

Dominant vegetation: Mostly black grama (Bouteloua eriopoda); scattered mesa dropseed (Sporobolus flexuosus) and soaptree yucca (Yucca elata)

Average annual production: Perennial grasses, 346 kg/ha.

Precipitation (cm)[1/] 1961-1970: Mean 18.9; range 11.5-34.9

Horizon and depth, cm	Soil morphology (in part)[2/]	Soil moisture (days)[3/] at stated depths: the mean, range and simple correlation (r) between annual precipitation and days of moisture at each depth.	
C, 0-5	Sand, loose, soft, single grain, massive, noncalcareous	10 cm	193.9 64-321 0.51
A2, 5-10	Fine sandy loam, massive, soft, noncalcareous	25 cm	212.2 99-336 0.64
B1t, 10-23	Fine sandy loam, massive, slightly hard, noncalcareous	40 cm	158.5 32-333 0.67
B21t, 23-36	Fine sandy loam, massive, slightly hard, noncalcareous	53 cm	116.8 0-350 0.70
B22tca, 36-46	Fine sandy loam, massive, slightly hard, calcareous	68 cm	96.5 0-278 0.71
B3ca, 46-71	Sandy loam, blocky, slightly hard, calcareous	20-30 cm[4/]	212
K1, 71-79	Very gravelly sandy loam, crumb, loose, calcareous		
K2m, 79-90	Carbonate-cemented material, massive, extremely hard, calcareous		

1/ Annual precipitation, excluding daily amounts less than 0.63 cm.

2/ See Appendix for complete description.

3/ Number of days annually with the moisture potential between 0 and -15 bars.

4/ The 10 cm of the moisture control section (from 20 to 60 cm in these soils) that is moist for the longest cumulative time.

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.

A large pipe (see section 152 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 that begins at about the same depth as that in the described soil. Grama grass was well developed over the pipe and there appeared to be no difference in the vegetation of soils in the pipe and soils adjacent to the pipe.

55. SURFICIAL FEATURES AND PROCESSES

56. THE SOIL SURFACE AND UPPER HORIZONS

57. Surficial sand and crust

A thin (about 1 mm or less) discontinuous layer of reddish brown sand occurs on the surface of many soils regardless of color and texture of the surface horizon. This sand appears to represent recent and current eolian additions. In many places some of this sand has moved into the A horizon, occurring beneath pebbles and between plates where its presence is revealed by its color and texture.

In low-gravel materials with little clay a smooth crust, usually less than 1 mm thick, is common at the very surface of the soil (fig. 16). It may be partly breached during dust storms but seems to reform quickly. It is thought to be due to drying of surface water following torrential rains, when the infiltration rate is exceeded and water is standing or moving slowly over the soil surface. When the water dries, the fine particles it contains settle on the surface, forming a smooth film. The film and adhering fine earth constitute the crust. Miller (1971) shows a photograph of what may be a similar film at the top of an irrigation furrow. Miller cites these films as being more important than vesicles in determining infiltration.

Polygonal cracks form on surfaces of materials with more clay. Such cracks are most prominent in clayey materials of Isaacks' Lake Playa (fig. 17; section 189). The larger cracks range up to several cm wide and delineate polygons. The upper 5 cm either breaks easily or is already broken into plates and blocks. Where these occur along margins of the cracks the fragments fall into them during dry seasons. This is a major cause for mixing of playa materials (section 189).

58. Desert pavement and pebble coatings

Prominent concentrations of coarse fragments on the surface have been termed "desert pavement". The pavement may be due to several factors. In very gravelly materials the pavement is due simply to the presence of pebbles in the deposit. In other instances, particularly in older soils, the concentration of pebbles is due to deflation of fines by water and/or wind. The number of coarse fragments on the surface can be considerably increased and their size decreased by fracture in place. This is indicated by clusters of rock fragments that fit perfectly when placed together. This feature is common on Pleistocene surfaces but is generally rare on Holocene surfaces.

In some soils coarse fragments are abundant both on the surface and in upper horizons. But many soils have concentrations of pebbles at the surface and few or no pebbles for a few cm beneath the surface (fig. 18). Another explanation is required for this; Springer (1958), after field observations and laboratory experiments, postulated that the pebbles are lifted slightly when the soil swells after it is moistened. When the soil dries it shrinks, forming cracks in the fine earth. Pebbles cannot move into the cracks because of their size, but fine earth can. If this process is repeated many times, the filling in of fine earth beneath the pebbles and subsequent swelling when wetted would lead to

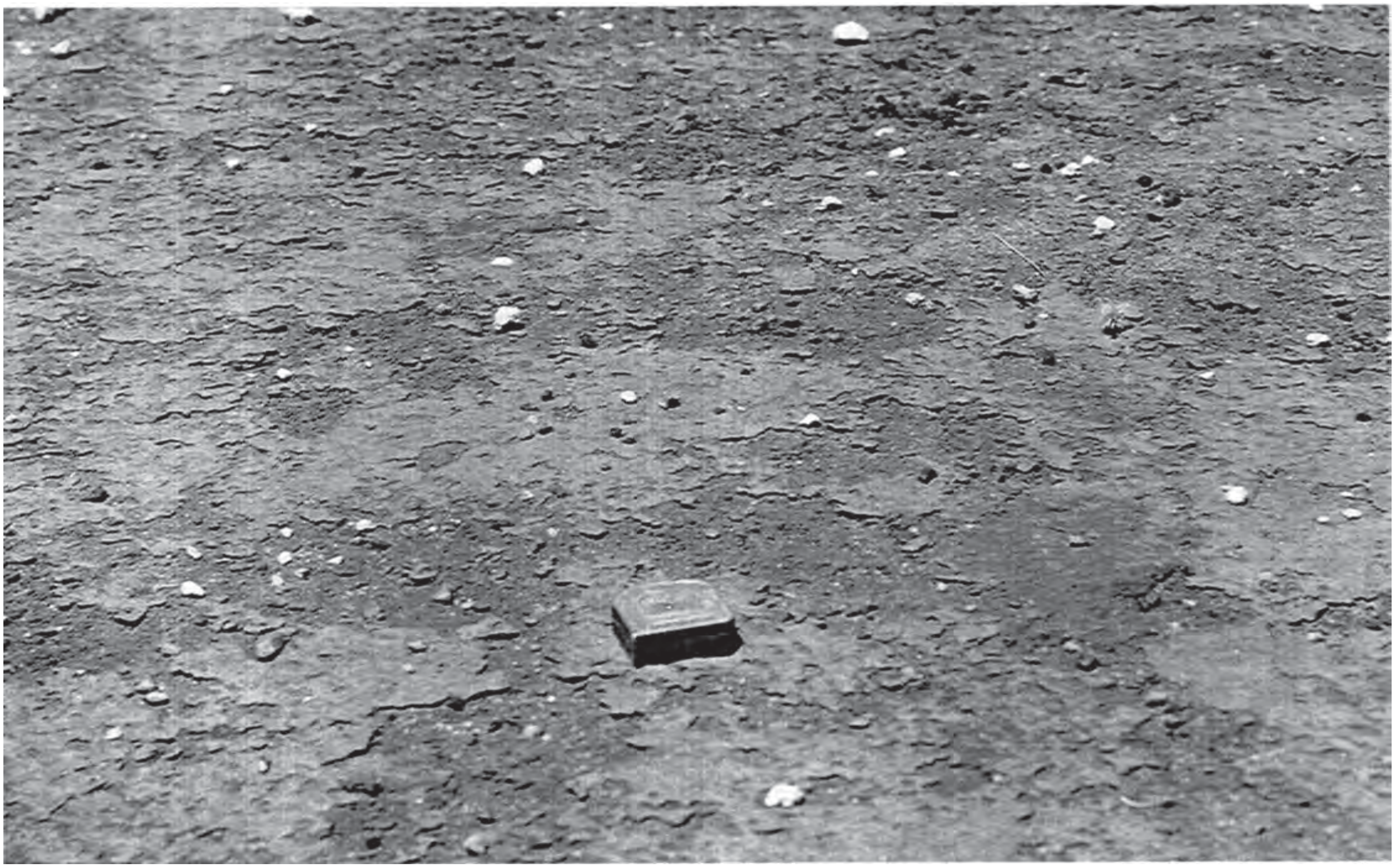


Figure 16. Surface of Cruces soil, upper La Mesa, after a spring dust storm. Wind-blown sand has breached the thin surficial crust. The tape in the center is 2 in (5 cm) wide.

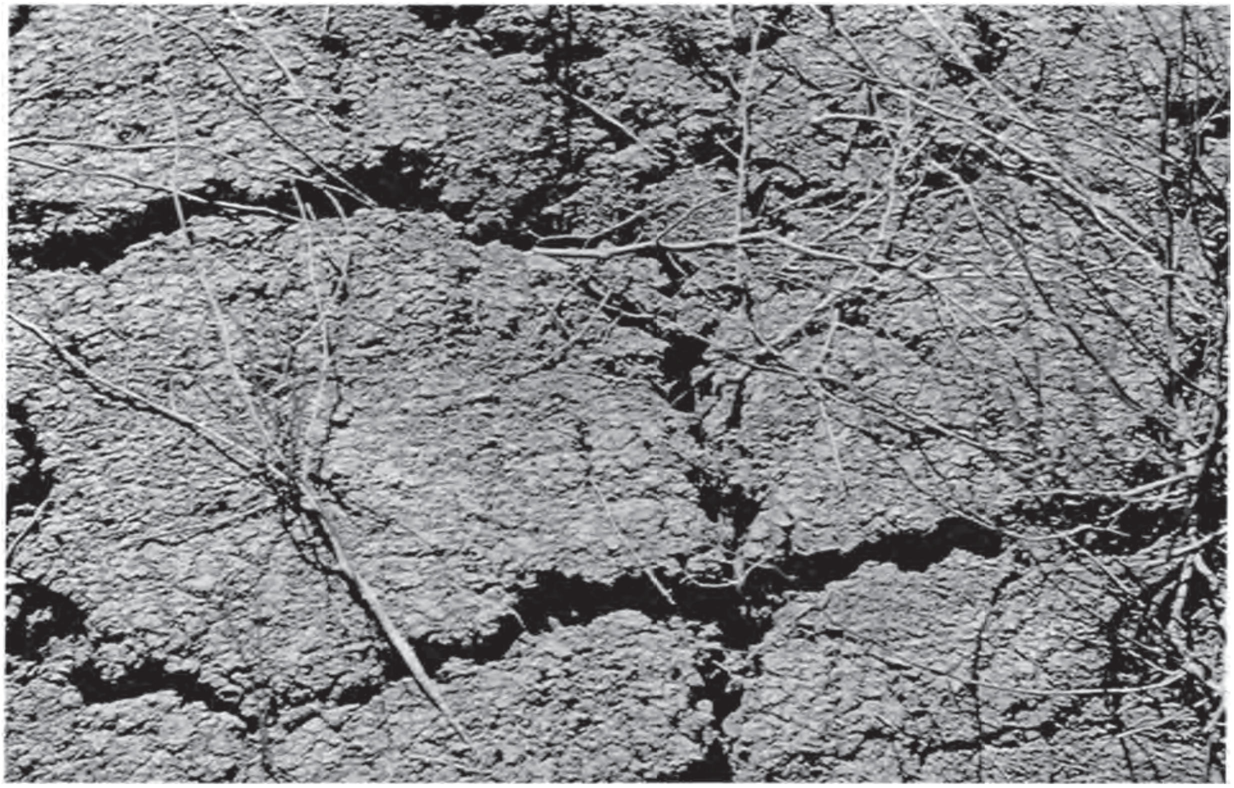


Figure 17. Surface of Dalby 60-16, a Typic Torrert, during a dry time. Width of the crack shown is about 3 cm. The large polygons are cracked into much smaller ones and some of the material adjacent to the cracks falls or is washed into them.

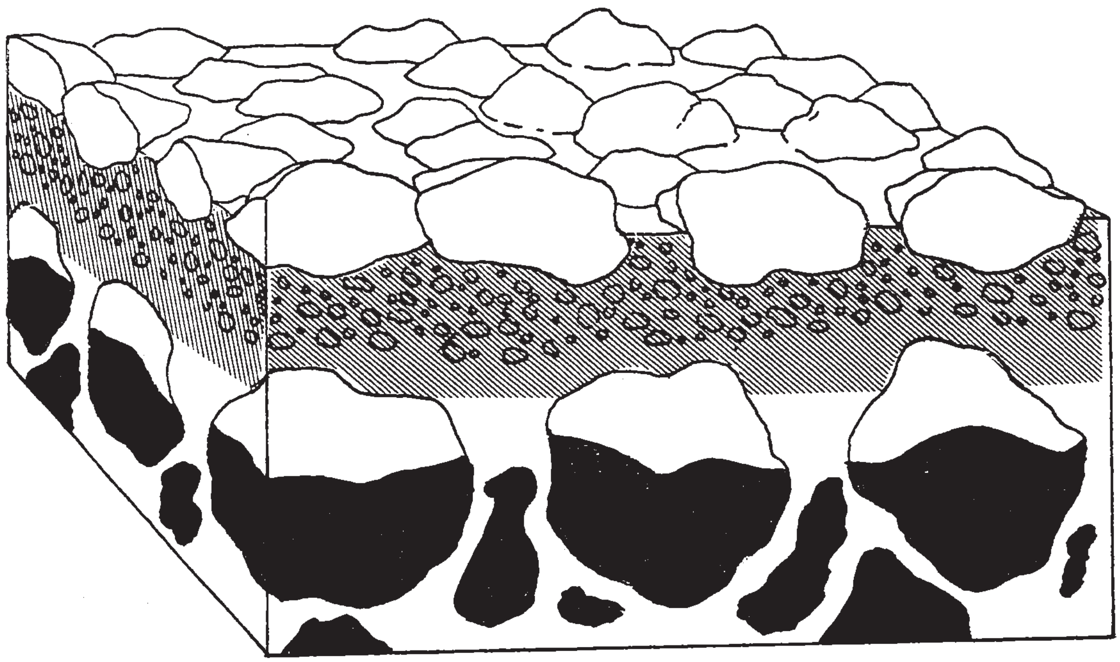


Figure 18. Diagram of a soil surface and upper horizons that are common in Calciorthids and Paleorthids of stablest ridge crests (e.g., Monterosa 66-2). The desert pavement is underlain by a thin, vesicular A horizon. More pebbles are on the surface than in the vesicular horizon (diagonal pattern) just beneath the pavement. The top of the B horizon has carbonate-free pebble tops but carbonate-coated pebble bottoms. Depth to the pebble tops is about 5 cm.

upward thrust. Over time, most or all pebbles would move to the surface. Freezing and thawing would produce a similar effect (Springer, 1958). Since both wetting and drying, and freezing and thawing cycles are common in the study area, it seems likely that these processes are at least partly responsible for concentrations of pebbles on the surface where it is underlain by nongravelly horizons.

Very gravelly soils with macroscopic carbonate throughout often have a zone (at about 5 cm depth) in which the tops of many pebbles are carbonate-free, but the bottoms are prominently coated with carbonate (fig. 18). If the pebbles are of noncarbonate rock, some of their tops may be stained with a thin film of reddish brown clay and associated iron oxides. The clay coatings may be relicts from an earlier period when most or all of the B horizon was carbonate-free. This shallow zone is wetted fairly frequently, and the clay coatings may have been preserved because the amount of moisture on pebble tops is still enough to keep them free of carbonate. Another interpretation is that the coatings may in part reflect current and localized clay accumulation at places where moisture can concentrate near the surface and where carbonate has not yet accumulated. The zone of carbonate-free pebble tops may represent the top of a stable zone that is unaffected (or little affected) by the shrink-swell, freeze-thaw cycles resulting in upward movement of pebbles discussed above.

On stable surfaces, "desert varnish," or stain, occurs on coarse fragments other than limestone. The composition of desert varnish has been determined by Engel and Sharp (1958) and by Hooke et al. (1969) to be mainly iron and manganese oxides. The varnish is commonly black on that part of the pebble above the land surface. A reddish brown, red, or yellowish red color marks the part of a pebble that has been below the surface of soils with argillic horizons (fig. 19). Colors are redder on Holocene surfaces than on Pleistocene surfaces. Where considerable deflation has occurred, the former land surface is marked by the top of a band of these colors now above the present surface. In Calciorthids and Paleorthids the varnish on pebbles of stablest parts of ridge crests is usually black. Where the pebbles are small and rest on the surface instead of partly in the soil, some are entirely coated with black varnish. Reasons for this are not known, but it may be due in part to rotation of pebbles by frost, exposing all parts of the pebbles to all aspects of the atmosphere.

59. Thin upper horizons

The A horizons of soils in the arid part of the study area are commonly light-colored and thin (usually about 5 cm). Some qualify as A2 horizons. Many soils of the semiarid zone have A horizons that qualify as A1 horizons. A horizons that do not qualify as either A1 or A2 are designated simply A (section 28).

Thin A horizons are generally vesicular in part, as described by Springer (1958). Vesicles can form rapidly since a well-developed vesicular horizon was observed in a deposit filling a tire track known to be less than two years old. This agrees with the work of Springer (1958) who formed vesicles in the laboratory and attributed their formation to the entrapment of air below infiltrating water. Air bubbles moved to the soil surface and escaped, in some instances leaving openings behind. Platy structure is another feature of thin upper horizons. This may be due to frequent wet-dry and freeze-thaw cycles in the study area. In laboratory experiments Miller (1971) observed that platy structure was

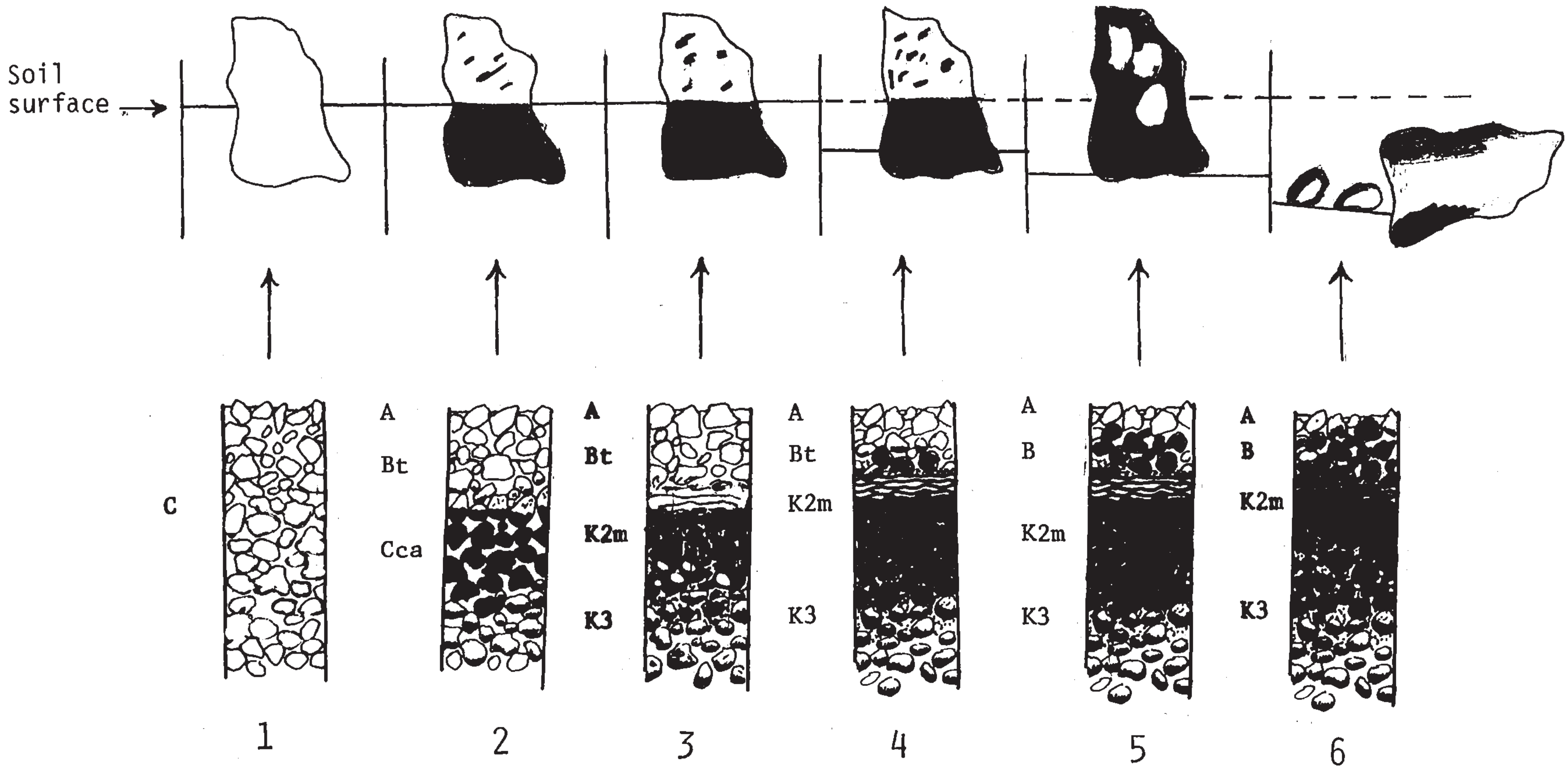


Figure 19. The evolution of various coatings on rhyolite cobbles, and relation of the coatings to chronology and soil development. The illustrative cobbles are set in the soil at depths ranging from several to a few cm but the upper part is exposed to the atmosphere, as shown. In profiles, carbonate accumulations are shown in black for clarity. In cross sections of the soil surface and cobble, black designates the coatings indicated for each of the six steps. Solid line represents the present ground level; dashed line represents a former ground level. (1) In freshly deposited parent materials: no coatings. (2) In Holocene Haplargids: discontinuous black coatings on above-ground portion of pebble; reddish brown coating on below-ground portion that is in the Bt horizon. (3) In a Haplargid of late-Pleistocene age: discontinuous black coatings on above-ground portions, reddish brown and red coatings on below-ground portion that is in the Bt horizon. (4) In Paleargid of late or mid-Pleistocene age with some soil truncation: the reddish brown coating once below the surface of the ground is now above the ground because of soil truncation. (5) In Paleorthid of late or mid-Pleistocene age: with continued soil truncation the cobble gradually approaches the surface; only very small parts remain below the ground surface. Many coarse fragments are almost wholly stained black. (6) In Paleorthids of late or mid-Pleistocene age: with continued truncation, additional pebbles are moved to the surface. Some of these pebbles are partially to wholly coated with carbonate that accumulated on the pebble when it was in a subsurface horizon. By this time, many coarse fragments involved in step 5 have moved downslope in dissected terrain.

induced by repeated wetting and drying. Both vesicle formation and the formation of platy structure may be related to brief periods when the thin upper zone is saturated or near saturation (section 49).

One kind of light-colored A horizon occurs in highly calcareous soils ranging from several hundreds to scores of thousands of years in age (see pedons 60-14, 60-15, 60-17, 65-1, 66-6, 66-7, 68-7, Appendix). Conclusive evidence for eluviation of clay or iron has not been found in these soils.

A somewhat loose, mixed-appearing horizon occurs in places at the surface, and rests abruptly on another A horizon or on a B horizon. This kind of A horizon ranges from about 1 to 3 cm thick and has been observed only in relatively coarse-textured materials, generally sandy loams or loamy sands. Occurrence of this A horizon in materials of this texture alone suggests that it can be caused by disturbance (possibly by freeze-thaw cycles, or by soil fauna); or, its looseness and lack of structure may be due simply to the relatively coarse texture.

Some A horizons have evidence of clay eluviation and are designated A2 horizons. These horizons are generally most readily seen in nongravelly materials of relatively fine texture, because their gray color (in contrast to the underlying Bt horizon, which is redder) is most apparent in such horizons. The evidence of eluviation is generally found both in the eluvial horizon itself and in the underlying illuvial horizon. Bucklebar variant 59-8 illustrates (table 43); its A2 horizon has been well preserved by a thin deposit of overlying C horizon material. In thin section, many of the coarser grains in the A2 horizon are free or nearly free of clay. In the underlying B2t, sand grains are prominently coated with oriented clay. Both clay and iron increase from A to B (table 43). These factors support an A2 designation. In pedon 59-8 the A2

* * *

Table 43. Data for upper horizons of Bucklebar variant 59-8.

Horizon	Depth	Sand[1/]	Silt[1/]	Clay[1/]	Extractable Fe	Carbonate < 2 mm	Organic carbon
	cm	pct	pct	pct	pct	pct	pct
C	0-5	78	13	10	0.7	0.2	0.1
A2	5-13	70	19	12	0.8	0.1	0.2
B21t	13-28	62	12	26	1.0	1	0.3

1/ Carbonate-free basis.

* * *

horizon has developed in a deposit of Holocene age and must be presently forming.

The A2 horizon commonly occurs at the surface or is overlain by one to several cm of disturbed-appearing A horizon discussed previously. Many A2 horizons are very susceptible to erosion because of their thinness and common occurrence at the very surface of the soil. Thus they have been truncated in many areas. In places these A2 horizons might appear to be young sedimentary features because they occur in broad, topographic lows and thin indistinct layers of reddish brown sand occur between some of the grayish plates. This gives a stratified appearance. This kind of A2 horizon may occur in topographic lows because such areas are often the stablest, best-vegetated parts of a landscape that is being eroded in other places. Sand of eolian origin could move into the soil through polygonal cracks which are often present in surfaces of soils of topographic lows, and could move along plates to suggest stratification. These grayish horizons also occur on narrow ridges where such a thin, uniform layer of sediment at the surface could not be deposited. These horizons are far too consistent in their morphology and in their genetic relation to underlying horizons, for a given soil, to owe their character to sedimentation.

In soils with pervious parent materials (e.g., pedon 67-4, Appendix), A2 horizons have probably gained some clay since the start of soil formation because of atmospheric additions. Such gain in clay would not conflict with the viewpoint that much of the clay in the B2t horizon of such soils probably was derived from the atmosphere. Such atmospheric additions of clay are suggested by the common coarse texture of the materials and by the lack of weathering.

The silicate clay percentage of A horizons has a narrow range (table 44). The range of 8 to 14 percent clay for the A horizon encompasses most Argids. In rhyolitic alluvium the clay in the A horizon tends to be higher for soils of late-Pleistocene and older soils than for the Holocene soils. Apparently there is a strong tendency for developmental processes to result in a narrow range in clay percentages for A horizons of Argids.

Table 45 compares the uppermost cm with horizons below. No large differences are apparent in the uppermost cm. Nearly all are low in organic carbon. The similarity in particle size for the uppermost cm of Monterosa 66-2 and Upton 66-5 is supporting evidence for an appreciable eolian addition since parent materials and related particle size distribution are quite different for the two soils. Soils on stable sites and formed in very gravelly rhyolitic alluvium tend to have more silt and very fine sand in surface horizons (Cruces variant 59-16 and Monterosa 66-2, table 45) than do soils formed in nongravelly materials. Pinaleno 67-4 and Caralampi 59-15 (Appendix) also illustrate.

Table 44. Silicate clay percentages[1/] for A, A1 or A2 horizons of Argids, and the maximum clay percentage in the associated B2t horizon, by parent materials and climate.

Pedon	Age	Clay A, A1, A2	Clay B2t
Rhyolitic alluvium: arid			
66-16	Late-Holocene	9	12
67-4	Mid-Holocene	8	15
67-5	Latest Pleistocene	9	18
59-15	Late-Pleistocene	12	28
60-1	Late-Pleistocene	13	22
59-16	Late-Pleistocene	14	23
70-8	Late mid-Pleistocene	14	34
Rhyolitic alluvium: semiarid			
60-23	Late mid-Pleistocene	12	
60-5	Mid-Pleistocene	14	74
Monzonitic bedrock or local colluvium: semiarid			
66-9	Pleistocene	12	17
66-10	Pleistocene	12	23
66-15	Pleistocene	12	27
70-1	Pleistocene	10	24
Ancient river alluvium: arid			
61-7	Mid-Pleistocene	10	18
61-8	Mid-Pleistocene	8	15
66-12	Mid-Pleistocene	9	23
72-1	Mid-Pleistocene	10	19
72-2	Mid-Pleistocene	13	18
72-3	Mid-Pleistocene	13	21

1/ Carbonate-free basis

Table 45. Laboratory data for uppermost one cm and two horizons below.

Depth[1/]	Sand, mm 0.25-0.1	Sand, mm 0.1-0.05	Silt	Clay[2/]	> 2 mm Vol.	Carbonate	Organic carbon
cm	pct	pct	pct	pct	pct	pct	pct
Petrocalcic Paleargid (Cruces 59-16), rhyolite alluvium							
0-1	17	31	30	13	15[3/]	-	0.44
1-5	18	28	30	14	25	-	0.29
5-15	19	24	23	18	40	tr	0.37
Typic Haplargid (Dona Ana 65-7), ancient river alluvium							
0-1	34	15	9	11	-	1	0.17
1-4	42	17	7	11	-	1	0.21
4-10	44	19	7	12	-	1	0.20
Ustollic Paleorthid (Monterosa 66-2), rhyolitic alluvium							
0-1	28	20	27	14	50	1	0.16
1-5	26	19	27	18	10	2	0.23
4-13[5/]	32	19	16	18	40	5	0.71
Typic Torriorthent (Canutio 66-3), rhyolitic alluvium							
0-1	21	21	22	9	40	tr(s)	0.15
1-5	21	22	23	8	15	tr(s)	0.13
5-15	19	20	20	11	25	tr(s)	0.20
Typic Paleorthid (Upton 66-5), alluvium from calcareous sedimentary rocks							
0-1	28	25	28	11	50[4/]	12	0.19
1-5	21	23	34	18	15[4/]	22	0.14
5-8	20	22	36	17		27	0.11

1/ 0-1 cm includes desert pavement if present but measured from surface of fine earth within which pebbles are partially embedded.
2/ Carbonate-free basis.
3/ Desert pavement removed.
4/ < 20 mm.
5/ Adjacent pedon.

60. Clay eluviation

The question arises why eluviation of clay from the upper 5 cm of soils is common, relatively rapid, and apparently enhanced by absence or near-absence of carbonate. The idealized moisture profile (section 49) that results upon rapid wetting of initially dry soil with a morphology that leads to low hydrodynamic dispersion (Rose, 1973) should be conducive to eluviation of clay from the surficial zone. Once saturated, the fabric of the surficial zone would lose the coherence imparted by the presence of air-water interphase. The state of lowered coherence would occur immediately after the fabric had been subjected to both the mechanical stress of the impact of water droplets if the precipitation event were rainfall and the very large forces generated when initially dry clay is wetted. Clay should be brought into suspension by the disruptive forces and would be moved downward. If the water movement is frontal (hydrodynamic dispersion, low), according to the model of wetting discussed in section 49, the distance the clay is moved would be short, probably not exceeding a few cm. If the water movement is by mass flow down continuous large voids (high hydrodynamic dispersion), the clay may be moved several dm or more.

Implicit in the model discussed in section 49 is rapid wetting of the upper part of the soil, with the rapidity increasing toward the soil surface. The forces generated when dry clay is wetted rapidly commonly are highly disruptive. Kemper *et al*. (1974) describe two causes of disruption in rapid wetting: (1) Water drawn into the center of an aggregate after the perimeter has been wetted causes compression of air. Pressure builds up until the air bursts through the wetted periphery of the aggregate causing sloughing. (2) Rapid, non-uniform swelling results in very local differences in expansion across changes in water contents, which in turn leads to large shear stresses. G. G. S. Holmgren (personal communication) attaches importance to the osmotically-induced swelling pressures due to the transitory greater ion concentration near the clay surface.

Dispersion of clay is favored by the combination of a high Sodium Adsorption Ratio (SAR) and a low Total Dissolved Salts (TDS).

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad \text{(Richards, 1954)}$$

As SAR increases the proportion of the exchange capacity satisfied by sodium rises. There is evidence that dispersed clay occurs as associations of platelets (referred to both as "tactoids" and "domains" by different workers) and that in a situation where the counter cations (ions that satisfy charge deficiency) are largely calcium with some sodium, that the sodium occurs on the outside of the tactoid (Shainberg and Caiserman, 1971; Shainberg, Bresler and Klausner, 1971). McNeal and Coleman (1966) and McNeal (1968), to rationalize experimental data on the influence of sodium saturation on hydraulic conductivity and swelling, postulate that different tactoids are either completely calcium or sodium saturated. For purposes here either proposal may be invoked. Both lead to a much more sensitive relationship between modest proportions (less than 10 percent) of exchangeable sodium and dispersibility than would be predicted on the assumption that sodium and calcium are uniformly distributed throughout the tactoid or domain. Table 45a presents an estimate of the average

Table 45a. The simple average ionic concentration of the principal cations in the precipitation (dry dust excluded) and the associated Sodium Adsorption Ratio (SAR) for the three closest stations to the project (Lodge *et al.*, 1968).

Cation	Concentration	
	mg/l	me/l
Ca	4.6	0.23
Mg	0.5	0.04
Na	1.2	0.05
K	0.5	0.02
TDS		0.34
SAR	0.14	

* * *

ionic concentration of the principal cations for the precipitation on the project. For short periods immediately after wetting under the infiltration model discussed in section 49, the soil solution in the surficial horizons may be very similar to that of the precipitation, for which the data in table 45a are the best estimate available of the chemical characteristics.

A figure of 0.5 me/l (Emerson, 1971; Quirk and Schofield, 1955) for TDS would seem a reasonable minimum concentration to maintain flocculation, assuming no sodium in the system and calcium is the only cation. The TDS for the precipitation (table 45a) is somewhat below 0.5 me/l, suggesting that the clay in calcium-saturated soil fabric might on a transitory basis exhibit at least slight dispersion assuming wetting under conditions of very low hydrodynamic dispersion.

During pluvials, under conditions of denser vegetation and possibly hence a smaller contribution to the atmosphere of carbonate-bearing dust from the soil surface, it seems reasonable to postulate that the calcium concentration would be lower relative to sodium, and possibly also TDS would be lower since calcium is the major cation. Such changes from the current composition of the precipitation would favor clay dispersion.

The average TDS over all of the precipitation (table 45a) may be higher than that in the latter part of a particular storm. Similarly, the average SAR may be lower than the SAR near the end of a storm. Both differences would act to make the precipitation during intervals of certain storms more dispersive than the analyses in table 45a would indicate. The reason is that early in the storms the atmosphere is scavenged of the larger solid particles by the falling droplets.[2/] Dust in the project area contains carbonate (section 40), and calcium is the principal cation in the precipitation (table 45a). If an appreciable portion of the ionic calcium originates from the scavenging of carbonate-containing dust particles, then it is a reasonable conjecture that the TDS should decrease and the SAR should increase as the storm event progresses.

The expression of the A2 horizon and the movement and accumulation of clay in the B position (the transmission zone of figure 12), to form argillic horizons, apparently is impeded by fine-grain carbonate in surficial horizons (section 86). Atmospheric CO_2 pressure would be sufficient to maintain a calcium ion concentration of about 1 me/l if solid phase $CaCO_3$ is present, in excess of the 0.5 me/l minimum for flocculation of calcium-saturated clay discussed previously.

Maintenance of a high proportion of calcium saturation may be favored by the combination of warm season precipitation and drying between precipitation events. For a short period after wetting of an initially dry soil the rate of CO_2 evolution by microorganisms commonly increases rapidly, and in a matter of hours may become appreciable (Chahal and Wagner, 1965). A rise in CO_2 partial pressure increases the calcium ion concentration in the soil solution if the soil is calcareous (Kemper and Miller, 1974). This rise in calcium ion concentration would reduce SAR and lead to replacement of exchangeable sodium by calcium.

The high soil temperatures in upper horizons during the summer when these soils are subject to rapid wetting from intense local storms would act to reduce the amount of CO_2 dissolved in the water, and to an extent reduce the calcium ion concentration. But, as the relatively low calcium and magnesium concentrations in surficial water of arctic limestone areas indicates, the temperature effect is relatively a small factor (Embleton and King, p. 11).

Soil material high in carbonate clay does disperse under the physical disaggregation of the standard particle size without the addition of dispersing agents (pedon 61-2, Appendix). An explanation for this apparent discrepancy from the foregoing is that the CO_2 partial pressure in the setting cylinder is controlled by that of the atmosphere, since the organic matter has been removed and the soil sterilized by treatment with hydrogen peroxide. Another possibility is that under conditions of extreme physical disaggregation silicate clay packets precipitate on the surface of the particles of carbonate and limit their solubility. Resultantly, the calcium ion concentration in the water of the setting cylinder may be appreciably below that in the soil.

2/ Zinc and silver concentrations in the precipitation during the first 24 minutes of a summer storm in northwest Nebraska (near Chadron) decreased twofold (Steffe, 1970). This supports the conjecture for the study area that the latter stages of the local summer convection storms, which are the major kind of storms during the season of maximum precipitation, have precipitation with lower TDS than the average for the event.

61. BARREN VS. VEGETATED STRIPS

Large barren and intervening grassy strips are common in places on the lower piedmont slopes and basin floors. The great contrast in vegetative status raises questions as to origin and soil morphology. The strips are well expressed only in finer-textured horizons such as loam, clay loam and silt loam, suggesting a relation to soil texture. They range from several to many m wide and are approximately on the contour, suggesting a relation to water movement. Grass (mostly tobosa and burro grass) is usually dominant in the grassy strips, with only scattered shrubs. Four areas with such strips were studied (table 46; figs. 20 to 22).

Where the barren and vegetated strips are distinct the boundary between them is commonly marked by truncation of the A horizon, with the barren strip occurring just downslope (fig. 20). The A horizon is coarser-textured and more pervious than the underlying Bt horizon; thus soil truncation is important since it brings finer-textured, harder, and less permeable horizons to the surface. Differences in runoff and run-in due to these differences in texture, consistence and permeability are thought to be responsible for the presence or absence of the grass. Because of extra moisture from run-in and because the soil beneath the grassy strip is more pervious, it should be moistened deeper than the soil of the barren strip. This is indicated by observations: in a single rainstorm on dry soil, a barren area wetted only to a depth of 1 cm whereas a grassy area only several m downslope wetted to 36 cm. During the rainy season as a whole these differences in moisture would probably not be as great. However, the observed moisture differences do present one reason why the barren strips are barren and the grassy strips are grassy--there is considerable runoff, even during small storms, from the barren into the grassy areas.

Organic carbon values (table 46) indicate that the erosion, runoff and run-in at the scale discussed have not greatly affected the amount of organic carbon at 3 of the 4 sites. At site 3 the effect was apparently great enough that the soil in the barren strip is in a Typic instead of an Ustollic subgroup. Part of the difference, however, may be due to less clay in the soil of the barren strip.

The barren strips were present before 1936 since they are distinct on the 1936 aerial photos. However, several factors suggest they are a relatively recent feature. (1) Organic carbon does not differ greatly between most of the strips (table 1). (2) Occasional stubs of grass clumps are present in some barren strips (site 2). (3) Soils of the barren strips have the same horizon sequence except for a thin A horizon (site 1). The barren strips may have been started (or accentuated) by overgrazing, which has occurred in the study area and which is one of the major factors responsible for the development of coppice dunes (following section). On the other hand, barren strips might have developed without overgrazing if moisture became insufficient for maintenance of a continuous stand.

62. COPPICE DUNES

Melton (1940) used the terms "coppice dune" and "shrub-coppice dune" to designate dunes formed by wind in conflict with bunch or clump vegetation. He further states "...on the disappearance of grasses and other effective sand

Table 46. Characteristics and organic carbon contents for soils of the barren and grassy strips at four sites.

Site	Landscape and general vegetative character	Condition of strip	Organic carbon %	Pedon or satellite	Classification
1	Fan-piedmont sloping 1 percent. Has scattered patches of tobosa grass and burrograss; barren spots are common just downslope from these patches.	Grassy (Scattered tobosa clumps; a few burrograss clumps.)	0.31[1]	just north of pedon 68-9 sample trench	Typic Haplargid, fine-loamy
		Barren	0.35[1]	just north of pedon 68-9 sample trench	Typic Haplargid, fine-loamy
			0.32	pedon 68-9	

Comments: A study trench was dug across the contact of the grassy and barren strip (fig. 20) at Site 1 but not across the contacts at the other sites. A thin C horizon, with sedimentary strata still preserved, overlies an A2 horizon in the grassy area (fig. 21). This C horizon material has been in place long enough for burrograss clumps to become rooted in it but shows no evidence of development of an A2 horizon, which is preserved beneath it. The thin C horizon and underlying A2 horizon are not present beneath the barren strip. However, all other horizons extend without change from the grassy strip to the barren strip. The disappearance of the thin C and A2 horizons exactly coincides with the boundary between the grassy and barren strips. The barren strip was apparently caused by truncation of these horizons.

Organic carbon contents are quite low for both the barren and the grassy strip. The values are essentially equal, rather than being higher in the grassy strip. One reason for this may be the diluting effect of the 0 to 8 cm layer (in the grassy area) which contains very little clay, and probably little organic carbon. This would be expected to weight the composited sample towards a lower value. The soils of both the barren and vegetated strips are in the same series and have too little organic carbon for the Ustollic subgroups.

Site	Landscape and general vegetative character	Condition of strip	Organic carbon %	Pedon or satellite	Classification
2	Broad drainageway sloping 1 percent. The drainageway is generally grassy but has scattered barren spots that show less evidence of erosion than at Site 1.	Grassy (Dense stand of tobosa.)	0.94	69-8	Ustollic Haplargid, fine
		Barren	0.78[1]	40 m north	Ustollic Haplargid, fine

Comments: The organic carbon from both the sampled pedon and the composited sample is ample to place these soils within the Ustollic subgroups. Hence, the absence of grass at the present time has not affected the classification. Presence of the barren spots without truncation suggests that only very minute differences in the microrelief can cause moisture to infiltrate in some places but not in others.

Site	Landscape and general vegetative character	Condition of strip	Organic carbon %	Pedon or satellite	Classification
3	Fan-piedmont toeslopes. Slope is ½ percent. Alternating barren and grassy strips are very prominent.	Grassy (Dense stand of tobosa.)	0.84	61-3	Ustollic Haplargid, fine
		Barren	0.35	67-6, 0.1 m south	Typic Haplargid, fine

Comments: The lower organic carbon of pedon 67-6 may be due to less clay. However, the site appears to have undergone somewhat more erosion than the barren site near pedon 69-8 (there are no stubs of grass clumps) and a grassy cover may have been gone from this site longer than from the barren spot near pedon 69-8. Both erosion and lower clay content may have contributed to the lower values of organic carbon.

Site	Landscape and general vegetative character	Condition of strip	Organic carbon %	Pedon or satellite	Classification
4	Fan-piedmont sloping 2 percent. There are alternating areas of burrograss and barren areas, with small scarps between.	Grassy (Scattered burrograss clumps.)	0.75	60-15	Typic Torrifluvent, fine-silty
		Barren	0.75[1]	7 m west	Typic Torrifluvent, fine-silty

Comments: Both pedons would be in an Ustollic subgroup if an argillic or calcic horizon were present. However, Ustollic intergrades are not recognized in the Entisols.

1/ Composited borings to 38 cm. Other values are weighted averages (to 38 cm) of sampled pedons.

Figure 20. Site 1. The trench is in Berino, a Typic Haplargid (pedon 68-9). The barren and grassy strips are at the left of the trench.

Figure 21. Closeup of barren and grassy strips and of upper horizons of Berino 68-9 (just to the right of the tape and an adjacent pedon to the right (marked by knives). Disappearance of the grass coincides with erosion of the youthful C horizon material (above the uppermost jackknife) and the A2 horizon (between the two jackknives). Scale is in feet.

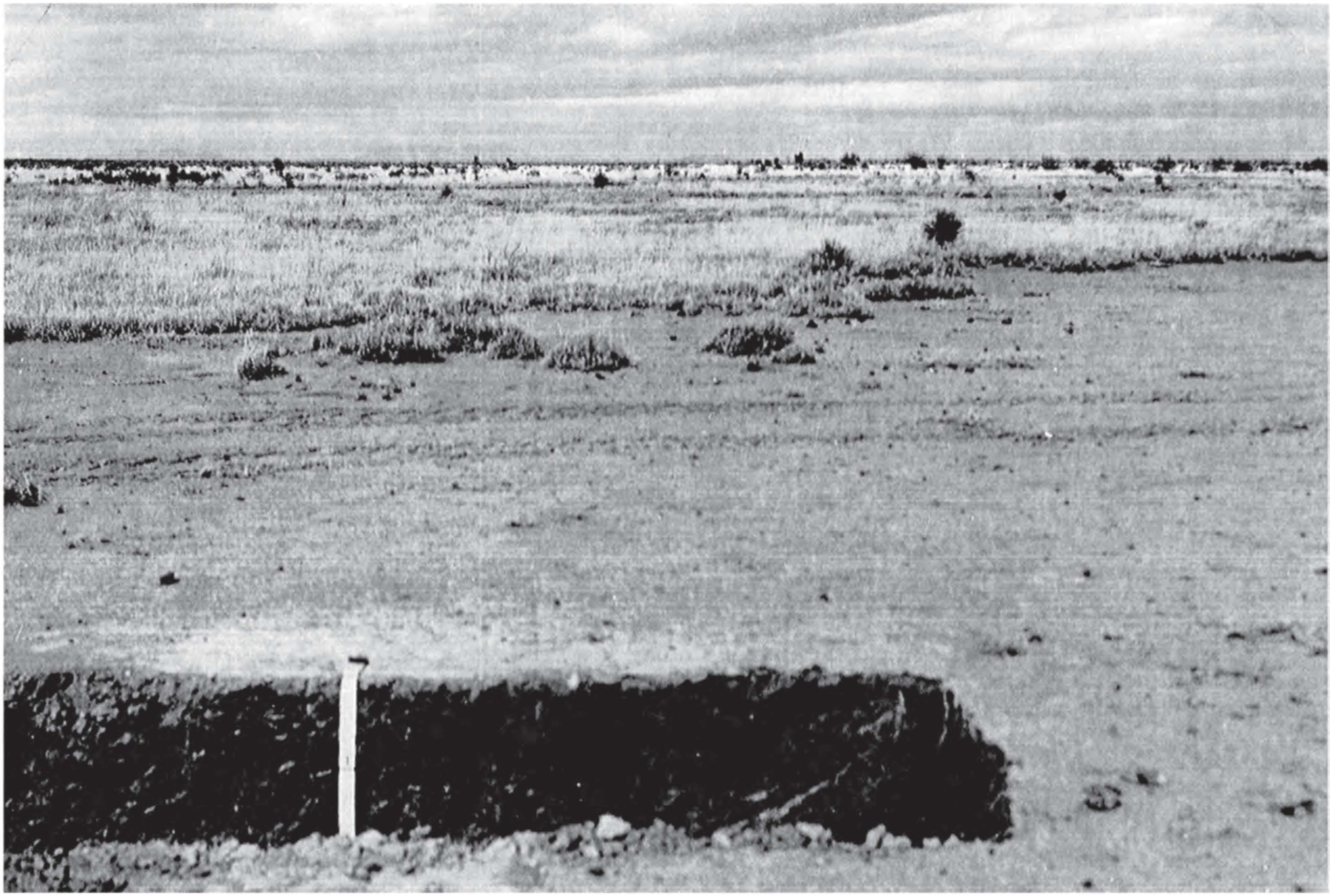


Figure 22. Pedon 67-6, site 3. The barren and grassy strips are quite distinct and separate from each other. Pedon 61-3 was sampled in a grassy area 0.1 mi to the north. Scale is in feet.

binders with climatic change, overgrazing, etc., remaining clumps of shrubbery may trap a noticeable amount of blowing sand. Mesquite bush...grows vigorously on loose sand and is not readily killed by slow sand burial. Sand which falls within the bush may thus stay for a considerable time. If this process continues, a mound of sand eventually is built and held together by the coppice.... Shrub-coppice dunes supported by mesquite bush are present in vast numbers in southeastern New Mexico and in adjoining districts in the southern High Plains."

Coppice dunes also occur in the Desert Project area. They are most common where surficial texture is sand, loamy sand or light sandy loam, and where there is little or no gravel. Morphology of the dune materials contrasts markedly with that of soils buried beneath the dunes. No A or B horizon is apparent in the dune materials, which are stratified and fresh-appearing. However, roots and occasional burrows of insects and animals indicate some mixing of the eolian sediments. The dunes are thickly covered with vegetation, mostly mesquite; there are a few four-wing saltbush.

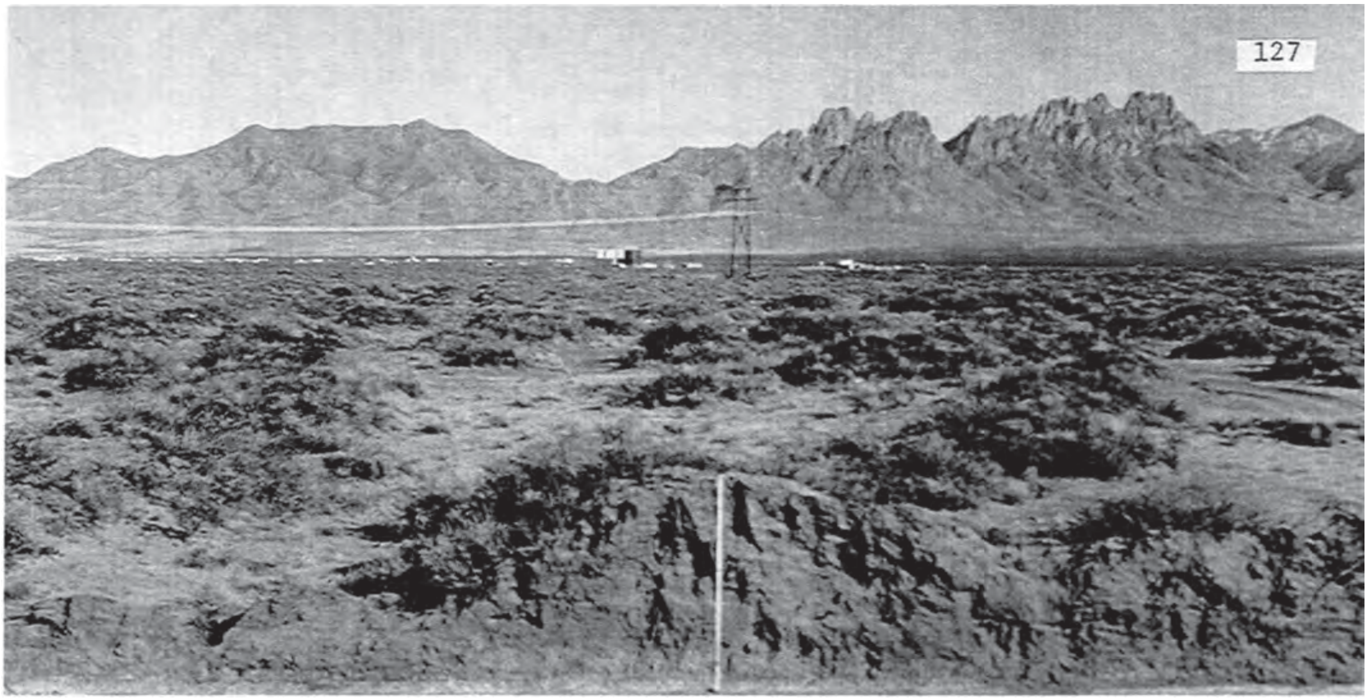
Soils in the dunes may be divided into two main kinds according to their color. One kind has 5YR hue (dry color commonly 5YR 5/4), which is caused by thin coatings of oriented clay and associated iron oxides on the sand grains. The other kind has 10YR hue (dry color commonly 10YR 5/3) and the grains lack the 5YR coatings. Both soils are Typic Torripsamments and are in the Pintura series. Analyses for both are presented in table 47.

Soils of 5YR hue. Figure 23 shows Pintura 68-1. The dune overlies the buried analogue of the Typic Haplargid, Berino, on the Jornada II fan-piedmont, which slopes 1 percent. Both the dune materials and upper horizons of buried and adjacent soils have 5YR hue and are reddish brown. Size distribution of the dune sand is very similar to the underlying A horizon (table 47). These relations indicate the dune materials were derived from adjacent soils. The reddish brown clay coatings contribute substantially to the total clay content; compare clay contents with Pintura 66-11, in which the sand grains lack the 5YR coatings. In Pintura 66-13 (see Appendix), similar to Pintura 68-1, it was found that a portion of the clay coatings on the sand grains is resistant to removal by the particle size analysis procedure (method 3A1, Soil Survey Staff, 1972); patchy coatings of reddish brown clayey material still remained on the grains. Treatment with dithonite-citrate (method 6C2, Soil Survey Staff, 1972) removed all of the clay, the sands were left clean and the clay content increased by about 1 percent.

The fresh appearance of dune exteriors, current eolian deposition and stratified interiors suggest that the dunes are young. Buffington and Herbel (1965) used field notes of early General Land Office Surveys in a discussion of recent vegetational changes on the Jornada Experimental Range, most of which lies just north of the study area. They state: "Since 1858 the grass cover has decreased tremendously....Vast areas having sandy soil are now dominated by mesquite sand dunes." Similar conclusions were reached for other areas by Gile (1966a) and York and Dick-Peddie (1969). Buffington and Herbel further stated "Seed dispersal, accompanied by heavy grazing and periodic droughts, appears to be the major factor affecting the rapid increase of shrubs." Mesquite seed passes through the digestive tract of cattle undamaged. Thus in addition to heavy grazing, at the same time the cattle spread mesquite seed. The mesquite

Table 47. Laboratory data for Typic Torripsamments of two coppice dunes.

		Sand					Silt	Clay		
Horizon	Depth	2-1	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05			$CaCO_3$ Equiv	Organic Carbon
	cm	pct	pct	pct	pct	pct	pct	pct	pct	pct
Pintura 68-1, 5YR hue										
C1	0-33	tr	1	8	52	25	5	9	tr	0.18
C2	33-102	tr	3	14	50	19	6	8	tr	0.21
C3	102-122	tr	2	13	56	17	4	8	tr(s)	0.21
Ab	122-142	tr	4	16	50	17	6	7	tr(s)	0.25
B1tb	142-152	tr	6	20	46	12	5	11	tr(s)	0.28
B21tcab	152-168	1	6	17	41	13	8	14	tr(s)	0.23
Organic carbon, 2.7 kg/m^2 to 102 cm										
Pintura 66-11, 10YR hue										
C1	0-28	tr	13	33	42	6	3	3	-(s)	0.15
C2	28-58	1	15	31	39	6	4	4	tr(s)	0.15
B2b	58-84	2	16	27	35	9	6	5	tr(s)	0.13
B3cab	84-109	2	15	27	36	9	6	5	1	0.10
C1cab	109-137	3	15	26	37	8	6	5	2	0.10
C2cab	137-163	4	21	30	36	3	3	3	1	0.06
C3b	163-188	3	21	30	36	4	3	3	tr	0.06
Organic carbon, 2.1 kg/m^2 to 109 cm										



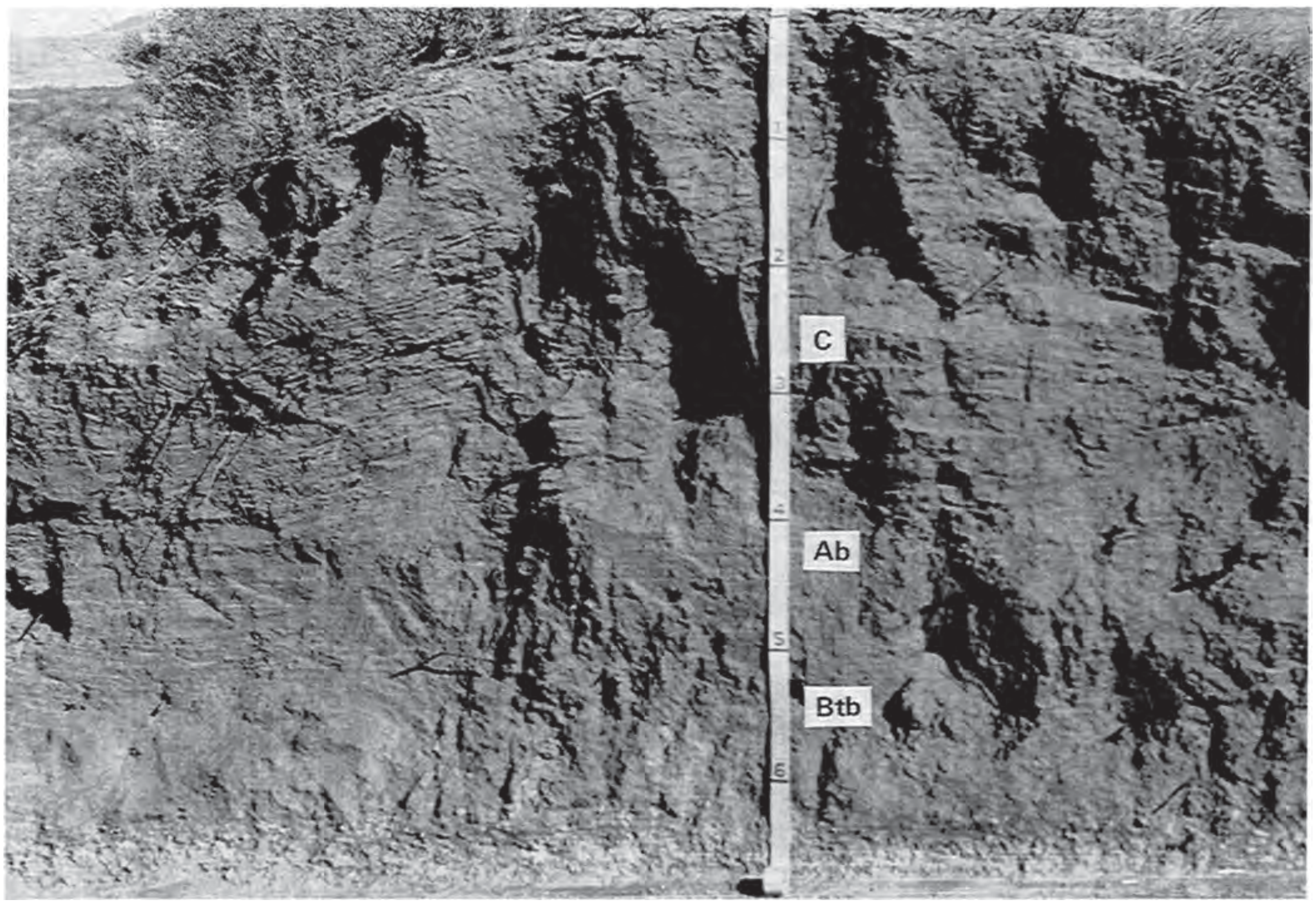


Figure 23. Upper. Landscape, Pintura 68-1. The dunes overlie the Jornada II surface. Torripsamments (Pintura soils) occur in the dunes. Typic Haplargids (Berino soils) occur between the dunes and are buried beneath them. Vegetation is mostly mesquite; there are a few four-wing saltbush.

Lower. Pintura 68-1, a Typic Torripsamment. Stratification is apparent in the dune materials, which rest on the buried analogue of Berino.

was not killed by sand burial but instead thrives in the dunes, as shown by the thick cover of mesquite (fig. 23).

Land survey notes were examined in the vicinity of Pintura 68-1. This area is now dominated by mesquite-covered coppice dunes; there is essentially no grass. Land survey notes indicate that the area had good grass in 1858.[3] For example, at the corner of sections 16, 15, 21 and 22, the following statement was made: "Land level prairie with good grama grass." At the corner of sections 15, 14, 22 and 23, it was noted that the area was "level with a growth of good grama grass."

The area was resurveyed in 1927 and the notes differ markedly from those in 1858. At the corner of sections 16, 15, 21 and 22, for example, the land is noted as level, with undergrowth, greasewood and mesquite. Grass was not mentioned. Dunes had started to form in this general area by 1927 as indicated by the following note at the 1/4 corner between section 13 and 14: "Set an iron post, 3 ft long, 1 in diameter, 27 in in the ground, on top of a small sand dune covered with mesquite." The dunes were well established and about in their present positions by 1936 as indicated by aerial photographs taken then. The dunes show as small dark dots on the aerial photographs (see soil map, section 149, for an example).

However, grass is still preserved in some areas. The following notes were made in 1858 about 2 mi north of pedon 68-1: "...on true line between sections 2 and 3. Over grassy prairie land, through scattering sotol." Grass also occurs in this area today. It is quite common in drainageways and in the basin floor; dunes do not occur in these areas, apparently because upper horizons are finer-textured (loam, clay loam and silt loam).

Dunes of lower La Mesa also have 5YR hue (Gile, 1966). See section 149 for discussion of these dunes.

Soils of 10YR hue. Figure 24 shows Pintura 66-11. The dune is on the shoulder of a Fort Selden ridge sloping 6 percent. These soils occur in the valley border. Vegetation on the dune is mesquite and creosotebush. The sandy sediments beneath the dunes were initially deposited by the ancestral Rio Grande and contain very little clay (table 47). Hues are 10YR both in the dune and in the underlying soil. Size of sand in the dunes is very similar to its size in the underlying horizons (table 47). These sediments contain less clay, more coarse sand and less of the finer sand fractions than the dunes with 5YR material. Water retention at 0.06 bar is half that for Pintura soils of 5YR hue, which have more clay.

Discussion. Color of both the 5YR and 10YR dunes are about the same as color of upper horizons of soils beneath the dunes. Particle size of the dune materials and upper horizons of soils beneath the dunes are also very similar. These factors indicate that sediments of the dunes were derived from upper horizons of soils between the dunes. In 5YR dunes the dune sediments were derived

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3/ Bureau of Land Management, Santa Fe, New Mexico

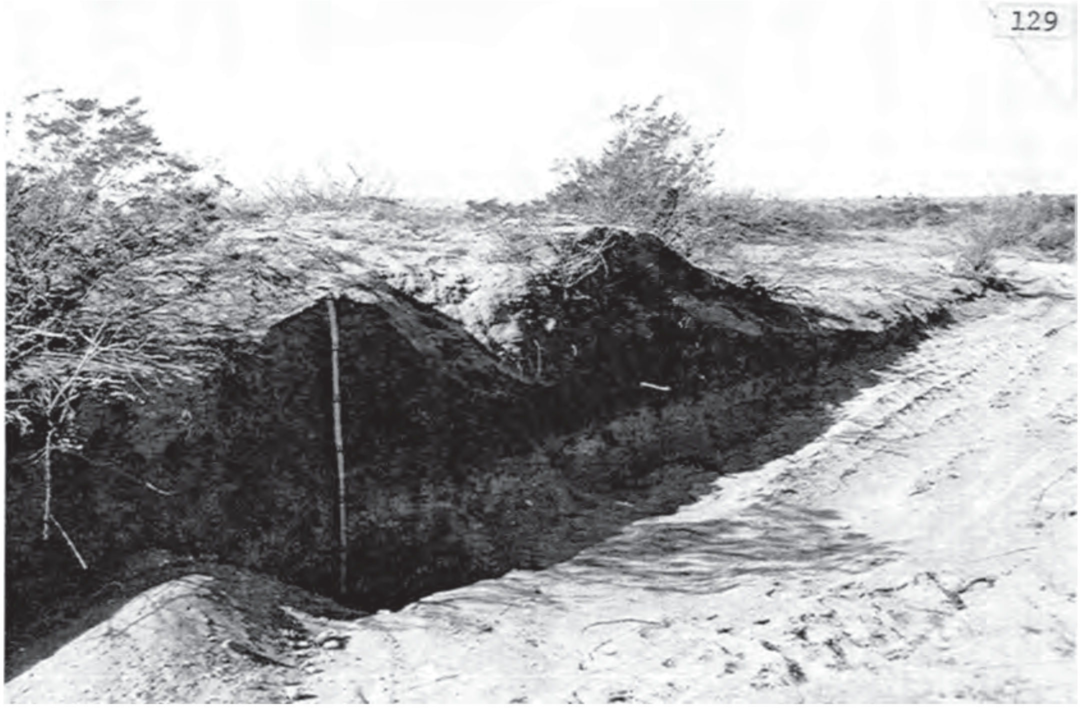


Figure 24. Upper. Landscape, Pintura 66-11. Torripsamments occur both in and between the dunes, but the one between the dunes (Bluepoint) is buried beneath the dunes (Pintura). Vegetation on the dunes is mesquite and creosotebush.

Lower. Pintura 66-11. Light-colored zone between 4 and 5 ft depth is the carbonate horizon of buried Torripsamment. Scale is in feet.

from upper horizons of adjacent Argids; in 10YR dunes the sand was derived from adjacent Torripsamments with sand grains lacking the reddish brown coatings. Land survey notes and present conditions indicate that dunes in this general area formed, and a drastic change in vegetation occurred within the last 100 years (Buffington and Herbel, 1965; Gile, 1966a; York and Dick-Peddie, 1969).

63. ORGANIC CARBON ACCUMULATION

The distribution of organic carbon with depth and the total amount are affected by vegetation, orographic position, content of coarse fragments, silt and clay content, landscape position as this determines runoff and run-in, and local differences in soil truncation.

Table 48 ranks the taxa placements of the soils in ascending order of amounts of organic carbon. Pedons with relatively low organic carbon ($\lesssim$ 2 kilograms) all occur in the arid part of the study area and have one or more of the following taxonomic characteristics: skeletal, petrocalcic horizon, sandy texture, Pedons with relatively high organic carbon ($\gtrsim$ 4 kilograms) either occur in the semiarid area along the mountain fronts (the Haplustolls) or have clay contents of 18 percent or more for the family control section.

Table 49 illustrates the influence of coarse fragment volume on the amount of organic carbon. The pedon with the greater coarse fragment volume has the higher percentage of organic carbon in the fine earth. But because of the diluent effect of the coarse fragments, the amounts of organic carbon on a volume basis are nearly the same. Concentration of the infiltrating water in the interstices would tend to improve the moisture relationship and increase the abundance of plant roots; consequently the organic carbon would be raised.

The orographic effect on amount of organic carbon indicated in table 48 is illustrated for Holocene soils in figure 25. The soils selected are developed in either skeletal rhyolitic or nonskeletal monzonitic alluvium, and they occur on stable sites. The boundary between the semiarid and arid parts of the project is at about 5000 ft along the mountain front, above which precipitation increases appreciably, temperatures are lower, and vegetation tends to be denser.

Organic carbon generally increases as clay content rises. Figure 26 shows the regression between amount of organic carbon and percentage of clay for 28 pedons of Typic or Ustollic Haplargids that occur in the arid part of the study area. The regressions are significant at the 1 percent level. The coefficient of variation is 50 percent. The pedons are closely defined, and the coefficient of variation is the maximum to be expected for various groupings of pedons.

The increase in organic carbon with clay is probably largely a reflection of greater vegetative growth on soils higher in clay. A fine-textured Haplargid had perennial grass yields (1960-1970) of 1055 kg/ha, whereas, a coarse-loamy Paleargid had only 346 kg/ha. A reason for greater vegetative growth on the finer textured soils is that they are subject to run-in whereas the coarse-loamy are not. Another reason is that a higher proportion of the water held at field capacity for the finer textured soils moves very sluggishly and is available for plants over a greater time after wetting.

Table 48. Amounts of organic carbon in ascending order.[1/]

Subgroup	Family	No. of pedons	Organic carbon kg/m² Avg.	Range	Rank order of pedons
Typic Paleorthids	Loamy-skeletal	1	0.7		
Typic Torriorthents	Sandy-skeletal	1	0.7		
Typic Paleorthids	Loamy	2	0.8		
Typic Haplargids	Loamy-skeletal	4	1.2	0.9-1.4	67-4, 67-5, 60-9, 66-16
Petrocalcic Paleargids	Loamy-skeletal	1	1.2		
Typic Calciorthids	Loamy-skeletal	1	1.3		
Petrocalcic Paleargids	Loamy	1	1.4		
Typic Haplargids	Sandy	2	1.5		
Typic Camborthids	Loamy-skeletal	1	1.8		
Petrocalcic Ustollic Pale-argids	Loamy-skeletal	1	1.9		
Ustollic Paleorthids	Loamy-skeletal	2	2.0		
Typic Haplargids	Coarse-loamy	9	2.1	1.2-3.1	66-1, 60-8, 70-6, 61-5, 70-5, 61-8, 62-3, 59-12
Typic Torriorthents	Loamy-skeletal	3	2.3	1.1-3.6	66-3, 61-6, 66-4
Typic Torrifluvents[2/]	Sandy	1	2.3		
Typic Camborthids	Coarse-loamy	2	2.3		
Ustollic Calciorthids	Sandy	1	2.4		
Typic Torripsamments[2/]		5	2.4	1.4-2.7	59-10, 59-17, 66-11, 68-1
Ustollic Haplargids	Loamy-skeletal	5	2.4	1.3-3.4	59-15, 59-14, 70-1, 66-10, 66-9
Typic Haplargids	Fine-loamy	16	2.9	1.6-4.5	68-6, 68-8, 60-7, 65-5, 65-7, 68-9, 60-13, 60-22, 59-8, 66-8, 68-2, 68-4, 61-4, 60-6, 59-7, 70-7
Typic Calciorthids	Coarse-loamy	4	3.2	2.5-3.9	60-2, 61-2, 61-1, 65-6
Typic Torrifluvents[2/]	Loamy-skeletal	1	3.4		
Typic Camborthids	Fine-silty	1	3.7		
Typic Torriorthents	Sandy	1	3.8		
Typic Torrifluvents[2/]	Coarse-loamy	2	4.1		
Torriorthentic Haplustolls	Coarse-loamy	1	4.6		
Pachic Haplustolls	Loamy-skeletal	1	4.6		
Torriorthentic Haplustolls	Sandy	1	4.7		
Ustollic Haplargids	Fine-loamy	3	4.8	4.7-4.9	60-18, 59-6, 66-15
Typic Torrert[2/]	Very-fine	1	4.8		
Ustollic Calciorthid	Fine-loamy	1	6.2		
Pachic Haplustolls	Coarse-loamy	1	6.7		
Ustollic Haplargids	Fine	3	7	4.6-10	60-21, 61-3, 69-8
Ustollic Calciorthids	Fine-silty	5	8.4	5.3-11	68-7, 65-1, 60-17, 60-14, 66-6
Typic Torrifluvents[2/]	Fine-silty	1	8.1		

1/ Amount is on a volume basis: kilograms in a volume one square m in cross-section and of variable depth, either the horizon boundary nearest to 1 m, or to a root-limiting zone (paralithic or lithic contacts, or petrocalcic horizon), if above 1 m.

2/ An appreciable portion of the organic carbon in some or all pedons placed in this taxon probably allogenic.

Table 49. Organic carbon for the 5 to 25 cm zone of two nearby pedons differing in volume of coarse fragments.

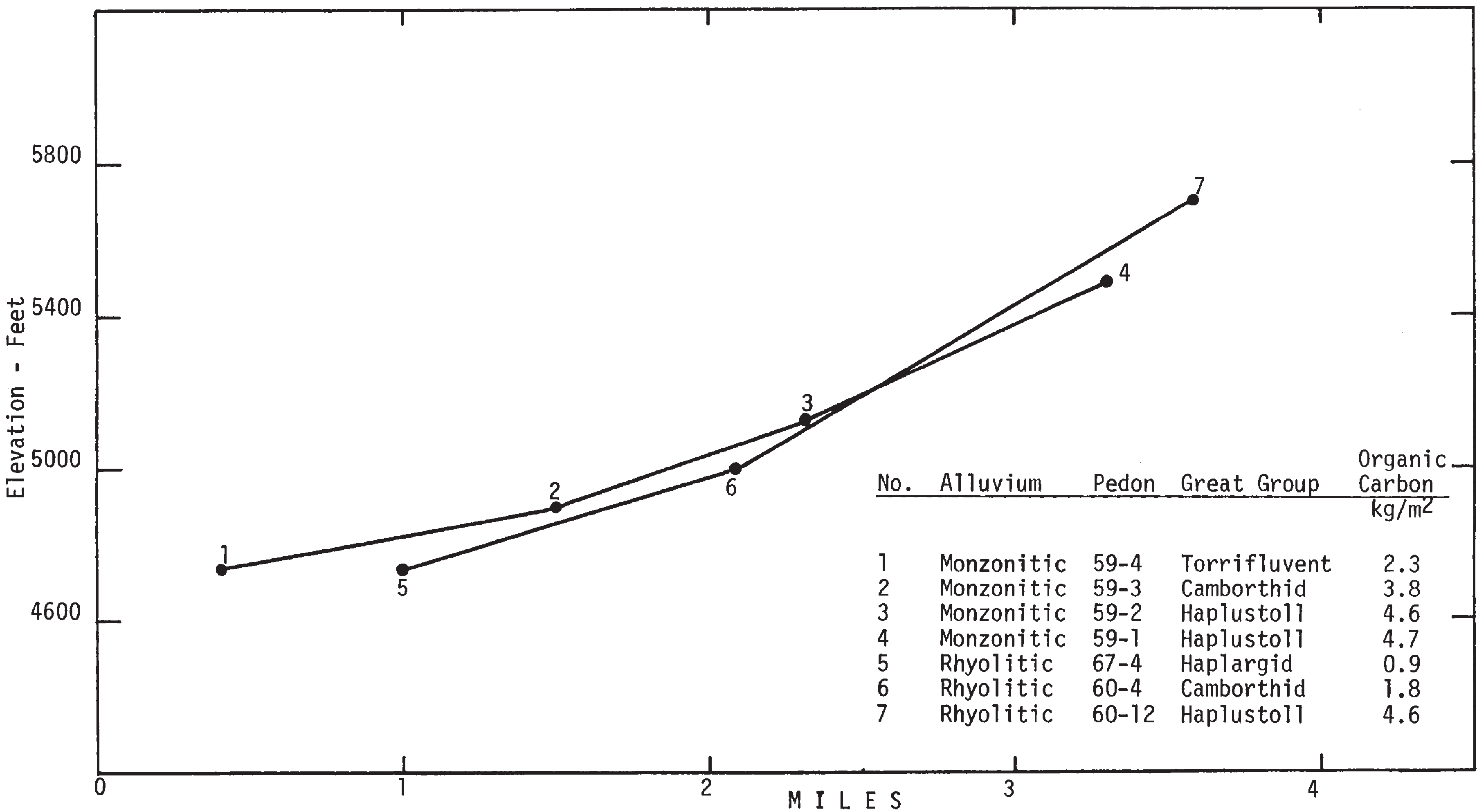
Pedon	Classification	Volume Coarse fragments	Organic carbon Fine earth	Total volume
		pct	pct	kg/m^2
66-16	Typic Haplargid, loamy-skeletal	60	0.38	0.44
	Typic Camborthid, coarse-loamy	10	0.16	0.38

Furthermore, organic matter closely associated physically with clay may be partially protected from microbiological breakdown. This may be a factor favorable to higher organic carbon in the finer textured soils.

In some soils the surface horizon has the highest organic carbon and the decrease with depth is regular. In other soils the maximum organic carbon is below the surface horizon or the decrease is irregular. Soils with the maximum organic carbon in the surface horizon (table 50) tend to have one or more of the following characteristics: relatively high total organic carbon; appreciable clay in surface horizon (greater than 18 percent) and/or small or no increase in clay from surface to subsurface horizons; overlying C horizon material; a larger volume of coarse fragments in the surface than in the subsurface horizon; occurrence in the semiarid part of the study area; and grass vegetation. Maxima in organic carbon below the surface horizon (table 51) are associated with one or more of the following: subjacent K2m horizon or other root-limiting horizon; appreciable increase in clay from overlying horizons; increase in volume of coarse fragments; occurrence in the arid part of the study area; dominantly shrub vegetation; gravelly desert pavement; relatively low organic carbon content. High temperatures at and just below the soil surface are thought to be an important factor leading to reduced organic carbon, particularly in soils with gravelly desert pavements.

Bailey (section 54) has shown that a K2m horizon increases the water available to plants in the horizon just above, and that roots are concentrated in this horizon. This would explain the increase in organic carbon just above the K2m horizons found in all but one of the Paleorthids and Petrocalcic Paleargids.

Nearly all of the soils in the semiarid part of the area are Mollisols or Ustollic intergrades. The Mollisols are mainly in Holocene parent materials and on stable sites. The Mollisol-Aridisol transition is of two types. In one, Holocene Mollisols gradually change to Holocene Aridisols with decreasing elevation (fig. 25). In the other, the transition is abrupt and occurs because soils of Pleistocene age have been truncated. Such



No.	Alluvium	Pedon	Great Group	Organic Carbon kg/m^2
1	Monzonitic	59-4	Torrifluvent	2.3
2	Monzonitic	59-3	Camborthid	3.8
3	Monzonitic	59-2	Haplustoll	4.6
4	Monzonitic	59-1	Haplustoll	4.7
5	Rhyolitic	67-4	Haplargid	0.9
6	Rhyolitic	60-4	Camborthid	1.8
7	Rhyolitic	60-12	Haplustoll	4.6

Figure 25. Orographic change in amount of organic carbon across the semi-semiarid boundary for soils developed in monzonitic and rhyolitic alluvium.

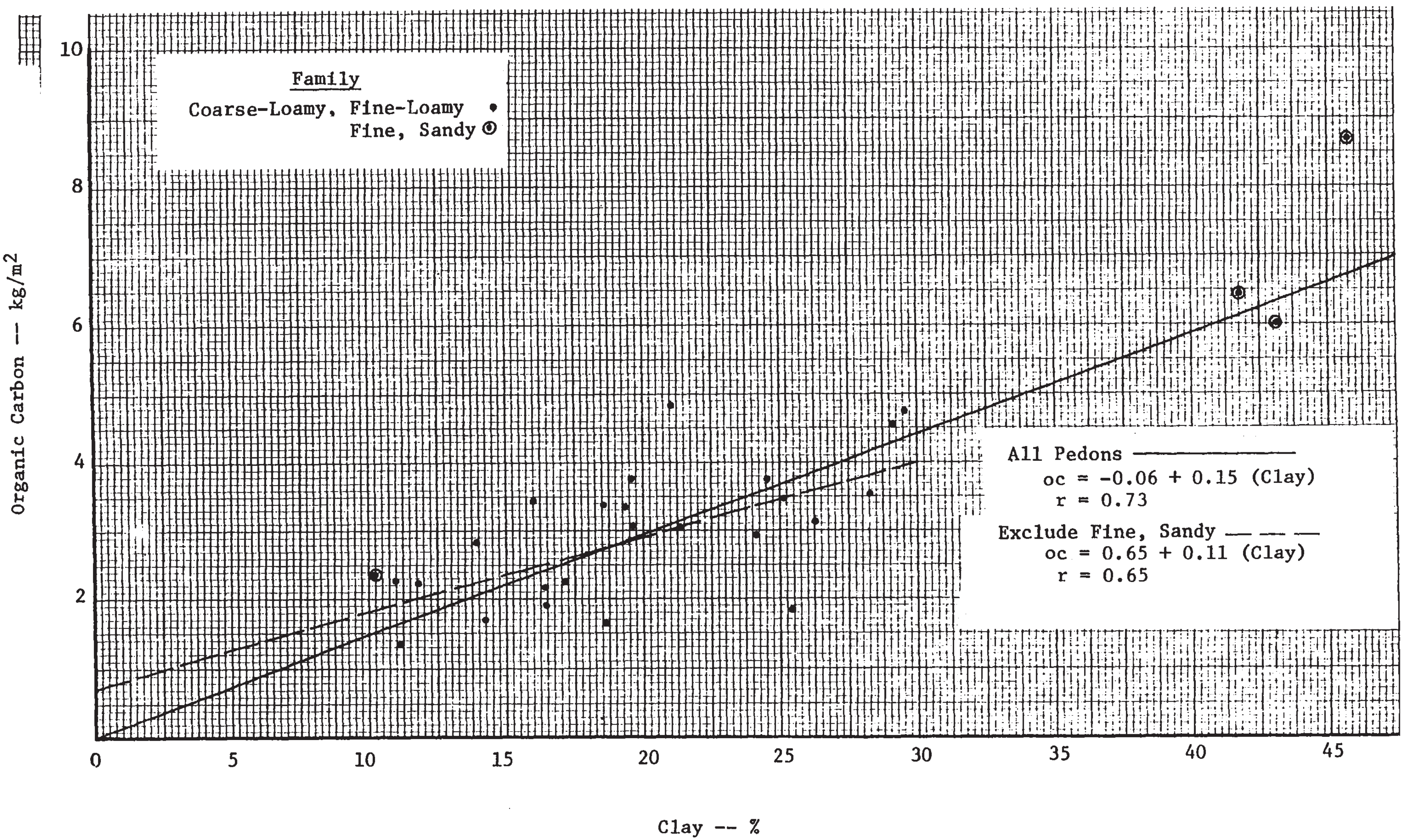


Figure 26. Amount of organic carbon versus clay percentage for Typic and Ustollic Haplargids from the arid part of the study area. The amount of organic carbon is the kilograms in a unit of volume one square m in horizontal cross section and extending through the horizon with a lower limit closest to one m. The clay percentage is the noncarbonate clay expressed on a carbonate-containing basis weighted for the upper 50 cm or to a K horizon, whichever is shallower. C horizons at the surface were excluded. All pedons contain less than 10 percent by volume coarse fragments within the upper 50 cm. The range in elevation is from 4200 to 4675 ft.

Table 50. Pedons with over 0.05 percent decrease of organic carbon from surface to subsurface horizons.

Pedon	Depth	Organic Carbon Surface	Organic Carbon Surface Minus Subsurface	Amount[1/]	Classification	Remarks
	cm	pct	pct	kg/m^2		
59-1	0-5	0.83	0.26	5.0	Torriorthentic Haplustoll coarse-loamy	Same clay percentage as subsurface; semiarid
59-2	0-3	1.03	0.36	4.9	Torriorthentic Haplustoll sandy	Same clay percentage as subsurface; semiarid
59-3	0-4	0.80	0.16	4.0	Typic Torriorthent sandy	Same clay percentage as subsurface; semiarid
59-6	0-13	0.73	0.18	4.8	Ustollic Haplargid fine-loamy	Overlying dune sand
60-3	0-10	0.41	0.10	0.8	Typic Torriorthent sandy-skeletal	Higher volume of coarse fragments than subsurface horizon
60-9	0-10	0.77	0.46	1.3	Typic Haplargid loamy-skeletal	Semiarid
60-10	0-5	0.50	0.07	0.9	Typic Paleorthid loamy	5 percent more clay in surface horizon
60-14	0-5	2.00	0.87	11	Ustollic Calciorthid fine-silty	Grass
60-16	0-5	0.58	0.13	4.6	Typic Torrert very-fine	64 percent clay in surface horizon
60-17	0-8	1.01	0.17	8.8	Ustollic Calciorthid fine-silty	Grass
60-18	0-8	1.17	0.69	4.7	Ustollic Haplargid fine-loamy	26 percent clay in surface horizon; grass
60-19	0-20	0.84	0.19	6.7	Pachic Haplustoll coarse-loamy	3 percent more clay in surface horizon
60-21	0-8	1.22	0.57	6.0	Ustollic Haplargid fine	37 percent clay in surface horizon; grass
61-2	8-13	0.57	0.21	2.7	Typic Calciorthid coarse-loamy	3 percent more clay than subjacent; overlying dune sand
61-3	0-8	1.78	1.10	6.4	Ustollic Haplargid fine	32 percent clay in surface horizon; grass
61-7	0-5	0.25	0.12	1.4	Petrocalcic Paleargid loamy	Same clay percentage as subsurface horizon
66-7	0-8	1.17	0.51	6.2	Typic Calciorthid fine-loamy	Grass
68-2	0-5	0.50	0.14	3.5	Typic Haplargid fine-loamy	19 percent clay surface horizon
68-7	0-5	0.75	0.07	5.3	Ustollic Calciorthid fine-silty	Grass
69-8	6-10	1.26	0.40	10	Ustollic Haplargid fine	Overlying C horizon; 28 percent clay in surface horizon; grass
70-7	0-7	0.81	0.27	4.6	Typic Haplargid fine-loamy	22 percent clay in surface horizon; grass

1/ Method 6A. Variable depth. Sum through horizon with lower limit nearest to 1 m.

Table 51. Pedons with organic carbon maximum below the surface horizon ranked in order of the increase in organic carbon[1/]

Pedon	Horizon Maximum Organic Carbon			Taxonomic Placement	Remarks
	Depth[2/]	Designation	Increase organic carbon[3/]		
	cm		pct		
66-3	15-23	2B3ca	0.09	Typic Torriorthent loamy-skeletal	Increase in coarse fragments; loose between pebbles and massive horizon above; desert pavement
59-8	8-23	B21t	0.10	Typic Haplargid fine-loamy	14 percent increase in clay over superjacent horizon
62-1	3-13	B21ca	0.10	Typic Paleorthid loamy-skeletal	K2m at 28 cm; desert pavement
66-1	18-28	K1	0.11	Typic Haplargid coarse-loamy	K1 contains loose parts. Large increase in coarse fragments in 2K2
67-3	3-10	A	0.12	Typic Camborthid coarse-loamy	No increase in clay; desert pavement
67-5	5-15	B1t	0.12	Typic Haplargid loamy-skeletal	8 percent increase in clay over superjacent horizon; desert pavement
60-6	18-28	A	0.13	Typic Haplargid fine-loamy	
60-11	4-18	K21	0.17	Ustollic Calciorthid sandy	Coincides with maximum in coarse fragment volume; desert pavement
61-4	15-35	B22tca	0.18	Typic Haplargid fine-loamy	Subjacent horizon 2K1 with 35 percent coarse fragments. Increase clay of 12 percent superjacent
66-16	15-25	B22tca	0.18	Typic Haplargid loamy-skeletal	Desert pavement
60-22	12-30	B21t	0.19	Typic Haplargid fine-loamy	11 percent increase in clay over superjacent
66-9	5-15	B21t	0.20	Ustollic Haplargid loamy-skeletal	5 percent increase in clay over superjacent; desert pavement
66-2	13-23	B22ca	0.21	Ustollic Paleorthid loamy-skeletal	Subjacent K1 horizon with discontinuous cemented plates; K21m at 36 cm; desert pavement
59-11	5-13	Bca	0.23	Typic Paleorthid loamy	Subjacent K2m; desert pavement
61-10	5-23	Bca	0.25	Typic Paleorthid loamy-skeletal	Increase 20 percent volume coarse fragments from superjacent; subjacent K2m; desert pavement
70-8	28-46	B23tca	0.25	Petrocalcic Ustollic Paleargid loamy-skeletal	Substantial increase coarse fragments and clay with depth; subjacent K2m; desert pavement
65-1	5-13	A	0.26	Ustollic Calciorthid fine-silty	
59-16	15-28	B22tca	0.29	Petrocalcic Paleargid loamy-skeletal	Increase clay and coarse fragments with depth; subjacent K2m; desert pavement
66-5	20-30	K1	0.31	Typic Paleorthid loamy	Subjacent K2m; desert pavement
65-6	10-23	B2ca	0.32	Typic Calciorthid coarse-loamy	Few parts loose and roots common; subjacent K1 with platy structure
66-4	4-13	Bca	0.32	Typic Torriorthent loamy-skeletal	Increase coarse fragments over superjacent; desert pavement
66-10	5-13	B21t	0.39	Ustollic Haplargid loamy	10 percent increase in clay over superjacent; desert pavement

1/ Pedons with < 0.1 percent increase were excluded unless the relative increase was 50 percent or more. Torrifluvents were excluded.

2/ Measured from base of overlying C horizon, if present.

3/ Increase relative to weighted average of horizons above, exclusive of overlying C horizons.

truncation is suggested by slight drainageways crossing the surface, and by preservation of mollic epipedons at stablest sites. This truncation has resulted in chromas or values that are too high for a mollic epipedon. The transition is abrupt instead of gradual because the Holocene Mollisols commonly occur on low terraces inset against the older, higher Aridisols.

Although soils in the arid part of the study area lack mollic epipedons, some have enough organic carbon for Ustollic subgroups. Soils of fine-silty or fine families low in gravel commonly are in Ustollic subgroups. Such soils commonly occur in landscape positions (basin floor and drainageways) favorable to run-in. Only a few soils in fine-loamy families are Ustollic, and these are all in the heavy end of the family.

Higher volumes of coarse fragments increase organic carbon percentages and the tendency towards Ustollic subgroups. The pattern is particularly complex where both coarse fragment volume and depth to a petrocalcic horizon are locally variable. In the most arid parts of the valley border both skeletal and nonskeletal Paleorthids and Paleargids are Typic. Near the mountain front, nearly all of the soils with petrocalcic horizons are in Ustollic subgroups or are Mollisols whether skeletal or not. But between the arid and semiarid areas there is a tension zone within which coarse fragment volume may determine whether the pedon is Typic or Ustollic.

64. CARBONATE ACCUMULATION

Horizons of carbonate accumulation are one of the most common horizons in the study area. The accumulations range from slight to prominent in various soils, and cause pronounced morphological changes in the carbonate horizon as it develops. Section 87, Laboratory Data Interpretation, discusses the relation of carbonate to bulk density and consistence; C-13 and C-14 isotope studies on carbonate; and aspects of carbonate mineralogy and particle size.

65. ORIGIN

The more prominent carbonate accumulations have commonly been termed "caliche" in the Southwest, and have been attributed to a number of origins. Some believed that these accumulations were caused by capillary rise. Udden (1923) wrote (concerning caliche of the High Plains):

> It is quite generally understood that caliche consists of material which has been brought up in solution to the surface from the underlying formations by water which rises by capillarity to replace such water as is being evaporated from the ground into the air in dry climates. Caliche is, therefore, a precipitate from aqueous solutions rising from below.

Others believed that the High Plains caliche was deposited in lakes. Elias (1931) believed that caliche (of the Ogallala caprock) in Kansas "was deposited on the nearly flat bottom of a very large and very shallow lake at the close of Ogallala time."

Frye (1945), also working in Kansas on the Ogallala caprock, stated:

> A review of the several hypotheses expressed for the origin of this unusual limestone leads to the conclusions that it was formed in lakes which occupied consequent depressions and possibly also abandoned channel segments, and that its accumulation was terminated by the entrenchment of streams at the beginning of the post-Ogallala erosion cycle.

Difficulties of developing caliche on the High Plains and in similar areas by the processes proposed above were pointed out by Smith (1940), Bretz and Horberg (1949) and Brown (1956). These difficulties involve physiographic problems for the occurrence of a large lake on the sloping High Plains surface, and physical problems of capillary rise from water tables to fit the caliche in various areas of its occurrence.

Price, Elias and Frye (1946) designated the caliche in the Ogallala caprock as algal reefs. Elias (1948) stated:

> ...it has been reasonably proved that (the caprock of the Ogallala)...is not secondarily enriched but is an originally deposited calcareous rock formation that belongs in the final phase of deposition of Ogallala time. Characteristic structure and extensive areal distribution of the pisolitic algal limestone in the caprock are similar to those in the algal limestone now being deposited along the shores of the Great Salt Lake.

Objections to an algal origin of the High Plains caliche were raised by Swineford, Leonard and Frye (1958), who stated:

> The absence of fossils, replacement of sand grains by calcite, anomalous distribution of detrital grains with respect to oolites and bulbous structures, and the inverted orientation of the bulbous structures themselves, all argue against algal origin of the rock.

Muckenhirn _et al._ (1949) stated that:

> ...much of the caliche of the southwestern United States, the Solonetz soils, most or some of the ferruginous hardpans in soils of dry regions, and probably the duricrusts occurring along water courses in Australia and other deserts are all correlated with water tables, present or past, and these, in turn, are related to relief.

Nikiforoff (1937) attributed "limey crusts or hardpan" formation in the Mohave desert to "upward capillary movement of the moisture from deep strata", also stating:

> Soils of the Desert type of formation are not subject to leaching and do not develop either eluvial or illuvial horizons.

Blake (1902), in Arizona, stated that caliche:

> ...has been generally assumed to be a deposition from some ancient lake, or body of water, covering the area in which it is found. But such a theory is untenable when all the phenomena are considered. The formation is clearly the result of upward capillary flow of calcareous water, induced by constant and rapid evaporation at the surface in a comparatively rainless region.

Others believed that the carbonates were deposited from moisture that moved from the surface downward. Forbes, in Arizona, stated (in Lee, 1905):

> My view of the formation of caliche is that in this region of scanty rainfall, which penetrates the ground from a few inches to a maximum of a very few feet--say 3 or 4--the rain water, containing a small amount of carbon dioxide, percolating from the surface to this maximum depth of, say, 3 feet, dissolves small portions of the calcium and magnesium bicarbonates in the form of normal carbonates, leaving in the course of time a layer of limy hardpan at the depths to which it penetrates.

Frye (1970) stated:

> The "Ogallala-climax" Soil caps the Ogallala Formation. The strongly developed caliche of this soil has been called "cap rock," "algal limestone," "pisolitic limestone," and "caliche." Regardless of its name, it is a most unusual rock. The fact that this carbonate layer originated as a soil caliche seems

> to be established beyond debate but its present form and character are attributable to a long and complex series of desiccations, brecciations, recementations, and additions....

Detailed studies of soils present strong evidence that the studied horizons of carbonate accumulation have formed by dominantly downward (with some lateral) movement of water from the surface. Hawker (1927) in southern Texas; Bretz and Horberg (1949) in southeastern New Mexico; Brown (1956) in the High Plains of Texas; Swineford et al. (1958) in the High Plains of Kansas, Oklahoma, and West Texas; Stuart et al. (1961) in Idaho; Gile et al. (1966) in southern New Mexico; Reeves (1970) in the High Plains of Texas and New Mexico; and Gardner (1972) in Nevada present evidence for pedogenic origin of carbonate horizons they studied. The presence of pedogenic horizons in these widely separated areas indicates that many of these horizons developed by soil-forming processes.

Most carbonate horizons in the study area are of pedologic origin, as indicated by these characteristics: (1) The horizons approximately parallel the soil surface. (2) In the arid part of the study area their upper boundaries are usually within a few cm to about ½ m of the soil surface and are or have been within reach of wetting. (3) Their morphology is distinctive, predictable, and differs markedly from that of adjacent horizons. (4) The horizons form in morphogenetic sequences that are related to time as discussed later. (5) Depth to the horizon of carbonate accumulation increases mountainward in soils of stable sites. This reflects the increase in precipitation and indicates an eluvial-illuvial relationship.

There is supporting geologic evidence that some of the carbonate accumulations could not have been emplaced from water tables or lakes. Arguments presented by Bretz and Horbert (1949) and Brown (1956) also apply in this area.

The calcium in the pedogenic carbonate is considered to have originated from carbonate in the parent material or from atmospheric additions, both precipitation and dry dust fall (section 40). In places the accumulations occur where the atmosphere is the only source of calcium. Calcium from the atmosphere would move into a soil whenever it is wetted. Calcium bicarbonate in solution moves downward through the soils each time they are wetted and calcium carbonate is deposited on drying. Carbonate tends to accumulate in the lower part of the zone that is wetted frequently under the climate existing at a given time in soil history. The carbonate occurs in places most accessible to percolating water. These are the surfaces of grains and peds, the interiors of still-pervious accumulations, and along channels formed by roots and soil fauna.

Some carbonate in the area is of geologic origin. An example occurs in ancestral deposits of the Rio Grande (the fluvial facies of the Camp Rice formation). These deposits are extensive on the east side of the valley south of Goat Mountain. The carbonate occurs as irregularly cemented beds that do not have pedogenic features. Bedding planes are usually well preserved, which is not the case in pedogenic accumulations of this magnitude.

Carbonate surrounding and cementing the grains is almost pure calcite, with little or no material other than calcite, whereas, carbonate of pedogenic origin commonly has an earthy appearance and contains other constituents such as silicate clay. Carbonate in these beds is thought to have been deposited by waters of the ancestral Rio Grande. In strongly dissected areas this carbonate is at or very near the surface and may be intimately mixed with carbonate of pedogenic origin.

Another example of carbonate of geologic origin is that emplaced from ground water along the top of buried Bt horizons. This carbonate occurs as nearly horizontal sheets a few mm to a few cm thick. Overlying sediments are commonly coarser textured, and carbonate has accumulated along the contact. This kind of carbonate has been observed beneath relict basin floors (now cut by stream valleys) that once must have had high water tables.

In places carbonate of uncertain origin is found in beds well below the normal depth of carbonate accumulation for the soils and cannot be related to a soil or land surface. Such accumulations may in places be observed in deep cuts in alluvial fans. Some of this carbonate is morphologically similar to pedogenic carbonate. This carbonate may have been deposited by laterally moving ground water, or from water that moved completely through soil horizons some distance above. The latter is thought to have happened during pluvials in very gravelly soils.

66. OROGRAPHIC RELATIONS

The relation of depth of carbonate leaching to current precipitation is best illustrated by Holocene soils because the effective moisture available during the development of these horizons must have been similar to that of the present. Figures 27 and 28 show the relationship. The pedons selected are developed in low-carbonate alluvium; and most or all of the carbonate was derived from atmospheric additions. Pedons are on sites selected to minimize the influence of runoff or run-in and to maximize infiltration. The sites are level, or very nearly level transversely. They lack gullies or drainageways, and are on slight ridges or terraces where there would be essentially no run-in from areas upslope. The materials are sandy loams and should be highly pervious.

The noncalcareous zone in both transects distinctly reflects the increase in precipitation toward the mountains (figs. 27, 28). In the transects in soils formed in monzonite alluvium (fig. 27), the general similarity of noncalcareous zones at elevations of 4300 and 4600 feet suggests that the precipitation between these two locations does not differ greatly (the noncalcareous zone is actually thicker at 4300 feet elevation). The considerable increase of the noncalcareous zone at 4800 feet, however, suggests that precipitation has definitely increased at this elevation. The transect in soils formed in rhyolite alluvium (fig. 28) is shorter. This is because areas along the valley border of the Rio Grande have been affected by valley downcutting, and landscapes are less stable than those represented by figure 27; also, the very gravelly sandy loam textures used in the transect are less common in the gentle slopes along the valley border.

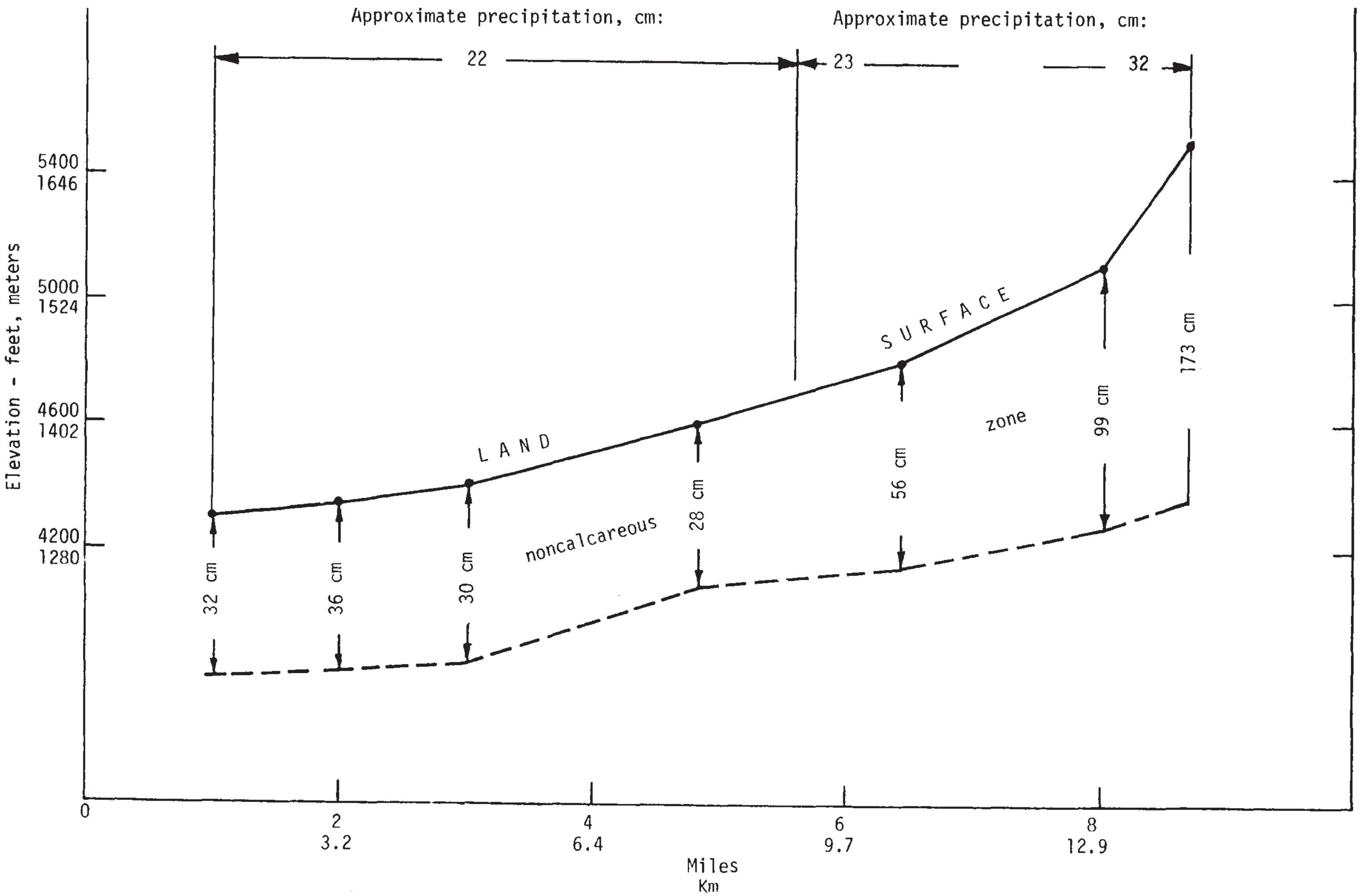


Figure 27. Relation of thickness of noncalcareous zone to increasing precipitation and elevation. Soils formed in low-gravel monzonite alluvium west of the Organ Mountains. Transect starts at pedon 70-5 (left) in section 26, T21S, R2E, and ends at pedon 59-1, in section 31, T21S, R4E. All soils are known to be less than about 7500 years old by radiocarbon dating. Precipitation data by interpolation from the New Mexico State University, Jornada Experimental Range and from Boyd's Ranch weather stations. Noncalcareous zone not to scale.

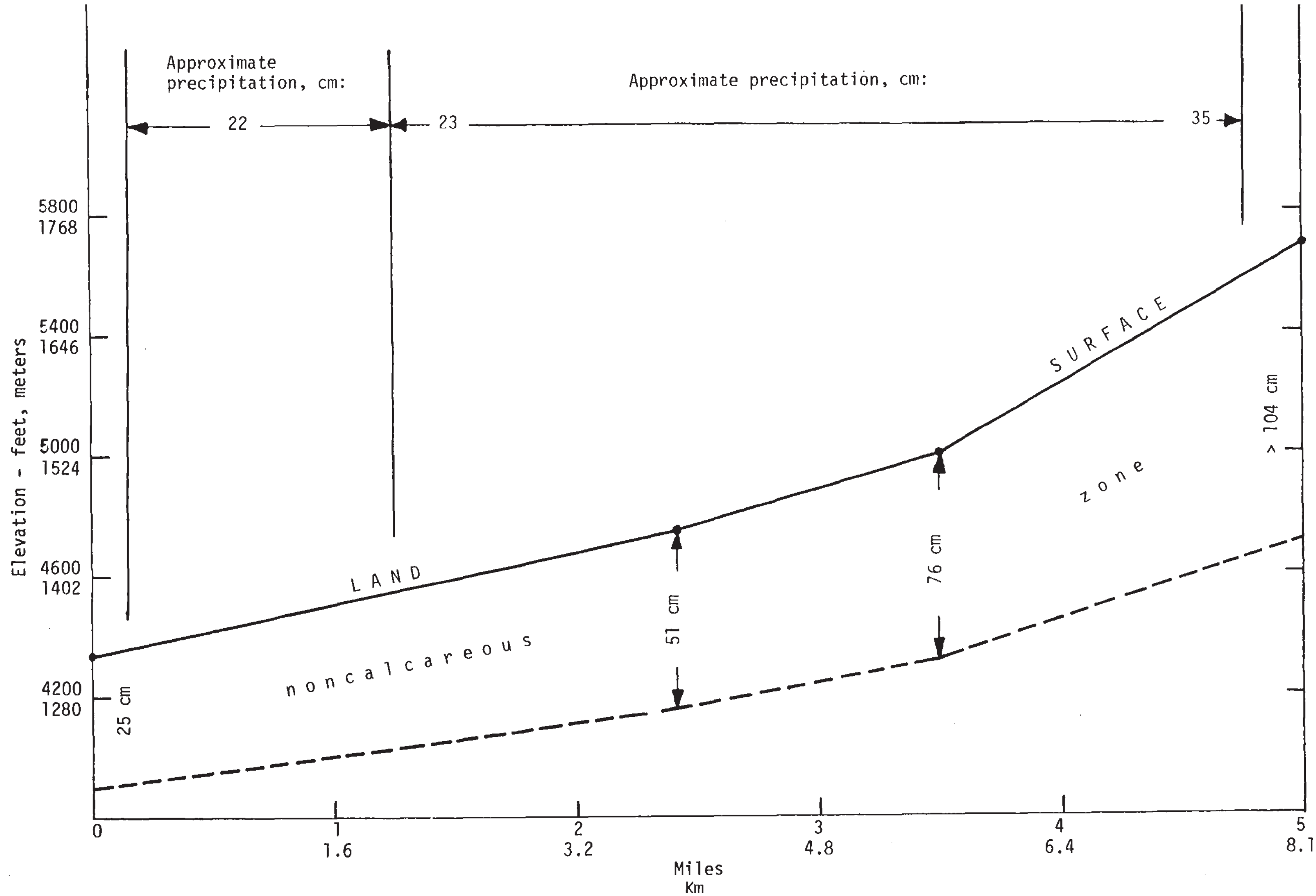


Figure 28. Relation of thickness of noncalcareous zone to increasing precipitation and elevation. Soils formed in gravelly rhyolite alluvium west of the Organ Mountains. Transect starts at pedon 66-16 (left) in section 30, T23S, R3E, and ends at pedon 60-12, section 13, T23S, R3E. All soils are known to be less than about 7500 yr old by radiocarbon dating. Precipitation data by interpolation from the New Mexico State University, Jornada Experimental Range and from Boyd's Ranch weather stations. Noncalcareous zone not to scale.

Noncalcareous horizons in soils of Pleistocene age do not reflect precipitation as clearly as do the Holocene soils because textures are finer, leading to lower infiltration rates and consequent higher runoff. Also, many soils of Pleistocene age have been truncated. Nevertheless, there is a definite thickening of the noncalcareous zone towards the mountains in soils of stablest sites and of late-Pleistocene or late-Mid-Pleistocene age. In the mountain canyons, carbonate leached in Pleistocene pluvials apparently moved almost completely out of the soils since they lack the prominent accumulations at shallow depths in soils of the same age downslope. Holocene carbonate accumulations are present in these soils of Pleistocene age. This is indicated by morphological similarity to the carbonate accumulations in nearby Holocene soils. Textures of soils of Pleistocene age are usually finer than adjacent Holocene soils, and consequently their Holocene carbonate accumulations tend to be shallower.

67. MORPHOLOGY

Carbonate occurs both as various kinds of segregations, between which there is little or no pedogenic carbonate (table 52) and uniformly throughout the horizon of accumulation (table 53).

68. MORPHOGENETIC SEQUENCES

Two morphogenetic sequences of carbonate accumulation have been described, one in high-gravel and the other in low-gravel materials (fig. 32). Carbonate morphology occurs in stages of increasing development that accord with increasing soil age and amounts of authigenic carbonate. (fig. 32). Table 54 summarizes the two sequences.
The more complex horizons contain carbonate forms that are relict from earlier stages. Carbonate horizons that contain the greatest variety of relict features occur on land surfaces shown to be older by geomorphic evidence. This lends phylogenetic significance to the stages of carbonate accumulation. The stage notations designate development of the horizon of carbonate accumulation as a whole in a given soil. They may also be used to indicate specific subhorizons within the overall horizon of carbonate accumulation.

Materials similar to the modern deposits in arroyo channels must have been the parent materials in which carbonate horizon formation started. Authigenic carbonate in arroyo deposits is restricted to a very few discontinuous, extremely thin flakes on pebbles or sand grains. A few pebbles with thick hard carbonate coatings occur in places; these could only have been derived from some carbonate horizon upstream. Such heavily coated pebbles are distributed randomly throughout the sediment rather than in a horizon.

69. Stage I

Gravelly: thin, discontinuous pebble coatings. Carbonate has accumulated as filaments and thin flakes on pebbles forming thin, discontinuous pebble coatings. Interpebble fine earth is usually calcareous but can be noncalcareous in the upper part of the horizon. In the last part of the stage, many or all pebble coatings are thin and continuous.

Table 52 . Forms of segregated carbonate.

Filaments. Soft threadlike forms ranging from about 1/4 to 2 mm in diameter. Filaments and coatings (below) are the first macroscopic forms to develop. Occur on ped surfaces, within peds, on pebbles, in root channels and insect burrows. Presently forming in many soils.

Coatings. Occur as thin, partial or complete coatings on sand grains, pebbles or peds. In very gravelly deposits carbonate tends to accumulate first on the bottoms of pebbles, reflecting movement of water from tops to the bottoms of the pebbles, where the carbonate accumulates as the water finally evaporates. At this stage, if the overlying horizon is noncalcareous, fine earth between the pebbles just beneath is commonly noncalcareous. Soft to hard.

Veins. Occur mostly between surfaces of prisms, completely coating and separating whole prisms in some instances. Range in thickness from about 1 mm to several cm. In the study area they are most common in buried soils, between prisms of B horizons that were once noncalcareous throughout. Many prism interiors are noncalcareous in part. Slightly to very hard.

Nodules formed by progressive accumulation. Roughly spherical or blocky forms that usually range from about 1/2 to 2 cm in diameter (fig. 29). Appear to have formed in insect burrows and in parts of former root channels, as indicated by partial fillings in these features. Similar to "cicada krotovinas" of Hugie and Passey (1963). A few live cicadas, and both empty and partially filled burrows have been observed in some soils. Soft to extremely hard.

Nodules formed by weathering. Roughly spherical or blocky forms that developed by weathering the upper subhorizons of calcic or petrocalcic horizons. Hard to extremely hard. Commonly range from about 1/2 to 5 cm in diameter with some considerably larger. In places they grade into plates. Most common along the tops of petrocalcic horizons, particularly very old ones near the surface (fig. 30). Apparently formed by water movement along the top of the petrocalcic horizon, mostly during pluvials, when more effective moisture would have been available. With time these nodules can be cemented and engulfed by younger carbonate as shown in figure 31.

Cylindroids in sands. Usually range from about 1 to 5 cm in diameter, are roughly vertical, and extend to depths ranging from a few cm to several meters. Where the materials are gravelly, some rest on rock fragments as large as or larger than the cylindroids (illustrating a case where carbonate accumulates on tops of the pebbles instead of on the bottoms). These kinds are usually cemented, with materials between them being loose and in places even noncalcareous. Appear to reflect water movement down and below root channels. Some consist largely of a carbonate-cemented shell containing a few fine roots and resemble rhizo-concretions described by Sherman and Ikawa (1958).

Cylindroids in finer materials. Cylindroidal forms, best exposed on a weathered face where softer materials have been eroded away (fig. 29). Most have roughly vertical orientation; some are diagonal and a few are horizontal. Range from about 1/2 to 2 cm in diameter and from a few to 25 cm in length. Most appear to be fillings in old root channels and insect burrows, and are similar to nodules except for their length. Best developed in moderately fine and fine-textured materials with little or no gravel. Many have been fractured and more or less mixed with adjacent materials, giving discrete nodular or disk-shaped forms (fig. 29).

Concretions. Occur as indurated, rounded forms that apparently grew outward from the center. In the study area they have been observed only along bedding places of nongravelly basin-floor sediments and may be of geologic, rather than of pedologic origin (may have been emplaced by ground water).

Clusters. Agglomerations of a few to many carbonate-cemented nodules (in nongravelly materials) and pebbles (in gravelly materials). Carbonate has accumulated to a degree that internodular and interpebble material has cemented the material into isolated masses that are separated by low-carbonate material.

Plates. Isolated plates of carbonate-cemented material occur above calcic and petrocalcic horizons (fig. 31). Formed by fracture of once-continuous subhorizons in the upper part of a calcic or petrocalcic horizon. Material may be indurated or nonindurated. Hard to extremely hard.

Table 53. Morphology of horizons with continuous carbonate.

Laminar. Consists of poorly to well-defined carbonate laminae that range in color from white to brown or reddish brown. They are about parallel, roughly horizontal, and more or less planar (fig. 31). Thickness of individual laminae ranges from about .01 to 2 mm. The surface is smooth and gently undulating. Amplitude of the undulations is generally not greater than a few cm. One to several laminar horizons occur in the upper part of most petrocalcic horizons and they are numerous in many very old petrocalcic horizons. Laminae also occur as linings in old pipes and as coatings on prisms in thick, old petrocalcic horizons. The laminar horizon is commonly the hardest and most dense part of the petrocalcic horizon.

Platy. Occurs in the upper part of some calcic and petrocalcic horizons. Common in many thick petrocalcic horizons (fig. 30), in which the laminar horizons and underlying horizons occur as grossly platy units. In many places, laminae occur together with underlying nodular or massively cemented carbonate in vertical sequence of several platy units. Some plates constitute the upper parts of huge (1/2 to 1-1/2 m thick), tightly fitting prisms that extend downward into petrocalcic horizons. Indurated in petrocalcic horizons but usually not in calcic horizons except where a once-continuous petrocalcic horizon has been broken up, as by landscape dissection.

Nodular. Similar to the segregated type but here the carbonate occurs throughout the horizon. Nodules may represent the carbonate maximum, or they may occur below the carbonate maximum. Some nodules in most calcic horizons are indurated. Many or all nodules are indurated below petrocalcic horizons.

Massive. No definite arrangement of natural lines of weakness. Massive carbonate is most common in petrocalcic horizons, below the laminar horizon. Carbonate coatings on pebbles are commonly 1 mm or more in thickness and many pebbles are separated by carbonate. Consistence is slightly to extremely hard. In some areas massive carbonate occurs along sedimentary strata. The more prominent examples of the latter have a bedded appearance.

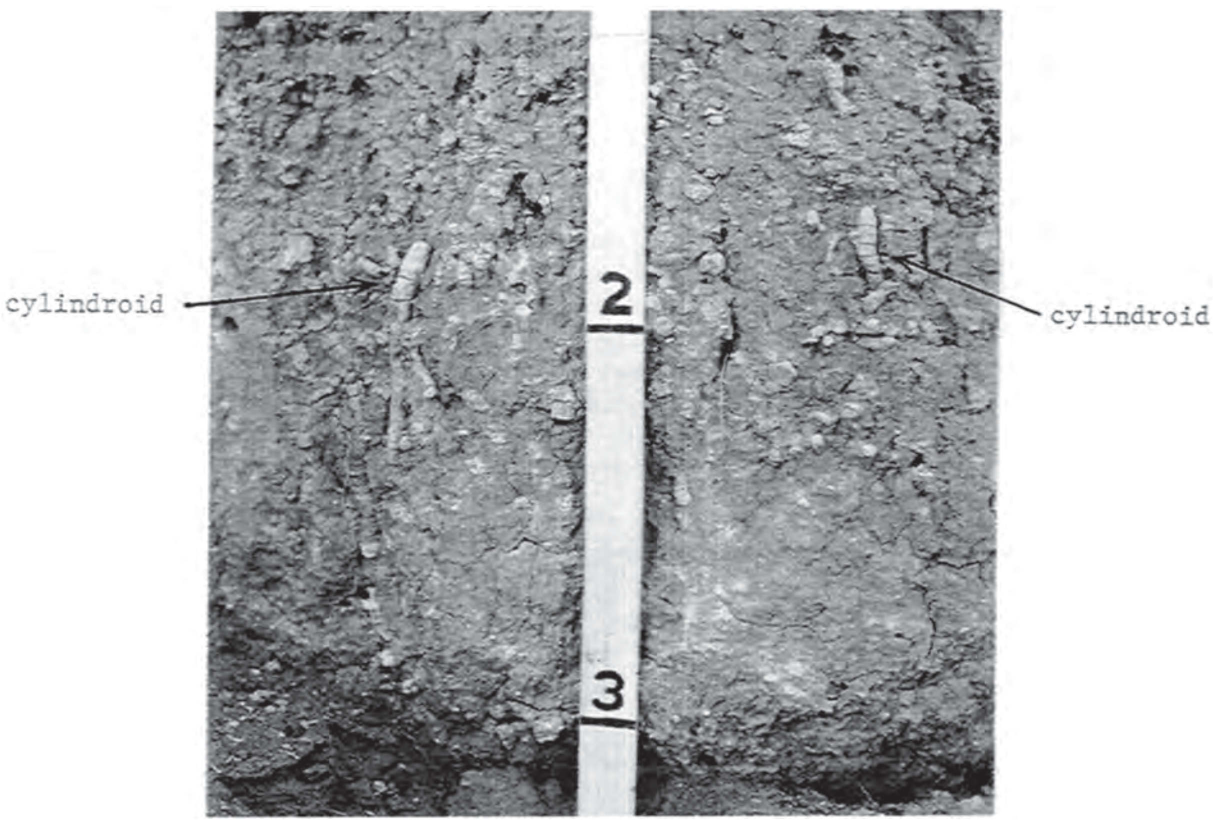


Figure 29. Upper. A Typic Haplargid (Berino series) with carbonate nodules and cylindroids. See closeup below. Scale is in feet.

Lower. Carbonate nodules and cylindroids. Two prominent cylindroids indicated. Shorter, rounded forms are nodules, some of which once were cylindroids but now are broken and mixed with adjacent material.

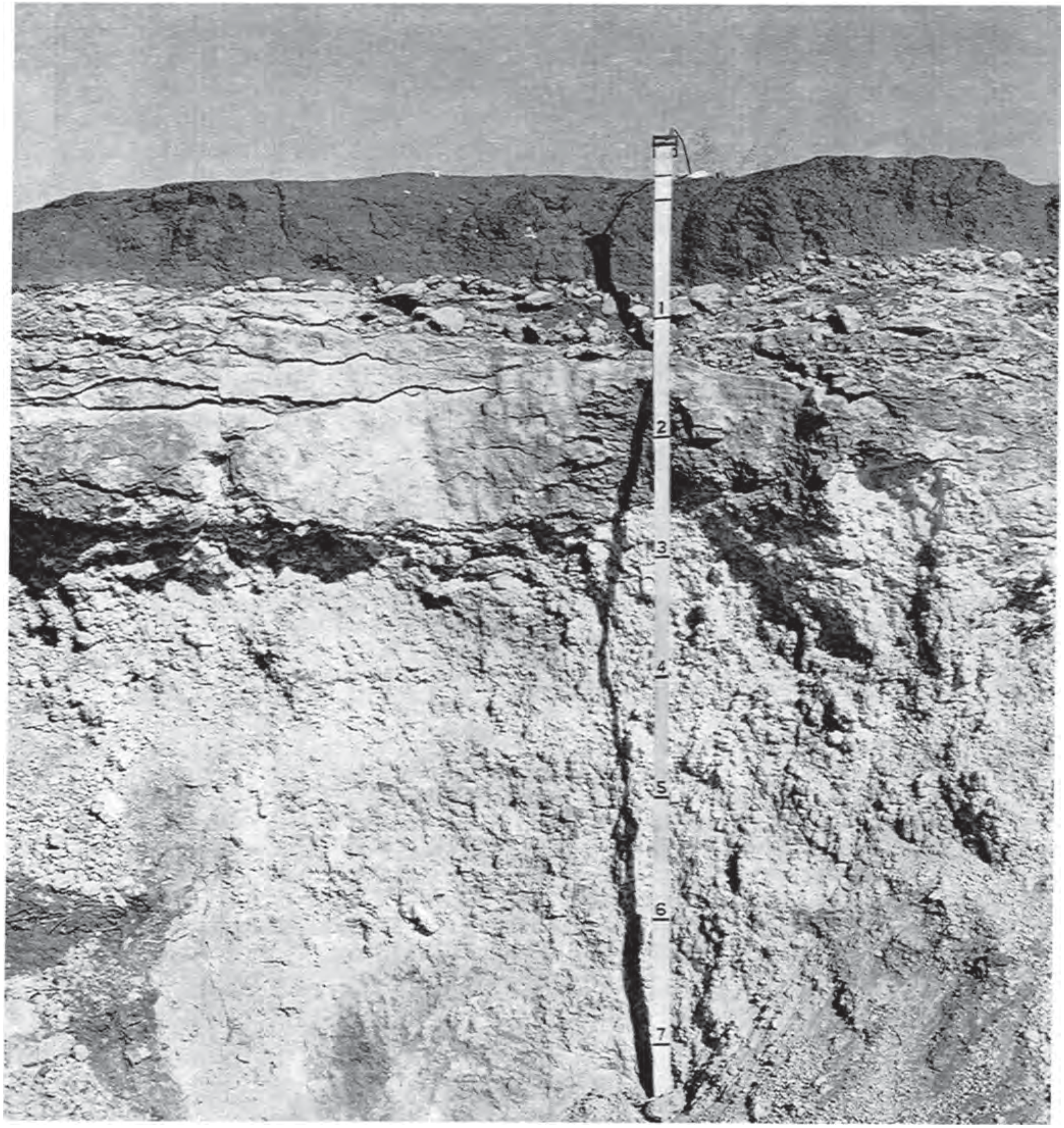


Figure 30. A Petrocalcic Paleargid of mid-Pleistocene age, in nongravelly materials on upper La Mesa surface. The smooth face of the K2m horizon (to the left of the two-foot mark) is the face of a very coarse prism which can be platy or massive internally. The plates in the left side of the K2m horizon are indurated, extremely hard and cannot be moved by hand. Scattered small nodules and plates (formed by weathering) rest on top of the K2m (petrocalcic) horizon, which is in stage IV of carbonate accumulation. Scale is in feet.

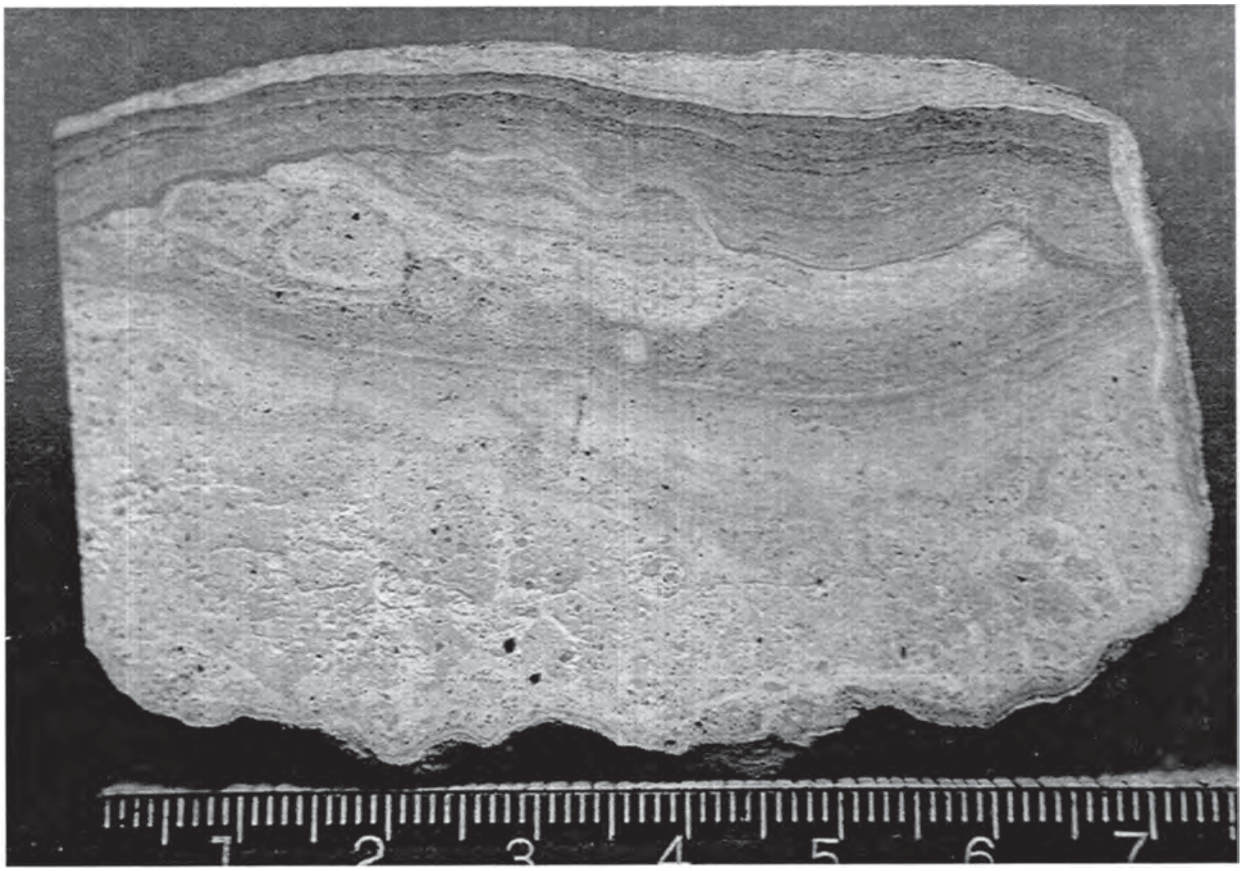


Figure 31. Vertically oriented polished section of laminae and underlying carbonate-cemented material, from a plate resting on a K2m horizon like the one shown in figure 30. At least 5 sets of laminae are apparent. Most sets of laminae have been truncated by younger, overlying sets. The youngest, outer set truncates all older sets, the underlying material, and continues around the bottom of the plate. Laminae beneath the uppermost set were formed prior to fracture of a formerly continuous, upper subhorizon of a K2m horizon. Detrital material, including distinct nodules at left, resting on the second set from the bottom, has been engulfed by subsequent laminae.

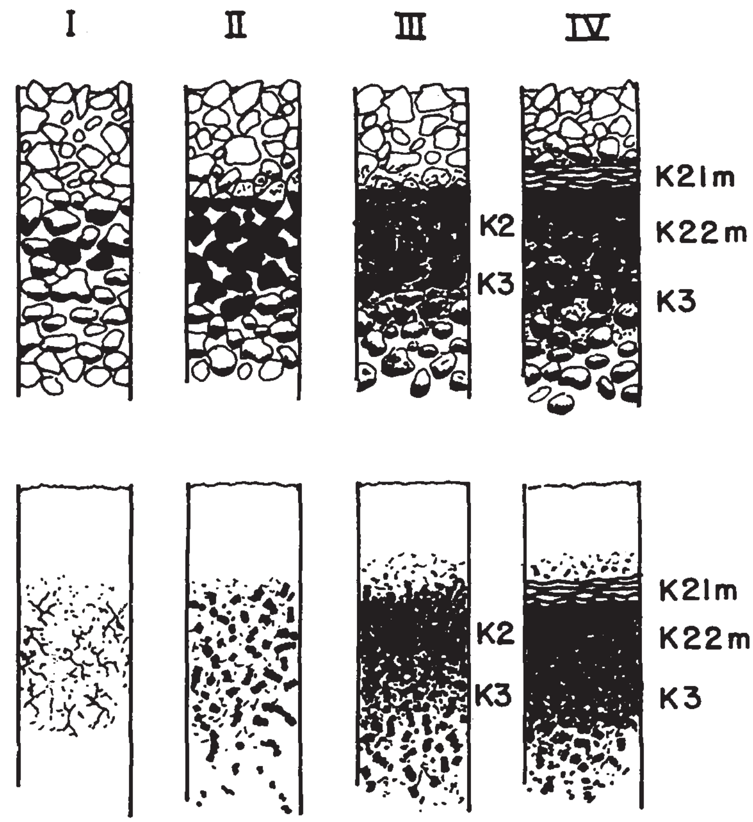


Figure 32. Schematic diagram of the diagnostic morphology of the stages of carbonate horizon formation in gravelly and nongravelly materials. Carbonate accumulations are indicated by black forms and shadings for clarity.

Table 54. Stages of carbonate accumulation in the two morphogenetic sequences.

Stage and general character	Diagnostic carbonate morphology	
	Gravelly Soils	Nongravelly Soils
I Weakest expression of macroscopic carbonate	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II Carbonate segregations separated by low-carbonate material	Continuous pebble coatings, some interpebble fillings	Few to common nodules
III Carbonate essentially continous; plugged horizon forms in last part	Many interpebble fillings	Many nodules and internodular fillings
IV Laminar horizon develops	Laminar horizon overlying plugged horizon	Laminar horizon overlying plugged horizon

Nongravelly: few filaments or faint coatings. The horizon of carbonate accumulation is characterized by a few filaments or faint carbonate coatings on sand grains. Carbonate filaments are common in the last part of the stage.

70. Stage II

Gravelly: continuous pebble coatings, some interpebble fillings. The horizon of carbonate accumulation has continuously coated pebbles and some interpebble fine earth is calcareous and is whitened in part, but is dominantly uncemented, with cementation restricted to occasional clusters of several pebbles and the interstitial fine earth. Development of stage II morphology from stage I consists of closing remaining gaps in the coatings on the pebble surfaces, and in places, extending bridges of carbonate to fine earth immediately adjacent to pebble surfaces. In addition, carbonate coatings of stage II are thicker than those of stage I. The duration of stage II is quite short in gravelly materials because of the very low pore space available for carbonate accumulation.

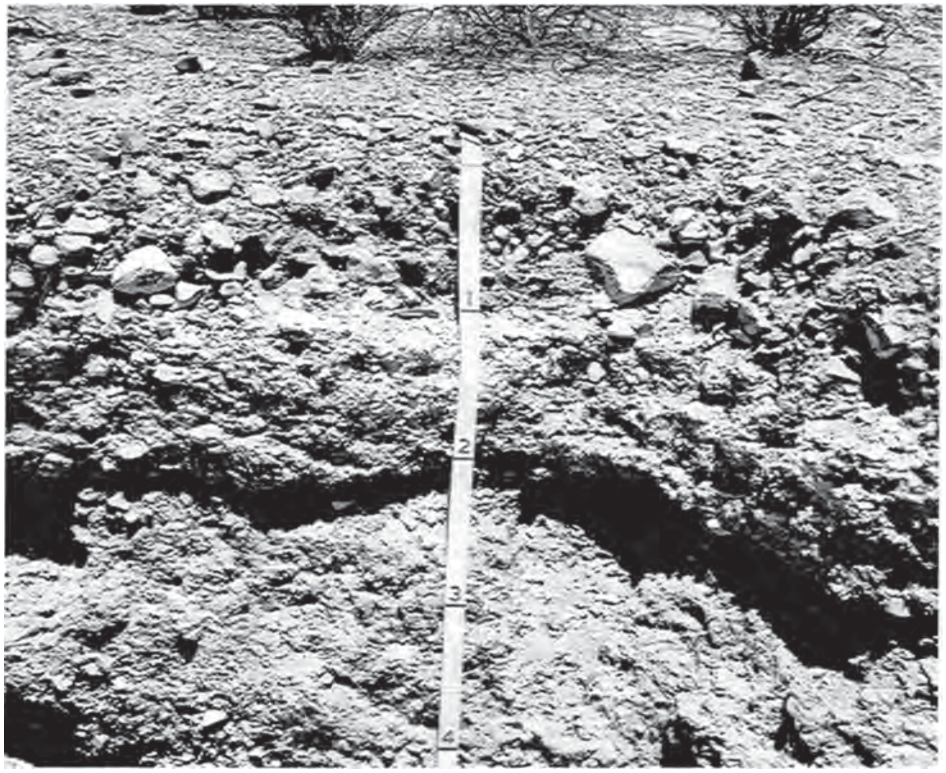
Nongravelly: few to common nodules. This stage of carbonate accumulation is characterized by prominent concentrations of authigenic carbonate in the form of nodules or cylindroids. The nodules are slightly to extremely hard; some are cemented. The matrix material is commonly reddish brown or brown, being at most only slightly whitened by carbonate, and it has a fabric characteristic of a B or C horizon. The matrix is commonly calcareous, but can be noncalcareous in part. Some nodules are cylindroidal in shape.

71. Stage III

The diagnostic feature is continuity of the fabric high in authigenic carbonate.

Gravelly: many interpebble fillings. Carbonate has accumulated to such a degree that in the upper portion of the horizon all or nearly all pebbles are thickly coated with and separated by carbonate. Cementation by carbonate is largely continuous. A horizon in stage III of accumulation is illustrated by Casito 60-1 (fig. 33). In the last part of this stage of carbonate accumulation, most of the interstices between pebbles are filled or plugged with authigenic carbonate. Bulk density is increased and infiltration rate is markedly reduced. When plugged, all parts resist slaking when an air dry piece is placed in water. Prior to plugging, parts of stage III horizons soften markedly on wetting, and slake when placed in water; texture can be evaluated in the field. The upper boundary of the plugged horizon consists of pebbles affixed in and protruding from carbonate-cemented fine earth (fig. 33).

Stage III horizons are morphologically related to stage II. Carbonate pebble coatings in stage III are clearly distinguishable from carbonate that fills interstices between the coated pebbles by the dense fabric, scarcity of skeletal grains, and abruptness of the outer boundary. These coatings are similar to those of stage II and are interpreted as being largely relicts from stage II. Hence the pebble coatings should be older than the carbonate between the coatings and carbonate for the whole horizon. This is supported by radiocarbon ages (table 55). Figure 34, although of a stage IV horizon, shows the kind of coatings found in late stage III horizons.



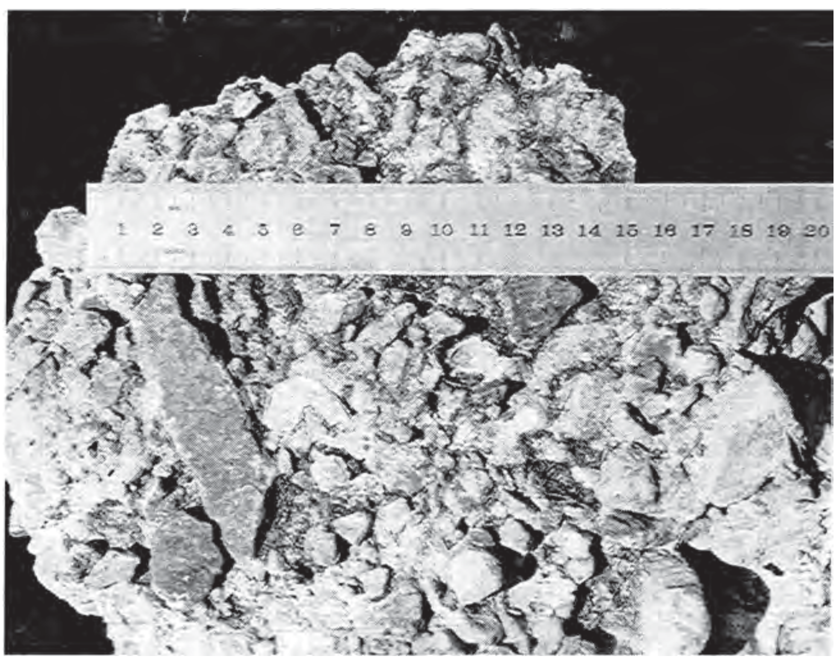


Figure 33. Upper. A Petrocalcic Ustollic Paleargid of late-Pleistocene age (Casito 60-1). The top of the plugged horizon and the petrocalcic horizon are at the one-foot mark. The horizon is in stage III of carbonate accumulation and the petrocalcic horizon is marginal.

Lower. The irregular, pebble-studded upper surface of the plugged horizon shown above (vertical view).

Table 55. Carbonate C-14 ages for different forms of carbonate in Cruces variant 59-16[1/]

Horizon and depth	Material	C-14 Age kyrs
B22tca	Whole sample	5.7
15-28 cm	Pebble coatings[2/]	10.2
	Fine earth[3/]	1.3
K21m	Soft upper laminae	4.6
28-30 cm	Hard lower laminae	13.9
	Non-laminar	18.3
K22m	Whole sample	15.3
30-64 cm	Pebble coatings	27.9

1/ Complete C-14 data in table 60, section 89.

2/ Pebbles ground and sample includes carbonate within cracks in pebbles as well as coatings.

3/ Computed from carbonate contents and C-14 activities of whole sample and pebble coatings.

Figure 34. Polished section of plugged horizon, Cruces variant 59-16. Pebbles are widely separated by carbonate, as is typical of plugged horizons. Carbonate coatings are mainly on the bottoms of pebbles, and there is no evidence of brecciation, rotation and recementation as is found in certain very old Km horizons.

The upper horizon is a K2 or K2m horizon; the lower horizon is either a K3 of Cca depending on the continuity of the authigenic carbonate coatings. A transitional K1 or Bca horizon occurs above some K2 and K2m horizons.

Nongravelly: many nodules and internodular fillings. At this stage, practically the entire horizon is carbonate-impregnated and most skeleton grains are coated with carbonate. Nodular forms, some cylindroidal in shape, are embedded in the horizon and suggest a genetic relationship to the preceding stage. A few reddish brown, low-carbonate inclusions may be present in less strongly carbonate-impregnated examples, and at the upper boundary of some horizons. In the last part of this stage of development, many skeleton grains are separated by carbonate and most pores are plugged by carbonate. The horizon is then cemented and can be indurated.

The upper, more prominently carbonate-impregnated part of the stage III carbonate horizon is a K2 horizon. The horizon below is either a K3 or Cca. The upper fringe of carbonate accumulation is a transitional K1, a Bca, or an Aca horizon.

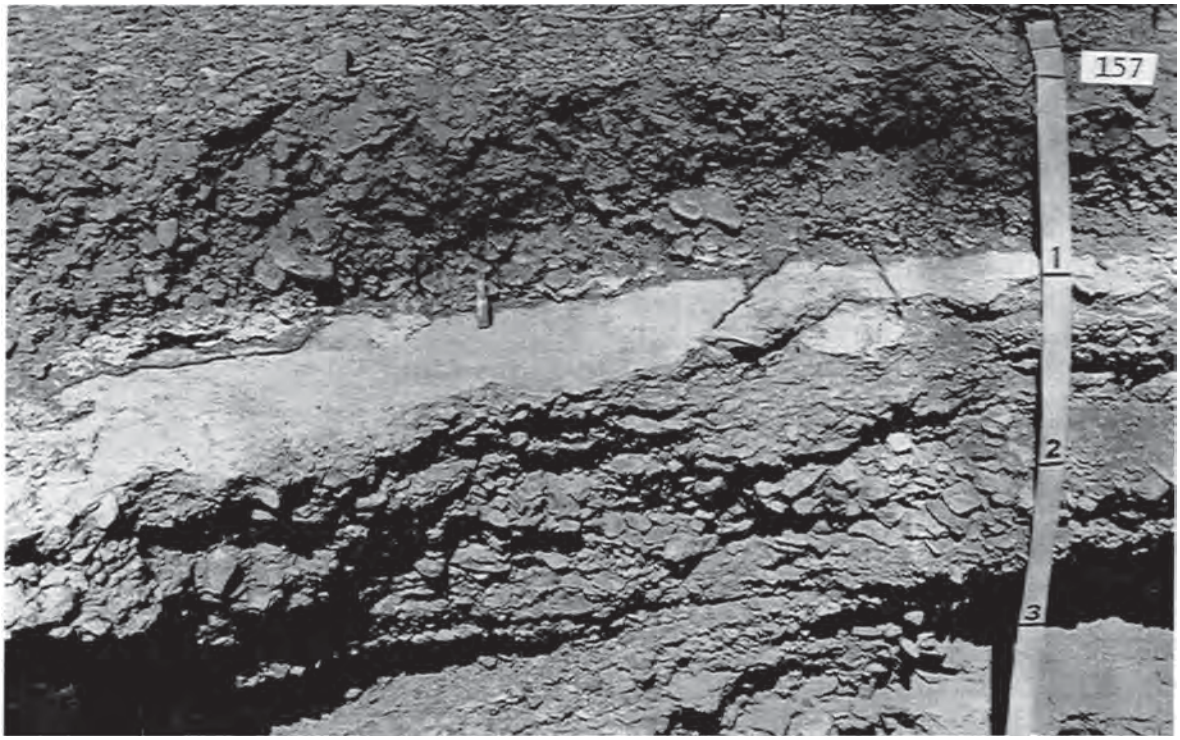
72. Stage IV

The diagnostic features of this stage are an indurated horizon of thin, roughly horizontal carbonate laminae and an underlying strongly cemented, carbonate-plugged horizon. Similar thin carbonate layers are found in the plugged horizon, but they are restricted to irregular and sharply curving surfaces, such as pebble bottoms, and do not extend between more than a few pebbles.

Gravelly: laminar horizon overlying plugged horizon. Stage IV is illustrated by a pedon near Cruces variant 59-16 (fig. 35). The laminar horizon, consisting primarily of carbonate, contains markedly less gravel than adjacent horizons and its noncalcareous fine-earth component contains more clay and organic matter. In some soils the horizon overlying the K2m has 50 percent or more of K-fabric and is designated K1.

Carbonate coatings around pebbles of the plugged horizon recall stage II morphology; the combination of coatings and interstice fillings recall stage III. Lateral gradation between stages III and IV occurs in soils of the Picacho surface and indicates the close genetic connection between the two stages. In older soils there may be several laminar subhorizons and the plugged horizon may be thicker, yet the basic elements of stage IV morphology continue.

The carbonate in Cruces variant 59-16 differs widely in C-14 age depending on the subhorizon and the morphology within the horizon (table 55). Pebble coatings illustrated in figure 34 have much greater age than carbonate in the interstices between pebbles; this is the case both for the B22tca horizon and for the K22m horizon. This would be expected by the morphogenetic relations discussed earlier. Denseness and resultant resistance to solution and reprecipitation of carbonate, and consequent exchange with atmospheric CO_2, is probably another factor. The laminar subhorizon and adhering plugged subhorizon (fig. 35) show a large increase with depth in C-14 age. The soft upper



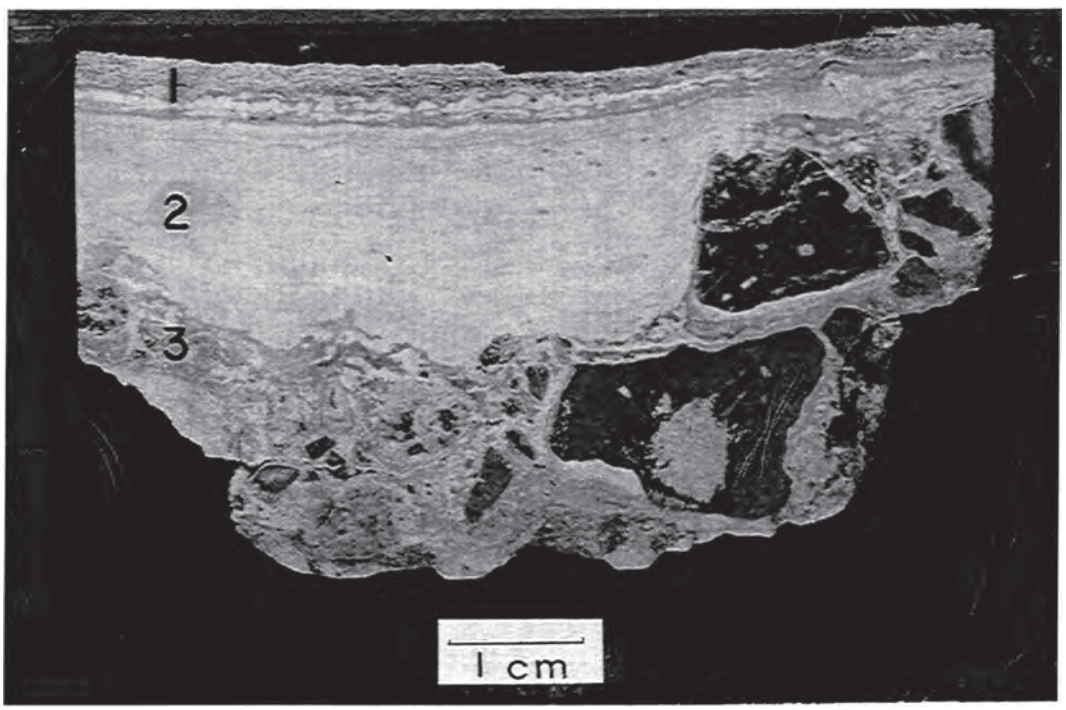


Figure 35. Upper. A Petrocalcic Paleargid, Cruces variant (in very gravelly rhyolitic alluvium) of late-Pleistocene age. The top of the laminar horizon and the petrocalcic horizon is at the one-foot mark. Note the roots resting on the top of the petrocalcic horizon. The horizon is in stage IV of carbonate accumulation.

Lower. A vertically oriented, polished section of the upper K2m horizon showing the laminar horizon and upper 2 cm of the carbonate-plugged horizon. The laminae fill and smooth over the depressions between protrudent pebbles of the pre-existing plugged horizon (see fig. 33). Rhyolite pebbles in the plugged horizon are separated by authigenic carbonate as are scattered sand grains in the laminar horizon. Zones dated by radiocarbon methods (see table 55) are: (1) soft upper carbonate laminae, (2) hard lower carbonate laminae, and (3) carbonate of adhering upper portion of plugged horizon. The section is from a pedon nearby the one shown above.

laminae, in fact, have a lower age than the pebble coatings in the B22tca above. The relatively low C-14 age for the soft laminae is consistent with the genesis of the laminar horizon, to be discussed, which assumes episodic wetting to very low tension of the uppermost part of a developing laminar horizon. The inversion between the C-14 age of 18.3 kyr for the uppermost part of the plugged horizon and 15.3 kyr for the middle and lower part is probably a reflection of differences in the rate of exchange with environmental CO_2. The middle and lower part of the plugged horizon contains powdery portions within which fine roots occur. This suggests occasional wetting by water moving through cracks in the laminar zone and spreading laterally into the less dense and more pervious parts of the horizon beneath.

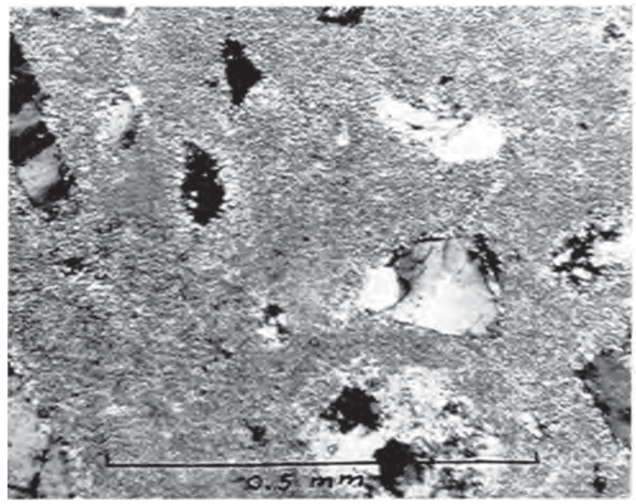
Nongravelly: laminar horizon overlying plugged horizon. Nongravelly soils require much longer to reach stage IV of carbonate accumulation than do gravelly soils. Soils with stage IV horizons formed in nongravelly materials are restricted to the mid-Pleistocene La Mesa surface, whereas in gravelly materials soils with stage IV horizons occur on the late-Pleistocene Picacho surface. Further evidence of the effect of gravel is provided by soils of late-Pleistocene age, in which there are abrupt facies changes from gravelly to nongravelly materials. In the nongravelly material the carbonate horizon is nodular, stage III, and is not indurated, whereas at boundaries to gravelly material the morphology changes to stage IV (plugged horizon and overlying laminar horizon).

In places the upper part of the K2m horizon is fractured into gross plates (fig. 30). Where considerable mixing has occurred, a transitional K1 horizon may be described. The overlying material may contain a distinct A to B horizon sequence, or may consist of only an Aca horizon derived in part from the carbonate horizon itself. On casual inspection the plugged horizon appears to be massively cemented, but in large exposures it can be seen to consist of very coarse prisms roughly ½ to 1 m or more in diameter (fig. 30); the prism faces are coated with thin layers of laminar carbonate. Sand grains in plugged horizons are widely separated by carbonate (fig. 36).

Figure 36 shows the distribution of $CaCO_3$ equivalent in soils illustrating stages I-IV of carbonate accumulation in nongravelly materials. There is a progressive increase in carbonate accumulation with increasing age.

73. GENESIS OF THE LAMINAR HORIZON

If the plugged horizon formed in thick, freely drained sediments which had undergone little erosion or deposition, then the depths between which it had formed would correspond to the depths of frequent wettings by unsaturated flow. As the final carbonate impregnation of the plugged horizon occurred and its macropores were filled, the zone of maximum carbonate accumulation would be forced upward. With impregnation completed, the plugged horizon interposes a zone only slowly pervious to moisture flow above the depth of most frequent wetting and well above the depth to which wetting



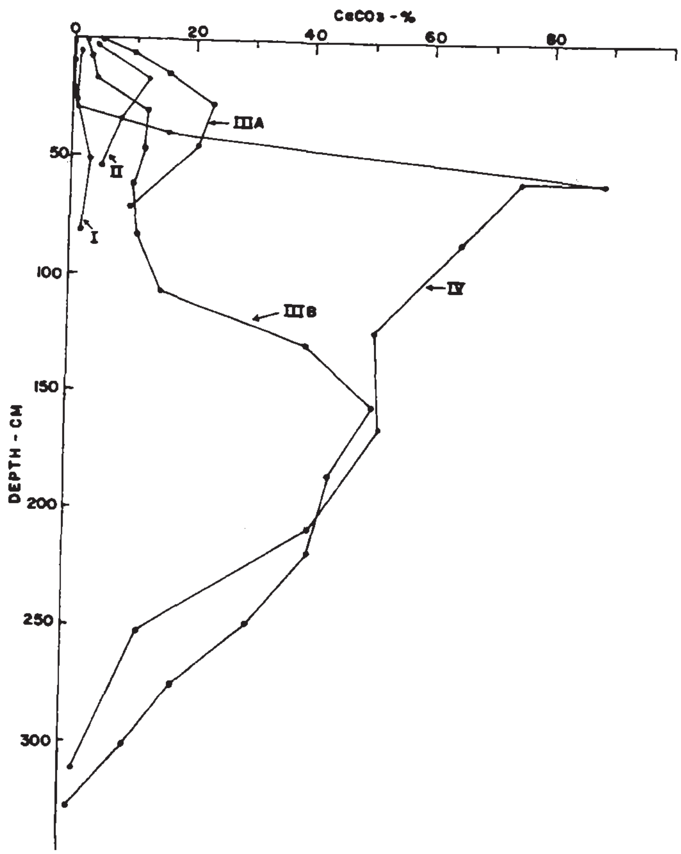


Figure 36. Upper. Thin section of plugged (K22m) horizon of Cruces 61-7. Sand grains are widely separated by carbonate.

Lower. Carbonate content of soils illustrating stages I to IV of the morphogenetic sequence of carbonate accumulation in nongravelly materials. I = stage I of carbonate accumulation, Bluepoint 59-10 (Fillmore surface); II = stage II, Mimbres phase 66-14 (Leasburg surface); IIIA = stage III (early) Algerita 60-2 (Picacho surface); IIIB = stage III (nearly plugged) Onite phase (lower La Mesa); IV = stage IV, Cruces 61-7 (upper La Mesa).

from a heavy storm would reach. Development of the laminar horizon is initiated at this point. Infiltrating water concentrates at the top of the carbonate-plugged horizon to the extent that a thin zone of free water results. This water collects in hollows along the top of the plugged horizon. Deposition of carbonate as these water films evaporate explains the thinness of the laminar zone and its tendency to fill low spots in the upper surface of the plugged horizon (fig. 35). This accounts for the extension of the laminar horizon down prism faces. It also explains the occurrence of the laminar horizon only on a material of relatively low permeability (other dense materials can substitute for the plugged horizon).

The numerous laminae suggest that carbonate accretion is episodic. The mode of formation proposed implies that carbonate in the upper laminae should be younger. Such is the case for the Petrocalcic Paleargid shown in figure 35. Moisture is reaching the laminar horizon of certain soils in the area (section 48) and it is probably developing slowly in these soils. Many laminar horizons, however, formed primarily during a Pleistocene pluvial, when they were more frequently moistened. Radiocarbon dates for Cruces 61-7 (section 152) indicate that some laminar horizons have formed rapidly.

Differences between the laminar and plugged horizons are so great that the fabrics differ in kind. The laminar horizon has much more carbonate than the plugged horizon and essentially no allogenic skeletal grains. Rather than the carbonate being a filling between skeleton grains, the laminar horizon consists almost entirely of carbonate, and the allogenic skeleton grains are incidental. The laminar horizon is a new soil horizon in the sense that it consists almost entirely of authigenic material and hence thickens the soil by its own thickness. The overlying horizons must have been displaced upward from their original position.

There may be only one laminar horizon (fig. 35) or several, as in the ancient soils of La Mesa (figs. 30,31). In places the latter horizons show evidence of fracture, weathering and recementation. In multiple sets, the laminar horizons may parallel one another, or one set may truncate angularly another. Pipes descend into many petrocalcic horizons and are lined with laminae (section 152). The still older soils of the Rincon surface (Hawley, 1965) have harder, denser, and more complex stage IV horizons.

Usually the noncalcareous fine earth of the laminar horizon is higher in silicate clay and organic carbon than adjacent horizons (table 56). Clay and organic matter suspended in downward-moving water are probably deposited on top of and then incorporated in the upward-developing laminar horizon. Organic matter probably is also contributed from roots that are impeded by the laminar horizon and concentrate immediately above it. Fine earth may loosen, drop to the surface of the laminar horizon, and subsequently be engulfed. Thin section observations and laboratory analyses indicate that relatively browner laminae are higher in clay and organic carbon than the associated whiter laminae (table 56).

Table 56. Laboratory data for laminar and plugged horizons.

Pedon Classification Parent material source	Material analyzed	Carbonate[1/]	Organic[1/] carbon	Clay[1/]
		pct	pct	pct
Cruces variant 59-16	Laminar horizon			
Petrocalcic Paleargid	Soft, upper part	74	1.9	53
Rhyolite	Hard, lower part	83	0.91	31
	Plugged horizon[2/]	46	0.46	24
Cruces 61-7	Laminar horizon			
Petrocalcic Paleargid	Whole	89	0.82	36
Ancient river alluvium	Browner upper portion	91	1.3	45
	Plugged horizon[2/]	75	0.29	26
Tencee 62-1 Typic Paleorthid Calcareous sedimentary rocks	Laminar horizon	75	1.4	28
Upton 66-5	Laminar horizon			
Typic Paleorthid Calcareous sedimentary rocks	Hard, lower part	88	0.60	
Terino 70-8	Plugged horizon			
Petrocalcic Ustollic	Whole	63	0.43	25
Paleargid Rhyolite	Pebble coatings[3/]	86	3.8	

1/ All on < 2 mm basis. Organic carbon and clay on carbonate-free basis.
2/ That portion of the plugged horizon adhering to the laminar horizon, 2-5 cm thick.
3/ Flaky, hard carbonate coatings of 2.5Y hue that adhere to pebbles.

In field examination the laminar horizon appears to break down completely on acid treatment, and therefore carbonate seems to be the only cementing agent. Laboratory studies confirm this. The clay appears to disperse completely after carbonate removal. As evidence, the ratios of exchange capacity to clay are not unusually high for the laminar horizon (table 56) and optical examination does not indicate more clayey material in the sand than in other horizons of the pedons. Further, total analysis data do not suggest silica accumulation (table 57).

74. DISINTEGRATION OF STAGE IV HORIZONS

Many stage IV horizons have disintegrated after they formed. Initiation of the process is well shown by soils of the late mid-Pleistocene Jornada I surface. Monterosa 67-2 (fig. 37) illustrates. It occurs on a relatively broad remnant of the fan-piedmont and slopes 2 percent to the southwest. The site is fairly stable, with no drainageways apparent in the vicinity of the site. This soil has a cambic horizon and a petrocalcic horizon. An argillic horizon was probably present at one time since argillic horizons do occur eastward in soils on stabler remnants of the Jornada I surface. At pedon 67-2 and vicinity, however, it has been obliterated by a combination of soil truncation, carbonate engulfment and mixing by soil biota. The uppermost laminar horizon has been broken and the fragments mixed in varying degree with fine earth (fig. 37; see also description in Appendix).

Reasons for breakup of the uppermost laminar horizon may be as follows. These Paleorthids have been truncated to some degree as indicated by their occurrence on ridge crests and the presence of nearby drainageways tributary to the ridge crests. Such truncation brings the petrocalcic horizon closer to the surface, concentrating the activity of soil fauna and flora in a smaller space; and it could increase growth of biota in cracks and holes that occur in upper subhorizons of most petrocalcic horizons. Soil truncation would also reduce the amount of infiltrating moisture needed to reach the petrocalcic horizon. Moisture could leach carbonate adjacent to cracks and holes, enlarging them; this carbonate could accumulate in deeper subhorizons. Continued growth of both carbonate crystals and roots in these places would force sections of the horizon apart so that it would no longer be continuously indurated.

The radiocarbon age of carbonate in the K2m horizon is 19.7 kyr (section 89). This age may seem young when the late mid-Pleistocene age of this soil is considered, particularly since the dated horizon underlies the lowermost laminar horizon. Clearly there must have been some exchange with environmental CO_2 after emplacement of the carbonate. Such youthening would have been expedited if the uppermost laminar horizons were fractured and the soil truncated.

Such breakup of the laminar horizon may be similar to the formation of pseudo-anticlines described by Price (1925) in Mexico. Price attributed uplifting and buckling of shale and limestone beds to the growth of caliche between the beds.

Table 57. Total analyses for the carbonate-free fine earth from the K21m horizons of Cruces variant 59-16 and Cruces 61-7.

Pedon	Material	Sample No.	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	K_2O	MgO	Ignition Loss	Total 1/	Clay
		<----------				Pct						---------->
Cruces var. 59-16	Soft, upper laminar	15029	58.8	16.5	4.72	0.68	1.06	3.08	1.81	9.44	96.1	53
	Hard laminar 2/	15030	66.3	12.9	3.36	0.54	0.89	3.72	1.92	6.04	95.7	31
	Plugged 3/	15031	74.2	10.2	3.34	0.55	0.76	2.66	1.30	3.64	96.7	24
Cruces 61-7	Laminar part 4/	14991	68.2	11.2	4.35	0.76	1.23	2.45	2.09	6.14	96.42	36
	Calculated 5/		68.2	11.3	4.74	0.59	1.27	2.12	2.09	6.09	96.40	
	Plugged part 5/	14992	76.6	8.40	2.36	0.40	1.48	2.16	2.05	5.08	98.53	26
	Calculated 5/		76.2	8.78	2.67	0.32	1.48	1.92	2.05	5.07	98.49	

1/ NaO not analyzed; hence percentages should not add to 100.

2/ No evidence of silica cement was found in the carbonate-free 0.05-0.02 mm under the petrographic microscope. The clay was treated with 0.5 N NaOH according to the procedure by Jackson (1956) for determination of amorphous silica. Values of 5.9 and 2.9 percent were obtained for silica and alumina removed, respectively. The same treatment on ground rhyolite gravel yielded 5 percent silica. The procedure would not seem specific for a silica cement.

3/ Adhering to laminar zone; 2-5 cm thick.

4/ Whole laminar zone inclusive of softer upper portion.

5/ Elemental percentages computed to a base free of carbonate using total analyses on the whole sample and after removal of the carbonate. Similarity of these computed values to the measured values supports the idea that little material is removed by the pH 5 NaOAc treatment except carbonate.

The amount of material other than from dissolved carbonates in the acidic solution was determined directly. A given weight of sample was treated with a pH 5 NH4OAc solution to dissolve the carbonate. An aliquot of the solution was removed and treated to drive off the ammonium salts and convert the Ca and Mg to sulfates. The weight of solids was then compared with the computed weight based on the Ca and Mg in another aliquot. The experimentally determined weight exceeded the calculated by 0.6 percent for the laminar part and by 0.5 percent for the plugged part.

Figure 37. Upper horizons of Monterosa 67-2. Platy, light-colored fragments above the continuous surface of the Km horizon once were part of continuously cemented laminar horizons. The fragments occur just above the Km horizon (particularly at the right) and extend upward to about half way between the top of the Km horizon and the soil surface. Scale is in feet.

75. CHRONOLOGY

Chronology of the morphogenetic sequences, in three physiographic areas is shown in table 58. The chronology is the same in the valley border and the fan-piedmont because they are in the same climatic zone. In the mountain canyons, however, a much longer time is required for development of the various stages because of the greater precipitation. Observations elsewhere in the Southwest and in Mexico indicate that the stage nomenclature may be related to the chronology of other soils with carbonate horizons. Relation of the morphogenetic sequences to the soil chronology may differ from place to place because of different moisture conditions or different amounts of carbonate in the atmospheric additions. However, the same general principles apply, so that the stage nomenclature would appear to be useful as a morphogenetic indicator wherever pedogenic carbonate occurs in soils.

76. QUANTITY OF CARBONATE

Tables 59 and 60 concern the relationship between carbonate percentage and expression within stage III. Data in table 59 suggest that a minimum of 15 to 20 percent carbonate on a less than 2 mm basis is required before a horizon enters stage III--that is, qualifies as a K2 horizon. Higher carbonate percentages, in excess of 40 percent, are required for the plugged horizon (or nonlaminar K2m), which represents the maximum development of stage III. Similar percentages are required on a fine-earth basis whether the materials are gravelly or nongravelly. Figure 36 shows the distribution of carbonate percentage with depth for pedons representative of the four stages as expressed in low-carbonate, nongravelly alluvium.

The amount of carbonate accumulated through pedogenesis at the present land surface has been calculated for pedons formed in low-carbonate parent materials. Table 60 presents these amounts stratified for nongravelly and gravelly pedons by stage (section 68) of the carbonate horizon. Horizon thickness is not a criterion of stage but does determine the amount of carbonate. Difference in thickness is an important reason for the large range in the amount of carbonate for a given stage. Other reasons for the wide range is the influence of texture and volume of coarse fragments. Amounts of carbonate in a given stage are lower for the gravelly pedons. For this reason, as discussed in section 72, stage IV develops more rapidly in gravelly soils.

77. RATE OF CARBONATE ACCUMULATION

The amount of carbonate (kg/m^2 to variable depth) have been grouped by soil age and estimates made of the rate of carbonate accumulation (table 61). The pedons selected occur on stablest sites where maximum carbonate accumulation would be expected.

The ranges in the rates of accumulation for the various age classes fall mostly between 1 and 10 $kg/m^2/kyr$. Considering the uncertainties, no significance should be attached to differences among the soil age classes. The maximum amount of carbonate added from current atmospheric sources of calcium (section 40) has been computed as about 2 kg/kyr, within the range of the computed rates of carbonate accumulation.

Table 58 . Stages of the morphogenetic sequences in arid and semiarid parts of the study area.

Stage: Nongravelly soils	Stage: Gravelly soils	Youngest geomorphic surface on which stage of horizon occurs and age - years B.P. or epoch	
		Arid (valley border)	
I	I	Fillmore	100 to 4000 years (Holocene)
II	II, III	Leasburg	Latest Pleistocene 7500 to 15,000
III	III, IV	Picacho	Late-Pleistocene 25,000 to 75,000
III	IV (multiple laminar zones)	Jornada I	Late-mid-Pleistocene 200,000 to 400,000
IV		La Mesa	Mid-Pleistocene 400,000 to 800,000
		Arid (fan-piedmont)	
I	I	Organ	100 to 7500 years (Holocene)
II	II	Isaacks' Ranch	Latest Pleistocene 7500 to 15,000
III	III, IV	Jornada II	Late-Pleistocene 25,000 to 75,000
III	IV	Jornada I	Late-mid-Pleistocene 200,000 to 400,000
		Semiarid (canyons in the Organ Mts.)	
		Organ	100 to 7500 years (Holocene)
	I	Jornada II	Late-Pleistocene 25,000 to 75,000
	II	Jornada I	Late-mid-Pleistocene 200,000 to 400,000
	III, IV	Dona Ana	Mid-Pleistocene

Table 59. Carbonate percentage on < 2 mm basis for K2 and nonlaminar K2m horizons of pedons developed in low-carbonate parent material.

Horizon	No. of pedons	Carbonate[1] Range	Median
		pct	
K2m, nonlaminar			
Very gravelly	3	46-62	55
Nongravelly	4	35-53	51-53
K2 (nongravelly)	16	14-40	22-23

1/ If more than one K2 or K2m horizon, single horizon selected having lowest carbonate percentage.

* * *

Table 60. Amount of carbonate for pedons developed in low-carbonate alluvium. Ordered by stage of carbonate horizon and volume of coarse fragments.

Stage and composition	No. of pedons	Amount of carbonate[1] Range	Median
		kg/m^2	
I			
Nongravelly	10	-0.8-55[2]	11-12
Gravelly	2	-1.9-4.9[2]	
II			
Nongravelly	4	25-75	46-68
Gravelly	2	22-24	
III			
Nongravelly	16	85-1400	250-300
Gravelly	4	96-250	140-160
IV			
Nongravelly	2	1400-1800	
Gravelly	4	260-330	260-300

1/ To variable depth determined by lower limit of carbonate accumulation associated with pedogenesis of soil at land surface.
2/ Negative values because an initial carbonate content of 1 percent was assumed in the fine earth.

Table 61. Amount and rate of carbonate accumulation for pedons grouped by soil age, in the arid part of the study area.

Epoch	Estimated range in age	Geomorphic surface	Pedons[2/]	Range in carbonate as $CaCO_3$ Total[1/]	Range in carbonate as $CaCO_3$ Accumulation rate
	kyrs			kg/m^2	$kg/m^2/kyr$
Holocene	1-4	Fillmore	66-16, 59-10	5-12	1-12
	2-4	Organ	67-3, 61-5, 62-3, 68-4, 59-5	8-20	2-10
Latest Pleistocene	8-15	Leasburg	61-9	46	3-6
Latest Pleistocene	8-15	Isaacks' Ranch	67-5, 70-6, 59-6, 59-7	22-75	1-9
	25-75	Picacho	60-1, 59-13, 60-2, 59-16	140-260	2-10
Late Pleistocene	25-75	Jornada II	68-9, 60-22, 61-4, 70-7, 59-8	213-300	3-12
Late mid-Pleistocene (youngest)	200-300	Jornada I	60-6, 60-7	751-834	2-4
Late mid-Pleistocene (oldest)	300-400	Jornada I	68-6, 60-21, 61-3, 61-1	795-1090	2-3
Mid-Pleistocene (youngest)	400-500	Lower La Mesa	61-8, 65-7	1200-1370	2-3
Mid-Pleistocene (oldest)	> 500[3/]	Upper La Mesa	66-12, 61-7	1380-1840	2-3

1/ Calculation follows Method 6A.

2/ Order of ascending amount of carbonate. The very gravelly pedons of Jornada I (pedons 61-10, 66-2, and 70-8) were excluded because of their lower carbonate values than low-gravel soils of the same age. It is thought that, during pluvials, some pedogenic carbonate moved deeper than the sampled horizons in very gravelly materials.

3/ 600-800 kyrs assumed for calculation.

78. SILICATE CLAY ACCUMULATION

Reddish-brown and red horizons of silicate clay accumulation are extensive in the study area. Evidence presented later indicates they contain illuvial clay and are Bt horizons. Their upper boundaries are commonly at a depth of about 5 to 10 cm. Most Bt horizons range from about 15 cm to 1 m thick in the arid part of the study area. In soils of stable sites Bt horizons gradually increase in thickness toward the mountains where precipitation is greater (section 10). Sand grains and pebbles in these horizons are at least partially coated with oriented clay, and if the criterion for clay increase is met they qualify as argillic horizons (Soil Survey Staff, in press). If the clay increase is not met the Bt horizon is a cambic horizon if it is fine enough, extends below 25 cm, and does not contain the carbonate maximum.

Typically the upper part of the argillic horizon contains little or no carbonate. But in some soils, all subhorizons of the Bt horizon contain appreciable carbonate. In this study the Bt horizon must have at least 10 percent by volume of Bt fabric to be recognized as an argillic horizon.

All of the parent materials contain silicate clay. Some of it originated by weathering of igneous rocks in the mountains. Other clay has been released through the weathering of sedimentary rocks in the San Andres and Robledo Mountains. Commonly, parent materials of the fan-piedmont contain some clay eroded from soils upslope. Dry dust fall also contains clay (section 44). Mineralogy of the clay is discussed in section 88. Information on the proportion of fine clay is presented in section 93.

79. EVIDENCE OF CLAY ILLUVIATION

Formerly it was thought that the clay accumulation in arid soils was due to in-place weathering (Nikiforoff, 1937; Brown and Drosdoff, 1940; Agricultural Experiment Stations, SCS, 1964). However, later work indicates an illuvial origin for much of the clay despite the absence of clay skins on peds and in pores (Gile and Grossman, 1968; Smith and Buol, 1968; Nettleton *et al.*, 1969, 1975). The morphogenetic evidence of silicate clay accumulation is not as prominent as for horizons of carbonate accumulation. In most instances some of the clay in the horizons of clay accumulation was probably present when soil development started; and the identification of illuvial clay is much more difficult. Nevertheless, a number of factors indicate clay illuviation and suggest that the absence of clay skins is caused by unfavorable conditions for their formation or preservation rather than a lack of illuvial clay.

(1) Soils of stable sites have a thin, grayish A2-like horizon with less clay than the underlying reddish-brown or red B horizon. The grayish color is most apparent when dry.

(2) Prominent coatings of oriented clay on sand grains and pebbles are a distinctive micromorphological feature of the Bt horizons. These coatings do not of themselves demonstrate clay movement subsequent to initiation of soil development because some of the clay on sand grains could be inherited from parent materials. In this respect the oriented coatings differ from clay skins on ped surfaces, which postdate the ped surface and hence must

have formed after soil development was initiated. The oriented coatings do provide evidence for illuviation where their maximum expression coincides with the clay maximum. They are in fact the only marker of clay illuviation to be expected in massive Bt horizons.

(3) Prominent clay skins are in pipes of Bt material that penetrate underlying horizons of carbonate accumulation. Their presence deep in the soil where water content is nearly constant and roots and fauna seldom penetrate suggests that the absence of clay skins in Bt horizons at shallower depths may be due to physical disruption.

(4) Clay skins do occur in certain soils of the semiarid portion of the study area. This suggests that clay skins would form in soils of the arid part of the study area if they were more moist.

(5) Reddish coatings of silicate clay have been observed on and in cracks in the tops of petrocalcic horizons that underlie argillic horizons at shallow depths (e.g., less than about 30 to 40 cm in observed areas of upper La Mesa). This clay must have illuviated from the overlying B. Similar, though less prominent, coatings occur in upper parts of many calcic horizons that underlie argillic horizons.

(6) Distinct linear bodies of oriented clay occur within many peds. Some of these linear bodies are interpreted as former clay skins, now inside the peds because of the development of new ped faces as the soil wetted and dried. Buol and Yesilsoy (1964) and Nettleton et al. (1969) have made the same interpretation.

(7) Laboratory studies by the junior author showed that wetting and drying of a mixture of sand grains and silt-size aggregates of clay did not produce coatings of oriented clay on the sand grains. Formation of such coatings evidently requires prior disaggregation of the clay, as would be its state during illuviation. This agrees with the work of Thorp et al. (1959). In leaching experiments dealing with aspects of clay movement, they state: "...clay is brought into suspension and moves through the soil as individual clay particles."

(8) Only slight weathering of primary minerals was found in the oldest argillic horizons. This suggests that little clay was produced by weathering in place.

(9) Some clay was apparently derived from atmospheric additions, particularly in pervious sediments (section 82). Such clay would be illuvial since it must have moved from the surface downward.

(10) The clay increase consists largely of fine clay, and ratios of fine to total clay meet the requirements of the argillic horizon (section 93; Soil Survey Staff, in press).

(11) Relation of the horizon of silicate clay accumulation to the horizon of carbonate accumulation suggests illuviation. In Holocene soils, the horizon of silicate clay accumulation is just above or extends slightly into the carbonate horizon. This arrangement would be expected on a theoretical basis if the accumulations are illuvial. That is, the clay would move downward in suspension (Thorp et al. 1959) and accumulate in a zone that is

wetted frequently during the rainy season. Bicarbonate, being in solution rather than suspension, would be expected to move deeper than the clay and then precipitate below it as the soil solution dries.

(12) In sandy and sandy loam parent materials there is good relation of increasing clay with increasing soil age back to the late-Pleistocene. When the virtual absence of weathering is considered, this suggests an illuvial origin for some of the clay. The increase in clay accumulation occurs in soils that also increase in carbonate, suggesting illuvial origin for part of the clay as well as for the carbonate.

80. DEVELOPMENT OF Bt HORIZONS

Development of Bt horizons and their relation to age are illustrated in low-gravel and high-gravel soils because coarse fragments strongly influence morphology of the Bt horizon and the chronology of its development. Data for illustrative soils are in table 62.

81. Low-gravel soils

Pajarito 67-3 (section 159) illustrates a Bt horizon that has some translocated clay, as indicated by a clay increase, slightly redder color, and more distinct clay coatings on sand grains and pebbles. The clay increase is not enough for an argillic horizon but the B horizon does qualify as a cambic horizon. Charcoal dated at about 4200 years occurs in the C horizon (section 159). This soil may be about 4 kyr old if the sediment above the charcoal was deposited soon after the fire. Upper horizons are pervious; all genetic horizons are moistened by present precipitation and are presently forming.

Nearby in some soils the 3 percent increase in silicate clay is met and these soils illustrate incipient development of the argillic horizon. Such soils have parent materials with slightly more clay and/or date from slightly earlier in the Holocene. Thus 4000 yr may be about the minimum age for Argid development in noncalcareous, low-gravel materials of the arid part of the study area.

Onite 62-3 (fig. 38) shows a Bt horizon that qualifies as an argillic horizon. The soil may be as much as 7 kyr old if it started to develop in the hiatus mentioned by Haynes (5800 to 7100 yr B.P.; Haynes, 1968). The argillic horizon is a noncalcareous, massive, slightly hard and hard sandy loam, with 5YR hue that is distinctly redder than adjacent horizons. Under a 10X hand lens, the sand grains in the B2t horizon have a reddish, stained appearance. In thin section the reddish stains appear as coatings of oriented clay on the sand grains (fig. 38). Nearly all of the clay occurs as simple free grain argillans (Brewer, 1964). The clay maximum is coextensive with the zone of maximum expression of the oriented clay coatings on sand grains, which is evidence that the coatings are in part composed of illuvial clay. Upper horizons are highly pervious; the argillic horizon is within reach of present precipitation. The carbonate horizon is stage I. There is slight overlap between silicate clay and carbonate accumulation (table 62).

Table 62. Chronology and selected data for low-gravel and high-gravel soils illustrating development of the argillic horizon.

Low-gravel: All soils have formed in monzonitic alluvium except Cruces 61-7, which formed in ancient river alluvium.

High-gravel: All soils have formed in rhyolitic alluvium.

HOLOCENE (Late, Mid, Early(?) — to 7500 Years B.P.)

Low-gravel

Pajarito 67-3, Typic Camborthid, ridge on fan-piedmont sloping 2 percent. (Soil age: Mid)

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A	0-3	7	tr(s)	7.5YR 5/4
A	3-10	9	tr(s)	7.5YR 5/4
B21t	10-20	9	tr(s)	6YR 5/4
B22t	20-28	9	tr(s)	6YR 5/4
C1ca	28-58	8	2	
C2ca	58-91	9	3	
C3	91-127	4	1	

Clay, kg/m3:100.
Volume > 2 mm, 0-100 cm:10 Pct.

Onite 62-3, Typic Haplargid, ridge on fan-piedmont sloping 1 percent. (Soil age: Early(?))

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A2	0-5	7	tr(s)	7.5YR 5/3
B1t	5-8	12	tr(s)	6YR 5/4
B21t	8-20	14	tr(s)	5YR 5/4
B22t	20-30	14	1	5YR 5/4
IIC1ca	30-43	13	5	
IIIC2ca	43-61	11	3	
IVC3ca	61-76	8	3	

Clay, kg/m3:110[3].
Volume > 2 mm, 0-100 cm:15 Pct[3].

High-gravel

Pinaleno 66-16, Typic Haplargid, on terrace sloping 2 percent. (Soil age: Late)

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A2	0-5	9	-(s)	6YR 5.5/4
B21t	5-15	12	tr(s)	5YR 4.5/4
B22tca	15-25	12	1	5YR 4.5/4
C1ca	25-58	9	2	
C2ca	58-94	8	3	
C3ca	94-132	7	1	
B2	5-25	10	tr(s)	

Clay, kg/m3:52.
Volume > 2 mm, 0-100 cm:60 Pct.

Pinaleno 67-4, Typic Haplargid, on fan sloping 4 percent.

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A2	0-5	8	tr(s)	7.5YR 5/4
B1t	5-18	11	tr(s)	6YR 5/4
B2t	18-30	15	tr(s)	5YR 5/4
B3t	30-51	13	tr(2)	7.5YR 5/4
C1ca	51-71	9	2	
C2ca	71-94	8	1	
C3	94-147	4	1	

Clay, kg/m3:55.
Volume > 2 mm, 0-100 cm:60 Pct.

PLEISTOCENE (Latest, Late, Late-mid, Mid)

Low-gravel

Bucklebar 59-7, Typic Haplargid, in broad drainageway sloping 1 percent. (Soil age: Latest)

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A	0-15	14	1	10YR 5/3
B21t	15-38	22	tr	5YR 4/3
B22tca	38-58	23	3	5YR 5/4
C1ca	58-97	19	8	
C2ca	97-127	27	6	
Bbca	127-147	23	8	

Clay, kg/m3: 270.
Volume > 2 mm, 0-100 cm : 5 Pct.

Berino 60-7, Typic Haplargid, on fan-piedmont sloping 1 percent. (Soil age: Late)

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A	5-13	14	tr	5YR 5.5/4
B21t	13-33	28	tr	2.5YR 4/4
B22tca	33-43	33	2	5YR 4/5
K11	43-66	24	9	
K12	66-91	20	10	
K2	91-140	18	15	
C1ca	140-157	13	8	
IIC2ca	157-165	12	7	

Clay, kg/m3:310.
Volume > 2 mm, 0-100 cm:3 Pct.

Cruces 61-7, Petrocalcic Paleargid, on basin floor, nearly level. (Soil age: Mid)

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A	0-5	10		5YR 5/4
B1t	5-18	9		5YR 3.5/4
B1t	18-25	13		5YR 3.5/4
B21t	25-36	15	1	4YR 4/4
B22tca	36-48	17	16	7.5YR 5/2
K21m	48-74	23	75	
K22m	74-102	18	65	
K23m	102-150	19	51	
K31	150-185		52	
K32	185-236		41	
C1ca	236-272	5	13	
C2	272-353	5	2	

Clay, kg/m3:150.
Volume > 2 mm, 0-100 cm:< 1 Pct.

High-gravel

Pinaleno 67-5, Typic Haplargid, on fan sloping 3 percent.

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A1	0-5	9	tr(s)	7.5YR 5/4
B1t	5-15	17	tr(s)	5YR 5/4
B2t	15-36	18	tr(s)	5YR 5/5
B3t	36-51	18	tr(s)	6YR 5/4
C1ca	51-64	16	4	
K&C2ca	64-89	11	11	
C3ca	89-104	7	7	
C4ca	104-124	7	4	
C5ca	124-160	7	2	

Clay, kg/m3:75.
Volume > 2 mm, 0-100 cm:65 Pct.

Caralampi 59-15, Ustollic Haplargid, on fan sloping 4 percent.

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A2	0-6	12	-(s)	7.5YR 5/4
B21t	6-23	26	-(s)	2.5YR 4/4
B22t	23-43	28	tr(s)	2.5YR 4/6
B3ca	43-71	14	4	
K&C	71-109	13	10	
Cca	109-145	8	6	

Clay, kg/m3:87.
Volume > 2 mm, 0-100 cm:70 Pct.

Terino 70-8, Petrocalcic Ustollic Paleargid, on fan-piedmont sloping 3 percent. (Soil age: Late-mid)

Horizon	Depth (cm)	Clay[1] (pct)	Carbonate[2] (pct)	Dry color
A2	0-5	14	tr(s)	7.5YR 6/3
B21t	5-18	30	tr(s)	4YR 4.5/5
B22t	18-28	32	tr	2.5YR 4/6
B23tca	28-46	34	6	5YR 5/4
K2m	46-64	25	63	
K31	64-82	14	41	
K32	82-121	16	29	
K33	121-159	12	25	
C	159-179	9	4	

Clay, kg/m3:86.
Volume > 2 mm, 0-100 cm:55 Pct.

1/ Silicate clay from carbonate-free < 2 mm.
2/ < 2 mm.
3/ To 76 cm.

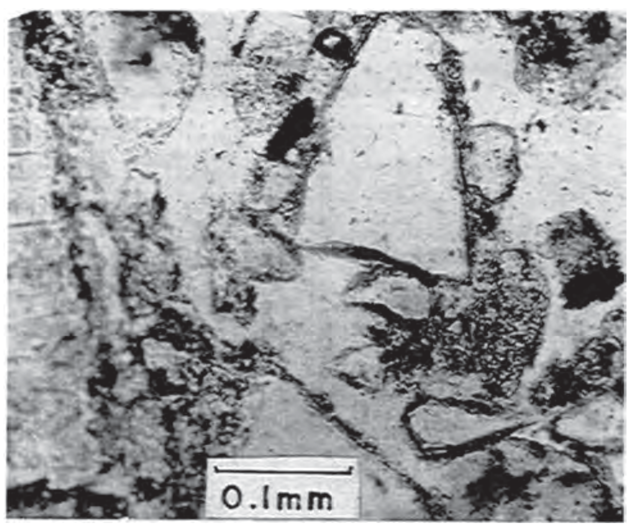


Figure 38. Upper. Onite 62-3. The argillic horizon extends from about 5 to 30 cm. Scale is in feet.

Lower. Thin section of B21t horizon, Onite 62-3. Oriented clay coatings appear as dark coatings on the light-colored grains. In places the coatings are connected. Many grains are separated by voids. Plain light.

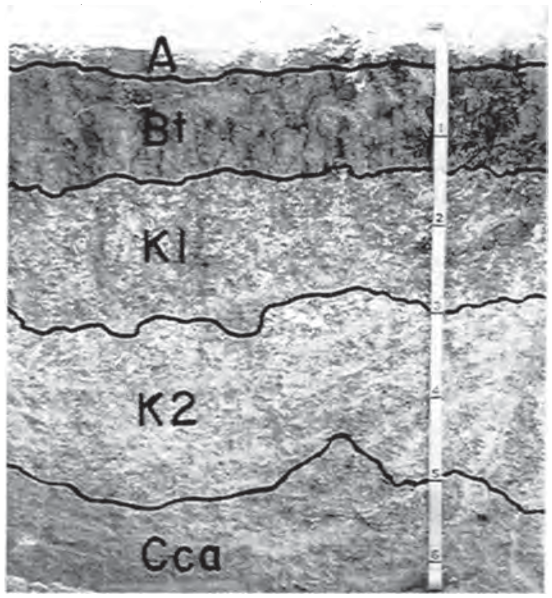
Bucklebar 59-7 exhibits a more distinct argillic horizon than Onite 62-3. In contrast to the incipient nature of the argillic horizon in many soils of the Organ surface, the next older soils of this area (soils of the Isaacks' Ranch surface) have argillic horizons that are continuous and distinct. The silicate clay bulge is more prominent (table 62) and extends deeper than in soils of Organ age. However, the argillic horizon is not redder than 5YR; hues redder than this are found only in older soils discussed later. The horizon of carbonate accumulation also differs. Instead of the stage I horizon as in Onite 62-3, there is a distinct stage II horizon consisting of carbonate nodules separated by low-carbonate zones. Greater development of this soil, as compared to the Holocene soils, is thought to be due to minor pluvials of latest Pleistocene (about 7500 to 13,000 yr ago).

Berino 60-7 (fig. 39) illustrates an argillic horizon that formed partly during a major pluvial. This argillic horizon must have formed primarily during the Pleistocene, as indicated by the morphological similarity of the argillic horizon to its buried analogue that underlies soils of Isaacks' Ranch age. The field relations are discussed in section 166.

The morphology contrasts with that of the younger argillic horizons discussed previously. The argillic horizon of Berino is thicker, more clayey and less pervious, with moderately expressed peds; smooth, reflective surfaces are common. This suggests clay skins, but they have not been found in thin section. In places, ped surfaces sharply bevel or intermittently parallel zones of preferred clay orientation, but the occurrence and expression of these zones appear to bear no relationship to ped surfaces. There is evidence of clay illuviation within peds. Moderately thick oriented clay coatings are on many sand grains and most grains have at least patchy coatings of oriented clay. Other bodies of oriented clay (glaebules) are common. Some may be parts of clay skins that formed on ped surfaces and subsequently were incorporated within the peds. Others may be relict fillings of oriented clay in large intraped voids. Clay skins do occur in downward extensions of Bt horizons (pipes, section 84) that in places penetrate the underlying K horizon. These clay skins can be clearly seen with a hand lens. They must have formed in the Pleistocene since in buried soils they occur below reach by modern precipitation and show no morphological connection through the overlying soil. Their presence shows that clay skins did form in the Pleistocene and supports the thin section evidence for the obliteration of clay skins and incorporation of fragments within the peds.

It is thought that during pluvials of the Pleistocene, argillic horizons with clay skins were common in the arid part of the study area. Argillic horizons of Holocene soils developed in drier conditions than during the Pleistocene pluvials, and uniformly lack clay skins. During the Holocene there has apparently been a strong tendency towards obliteration of clay skins.

Physical mixing is considered responsible for the absence of clay skins in soils at the land surface of the arid part of the study area. The argillic horizon is relatively shallow and occurs in the zone where large changes in water content occur. The fabric is subject to wetting when near air dry; such



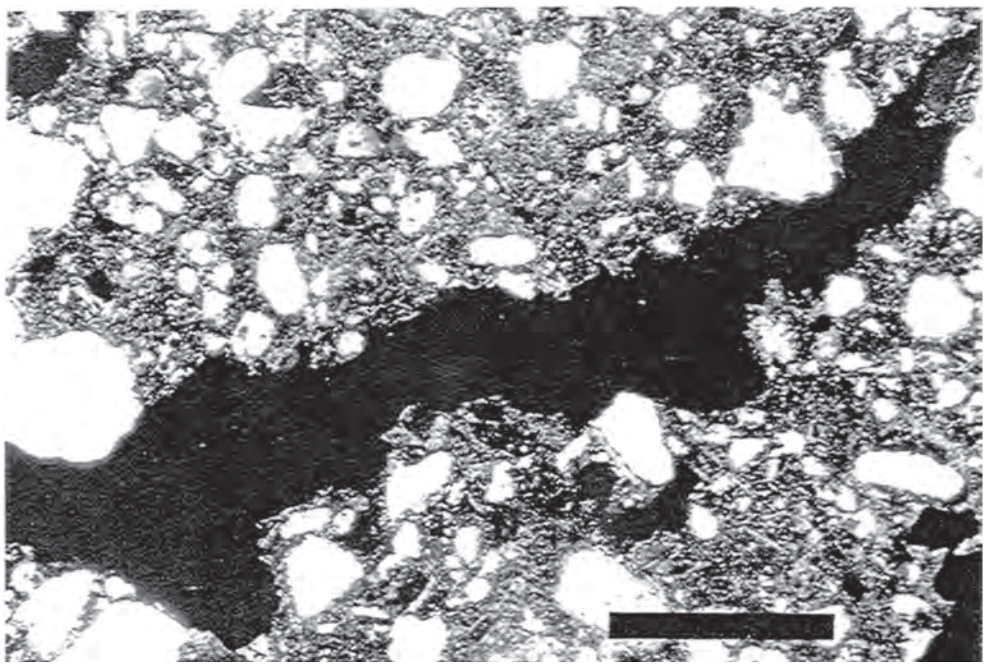


Figure 39. Upper. A Typic Haplargid, Berino 60-7. Scale is in feet.
Lower. Thin section of B22tca horizon, Berino. Oriented clay coatings occur on sand grains but ped faces are not coated with oriented clay; note sand grains bordering ped face. Plasma completely fills voids between sand grains, in contrast to Onite 62-3. Crossed polarizers. Bar scale = 0.5 mm.

wetting is highly disruptive. Roots and fauna are disruptive and both are concentrated in the lower portion of the zone of periodic wetting, where clay illuviation would be expected. Argillic horizons of medium or fine texture have moderate structural expression, which indicates that the horizon has undergone appreciable repetitive volume change. Surfaces of peds would be abraded during expansion and new ped surfaces formed during contraction. Thus, fragments of former clay films may have been incorporated within peds and are seen today in thin section as glaebules.

Another prominent difference of Berino 60-7 is that it has a thick K horizon not present in the younger soils. Several lines of evidence suggest that the argillic horizon once extended into the position now occupied by the K horizon, but has since been engulfed by carbonate. This evidence includes the presence of volumes of reddish-brown Bt material in the K, extension of the silicate clay bulge into the K, and the similar percentages of silicate clay for carbonate nodules and internodular material in the K11 horizon. This engulfment of the lower part of a formerly thicker argillic horizon is not an isolated occurrence but instead is the common situation in soils of Pleistocene age.

Data for Berino 60-13, a soil similar to Berino 60-7, provide additional evidence for illuviation. Fine clay (less than 0.0002 mm) largely accounts for the bulge in clay (fig. 40). Elemental analyses for the 2 to 0.0002 mm do not change with depth (fig. 40). This supports illuviation rather than weathering as the principal mechanism for clay accumulation.

Cruces 61-7 (section 152) illustrates the lack of correspondence for certain mid-Pleistocene soils between the moderate expression of the argillic horizon and the strong carbonate accumulation beneath. Although the argillic horizon increases in development up to late-Pleistocene time, after this the accumulation of silicate clay appears to slow markedly. This may be related to decreased infiltration rates caused by the accumulated clay; to the character of the soil surface; and to biotic activity (section 85).

The reddish-brown color and prismatic structure are the more prominent features of the argillic horizon. The prisms are either massive internally or have weak subangular blocky structure. Ped surfaces are not smooth or reflective, and lack clay skins. Thin sections of the noncalcareous part of the argillic horizon show distinct oriented clay coatings on sand grains but no clay skins. Nodules of K fabric in the B23tca horizon contrast sharply with low-carbonate parts in which sand grains are strongly coated with oriented clay. Both morphology of the B23tca horizon and extension of the clay bulge for the carbonate-free material into the upper part of the K horizon indicate carbonate engulfment of the lower part of a formerly thicker argillic horizon.

82. High-gravel soils

Morphology of the argillic horizon in very gravelly materials differs markedly from argillic horizons in materials with little or no gravel. Structure and disposition of the fine earth is largely controlled by the pebbles. Fine earth occurs as pebble coatings and interpebble fillings rather than as peds bounded by planar surfaces. The clayey pebble coatings

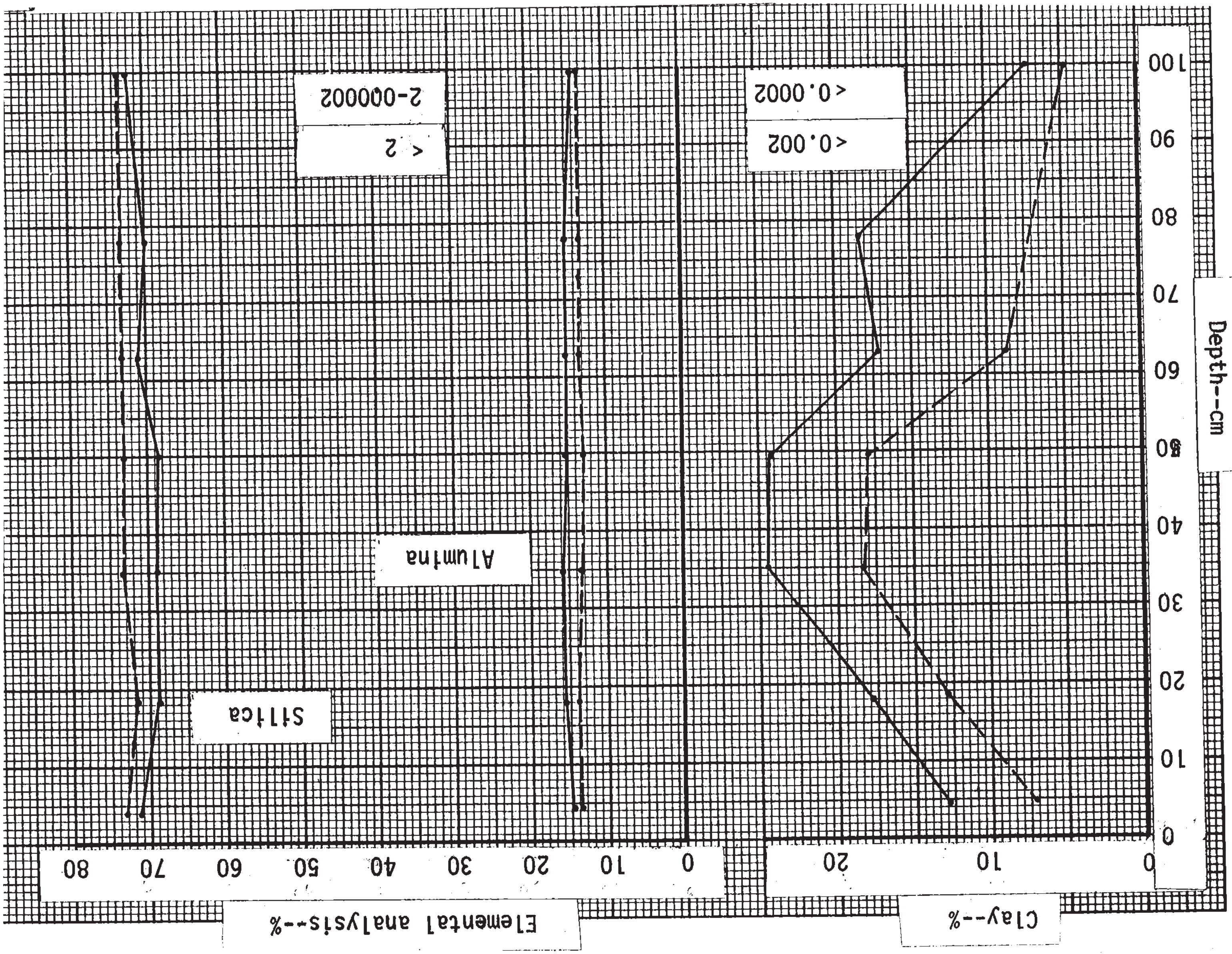


Figure 40. Distribution with depth of clay, alumina and silica for Berino 60-13 (carbonate-free basis).

can be seen with the naked eye. In thin section the coatings appear as strongly oriented clay that rests abruptly on the pebbles, which apparently are favorable sites for silicate clay accumulation. In contrast to the surfaces of peds of fine earth that move inward and outward as the ped expands and contracts on change in moisture, the surfaces of pebbles remain stationary unless the pebble is displaced. Volume changes of the soil on moistening are small because of the low proportion of fine earth per unit volume and the tendency of the fine earth in each interstice to act as an independent unit.

Another effect of high gravel content is that the numerous pebbles would confine the soil solution to relatively small volumes, which should speed the illuviation of silicate clay. Hence the time available for very gravelly cambic horizons to exist in the developmental scale would be expected to be shortened. A few do exist, however (section 138). The more rapid development of Argids in very gravelly, than in nongravelly materials, is illustrated on a regional basis by soils of the Organ surface. An illustration in soils of the Fillmore surface is presented in the following paragraph.

Pinaleno 66-16 (fig. 41) illustrates an incipient argillic horizon. On some of the stablest, oldest sites of the Fillmore surface, a weak Haplargid has formed in a period estimated to be from about 1000 to 2600 years. The increase in silicate clay is sufficient for an argillic horizon (table 62) Thin sections show thin but distinct coatings of oriented clay on sand grains and pebbles in the Bt horizon. The carbonate horizon is in stage I of carbonate accumulation, as is typical for soils of the Fillmore surface; carbonate occurs as thin coatings on pebbles and sand grains. There is little overlap between the two accumulations (table 62).

Presence of the argillic horizon in such a young soil is attributed to the high content of coarse fragments. In the adjacent low-gravel pedon (fig. 41) illuviation has been insufficient for an argillic horizon and the horizon in B position is a cambic horizon. This is evidence of the effect of gravel content in speeding the illuviation of silicate clay.

A developmental sequence of argillic horizons is illustrated by Pinaleno 66-16 and four other skeletal Argids (table 62; figs. 41-44). The greatest clay increase is in the two soils that formed partly in the full-glacial pluvial. This reflects the increased effective moisture available for clay movement. Clay content of the Cca horizon is low in all cases, suggesting that most of the clay in the maximum was derived from atmospheric additions. Several factors may be responsible for this close relation of clay illuviation to age in very gravelly materials. Such materials would be more pervious and more favorable for infiltration of clay from atmospheric additions than would materials with little or no gravel. The desert pavement provided by the gravelly materials should be more efficient in trapping clay from atmospheric additions. Mixing by soil fauna should be less in very gravelly materials than in materials low in gravel. As in the low-gravel Argids of Pleistocene age discussed earlier, there is evidence of carbonate engulfment of the lower part of a formerly thicker argillic horizon. This is indicated by the occurrence of discontinuous reddish zones in the upper part of the horizons of carbonate accumulation, and extension of the silicate clay maximum for the carbonate-free fine earth well into the horizons of carbonate accumulation.

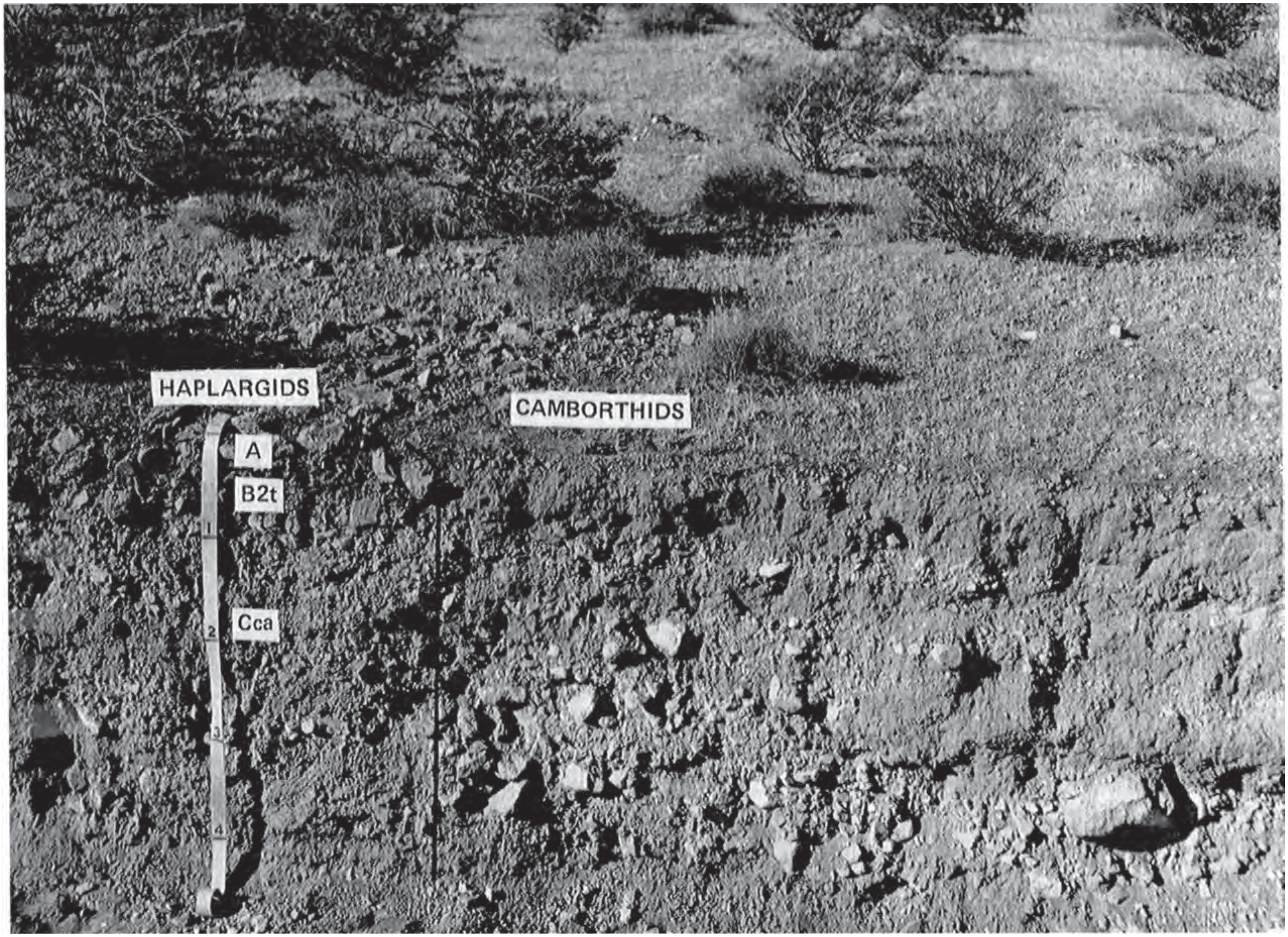


Figure 41. Pinaleno 66-16, a Typic Haplargid (at left) on the Fillmore surface, illustrates incipient development of the argillic horizon in very gravelly materials. Vegetation is creosotebush and ratany. Slope is 2 percent. This site illustrates marked differences in particle size and in the character of the soil surface caused by abrupt facies changes in the alluvium. The zone high in coarse fragments represents the main channel zone of the stream that deposited the alluvium. The low-gravel zone at the right is away from the main channel zone and the soil there is a Camborthid (Pajarito series) instead of a Haplargid. Scale is in feet.

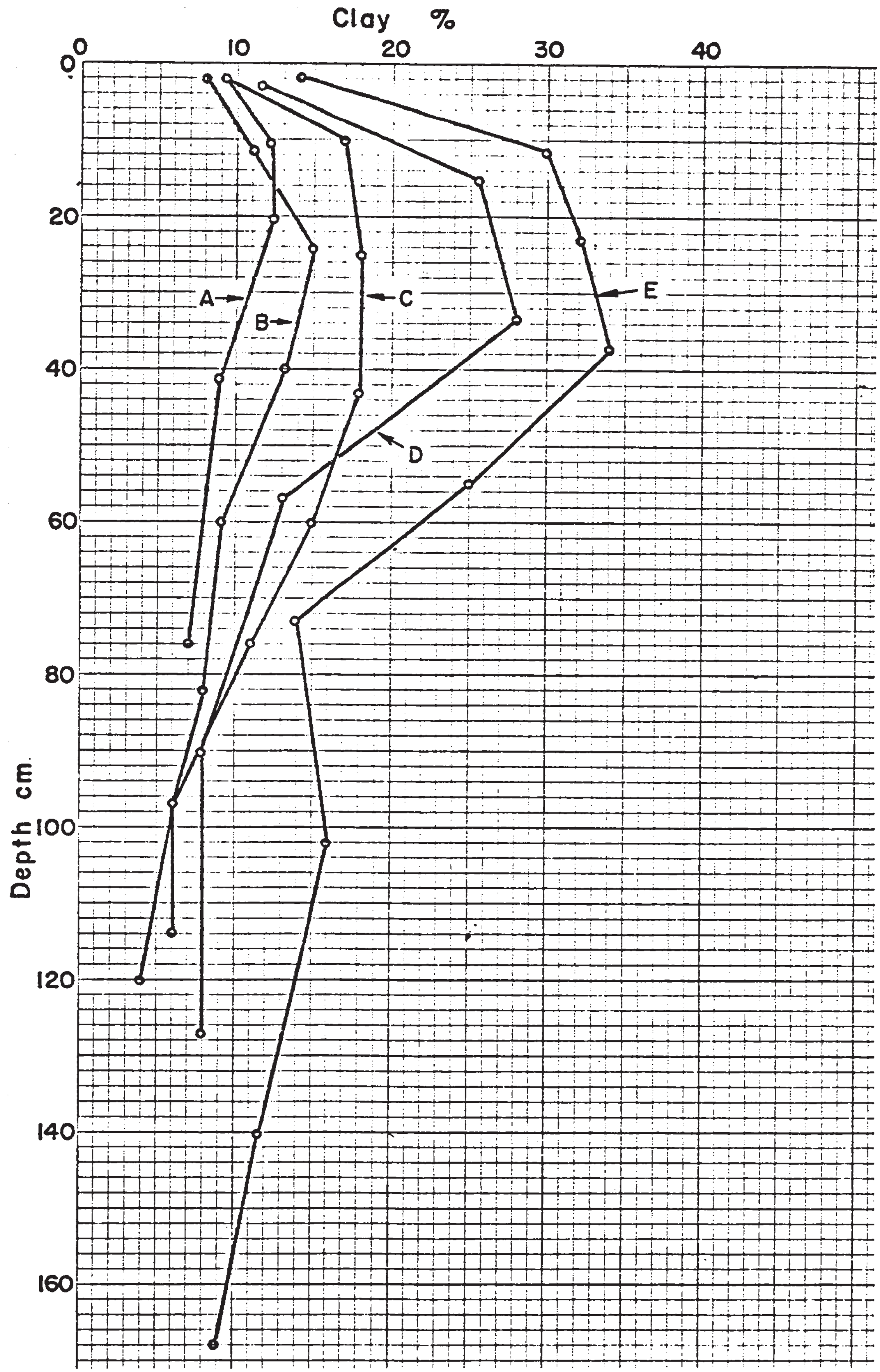


Figure 42. Clay distribution (carbonate-free) for five skeletal Argids: A = Typic Haplargid of late-Holocene age (Pinaleno 66-16); B = Typic Haplargid of mid-Holocene age (Pinaleno 67-4); C = Typic Haplargid of latest Pleistocene age (Pinaleno 67-5); D = Ustollic Haplargid of late-Pleistocene age (Caralampi 59-15); E = Petrocalcic Ustollic Paleargid of late mid-Pleistocene age (Terino 70-8).

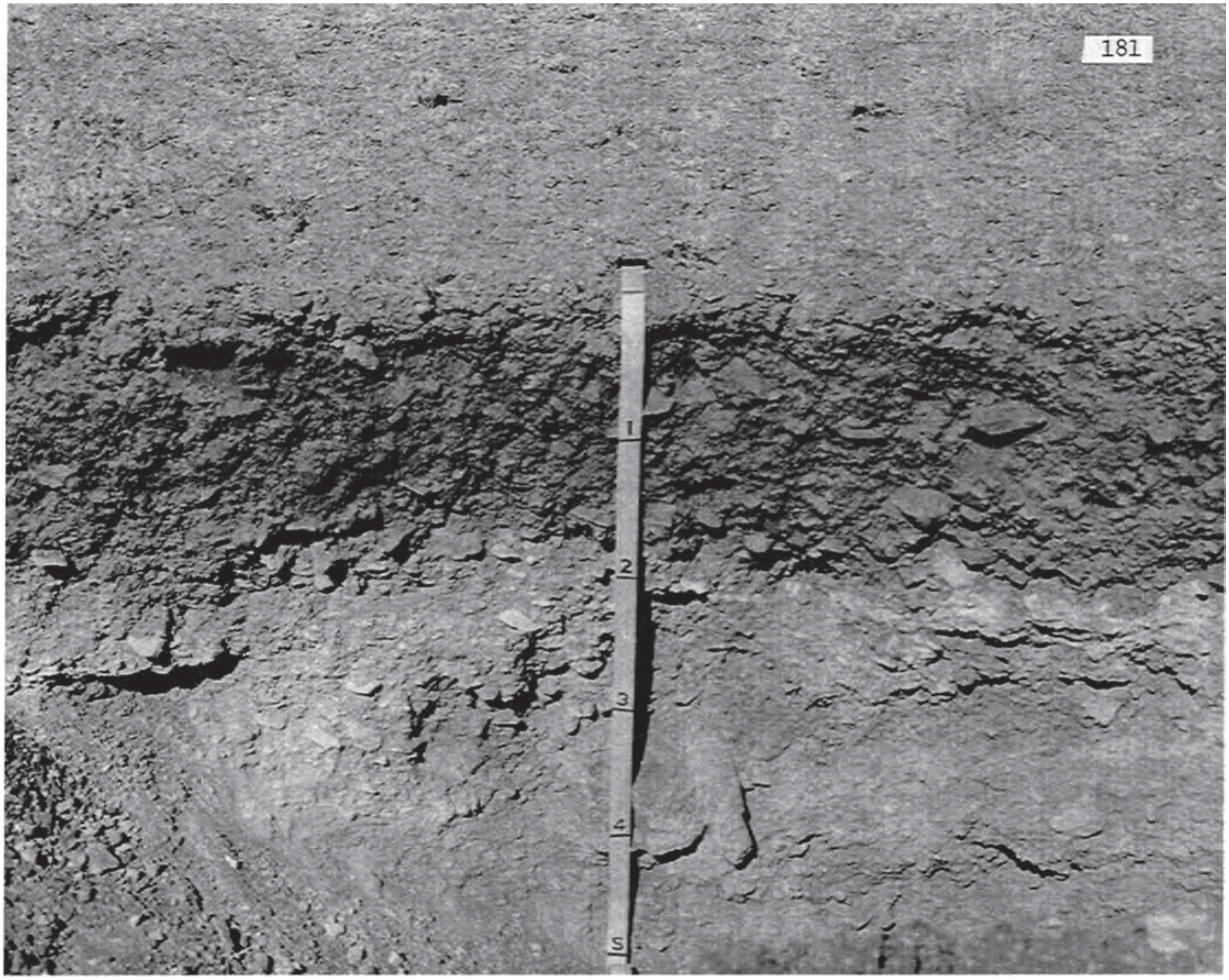


Figure 43. Pinaleno 67-5, a Typic Haplargid. Scale is in feet.

Figure 44. Terino 70-8, a Petrocalcic Ustollic Paleargid. Scale is in feet.

Carbonate accumulation increases with age except for Pinaleno 59-15. This soil occurs near the semiarid zone along the mountain front; in such areas the amount of carbonate, particularly in soils of late-Pleistocene age, shows more variation than in the arid part of the study area. In soils of this age and location, precipitation of the pluvials apparently moved carbonates to substantial depths in soils that were not carbonate-plugged at the time of the pluvials. Nearby, however, some soils of the same age do have more carbonate.

The weights of silicate clay in a cubic m given in table 62 are affected by the volume of coarse fragments and to a lesser extent by the authigenic carbonate accumulated. Consequently, the quantity of clay is not necessarily in accord with the size of the clay bulge for the noncarbonate fine earth (table 62). Terino 70-8, of late mid-Pleistocene age, has a similar weight of clay in a cubic m as the late-Pleistocene pedons, despite a larger bulge in silicate clay. The relative amounts for the mid-Pleistocene soils are somewhat reduced because the silicate clay bulge extends below 1 m.

83. Color

Hues of the Bt horizon become redder and chromas higher with increasing age. Holocene soils have Bt horizons with hues no redder than 5YR and chromas no higher than 4 (table 62). In soils of Pleistocene age, many Bt horizons have 2.5YR hue and chroma of 6. Hues redder than 2.5YR do not occur in the arid part of the study area. Schwertmann (personal communication, U. Schwertmann) indicates that the red color almost certainly comes from hematite.

Section 94 gives iron data for a number of soils with Bt horizons. The mean iron content of the Bt maximum for soils of Holocene and Pleistocene age are the same (0.9 percent). Only soils of the arid zone were used to determine the means. Soils of latest Pleistocene age were omitted to give a comparison between Holocene soils and soils that developed partly during the full-glacial maximum. The identical means show that color can become redder without measurable change in the amount of iron. The occurrence of reddest hues only in soils that formed partly in the full-glacial pluvial suggests that increased moisture may be a factor in reddening of the Bt horizon.

Walker (1967) who worked in the Baja California, also found B horizons of desert soils to become redder with age. In his study area Walker attributed the increase in reddening to a change in the nature of the iron oxide pigment: the soils of younger Pleistocene age having a yellowish to reddish yellow amorphous ferric hydrate and the older soils having a red ferric hydrate that is either amorphous or too poorly crystalline to give a diagnostic X-ray diffraction pattern, and that may include some poorly crystallized hematite.

In Holocene soils of this area, distinct reddening in B horizons occurs only if parent materials contain appreciable biotite and/or hornblende (compare description of Bluepoint 59-10 and Pinaleno 67-4, Appendix). Redder colors of Bt horizons such as in Pinaleno 67-4 may have been caused by slight weathering of these minerals in the A2 horizons, and subsequent translocation of iron (along with clay) to the Bt horizons. Such weathering may have been facilitated by coincidence of the extremely high summer temperatures with the moist season, particularly in soils with gravelly surfaces. Smith and Buol (1968) and Nettleton _et al._ (1975) found evidence of weathering in A horizons of desert soils.

Holocene soils developed in alluvium from calcareous sedimentary rocks usually show no reddening from the 10YR (or 7.5YR) parent material. Some reddening is found in soils of Pleistocene age if the parent materials have only moderate amounts of high-carbonate materials, but hues are not redder than 5YR. B horizons with 5YR hue develop only after removal of most or all carbonate. Slight variations in initial carbonate content and texture may determine if all of the allogenic carbonate was removed. Consequently, the gradation from 5YR to 7.5YR hue is often in intricate pattern. No reddening is found in soils with very high content of carbonate rock fragments, even in soils of Pleistocene age.

Black filaments and coatings occur on peds both in Bt and K horizons of certain old Argids. The coatings and filaments are thought to consist of iron and manganese oxides. In the arid part of the study area these features occur in soils of Jornada I age where they are in buried position (pedons 60-6, 60-7, 70-7, 59-9, 59-12). They have been observed in soils at the land surface only in soils of Jornada I age along the mountain front. In these soils the coatings and filaments occur in the middle and lower parts of Bt horizons of loamy-skeletal, Ustollic Haplargids (pedon 59-14).

Total manganese was determined on selected horizons of pedons 59-6 and 59-8 (Appendix). The objective was to evaluate whether the browner and less red argillic horizons contain more manganese, which would tend to darken the soil fabric. No evidence was obtained that the difference in color is related to manganese oxides.

84. PIPES

Commonly Bt horizons of a given soil do not range greatly in their thickness. In places, however, there are prominent downward extensions of the Bt horizon. These downward extensions are roughly funnel-shaped and are termed pipes. This section briefly discusses the origin of pipes of Bt material. Discussions of pipes of other materials and of various ages are located in index 5.

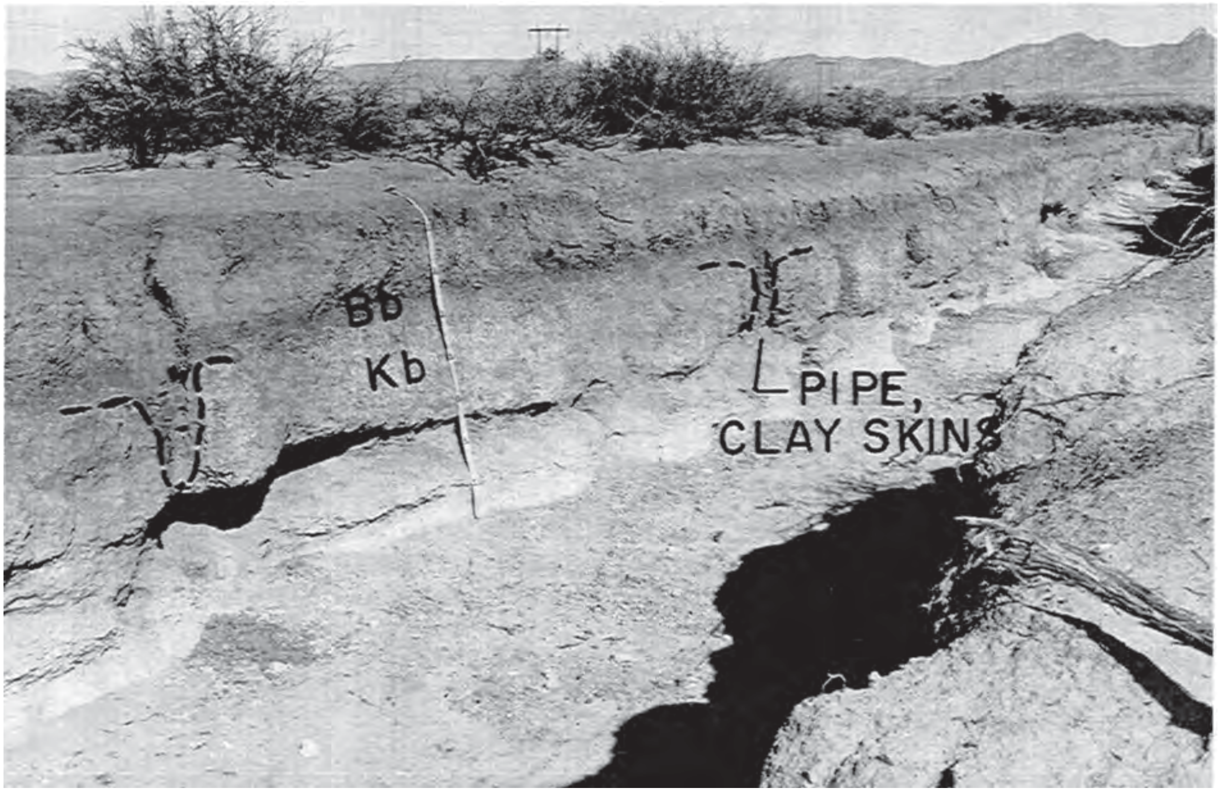
Pipes range in width from a few cm to 10 m or more, being widest and most complex in the oldest soils. Pipes have not been observed in Holocene soils; apparently the greater effective moisture of Pleistocene pluvials must have been necessary for their formation. But pipes are a characteristic feature of soils ranging from late to mid-Pleistocene in age, thus did not form all at once. They appear to be a normal feature of development, that formed largely or wholly in pluvials. In the study area pipes are more common in nongravelly soils since gravelly materials tend to plug with carbonate more rapidly (section 68).

Pipes appear to form as a result of local concentration of water. Some may be initiated by substantial differences in permeability due to animal burrowing and the filling of cavities created when large roots decay (fig. 45). The fillings are coarser than adjacent horizons and appear to have been blown or washed from A horizons of nearby soils. In root decay the interior decays first, resulting in a hole to be filled from above while the intact periphery of the root prevents filling from adjacent horizons. Eventually the root decays entirely, resulting in roughly vertical volumes of material that is coarser-textured and more pervious than adjacent horizons. Water would infiltrate to greater depths in these volumes and tend to keep them low in carbonates. The funnel shape may in part be due to the shape of the former root (fig. 45). It may also arise because the frequency of depth of wetting is progressively less with depth. Plugged and laminar horizons, because of their low permeability, would deflect water into pipes and increase the depth of flushing.

Figure 46 shows two pipes in a buried soil of late-Pleistocene age (Bb and Kb). The pipes must have formed in the Pleistocene since they are overlain by a deposit of latest Pleistocene age and there is no morphological connection to the present land surface.

Most pipes in soils of late-Pleistocene age are considered part of a pedon of the adjacent soil (since they occupy less than 1 m^2) and are in the same series as the adjacent soil. However, some pipes in soils of mid-Pleistocene age are considerably larger and are classified as different soils than the soils between the pipes.

Figure 45. Filling in root channel (left). The periphery of the root is still preserved. The filling is coarser-textured and more pervious than adjacent materials. Many pipes apparently started in such fillings. Scale is in feet.



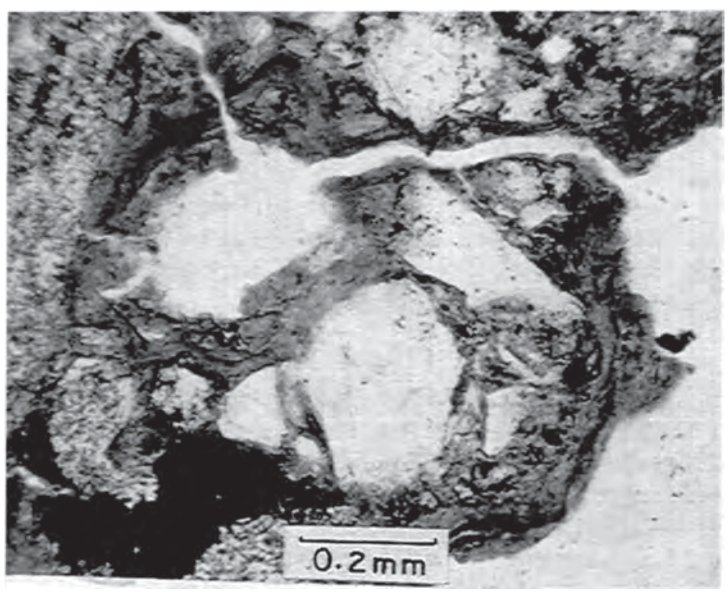


Figure 46. Upper. Berino variant 59-6, to the right of the tape. Two pipes are in the soil of late-Pleistocene age (Bb and Kb horizons). Scale is in feet.

Lower. Clay skin from pipe indicated above. The only clay skins on ped faces and in pores in the arid part of the study area are in pipes such as these. Relict clay skins line ped face (right) and pore (left). Plain light.

85. OBLITERATION OF THE ARGILLIC HORIZON

Obliteration of clay skins by wetting and drying, and partial engulfment of the lower parts of the argillic horizon by carbonate were discussed earlier. This section considers obliteration of the argillic horizon as a whole, and its effect on soil morphology and classification. The main obliterative processes are landscape dissection and associated soil truncation; carbonate engulfment; and mixing by soil fauna.

Landscape dissection and related soil truncation in the arid part of the study area results in carbonate in all subhorizons. The argillic horizon is preserved in stablest parts of ridge crests but has been truncated and carbonate-engulfed where ridges are rounded. The reasons for this are that truncation brings originally deeper carbonate horizons closer to the surface; and greater runoff (due to increased slopes) leads to decreased depths of wetting with resultant carbonate accumulation at shallower depths. The carbonate disrupts clay skins and clay coatings on skeletal grains and pebbles. The disruption is accentuated because places in which carbonate first accumulates are also places in which clay coatings develop. Crystallization of the carbonate is thought to push the silicate clay away from the surfaces of the skeletal material. As evidence, sand from K horizons after particle size analysis is nearly free of silicate clay, whereas patches of silicate clay are present on the sands from other kinds of horizons.

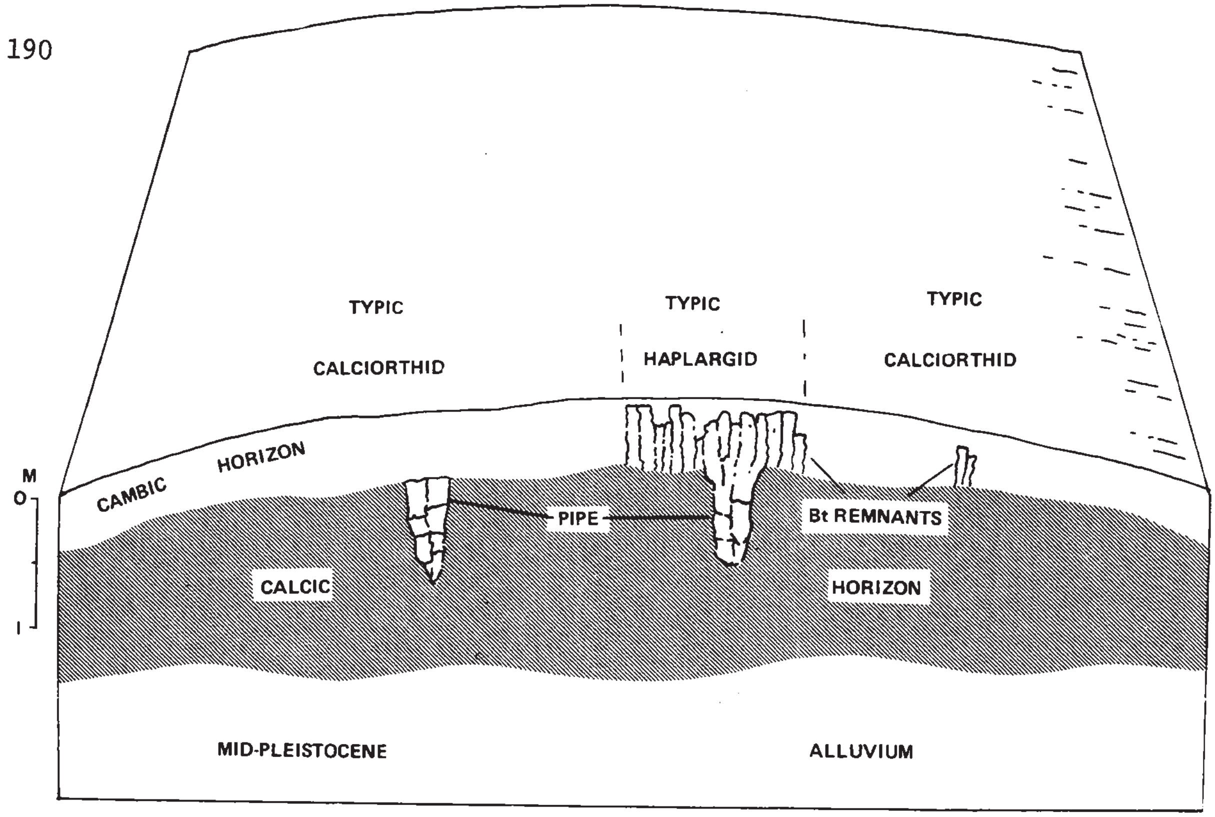
Casito 60-1 (fig. 33) illustrates an argillic horizon with strong influence of authigenic carbonate (table 63). Thin coatings of carbonate occur on pebbles throughout the argillic horizon. Some of the pebble coatings are discontinuous, and carbonate bridging from pebble surfaces to interpebble fine earth is rare. Sand grains in a few small volumes of fine earth and the tops of some pebbles are coated with reddish-brown, oriented silicate clay. This Bt fabric comprises about 20 percent of the volume. Since the horizon contains more than 10 percent of Bt fabric it is still considered an argillic horizon (section 20). However, Casito occurs on the shoulder of a slightly rounded ridge crest adjacent to an arroyo. As the slope becomes steeper down the shoulder, carbonate coatings on pebbles become continuous, less than 10 percent of reddish brown material is apparent and the soils are Paleorthids.

Argillic horizons have also been obliterated by soil fauna. Kangaroo rats and badgers destroy argillic horizons by the construction of tunnels and mounds. Termites obliterate argillic horizons by mixing. Burrowing is most intense in low-gravel materials with textures of sandy loam or calcareous light sandy clay loam because these materials are easier to dig. Algerita 61-2 (table 63; fig. 47) illustrates. Small insect burrows and workings, particularly those of termites, are common in the B horizon. Soil fauna have apparently mixed the B horizon material so that the soil lacks a maximum in silicate clay and sufficient Bt fabric for an argillic horizon. Several lines of evidence are supporting: (1) Argillic horizons occur laterally in soils less disturbed by fauna. (2) Thin sections of the B2ca horizon show scattered partial coatings of oriented clay on sand grains, although most coatings have been disrupted by carbonate. (3) Contiguous pedons have pipes containing Bt

Table 63. Selected data for soils illustrating the effect of authigenic carbonate, allogenic carbonate and soil fauna on argillic horizon development.

Pedon, Series Subgroup Parent Material Land Form Geomorphic Surface Soil Age	Horizon	Depth	Clay[1/]	Carbonate[2/]	Dry Color
		cm	pct		
Argillic horizon partly obliterated by carbonate.					
Casito 60-1	A2ca	0-6	14	1	7.5YR 5/4
Petrocalcic Ustollic	B2tca	6-28	19	8	5YR 6/3
Paleargid	K2m	28-43	16	23	
Rhyolitic alluvium	K3	43-64	15	21	
Terrace sloping 2 percent	C3ca	64-79	12	11	
Picacho surface	IIC4ca	79-104	15	9	
Late-Pleistocene	B2tca	18-30	23		2.5YR 4/6
	Clay, kg/m^3:110.				
	Volume > 2 mm, 0-100 cm:45 Pct.				
Argillic horizon obliterated by carbonate engulfment.					
Whitlock 60-2	A2	0-5	20	5	7.5YR 6/2
Typic Calciorthid	Bca	5-10	27	10	6YR 6/4
Mixed alluvium	K1	10-23	30	16	
Fan sloping 2 percent	K1	23-36	22	23	
Picacho surface	K2	36-58	27	21	
Late-Pleistocene	K31	58-89	10	10	
	IIK32	89-122	7	16	
	IIICca	122-137	8	5	
	Clay, kg/m^3:210.				
	Volume > 2 mm, 0-100 cm:10 Pct.				
Argillic horizon obliterated by fauna.					
Algerita 61-2	A	8-13	16	8	7.5YR 7/2
Typic Calciorthid	B1ca	13-28	13	9	6YR 6/4
River alluvium	B2ca	28-38	16	10	6YR 6/4
Basin floor, nearly level	K1	38-56	16	25	
La Mesa surface	K21	56-76	10	34	
Mid-Pleistocene	K22	76-112	7	37	
	K23cs	112-124	14	31	
	K3cs	124-142	12	11	
	C1ca	142-165	10	8	
	C2ca	165-185	10	6	
	Clay, kg/m^3:150.				
	Volume > 2 mm, 0-100 cm:2 Pct.				
Argillic horizon development prevented by allogenic carbonate.					
Upton 66-5	A	0-1	11	12	7.5YR 6.5/4
Typic Paleorthid	A	1-5	18	22	9YR 7/2
Alluvium from calcareous	B21ca	5-8	17	27	7.5YR 7/4
sedimentary rocks	B22ca	8-20	19	24	7.5YR 7/4
Fan sloping 3 percent	K1	20-30	14	28	
Picacho surface	K21m	30-34			
Late-Pleistocene	K22m	34-58	19	59	
	K3	58-74	12	55	
	Cca	74-102	21	58	

1/ Silicate clay from carbonate-free < 2 mm.
2/ < 2 mm.



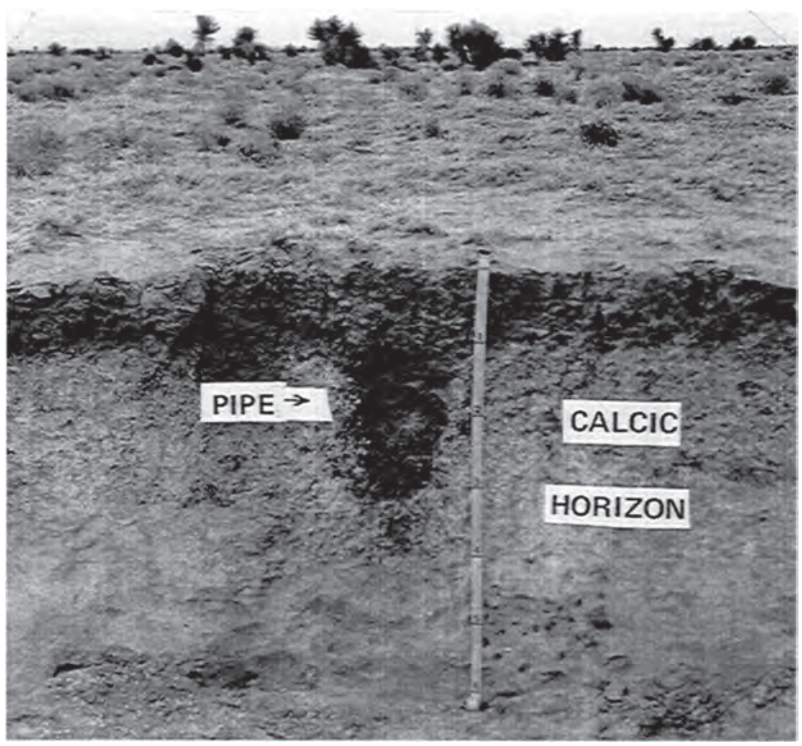


Figure 47. Upper. Cross section of ridge in the basin floor north of Isaacks' Lake Playa. Calciorthids are dominant over the ridge crest because B horizons have been mixed by soil fauna, but remnants of Bt horizons have been preserved in places (see below).

Lower. Truncated pipe near pedon 61-2. The top of the pipe, which once must have been connected to an argillic horizon, has been mixed by soil fauna and is now part of a calcareous cambic horizon above the calcic horizon. Distinct clay skins occur in the remnant of the pipe, which is still noncalcareous in part.

fabric that descend below the B horizons with numerous termite burrows (fig. 47). Soils with such pipes in other parts of the study area commonly have argillic horizons. (4) Some pedons have more clay in the A than in the B horizon, as is shown by Algerita 61-2 (table 63); termites could produce such clay distribution (Lee and Woods, 1971).

86. EFFECT OF ALLOGENIC CARBONATE

Goss *et al*. (1973) have reviewed the literature on the influence of carbonate on clay movement. In this project, soils developed in parent materials that contain high proportions of calcareous coarse fragments lack argillic horizons. This is true even of soils on the most stable sites, that started their development in late-Pleistocene, and that have been subjected to a Pleistocene pluvial.

Upton 66-5 illustrates a soil that contains abundant coarse fragments of limestone throughout. No Bt fabric is present in the B horizon; the high carbonate content precludes observing oriented clay coatings in thin section. The lack of an increase in silicate clay from the A to the B horizons cannot be ascribed to truncation since the site is very stable. No evidence of an argillic horizon was found.

However, argillic horizons have formed in Pleistocene alluvium with intermediate amounts of carbonate. Headquarters 60-18, an Ustollic Haplargid, formed in parent materials with a substantial component from noncalcareous rocks as well as limestone. The argillic horizon of these soils is calcareous in soils at the land surface. Analogues buried by Holocene deposits, however, are in places noncalcareous. This suggests that the carbonate was leached from the land surface soils during Pleistocene pluvials. The subsequent recharge by carbonate was probably accomplished by calcium in run-in water. However, soils of Holocene age formed in similarly calcareous parent materials lack argillic horizons. Reagan 60-14, an Ustollic Calciorthid, illustrates (section 163).

87. LABORATORY DATA INTERPRETATION

88. MINERALOGY

Mineralogical observations applicable to the project area as a whole are presented here. Information that form the bases for these observations are with the other characterization data in the Appendix. With a few exceptions, the mineralogical studies were undertaken to establish classification of the soils, not to study genesis. Thus mineralogical data for most of the pedons are incomplete. A few pedons were studied in detail. Detailed studies of single pedons or of parts of closely associated pedons are discussed in "other studies" sections of the mapping units. Index 2 locates work on the micromorphology, mineralogy, and total analyses in the Appendix.

88a. Sand and silt mineralogy

Table 64 lists the proportion of quartz, feldspar, microcrystalline grains, and mica in pedons developed in the four principal parent material sources. Figure 48 shows the relative percentages of quartz, feldspar and microcrystalline grains in the fine or very fine sand. Half or more of the separates are weatherable in the taxonomic sense. Quartz ranges from 35 to 55 percent. Most discrete grains of quartz and feldspar are fairly angular. The discrete feldspar grains are mostly orthoclase and albite with up to 25 percent in the oligoclase-anorthosite composition range. Biotite is appreciable in the sands for some samples; all samples of the coarse silt (0.05 to 0 0.02 mm) examined contain considerable mica.

Table 65 gives information on heavy minerals. Rhyolitic alluvium contains less hornblende and more zircon than monzonitic alluvium.

Individual grains commonly show alteration around the edges and along planes of weakness. But the parts away from these surfaces or planes are weakly altered if at all. Much of the alteration appears to be the result of geological process rather than pedogenic weathering. An illustrative thin section description follows for the B2t horizon of Berino 60-7: "Many feldspar grains show peripheral weathering that extends inward along zones of weakness. Ferromagnesian mineral inclusions (amphibole, pyroxene, biotite) occur in the rock fragments. These inclusions near the edge of the fragments show alteration. Discrete ferromagnesian grains are pitted, frayed, and appreciably altered, although overall they retain their optical properties. The epidote appears susceptible to physical breakdown."

Mineralogical changes indicating reduced pedogenic weathering with depth are slight. Argids formed in materials derived from rhyolite that occur on mid-Pleistocene geomorphic surfaces (Terino variant 60-5, Terino 70-8) have somewhat lower portions of microcrystalline grains in upper horizons. Pedons of Pleistocene age along the mountain front, such as Terino variant 60-5 and Coxwell variants 66-9 and 70-1 have somewhat less biotite in upper horizons.

Index 2. Micromorphology, mineralogy and total analyses in the Appendix, by dominant parent material and pedon number.

Table 64. Summary of mineralogy of the carbonate-free sand and silt ordered by parent material sources.

Pedon	Horizon	Depth	Fraction	Mineralogy[1] Quartz	Feldspar[2] Total	Feldspar[2]	Microcrystalline[3] grains	Mica[4]
		cm	mm	pct	pct		pct	pct
Monzonite								
			0.05–0.02	18	65[7]			17
59-2[5]	A13	20–41	0.1–0.5	25	55	(Or + Al) >> (Ol + An)	10	2
			0.25–0.1	20	55		15	2
			2–0.25	30	50		10	5
59-4	Clca	23–38	0.05–0.02	22	62			16
59-6	B21tca	13–30	0.1–0.05	40	40	(Or + Al) >> (Mi, Ol)	15	
	K2b	117–168	0.1–0.05		40	(Or + Al) (Mi, Ol)	15	
	K22b2	231–262	0.1–0.05		40	(Or + Al) (Mi, Ol)	15	
60-7	B21t	13–33	0.1–0.05	40	35	(Or + Al) >> (Ol + An)	20	
	K2	91–140	0.1–0.05	50	35	(Or + Al) >> (Ol + An)	10	
60-8	Clca	23–38	0.05–0.02	20	66[7]			14
60-9	B22t	23–48	0.05–0.02	23	68[7]			9
66-9[6]	B22t	15–33	0.1–0.05	10	60	(Or + Al) >> (Ol + An)	20	5
			2–0.1	20	50	(Or + Al) >> (Ol + An)	10	15
	B34	122–198	0.1–0.05	35	40	(Or + Al) >> (Ol + An)	15	2
			2–0.1	15	45	(Or + Al) >> (Ol + An)	5	30
70-1	B2t	11–21	0.1–0.05	35	45		10	0.5
			2–0.1	20	50		15	8
Rhyolite								
59-13	K2	13–18	0.05–0.02	15	75[7]			7
59-16	K21m	28–30	0.05–0.02	15	75[7]			10
60-4	Clca	43–74	0.05–0.02	20	65[7]			15
60-5[8]	B22tcs	38–58	0.05–0.02	27	58[7]			15
70-8	A2	0–5	0.1–0.05	40	25	(Or > Al) >> (Ol + An)	25	
	B21t	5–18	0.1–0.05	40	35	(Or > Al) >> (Ol + An)	20	
			0.25–0.1	45	25	(Or > Al) >> (Ol + An)	30	
	B23tca	28–46	0.1–0.05	40	35	(Or > Al) >> (Ol + An)	20	
	K32	82–121	0.1–0.05	40	30	(Or > Al) >> (Ol + An)	30	
	C	159–179	0.1–0.05	40	25	(Or > Al) >> (Ol + An)	35	
			0.25–0.1	40	25	(Or > Al) >> (Ol + An)	35	
Sedimentary rocks								
60-14	B22	56–76	0.1–0.05	50	35	(Or >> Al, Mi) >> (Ol + An)	10	
			0.25–0.1	50	35	(Or >> Al, Mi) >> (Ol + An)	10	
60-15	C2	38–64	0.1–0.05	40	40		20	
Ancient river alluvium								
59-10	Clca	43–64	0.25–0.1	35	40	Al > (Ol + An) > (Or + Mi)	25	
59-11	Bca	5–13	0.1–0.05	40	30	(Al + Or) > (Ol + An)	25	
	C4cm	48–71	0.1–0.05	40	30	(Al + Or) > (Ol + An)	25	
59-17[9]	Clca	48–71	0.25–0.1	45	30	(Ol + An) > (Or + Mi) > Al	25	
61-7	B21t	25–36	0.25–0.1	40	50	(Ol + An) > Or = Al	10	
	Clca	236–272	0.25–0.1	35	40	(Al > Or) >> (Ol + An)	25	
66-11	C3b	163–188	0.25–0.1	45	35	(Or + Al) >> (Ol + An)	20	
66-13	Cl	0–25	0.25–0.1	50	25	(Or + Al) >> (Ol + An)	20	
60-2[9]	Bca	5–10	0.1–0.05	45	25	(Or + Al) >> (Ol + An)	25	
	K31	58–89	0.1–0.05	35	40	(Or + Al) >> (Ol + An)	25	

1/ Because of rounding or the presence of numerals not listed, the percentages may not total 100.

2/ Al - Albite; An - Anorthite; Mi - Microcline; Ol - Oligoclase; Or - Orthoclase. The >> symbol indicates more than twice.

3/ Consist largely of composites of small crystals of feldspar, and commonly contain numerous, small opaque inclusions and lath-shaped grains of clay minerals. In some soils the microcrystalline grains are mostly fragments of the groundmass of volcanic rocks; in other soils, they are mostly feldspar crystals highly altered by geological process (sericitization). Commonly the microcrystalline grains have an index of refraction consistent with orthoclase or albite as the dominant minerals.

4/ Nominally biotite in sand fractions with some alteration to vermiculite possible. Identified only as mica in silt.

5/ Mica percentages by volume. Quartz includes oligoclase for 0.25–2 mm.

6/ Mica volume percentages; some chlorite included with biotite. 15% of feldspar oligoclase.

7/ Includes microcrystalline grains.

8/ Consult section 156 for other determinations.

9/ Some rhyolite influence.

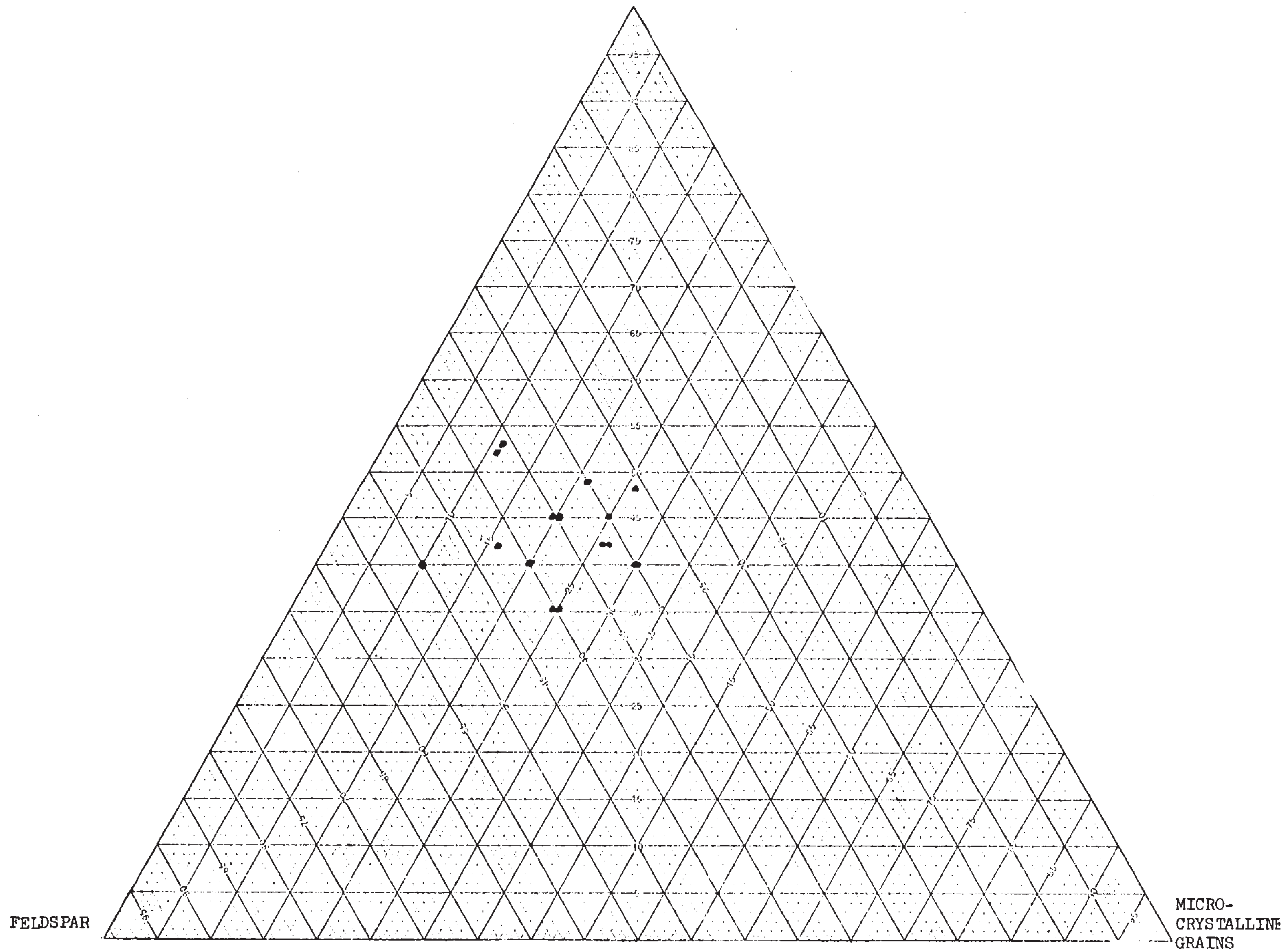


Figure 48. Proportions of quartz, feldspar, and microcrystalline grains in the carbonate-free 0.05-0.1 mm or 0.1-0.25 mm fractions. Pedons located in the arid part of the study area and developed in sediments derived from monzonite, rhyolite, ancient river alluvium or calcareous sedimentary rocks.

Table 65. Heavy minerals in the 0.05-0.02 mm of samples from soils formed in monzonite and rhyolite alluvium1/

Pedon	Horizon	Depth	Hornblende	Basaltic Hornblende	Epidote	Ore Minerals	Sphene	Garnet	Zircon	Tourmaline
		cm	←			pct				→
Monzonite alluvium										
59-2	A13	20-41	45	2	7	46	2	--	--	--
59-4	C1ca	23-38	29	5	15	51	3	--	--	--
60-8	B22t	23-48	30	4	21	45	4	--	--	--
60-9	B22t	28-84	38	--	4	35	--	--	--	--
Rhyolite alluvium										
59-13	K2	13-18	6	7	10	69	--	3	4	--
59-16	K21m	28-30	5	4	11	68	--	--	6	2
60-4	B22	25-43	18	12	9	49	--	--	7	4
60-5	B22tcs	38-58	8	7	13	61	--	1	6	2

1/ By Hsin-yuan Tu.

88b. Clay mineralogy[4/]

The clays from the dust samples contain small amounts of kaolinite, mica, and poorly ordered montmorillonite (table 26).

The clay in the residue from Paleozoic calcareous sedimentary rocks after carbonate removal consists of mica, with some kaolinite and a little chlorite (section 201). No montmorillonite or vermiculite were identified. Clays in soils developed in sediments derived from these rocks contain small amounts of kaolinite and mica, and small to moderate amounts of poorly ordered montmorillonite (pedons 66-6, 65-1, 65-5, 60-15, and 60-14). Clay mineralogy changes little with depth even in pedons such as 65-5, which has an argillic horizon.

Soils of Pleistocene age developed on high-biotite monzonite rocks (Coxwell variants 66-9, 66-10) contain well-ordered kaolinite, mica, montmorillonite, and in some instances, regularly interstratified mica-montmorillonite. The biotite alters to montmorillonite, often while the rocks are yet consolidated.

Holocene soils developed in alluvium derived from the high-biotite monzonite (pedons 62-3 and 69-8) contain small amounts of kaolinite and mica and small to moderate amounts of poorly ordered montmorillonite throughout the pedon. Pleistocene soils derived from the low-biotite monzonite contain small amounts of kaolinite and mica throughout the pedon. Montmorillonite is poorly ordered in upper horizons but is more abundant and better ordered in and below the K horizon (pedon 60-13).

Turning to rhyolite, soils formed in Holocene alluvium contain throughout small amounts of kaolinite and mica, and small to moderate amounts of poorly ordered montmorillonite (67-4). Soils developed in Pleistocene alluvium have a similar distribution of kaolinite and mica, but as with the Pleistocene soils in monzonite, the montmorillonite increases in abundance and degree of ordering within and below the K horizon (pedons 59-14, 59-15, 60-5).

Greater amounts of montmorillonite in the K horizon and improved ordering with depth may be a regional pattern. Buol and Yesilsoy (1964) found an increase in montmorillonite in the K horizon. For the particular pedon studied, however, the change may not have a pedogenic origin; there is evidence of a lithological change at the top of the K horizon. Frye *et al*. (1974) report that crystallinity improves with depth through the upper part of caliche sections located in east-central New Mexico.

An explanation for the better ordered montmorillonite within and below the K horizon is that it was largely emplaced in Pleistocene pluvials and during subsequent drier periods has not been subjected to appreciable pedogenesis. In shallower horizons pedogenesis has reduced the crystalline quality of the montmorillonite. An alternative explanation is that alteration from poorly ordered to well ordered montmorillonite occurred after the lower materials were isolated from surficial weathering by formation of the K horizon. Upper horizons are subject to greater return of potassium by vegetation, a manifestation of which is higher extractable potassium towards the soil surface. The increase in montmorillonite with depth may be in part a reflection of reduced potassium in the soil solution (see section 95 for discussion).

4/ Written by W. C. Lynn

89. CARBON C-14, C-13

Carbon isotope determinations on carbonate and on associated organic carbon are in table 66. Table 67 describes the details of the sampling and preparation procedures and gives characterization data that are not in table 66. Isotopes, Inc., performed the C-14 analyses with the exception of C-14 sample 25 which was analyzed by the U. S. Geological Survey. The samples for carbonate determination were submitted directly for analysis with no pretreatment. Analyses were performed on organic carbon associated with the carbonate for a few samples. The samples for age determination of the organic carbon were treated with a solution of $FeCl_3$ to remove the carbonate. The $FeCl_3$ solution kept the organic matter flocculated. Sample preparation in a number of instances involved contact with water. Sample 11 evaluates the effect of this contact. No reduction in C-14 age was found. Coatings of carbonate on pebbles were analyzed in a number of instances. For horizons with thick coatings, care was taken to obtain carbonate from a large number of pebbles in order to have a sample representative of the horizon.

Figure 49 compares age based on carbonate C-14 to soil age based on independent estimates. Carbonate C-14 ages appear useful to corroborate the relative ages of soils from late-Pleistocene through Holocene, but are of little value in distinguishing between late-Pleistocene and older soil horizons. As evidence, all C-14 ages of horizons of latest Pleistocene (8 to 15 kyr) exceed those of the horizons of Holocene age. Likewise, carbonate C-14 ages for horizons of late-Pleistocene and older (over 25 kyr) exceed those for the younger horizons. On the other hand, the carbonate C-14 ages for the horizons in the 25 to 75 kyr range in age are similar to those for horizons that exceed 200 kyr.

The carbonate in most of the horizons exceeding 200 kyr age, must have undergone exchange with environmental C-14 after emplacement since all but one has an activity high enough to obtain a date. Frye _et al_. (1974) present C-14 ages for carbonate from mid-Pleistocene and older carbonate accumulations in central-eastern New Mexico that are within the datable range. Apparently most carbonate accumulations associated with the land surfaces in the region have an activity within the datable range.

Age of carbonate when deposited is important to the use of carbonate ages for chronology. The carbonate C-14 ages in table 68 indicate that the initial age of authigenic carbonate is less than 3 kyr. Assuming initially dead carbonate, this would be equivalent to carbonate that had gone through two or more cycles of solution and precipitation.

Many investigators (e.g., Williams and Polach, 1971) have reported increasing C-14 ages with depth in the soil. Data in table 66 for pedon 59-16 (samples within numbers 13 to 21) indicate that contrasting soil components within individual horizons may differ greatly in C-14 ages. These data are discussed in section 72.

Table 66. Carbon isotope data for pedons of the project area[1/]

EPOCH AND GEOMORPHIC SURFACE	SOIL AGE	PEDON NUMBER CLASSIFICATION AND DOMINANT PARENT MATERIAL SOURCE	HORIZON AND DEPTH	MATERIAL	C-14 SAMPLE NO.	LABORATORY NUMBERS[2/]	CARBON ISOTOPE DATA: CARBONATE C-14 AGE	CARBON ISOTOPE DATA: CARBONATE δ(C-13)%	CARBON ISOTOPE DATA: ORGANIC CARBON C-14 AGE
	kyrs[1/]		cm				yrs BP		yrs BP
Holocene									
Organ	1.1-2.2	65-2 Typic Torrifluvent Sedimentary rocks	2C2ca 8-28	<0.05 mm from pebble coatings	1	I-4412 67L935	2,730 ±110	-3.6	
Organ	2-6	60-15 Typic Torrifluvent Sedimentary rocks	C3 64-86	Whole sample	2	I-5084 13216	10,580	+1.3	
Organ	2-4	67-1 Typic Torrifluvent Monzonite	C1ca 13-28	Pebble coatings	3	I-3008 67L134	4,430 ±135		
				0.02-0.002 mm from pebble coatings	4	I-2902 67L470	1,610 ±95		
Organ	2-6	67-4 Typic Haplargid Rhyolite	C1ca 51-71	Pebble coatings	5	I-4411 ?	3,360 ±195	-5.0	
Latest Pleistocene									
Leasburg	8-15	66-3 Typic Torriorthent Rhyolite	3C2ca 46-79	Pebble coatings	6	I-2728 66L678	7,240 ±130		
Leasburg	8-15	66-14 Typic Camborthid Mixed	B22cab 69-91	2-0.05 mm from soft nodules	7	I-2735 67L041	6,150 ±140		
Isaacks' Ranch	8-15	67-5 Typic Haplargid Rhyolite	C2ca & K 75-90	Pebble coatings	8	I-4413 67L937	10,700 ±140	-2.0	
Isaacks' Ranch	8-15	59-7 Typic Haplargid Monzonite	C1ca 70-97	Whole sample	9	I-2127 20848	8,010 ±130		
				2-0.05 mm	10	I-2733 67L038	7,880 ±150		
				Whole sample, water treated	11	I-2732 20848	8,430 ±140		
Late Pleistocene									
Picacho	15-25	66-1 Typic Haplargid Rhyolite	2K2 to 2C1ca 38-51	Pebble coatings	12	I-2732 67L037	21,400 ±490		
Picacho	25-75	59-16 Typic Haplargid Rhyolite	B22tca 15-28	Whole sample	13	I-374 15027	5,725 ±200		
				> 2 mm	14	I-1039 15027	10,226 ±400		
				< 2 mm	15	I-2222 11344			565 ±95
				< 0.002 mm	16	I-2223 11344			910 ±100
			K21m 28-30	Soft laminar part	17	I-375 15029	4,575 ±170		
				Whole hard laminar part	18	I-392 15030	13,850 ±600	+2.0	
					19	15030			9,550 ±300

1/ The age of pedons 65-2, 60-15, 67-1 and 67-4 is known by radiocarbon dating of buried charcoal at the site or by soil and geomorphic tracing from charcoal-dated sites. Ages estimated for the remainder (see section 75).
2/ Upper, Isotopes Inc. No.; lower, National Soil Survey Laboratory, Lincoln, Nebraska.
3/ U. S. Geological Survey No.

Table 66, continued

EPOCH AND GEOMORPHIC SURFACE	SOIL AGE	PEDON NUMBER CLASSIFICATION AND DOMINANT PARENT MATERIAL SOURCE	HORIZON AND DEPTH	MATERIAL	C-14 SAMPLE NO.	LABORATORY NUMBERS [2]	CARBON ISOTOPE DATA: CARBONATE C-14 AGE	CARBONATE δ(C-13)‰	ORGANIC CARBON C-14 AGE
	kyrs [1]		cm				yrs BP		yrs BP
Late Pleistocene, cont.									
				Whole nonlaminar part	20	I-391 15031	18,300 ±600		
			K22m 30-64	Whole sample	21	I-376 15032	15,300 ±400		
				Pebble coatings	22	I-2128 20849	27,900 +1,100 -1,000		
Picacho	25-75	66-5 Typic Paleorthid Sedimentary rock	K21m 30-34	Whole hard laminar part	23	I-2729 67L034	14,600 ±210	+0.1	
					24	I-2781 67L034			10,760 150
Picacho	25-75	60-2 Typic Calciorthid Mixed noncalcareous	2K32 89-122	Pebble coatings	25	I-2731 67L036	29,900 +1,400 -1,200		
Picacho	25-75	59-9 Buried soil Camp Rice	64-135	Nodules and vertical segregations	26	W-796 [3]	20,300 ±800		
Jornada II	25-75	59-6 Buried soil Monzonite	B2tb, K1b 80-100	Whole sample	27	I-2125 20846	11,700 ±170	-0.4	
			K2b 145-186	Whole sample	28	I-2126 20847	25,500 +800 -700	+1.1	
				2-0.5 mm	29	I-2734 67L039	29,000 +2,700 -2,100		
Late mid-Pleistocene									
Jornada I	200-300	59-6 Buried soil Monzonite	K22b2 231-262	Whole sample	30	I-4410 67L135	26,950 ±1,050	-1.2	
Jornada I	200-300	66-2 Ustollic Paleorthid Rhyolite	K22m 43-64	Pebble coatings	31	I-2730 67L035	25,200 ±500		
Jornada I	200-300	67-2 Typic Paleorthid Rhyolite	K22m 36-56	Pebble coatings	32	I-3009 67L192	19,700 ?		
Jornada I	200-300	59-9 Buried soil Camp Rice	165-226	Soft nodules	33	W-797 [3]	>30,000		
Mid-Pleistocene									
Upper La Mesa	600-800	61-7 Petrocalcic Paleargid Ancient river alluvium	K21m 48-74	Whole sample of hard laminar part of the middle of 3 subunits of laminar and massive K fabric.					
				Upper half	34	I-2131 20853	29,300 +1,400 -1,100		
					35	I-2779 20853			20,700 ±400
				Lower half	36	I-2224 20853	30,000 +1,500 -1,300		
					37	I-2780 20853			20,800 ±400
			K22m 74-102	Whole sample of upper part	38	I-4414 69L474	28,450 ±1,150	-5.5	

Table 66, continued

EPOCH AND GEOMORPHIC SURFACE	SOIL AGE	PEDON NUMBER CLASSIFICATION AND DOMINANT PARENT MATERIAL SOURCE	HORIZON AND DEPTH	MATERIAL	C-14 SAMPLE NO.	LABORATORY NUMBERS 2/	CARBON ISOTOPE DATA: CARBONATE C-14 AGE	CARBONATE δ(C-13)%	ORGANIC CARBON C-14 AGE
	kyrs 1/		cm				yrs BP		yrs BP
Mid-Pleistocene, cont.									
Upper La Mesa	600-800	(5 m east of pedon 61-7)	K21m	Whole sample of hard laminar part of upper laminar zone on edge of pipe.	39	I-2130 20850	20,900 ±400		
			K21m	Whole sample of hard laminar part from laminar lining of lower part of pipe.	40	I-2129 20850	31,800 +1,900 -1,500		

Table 67. Sampling procedures and characterization data for carbon isotope determinations.

C-14 Sample No.	Discussion
1	> 9 mm pebbles were cleaned with air jet and placed overnight in distilled water. Larger pebbles were scrubbed with a nylon vegetable brush; smaller were only agitated in water. Material removed was passed through 300 mesh sieve. The < 0.05 mm contains 45 percent total carbonate; 21 percent 0.02-0.002 mm carbonate; and 17 percent < 0.002 mm. The organic carbon percentage is 1.67 percent. Morphology consistent with a pedogenic origin. Pebbles consist of dark limestone, sandstone and siltstone, with appreciable component of pebbles of K-fabric. Treatment removed loose carbonate coatings but harder coatings remained.
3, 4	The > 5 mm pebbles were placed in water three days. Each pebble was checked to exclude fragments of detrital K fabric and pebbles heavily coated with carbonate. The pebbles were then placed in an ultrasonic machine and agitated to remove the carbonate coatings. The 0.02 to 0.002 mm from the coatings was obtained by sedimentation and decanting. The sample was dispersed as in Method 3A1, except that treatment with hydrogen peroxide was omitted and a solution of sodium phosphate glass adjusted to pH 8.5 with NaOH was used as the dispersing agent. The 0.02-0.002 mm contains 20 percent carbonate.
5	> 9 mm pebbles were separated by wet sieving and the carbonate coatings removed with a mechanical vibrating tool. Coatings were thin, patchy and flaky.
6	The > 2 mm pebbles were allowed to stand in water overnight, then dried and buffed with a stiff brush. Carbonate coatings were then removed using a mechanical vibrating tool.
7	Sand (2-0.05 mm) segregated from soft carbonate nodules. The samples were dispersed and the sand separated by Method 3A1, except that the dispersing agent was adjusted to pH 8.5 with NaOH. The sands from the nodules have a $CaCO_3$ equivalent of 26 percent. The sands from the internodular material (67L043), selected on the basis of minimum whitening by carbonate, have a $CaCO_3$ equivalent of 1.5 percent. The ratio of authigenic carbonate to allogenic carbonate for the sand from the nodules is calculated as 23. A portion of the sands from the nodules was crushed to pass 0.25 mm and examined under the petrographic microscope. All of the carbonate appears fine grain, consistent with authigenic origin.
8	> 20 mm pebbles were placed in water overnight and the surfaces abraided with a vegetable brush. The coatings for age determination were then removed with a mechanical vibrating tool.
9	Allowed to stand 24 hours in distilled water and then shaken overnight in a sealed container with distilled water. Water was withdrawn with filter candles after flocculation with ethanol and the sample then was air-dried.
10	Material noticeably whitened by carbonate was segregated from the field sample and dispersed by Method 3A1, except that treatment with hydrogen peroxide was omitted and sodium phosphate glass adjusted to pH 8.5 with NaOH was used as the dispersing agent. The < 2 mm contains 2.1 percent carbonate 2-0.05 mm, 1.5 percent 0.05-0.02 mm, 10.3 percent 0.02-0.002 mm, and 5.8 percent < 0.002 mm. Under the petrographic microscope, the carbonate in 20848 has the fine grain morphology consistent with pedogenic origin.
11	> 20 mm pebbles abraided with a stiff brush and loose material in indentations removed with a knife. Carbonate adhering then was removed with a mechanical vibrating tool to form the sample analyzed.
14	> 2 mm washed and ground.
16	Water-dispersible clay by Method 3A1c.
22	> 20 mm washed and loosely adhering carbonate removed with electric buffing wheel. Pebbles were then ground.
23	Soft, uppermost laminar material removed. Hard laminar part has $CaCO_3$ equivalent of 88 percent.
24	Whole hard laminar part contains 0.60 percent organic carbon on carbonate-free basis; upper and lower portions contain 0.52 and 0.53 percent, respectively.
25	Carbonate adhering to the > 20 mm pebbles. The pebbles were soaked in water for two days, dried, then scraped with a knife to remove the less strongly adhering material, followed by buffing with a stiff brush. The carbonate coating that remained was removed with a mechanical vibrating tool to form the sample for analysis.
29	Dispersed by Method 3A1, except that treatment with hydrogen peroxide was omitted and a solution of sodium phosphate glass adjusted to pH 8.5 with NaOH was used as the dispersing agent. The < 2 mm contains 23 percent total carbonate, 2 percent 2-0.5 mm carbonate, and 17 percent < 0.02 mm carbonate (Method 6E1b). As viewed under the petrographic microscope, all of the carbonate in the 2-0.5 mm consists of aggregates of much smaller crystals of carbonate, consistent with a pedogenic origin.
31	> 20 mm pebbles were soaked in water overnight, dried and the loosely adhering carbonate removed with a stiff brush and by scraping with a knife. Adhering carbonate was removed with a mechanical vibrating tool to form the sample. The $CaCO_3$ equivalent is 70 percent.
35	0.52 percent organic carbon on carbonate-free basis.
37	0.37 percent organic carbon on carbonate-free basis.

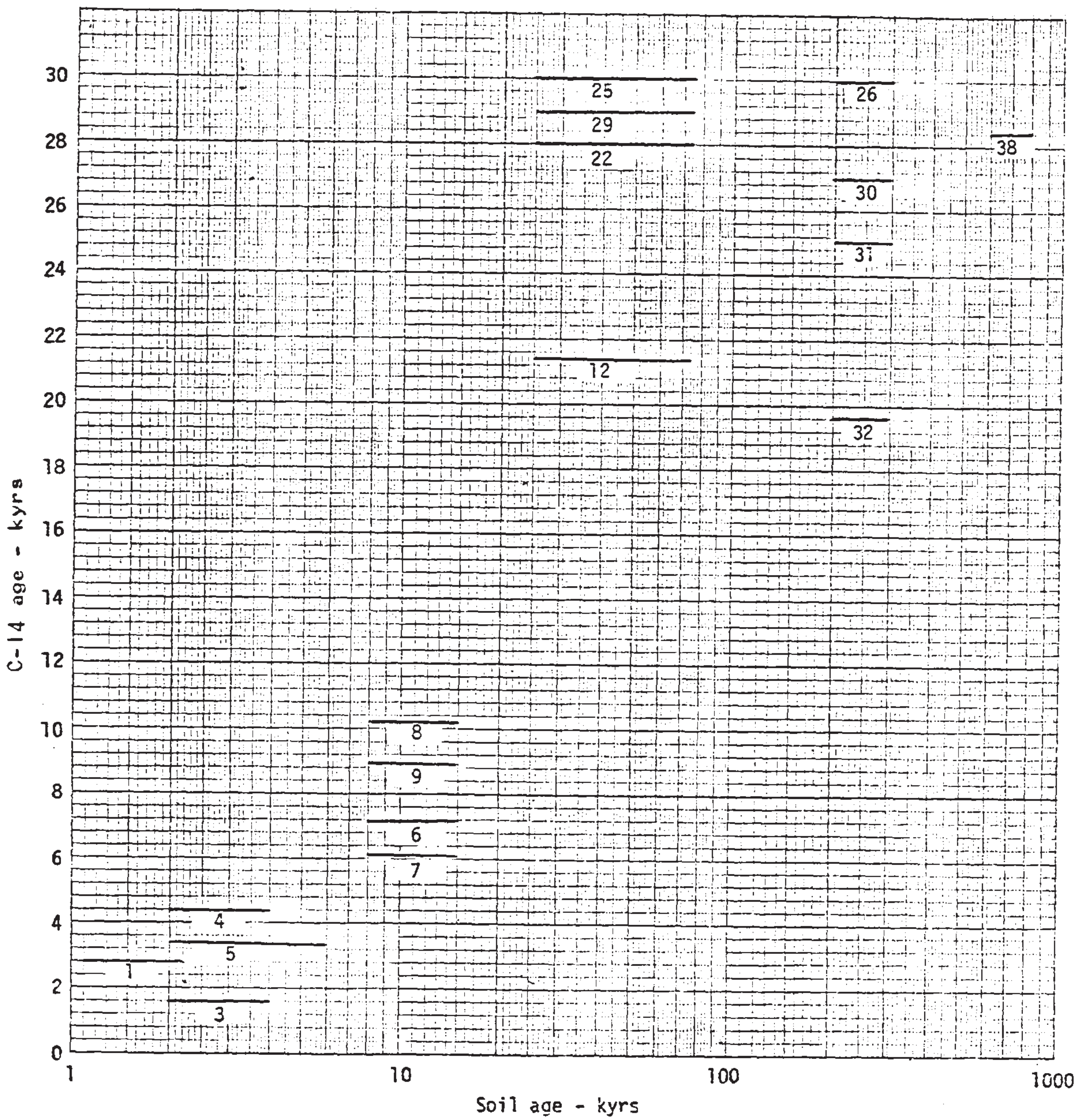


Figure 49. Carbon-14 ages of carbonate vs soil age range independently evaluated. The maximum carbonate ages available for other than laminar horizons were employed. Identification is by C14 sample number (table 66).

Table 68. Samples with youthful carbonate C-14 ages for estimation of initial C-14 age.

C-14[1/] sample no.	C-14 age of carbonate kyrs	Age of soil from other evidence kyrs	Comments
1	2.7	1.1-2.2[2/]	Forty percent of the carbonate in the < 0.05 mm is < 0.002 mm which may have an age below 2.7 kyrs.
3 4	4.4 1.6	2-4.0[3/]	Some of the carbonate coating the pebbles probably was inherited from pre-existing soils. The age of sample no. 4 is probably more representative of the authigenic carbonate.
13, < 2mm[4/]	1.3	25-75[5/]	Horizon occurs at shallow depth and is moistened periodically. One-third of the carbonate in the < 2 mm is < 0.002 mm, which may have an appreciably lower age.
5	3.4	2-6[6/]	Most of the carbonate is in the < 2 mm and should have a C-14 age substantially below that of the pebble coatings.

1/ Table 66.
2/ From charcoal dates.
3/ Minimum age estimated by soil and geomorphic tracing from charcoal dates; maximum age from charcoal date.
4/ Computed from ages of C-14 samples 13 and 14, and proportion of carbonate associated with > 2 mm.
5/ Late-Pleistocene age.
6/ Estimated by soil and geomorphic tracing from charcoal dates.

Table 69 contains C-14 ages for hard laminar zones of two soils of late-Pleistocene age with similar petrocalcic horizons. One soil developed in noncalcareous rhyolitic alluvium and the other in alluvium from calcareous sedimentary rocks of Paleozoic age. Similarity in ages of the organic carbon suggests that the laminar horizons were formed about the same time. The presence of limestone apparently does not greatly affect the age of authigenic laminar carbonate derived from it in part. Dates for the organic matter post-date the late Wisconsin pluvial maximum, but are within a period of effective precipitation probably greater than at present (Mehringer, 1967; Wendorf, 1961).

Similarity for the mid-Pleistocene soil in ages of the upper and lower parts of the laminar zone suggests it formed rapidly. The date of about 20 kyr for the organic carbon falls within the late Wisconsin pluvial maximum, from 17,000 to 23,000 yr ago (Martin, 1964).

The carbonate has an older age than the associated organic carbon for all three pedons. The differences for the mid-Pleistocene soil exceed any reported by Williams and Polach (1969, 1971). Initial age of authigenic carbonate may be partly responsible. The differences for the mid-Pleistocene soil, however, exceed 5.7 kyr, which is the theoretical age of dead carbonate after going through one solution-precipitation cycle. The difference, moreover, is much greater than the initial age of 3 kyr for carbonate suggested by data in table 68. Occurrence of pre-existing carbonate in the laminar zone is not a tenable explanation. A minimum of 30 percent allogenic dead carbonate would be needed to cause the initial age from 5.7 kyr, the maximum for authigenic carbonate, to 9 kyr. Such a proportion of allogenic carbonate is inconsistent with the morphology of the laminar subhorizon (section 73).

An alternative explanation for the difference is that since emplacement the organic carbon has had its C-14 age reduced more than the carbonate. Polished sections of laminar horizons reveal occasional cracks that have been sealed by carbonate. Roots may have entered these cracks and contributed modern organic carbon. The explanation assumes that the carbonate which later seals the cracks has had less effect on the C-14 ages than the organic carbon added.

Rightmire (Rightmire, C. T. 1967. A radiocarbon study of the age and origin of caliche deposits. M. A. Thesis, University of Texas, Austin) reports δC-13 values of -3 to -6 for soils from Hudspeth County, Texas, 60 miles (97 km) southeast of El Paso. Rightmire presents evidence that δC-13 becomes more negative with increasing C-14 age of the carbonate. The values in table 70 do not show this trend. Williams and Polach (1971) present δC-13 values for the carbonate in a number of Australian paleosols. Most values are negative, but a few are positive. The range is from -5.1 to +3.4, similar to the range for samples of this project. Leamy and Rafter (1972) found that the δC-13 becomes less negative with depth in Haplustalfs of New Zealand. They ascribe this to a reduction in the proportion of the carbon dioxide in the soil air originating from the decay of plant residues at progressively greater depths.

Table 69. Carbon-14 ages for the laminar carbonate of the petrocalcic horizon of three pedons.

Age, Parent Material	C-14[1/] Sample No.	Carbon-14 Age Carbonate	Carbon-14 Age Organic Carbon
		kyrs	kyrs
Late-Pleistocene Rhyolitic alluvium	18, 19	14	10
Late-Pleistocene Calcareous sedimentary rock	23, 24	15	11
Mid-Pleistocene River alluvium	34, 35 upper half	29	21
	36, 37 lower half	30	21

1/ Table 66.

Table 70. δC-13 values for carbonate arranged from negative to positive and associated C-14 ages.

C-14 Sample No.	Carbonate Isotope Values C-13[1/]	Carbonate Isotope Values C-14 age
		kyrs
38	- 5.5	28
5	- 5.0	3
1	- 3.6	3
8	- 2.0	11
30	- 1.2	27
27	- 0.4	12
23	+ 0.1	15
28	+ 1.1	26
2	+ 1.3	11
18	+ 2.0	14

1/ (R/Rst) - 1 x 1,000 where R and Rst are the ratios of C-13/C-12 for the sample and the standard, respectively.

The use of δC-13 to correct carbonate C-14 ages for the proportion of carbon originating from limestone (Rightmire) would widen the discrepancy between carbonate C-14 age and known soil age for a number of Australian paleosols (Williams and Polach, 1971). Such corrections have not been made.

90. CARBONATE Ca/Mg RATIO

Table 71 contains the ratios of calcium to magnesium for the carbonate in three pedons with strong accumulations of authigenic carbonate and developed in noncalcareous parent material. The ratios indicate that calcite predominates and that dolomite is a minor constituent if present at all. The decrease in the ratios with depth indicates either progressively more structural magnesium in the calcite or the presence of dolomite. The ratio of water soluble calcium to magnesium may decrease with depth in the soil because of exclusion of magnesium from the calcite precipitated at shallower depths, leading to the precipitation of carbonate with more structural magnesium at the greater depths. Relatedly, since calcite solubility rises as the magnesium content increases, there may be a tendency during successive solution-precipitation cycles for the higher magnesium calcite to be selectively dissolved from shallower depths and precipitated at greater depth.

90a. pH

pH values for representative pedons at different elevations are shown in table 71a. pH is consistently high--about 8 or above--in the arid part of the study area. It is lower in the mountains, where values decrease with increasing elevation.

pH values may not have differed greatly from present values, even in pluvial climates of the Pleistocene. In the arid part of the study area, soils of late-Pleistocene age must have formed in part during the Pleistocene pluvial climates, which had more effective moisture than now (section 11). Mountains of the study area presently have more effective moisture than the arid zone downslope (section 10), and could have a climate similar to that of the pluvials. In the mountains at nearly 6000 ft elevation, pH is still above 6 (table 71a). Thus pH values in the arid part of the study area could have been fairly high even in the pluvial climates. Further, in the arid zone even soils of late-Pleistocene age and formed in low-carbonate parent materials have prominent carbonate horizons (table 71a). Carbonate from atmospheric additions must have accumulated during the Pleistocene and would have kept the pH high.

Table 71. The ratio of calcium to magnesium for carbonates of three pedons formed in noncalcareous parent materials.[1]

Depth	Horizon	Carbonate analyses: Whole material, Measured	Carbonate analyses: Whole material, Calculated	Carbonate analyses: < 2 mm	Carbonate analyses: Ca/Mg
cm		pct	pct	pct	ratio
Typic Calciorthid, Nickel 59-13					
0-5	A2	3	3	6	38
5-13	B	10	10	15	57
13-18	K2	29	30	65	40
18-48	K31	10	7	35	38
48-69	K32	6	6	21	23
69-94	K33	3	3	10	15
94-132	Cca	2	2	7	7
Petrocalcic Paleargid, Cruces variant 59-16					
15-28	B22tca	4	10	10	52
28-30	K21m[2]	74	73	74	54
		80	78	83	50
		32	30	46	59
30-64	K22m	15	16	58	29
64-127	K3	8	9	23	19
Typic Paleorthid, Simona 60-10					
0-5	Aca	5	6	8	53
5-20	Bca	8	9	13	49
20-23	K21m	36	40	67	21
23-43	K22m	35	40	62	27
43-74	K22m	13	16	35	18
74-104	K3	7	10	21	14
104-127	Cca	3	4	7	12

1/ Measured carbonate values by methods 6E1a or 6E1c on whole-ground material and calculation to a base free of coarse fragments to obtain percentage for < 2 mm. The Ca and Mg were determined separately on samples of the whole material that were first leached with pH 8.2 N NaOAc to remove exchangeable Ca and Mg, and then dissolved using pH 5 N NH_4OAc buffer. The calculated amount of carbonate was obtained from the Ca and Mg extracted.

2/ From top to bottom, soft upper part of laminar zone; hard part of laminar zone; attached, nonlaminar material.

91. PARTICLE SIZE

92. Carbonate

The size distribution of inherited carbonate depends mainly on the mode of deposition of the sediment. If the carbonate is authigenic the size distribution becomes coarser as cementation progresses, until in an advanced stage the horizon is continuously cemented.

Carbonate of clay size (less than 0.002 mm) has been determined on a number of pedons. Nine Argids developed in noncalcareous parent materials were examined to determine the proportion of the total carbonate that is clay size. Only horizons with 10 percent or more carbonate were included. Most of the horizons are K horizons; none are indurated or Km horizons. For this set of 17 samples, the ratio of carbonate clay to total carbonate had a mean of 0.54 with a standard deviation of 0.15. The carbonate contents ranged from 10 to 34 with a mean of 20. Taking both this group of Argids developed in noncalcareous materials and Calciorthids or Torrifluvents developed from calcareous materials, a third or more of the carbonate in uncemented horizons with over 10 percent total carbonate is clay size.

In soils with carbonate to the surface but lacking appreciable carbonate cementation, the proportion of the total carbonate that is of clay size increases from the A horizon into the B horizon or K horizon beneath. Pedons 60-2 and 60-11 are illustrative of Calciorthids developed from noncalcareous parent materials. Pedons 60-14, 60-15, 60-17, 65-1, 66-6, 66-7, and 68-7 are examples of soils developed in calcareous parent materials; all are Calciorthids except 60-15, a Torrifluvent. A distinct bulge in carbonate clay is a feature of Holocene pedogenesis in high-carbonate parent materials (section 163).

Table 71a. pH and carbonate content of soils at different elevations and formed in monzonite or sediments derived from it.

Pedon, age classification, elevation	Horizon	Depth	pH[1/]	Carbonate
		cm		pct
Onite 70-5, Holocene	A2	0-6	8.1	tr(s)
Typic Haplargid;	B21t	6-16	8.0	tr(s)
coarse-loamy, mixed	B22t	16-32	7.8	tr(s)
4300 ft, 1311 m	B31tca	32-47	8.1	1
	B32ca	47-74	8.2	1
	C1ca	74-87	8.3	3
	2C2	87-157	8.4	tr
	3C3	157-169	8.5	1
	3B21tb	169-189	8.4	tr
	3B22tcab	189-215	8.4	4
	3B3tcab	215-239	8.4	5
	3B1tcab2	239-255	8.7	tr
	3B2tcab2	255-268	8.0	4
	3K2b2	268-278	8.3	40
Berino 70-7, late-Pleistocene	A2	0-7	8.2	tr(s)
	B21t	7-18	8.1	1
Typic Haplargid;	B22t	18-34	8.1	4
fine-loamy, mixed	B23tca	34-49	8.1	10
4300 ft, 1311 m	K2	49-71	8.2	23
	K3	71-100	8.6	24
	Bca	100-129	8.8	10
	Bcab1	129-153	8.5	7
	Bcab2	153-170	8.2	7
	B1tcab2	170-182	8.3	2
	B2tcab2	182-195	8.3	3
	K1b2	195-215	8.5	14
	K2b2	215-242	8.4	25
Sonoita 60-8, Holocene	A	0-8		tr
	B21t	8-23	7.6	-
Typic Haplargid;	B22t	23-48	7.6	tr
coarse-loamy, mixed	B3	48-81	7.6	tr(s)
5000 ft, 1524 m	2Cca	81-102	8.3	1
Coxwell variant	A1	0-5	7.2	tr(s)
66-10 (undifferentiated mountain	B21t	5-13	6.5	tr(s)
slopes and summits)	B22t	13-25	6.4	tr(s)
	B23t	25-43	6.6	tr(s)
Ustollic Haplargid;	B3	43-84	6.6	tr(s)
loamy-skeletal,	R1	84-132	6.7	tr(s)
mixed	R2	132-178	6.8	tr(s)
5850 ft, 1783 m				

1/ Method 8C1a (1:1).

93. Fine clay

Fine clay (less than 0.0002 mm) was determined on the carbonate-free soil material for some 30 pedons. The ratios of fine to total clay are given in table 72; these ratios are weighted averages for the horizons or zones specified.

In all instances the A horizons of the Argids have coarser clay than the associated Bt horizons. In most instances, the clay of the associated K horizons is finer than that of the Bt horizons. Coarser clay in the A horizon is not limited to the Argids. All but one of the 8 pedons in other orders also have coarser clay in the A horizon. The pedons in the Calciorthids and Torrifluvents are all developed in calcareous sediments derived from sedimentary rocks. Their noncarbonate clay tends to be coarser than that for the Argids, which mostly were formed in alluvium from igneous rocks.

Coarser clay in the A horizon appears general for the soils of the arid part of the study area, and is not restricted to soils in which there has been apparent clay accumulation. Intense heat and extreme desiccation in surface horizons may be responsible (section 47). Lower maximum temperatures and less intense desiccation may also explain the increase in fineness of the clay between Bt horizons and K horizons. In this regard, fineness of the clay in K horizons is consistent with their having an appreciable component of illuvial clay, the expected situation if they developed by carbonate engulfment of the lower part of once-deeper argillic horizons.

Table 72. Ratio of fine to total clay (0.0002/0.002 mm) of carbonate-free < 2-mm for zones of pedons arranged by great group or suborder.

Taxa	Pedon	Horizon or zone[1/]				
		A	Bt	K	C	Sub A to 100 cm
Argids	59-7	0.38	0.48		0.36	
	60-6	0.33	0.50	0.74		
	60-7	0.25	0.48	0.62		
	60-13	0.57	0.74	0.51		
	60-21	0.13	0.37	0.51		
	60-22	0.30	0.40			
	61-3	0.12	0.39	0.54		
	62-3		0.60		0.41	
	65-5	0.22	0.40	0.54		
	65-7	0.36	0.46	0.69		
	66-9	0.37	0.43			
	66-10	0.46	0.54			
	68-4	0.35	0.50		0.42	
	68-9	0.21	0.38	0.45		
	69-8	0.20	0.41		0.32	
	70-5	0.27	0.42		0.50	
	70-6	0.44	0.54			
	70-7	0.21	0.44	0.45		
	70-8	0.35	0.59	0.56		
	72-1	0.52	0.56	0.72		
	72-2	0.35	0.61	0.72		
	72-3	0.30	0.63			
	median	0.33	0.48	0.55		
Calciorthids	60-14	0.13				0.24
	60-17	0.13				0.27
	65-1	0.26				0.30
	66-6	0.16				0.14
	66-7	0.24				0.27
	68-7	0.10				0.32
Fluvents	60-15	0.32				0.45
Torrerts	60-16	0.14				0.36

1/ Horizons with less than 10 percent clay and buried horizons excluded.
A includes A, A2, and A3 horizons but not surficial C horizons.
Bt includes B1 and B2 horizons, but not B3 horizons.
K includes K1 and K2 horizons or to top of buried horizon, whichever is shallower, but not K3. Zone from bottom of lowermost A horizon to 100 cm designated "sub A to 100 cm."

94. EXTRACTABLE IRON

Extractable iron is strongly dependent on clay percentage in many soils. Table 72a summarizes the extractable iron and clay relationships for Argids of the study area. Figure 50 shows the relationship between extractable iron and silicate clay percentage for the subhorizon of the argillic horizon of Argids having maximum clay. The values tend to rise with increasing clay, but the scatter is large. Some of the scatter is related to parent material. This is shown by the lower iron relative to clay percentage for pedons developed in mid-Pleistocene river alluvium. The Holocene pedons do not have lower extractable iron relative to the clay than the Pleistocene pedons.

Table 73 compares extractable iron for weakly developed Holocene soils.

* * *

Table 73. Extractable iron and clay for Holocene pedons lacking subsoil diagnostic horizons. The percentages are weighted averages from the base of the surface horizon to 50 cm.

Pedon and parent material	Fe	Clay
	pct	pct
Monzonitic alluvium		
Aladdin 59-1	0.7	11
Hawkeye 59-2	0.9	6
SND 59-3	0.8	6
Vinton 59-4	0.9	7
Reworked river alluvium		
Bluepoint 59-10	0.4	5
Bluepoint 59-17	0.4	5

* * *

The pedons formed in reworked river alluvium have lower extractable iron than those formed in monzonite alluvium. The soils formed in the monzonitic alluvium contain more ferromagnesian minerals, which apparently is the reason for the higher extractable iron.

In some Argids the maximum in extractable iron coincides with the clay maximum, and both the A horizons above and the C horizons below contain less extractable iron commensurate with their lower clay percentages (table 72a). In other Argids, the extractable iron shows little relationship to clay. Figure 50a is illustrative. It contains a plot of the difference in extractable iron and of clay between the B2t horizon with maximum clay and the associated A horizons above or C horizons below. The principal point of the figure is the large scatter at clay differences above 10 percent. This large scatter illustrates the lack of consistency in the relationship with depth between extractable iron and clay.

Table 72a. Relations between extractable iron and clay of Argids.

Soil age and geomorphic surface	Parent materials[1/]	Pedon	B2t, clay maximum		Surface horizon		Increase A to B		C Horizon		Decrease B2t to C	
			Fe	Clay	Fe	Clay	Fe	Clay	Fe	Clay	Fe	Clay
			←———	———	———	———	pct	———	———	———	———	———→
Holocene												
Organ	M	59-5	0.8	12.2	0.8	12.1	0.0	0.1	0.8	7.4	0.0	4.8
	M	59-8	1.1	33.5	0.8	11.9	0.3	21.6				
	M	60-8[2/]	1.0	12.2								
	V	61-5	1.0	16.4	0.9	11.7	0.1	4.7	1.0	12.8	0.0	3.6
	M	62-3	0.8	14.1	0.9	7.3	-0.1	6.8	0.7	13.2	0.1	0.9
	R	67-4	0.9	15.4	0.9	8.2	0.0	7.2	0.7	9.2	0.2	6.2
	M	68-3	0.8	12.4	0.9	8.9[3/]	-0.1	3.5	0.6	8.0	0.2	4.4
	M	68-4	1.0	21.4	0.9	13.9[3/]	0.1	7.5	0.8	8.5	0.2	12.9
	M	70-5	0.9	19.9	0.7	12.3	0.2	7.6	0.8	10.7	0.1	9.2
Fillmore	R	66-16	0.8	12.3	0.9	8.6	-0.1	3.7	0.7	8.1	0.1	4.2
Latest Pleistocene												
Isaacks' Ranch	R	59-6	0.8	28.2	0.8	16.9	0.0	11.3				
	M	59-7	0.8	23.2	0.8	13.6	0.0	9.6	0.7	19.2	0.1	4.0
	M	70-6	0.9	16.1	0.8	12.6	0.1	3.5	0.7	12.4[4/]	0.2	3.7
Late-Pleistocene												
Jornada II	R	59-15	1.0	28.2	0.9	11.5	0.1	16.7	0.7	12.9	0.3	15.3
	M	60-7	0.9	33.4	0.6	14.4	0.3	19.0	0.6	17.5	0.3	15.9
	M	60-13	0.9	24.8	0.8	12.7	0.1	12.1	0.7	18.3	0.2	6.5
	L	60-18	1.0	36.1	0.9	26.0	0.1	10.1	0.8	23.5	0.2	12.6
	V	61-4	0.9	34.2								
	M	68-9	1.0	29.6	0.9	16.9	0.1	12.7				
	M	70-7	1.0	36.7	1.0	21.5	0.0	15.2	0.8	29.7[5/]	0.2	7.0
Picacho	R	59-16	0.8	22.4					0.9	13.3	-0.1	9.1
Late mid-Pleistocene												
Jornada I	R	59-14[2/]	1.1	33.0	0.9	13.1	0.2	19.9	0.8	14.7	0.3	18.3
	M	60-9[2/]	1.3	29.7	1.4	13.2	0.1	16.5	0.8	14.2	0.5	15.5
	V/AR	60-21	1.3	46.6	1.1	37.4	0.2	9.2				
	V/AR	61-3	1.0	47.3								
Mid-Pleistocene												
Dona Ana	R	60-5[2/]	2.1	74.2	0.8	14.1	1.3	60.1				
	AR	61-7	0.7	16.7	0.6	9.7	0.1	7.0				
	AR	61-8	0.5	15.0								

1/ M = monzonite; R = rhyolite; L = sedimentary rocks; V = mixed volcanics; AR = ancient river alluvium; V/AR = mixed volcanics over ancient river alluvium.
2/ Semiarid zone; others in arid zone.
3/ A2 horizon, subsurface.
4/ B3ca horizon.
5/ K3 horizon.

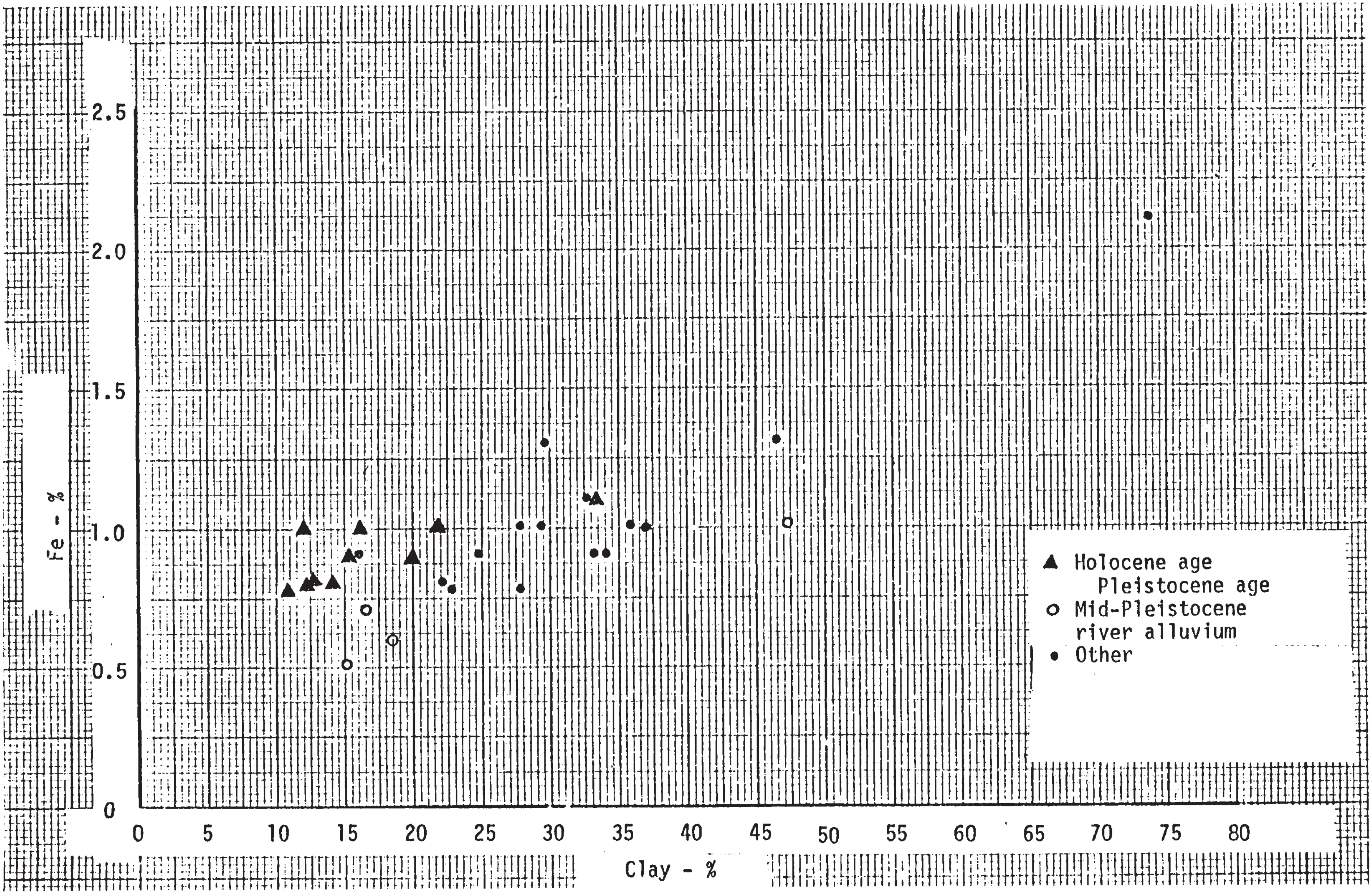


Figure 50. Extractable iron vs. silicate clay (both on carbonate-free basis) for the B2t horizon of maximum clay of Argids.

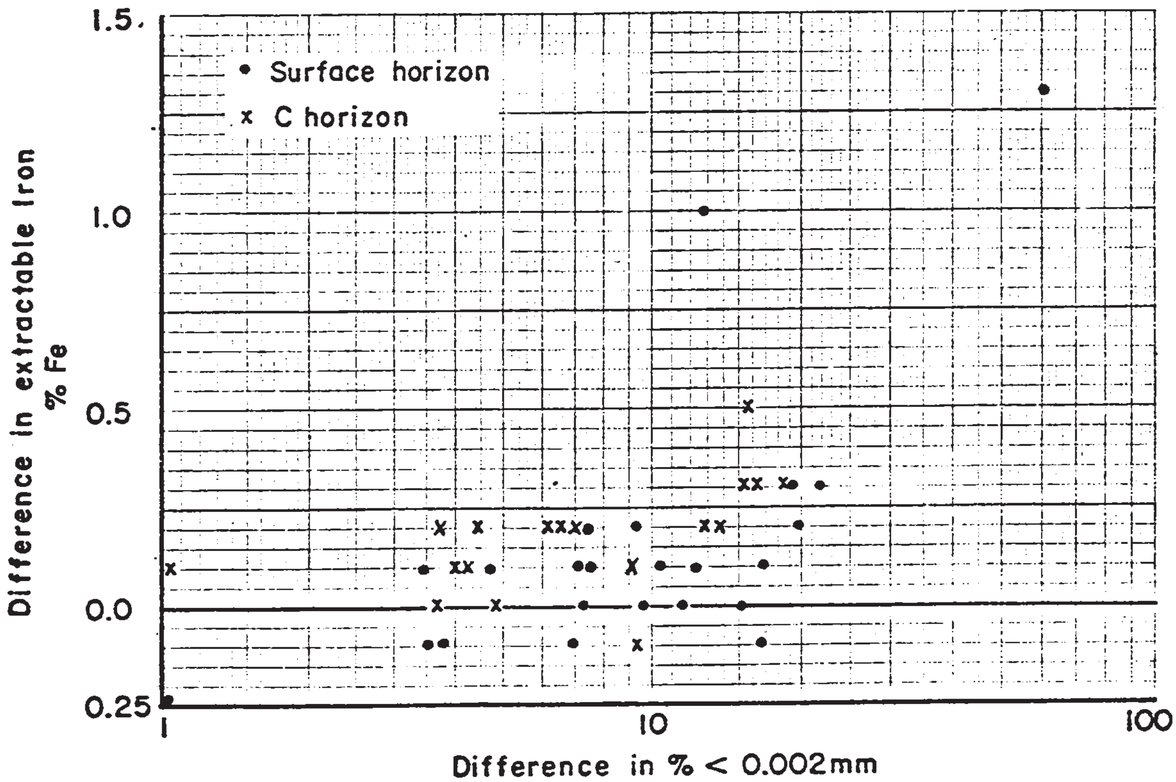


Figure 50a. Extractable iron versus clay of Argids on carbonate-free basis. Values for surface horizons and for C horizons are subtracted from the values for the associated clay maximum in the B2t.

95. ION EXCHANGE

Table 74 summarizes the ion exchange data for the Bt horizon of Argids and a depth from the base of the surface horizon to near 50 cm for pedons in other suborders. With one exception the pedons are located on the basin floor or the lower piedmont slope. In these positions, soils with appreciable extractable sodium or soluble salts (as evidenced by electrical conductivity) within moderate depths are more common than over the project as a whole. Although most soils of the study area have minor or no accumulations of extractable cations and soluble salts, certain very old soils of lower La Mesa do have fairly substantial accumulations (section 149).

The ratio of the cation exchange capacity by NH_4OAc to silicate clay ranges from 0.4 to 0.8. Within this range, Argids in fine families have low values, and so does the Torrert pedon. These pedons have mixed clay mineralogy in the taxonomic sense. Their ratios of exchange capacity to clay is consistent with placement in mixed families.

Extractable magnesium ranges from about 10 to 35 percent of the exchange capacity. It tends to be higher for pedons with appreciable extractable sodium.

Extractable sodium ranges from a trace to 12 percent with most of the pedons having 1 percent or less. Low extractable sodium for the Stellar pedons (fine Ustollic Haplargids) and for the Torrert pedon is noteworthy, suggesting that the local moisture regime may be very important in determining the extractable sodium relationships (see section 157 for further discussion).

Extractable potassium decreases with depth, and for that reason the average value for the upper 50 cm is a better value for comparison purposes. Extractable potassium as a percent of the exchange capacity ranges widely. For pedons of Onite the range is from 3 to 9 percent and for the soils overall the range is from a trace to 13 percent. The lowest value is for the Torrert, and the highest value is for the fine-silty Ustollic Calciorthid. Three pedons have an average of 2 me or more of extractable potassium in the upper 50 cm. They belong to a fine family of Ustollic Haplargids (pedons 60-21, 69-8) or to a fine-silty family of Ustollic Calciorthids (pedon 60-17).

Both the decrease in potassium with depth and the pattern of abundance among soils suggests that the intensity of vegetational return is important in determining the level of potassium. The soils with high potassium support appreciable perennial grass vegetation; hence, the organic carbon is relatively high. The Torrert, which has very low extractable potassium, supports only scattered blueweed, a perennial; most of the time it is barren. Argids tend to have more illite and less montmorillonite in upper horizons. This pattern has been noted in soils of other arid areas and ascribed to recharge by potassium originating from vegetation (Nettleton _et al_., 1973).

Calcium in the precipitation has been postulated as a major source of the calcium for the carbonate that accumulates in the soils (section 65). Appreciable sodium occurs in the precipitation and a mechanism is required to remove this sodium while retaining the calcium as carbonate. Junge and Werby (1958) report an average of about 1 mg/l of ionic sodium in the precipitation, roughly a third that of calcium; data in Lodge _et al_. (1968) support this value. The sodium from precipitation would be appreciable. Using a figure of 200 mm

Table 74. Summary of ion exchange and related data for pedons from the project area. Data are weighted averages for the indicated depths unless otherwise indicated.

Classification and Series	Pedon[1/]	Depth[2/]	Clay[3/]	Organic Carbon	Organic Carbon 0-50 cm	CEC by NH4Ac / Clay	Extractable bases as Pct. of CEC[4/] Mg	Na	K	K 0-50 cm	Ext. K 0-50 cm	Depth to Upper Boundary of Horizon: Ext.Na > 1 me	Conductivity > 2 mmhos/cm
			Pct	Pct	Pct		Pct	Pct	Pct	Pct	me/100g	cm	cm
Typic Haplargids													
Coarse-loamy													
Onite, gravelly variant	61-5	8-23	15.2	0.22	0.20	0.73	13	tr	10	8	0.8	86	61
Onite, deep, part. ind. phase	61-8	13-71	12.1	0.16	0.19	0.75	33	12	3	3	0.3	23	56
Onite, sandy subsoil var.	68-3	8-23	11.5	0.21	0.17[5/]	0.78	14	1	4	6	0.4	117	
Onite, thin-solum variant	68-5	5-23	11.2	0.19	0.22	0.89	16	2	6	6	0.6	48	64
Onite	70-5	6-32	18.7	0.22	0.19	0.61	15	1	6	6	0.7	157	169
Onite	70-6	6-41	15.2	0.16	0.15	0.70	20	tr	6	6	0.6	165	165
Onite, deep, part. ind. phase	72-1	5-26	11.5	0.13	0.12	0.69	25	3	13	9	0.8	40	61
Onite, deep, part. ind. phase	72-2	4-65	14.6	0.23	0.24	0.74	19	8	4	5	0.5	46	65
Sonoita	72-3	4-104	11.3	0.14	0.20	0.78	17	4	4	5	0.5	104	57
Fine-loamy													
Bucklebar	68-2	5-33	19.5	0.32	0.30	0.77	15	1	5	5	0.7	218	
Bucklebar	68-4	15-46	21.4	0.29	0.35	0.67	15	1	8	9	1.2	206	
Berino	68-9	3-43	24.8	0.32	0.30	0.65	22	1	7	7	1.1	185	
Berino	70-7	7-49	30.4	0.34	0.45	0.60	9	1	6	6	1.1	71	153
Dona Ana	61-4	5-33	26.7	0.53	0.50	0.71	14	tr	6	7	1.2	142	142
Dona Ana	68-6	8-58	17.1	0.33	0.33	0.75	13	3	8	6	0.7	58	
Ustollic Haplargids													
Loamy-skeletal													
Coxwell, shallow variant	70-1	5-21	20.6	0.55		0.67	16	1	4			21	
Fine													
Headquarters, clayey, sub. var.	69-8	10-79	47.7	0.60	0.85	0.59	18	4	6	7	2.0	49	79
Stellar, overflow phase	60-21	13-79	45.0	0.38	0.60	0.47	27	tr	11	11	2.6	305	
Stellar	61-3	8-58	43.4	0.48		0.53	24	tr	12			94	
Petrocalcic Ustollic Paleargids													
Loamy-skeletal													
Terino	70-8	5-46	31.3	0.71	0.61	0.66	15	1	5	5	1.1	159	
Clayey-skeletal													
Terino, thick solum variant	60-5	8-58	57.6			0.43	36	7	5	6	1.1	20	58
Typic Calciorthids													
Coarse-loamy													
Whitlock	60-2	5-58	21.7	0.21	0.21	0.63	30	12	4	4	0.6	36	
Algerita, part. ind. variant	61-1	13-46	9.6	0.32	0.31	0.82	16	3	4	5	0.4	81	81
Algerita	61-2	28-56	12.7	0.29		0.73	24	1	4			76	76
Ustollic Calciorthid													
Fine-silty													
Reagan	60-17	8-43	32.4	0.71	0.75	0.55	16	1	14	13	2.3	142	76
Typic Torrifluvent													
Fine-silty													
Glendale	60-15	5-38	21.9	0.73	0.70	0.61	15	1	8	8	1.0	86	64
Typic Torrert													
Very fine													
Dalby	60-16	5-48	61.6	0.34	0.35	0.51	14	tr	tr	tr	tr	114	114

1/ Pedons 61-8, 72-1, 72-2, 72-3 are in local association on lower La Mesa surface; the relationship of the ion exchange data to landscape and soil factors is discussed in section 149. Pedons 60-16, 68-3, 68-4, 68-5, 69-8, 70-5, 70-6, 70-7 occur in local association on and near basin floor; the relationship of their ion exchange data to landscape position is discussed in section 159.

2/ Depths for weighted averages, unless indicated as 0-50 cm. For Argids include B1t and B2t horizons; for others, subsurface horizon and horizons below to depth nearest to 50 cm. Some of the variability for a series, particularly in sodium, is relatable to differences in thickness of the zone averaged.

3/ Noncarbonate clay on carbonate-containing basis.

4/ Used maximum values for extractable cations of 0.04 me for trace amounts.

5/ Extended value for bottom horizon analyzed to 50 cm.

of precipitation, a bulk density of 1.5 g/cc, and assuming all of the precipitation infiltrates and is retained within a depth of 1 m, about 0.6 me per 100 g of sodium would be added in 1000 yr. Occasional deep wetting of the soil would seem necessary to remove this sodium and also the anions in the precipitation, now principally sulfate. This wetting must be sufficiently infrequent that carbonate would accumulate, but occur frequently enough to remove soluble salts.

A factor contributing to low extractable sodium in the upper parts of soils is the abundance of carbonate in the environment. Carbonate occurs in the dust that falls on the soil (section 40) and commonly outcrops upslope in areas over which runoff water moves, as well as usually being present in the soil horizons themselves. The effectiveness of this carbonate in leading to removal of exchangeable sodium, potassium and magnesium, and their replacement with calcium, depends on the carbonate solubility, largely controlled by the partial pressure of CO_2 in the atmosphere. As discussed in sections 60 and 157, the CO_2 partial pressure may rise in surficial horizons soon after a wetting event. A consequence, if the soils are sufficiently warm, would be an increase in the CO_2 partial pressure of the soil air. In turn, carbonate is dissolved and the calcium concentration in the soil solution would increase. Exchangeable sodium (and potassium) would be replaced by calcium. The effectiveness of carbonate, then, in maintaining a low exchangeable sodium (and potassium) level depends in part on the factors that control the partial pressure of CO_2 in the soil air. Two of these factors are the organic carbon content and the ease of air exchange between soil and the atmosphere. Under ponded conditions the exchange would be very low, and if the ponding is prolonged during the warm season, then the CO_2 partial pressure may become quite high. This is the mechanism proposed (section 157) for the low extractable sodium and potassium in the Torrert pedon, 60-16. Impedance of gaseous exchange, however, need not require ponded conditions. A corollary of the infiltration model (section 60) is that while water is infiltrating, the rate of CO_2 exchange with the atmosphere would be small. The critical question for soils of this project, except the small proportion subject to ponding, is whether infiltration is continuous for a long enough time for an appreciable increase in partial pressure of carbon dioxide.

96. COMPRESSIVE STRENGTH

Carbonate horizons not only range widely in carbonate content but also differ greatly in their physical properties such as hardness (both dry and moist) and infiltration rate. Four pedons were selected to study the relation of these properties to carbonate content (table 75).

In general, air-dry compressive strength of the soils increases to the horizon of maximum carbonate, then decreases (table 75). In pedon 1, moist compressive strength increases markedly with depth to the horizon of maximum carbonate, then decreases. Moist compressive strength of pedons 2, 3, and 4 increases slightly or decreases with depth, and reflects lack of substantial induration in the carbonate horizons. Air-dry compressive strength of laminar structural units and the underlying massive horizon (pedon 1) is 7880 and 3920 psi, respectively, much greater than that of certain fragipans (Grossman and Cline, 1957) and comparable to that of concrete (U. S. Bur. Rec. 1956). There is a correlation, significant at the 1 percent level, between both air-dry and moist compressive strength (fig. 51).

Table 75. Some physical characteristics of four soils with horizons of carbonate accumulation.

Horizon	Depth cm	Dominant manner of carbonate occurrence	$CaCO_3$	Bulk density	Infil-tration rate	Unconfined compressive strength 2/ Air dry	10 cm tension Strength	10 cm tension Water	Particle size distribution, mm 3/ Sand	Silt	Clay
			Pct	g/cc	in/hr	psi	psi	psi	Pct	Pct	Pct
Pedon No. 1, Petrocalcic Paleargid (Cruces)											
A	0-5		--	--	--	--	--	--	--	--	--
B21t	5-18		1	1.78	5.9	175	6	16	79	6	15
B22tca	18-30	Filamentary	1	1.68	4.9	85	4	20	75	8	17
K21m	30-63	Laminar	93	2.22	0.05	7880	5430	5	28	39	33
		Massive	65	1.93	--	3290	3170	6	69	14	17
K22m	63-102	Massive	62	1.73	0.5	1070	120	24	70	17	13
K3 4/	102-178	Nodular	54	1.65	--	2435	540	14			
	178-229	Nodular -Whole		--	--	--	--	--			
		-Matrix	18	--	--	--	--	--			
		-Nodular	77	1.65	--	1560	850	14			
Cca	229-315	Flaky	6	1.62	--	240	40	20	89	8	4
C	315-356		1	(loose)	--	(loose)	--	--	95	4	1
Pedon No. 2, Typic Calciorthid (Algerita)											
Alca	0-25	Filamentary	11	1.46	4.4	(soft)	--	--	79	8	13
K1	25-38	Nodular	25	1.43	3.9	(soft)	--	--	73	9	18
K2	38-89	Blocky	47	1.65	0.8	450	15	21	67	8	25
K31	89-114	Nodular	34	1.76	--	820	60	19	65	14	21
K32	114-165	Nodular -Whole	16	1.75	--	--	--	--	75	11	14
		-Matrix	7	1.75	--	--	--	--	77	9	14
		-Nodular	76	1.83	--	--	--	--	75	7	18
Pedon No. 3, Typic Calciorthid (Whitlock)											
Alca	0-23	Filamentary	9	1.52	2.6	(soft)	--	--	82	15	13
K1	23-53	Nodular -Whole	16	1.63	3.7	(soft)	--	--	71	15	15
		-Matrix	11	--	--	--	--	--	69	16	16
		-Nodular	28	--	--	--	--	--	67	16	17
K2	53-97	Massive	17	1.81	2.3	210	20	9	83	8	9
2Cca	97-142	Flaky	4	(loose)	--	(loose)	--	--	85	13	2
Pedon No. 4, Typic Haplargid (Bucklebar)											
C	0-25		2	1.30	1.7	(soft)	--	--	64	25	13
A	25-30		--	--	--	--	--	--		--	--
B21t	30-46		2	1.65	4.6	105	5	19	61	17	22
B22tca	46-64	Filamentary	5	1.63	3.0	195	4	21	47	29	24
B23tca	64-107	Nodular	10	1.62	4.5	135	3	20	60	25	15
2Cca	107-142	Flaky	4	(loose)	--	(loose)	--	--	83	10	7

1/ Most values are averages of duplicate determinations. Bulk density and most unconfined compressive strength determinations were made in triplicate. Data from Gile (1961).

2/ For some horizons, determinations could not be made because of (1) loose or soft consistence, or (2) small ped size. In the K3 horizon of pedon No. 1 and the K31 horizon of pedon No. 2, determinations were made on indurated nodules that occur in a nonindurated matrix.

3/ Carbonate-free basis.

4/ Subdivided for sampling.

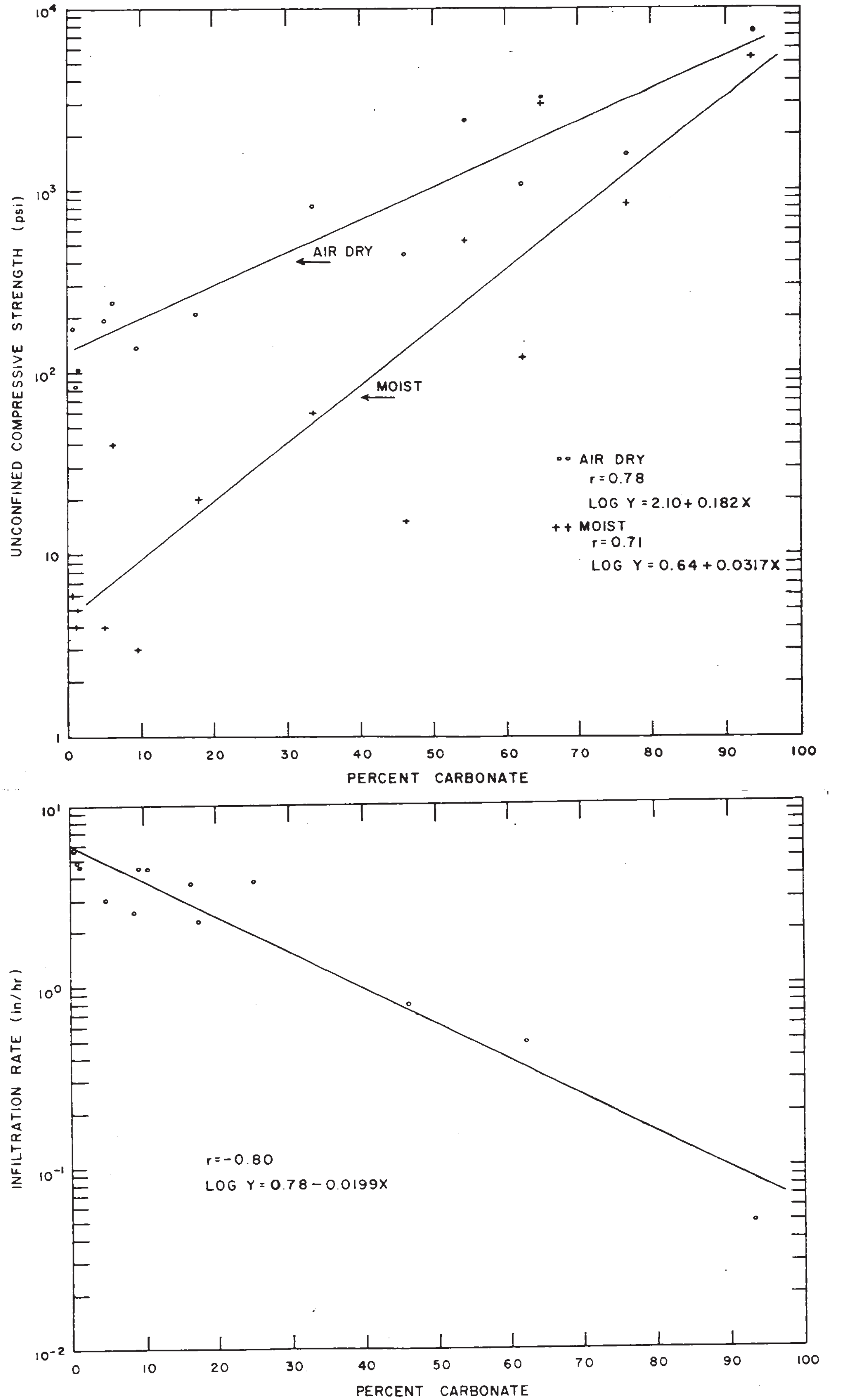


Figure 51. Upper. Relation between carbonate content and unconfined compressive strength.
Lower. Relation between carbonate content and infiltration rate.

Although the plugged horizon has high genetic significance, it usually does not have the extreme properties of the laminar horizon. Most plugged horizons soften noticeably when moistened, although they do not slake. Compressive strength drops sharply for the plugged horizon (pedon 1, 63 to 102 cm) particularly when moist. This horizon contains no laminar material.

A hardness of three or more is characteristic of the laminar horizon, but usually not of the plugged horizon. The values of compressive strength discussed previously are a direct reflection of the difference in hardness. The surface lamina scores readily with a knife. Underlying laminae score difficultly or cannot be scored with a knife and are extremely hard and indurated.

97. INFILTRATION RATE

Infiltration rates of the carbonate horizons range from 0.05 to 5.9 inches per hour. Statistical analysis reveals a highly significant correlation between carbonate content and infiltration rate (fig. 51). As carbonate content increases uniformly, infiltration rate decreases exponentially (fig. 51).

In pedons 1, 2 and 3, infiltration rates are higher in the surface soil than in the subjacent horizons of maximum carbonate. In pedon 4, the Cca horizon has an infiltration rate of 4.5 in/hr. Lowest infiltration rates (0.05 in/hr) were obtained for the laminar horizon. In contrast, the plugged horizon has an infiltration rate of 0.5 in/hr (a reading immediately below the laminar horizon might be somewhat less).

98. BULK DENSITY

Bulk density data were obtained for a minority of the horizons characterized. Surface horizons, skeletal horizons, and horizons low in clay could not be sampled because of low coherence. Table 76 contains bulk density data to illustrate the major trends with depth. In table 77 bulk densities of kinds of horizons are given.

Bulk densities within a pedon commonly increase in the K2 horizon and are a maximum there. Laminar K2m horizons in particular have high bulk densities. Maximum bulk densities in K2 horizons are attributed to carbonate-plugging by authigenic carbonate as discussed in section 72. The K1 and K3 horizons usually have lower bulk densities than associated K2 horizons. For most pedons the lower bulk densities are attributed to less pore filling by carbonate. In some soils K1 horizons are zones of active faunal and root activity, and as a consequence the bulk density is lowered.

Although within a pedon bulk density generally increases with carbonate content, the correlation among soils is poor. To illustrate, the linear correlation coefficient is only 0.15 for the relationship between bulk density and carbonate content of the twelve K2 horizons in noncalcareous parent material in table 77. Differences in silicate clay contents may be one reason for the poor correlation.

Table 76. Bulk density data for three pedons to illustrate common trends with depth.

Pedon, classification, parent material	Depth	Horizon	Bulk density[1/]	Carbonate
	cm		g/cc	pct
Cruces 61-7	5-18	B1t	1.86	-
Petrocalcic Paleargid;	18-25	B1t	1.78	-
loamy, mixed, shallow	25-36	B21t	1.70	1
Ancient river alluvium	36-48	B22tca	1.53	16
	48-74	K21m		
	Laminar		2.22	93
	Nonlaminar		1.93	65
	74-102	K22m	1.68	65
Dona Ana 65-7	4-10	B1t	1.60	1
Typic Haplargid;	10-18	B21tca	1.44	2
fine-loamy, mixed	18-33	B22tca	1.39	6
Ancient river alluvium	33-46	B23tca	1.31	10
	61-79	K12	1.70	31
	79-109	K13	1.70	25
Jal 65-6	4-10	B1ca	1.46	8
Typic Calciorthid;	10-23	B2ca	1.22	22
coarse-loamy, carbonatic	23-33	K1	1.39	51
Alluvium from calcareous sedimentary rocks	33-58	K21	1.49	52

1/ Clod bulk densities for fine earth; Cruces 61-7 air-dry; others 1/3 bar.

Bulk densities commonly are higher in the upper B and the lower A horizons than in the lower B horizon. All three pedons in table 76 show this trend. The horizon immediately above a shallow root-limiting K horizon usually has a lower bulk density than adjacent horizons. The decrease in bulk density with depth is attributed to the low activity in upper horizons of fauna and the scarcity of plant roots due to periodic extremely high temperatures and intense desiccation (section 47).

The Torrifluvents and most of the Calciorthids have developed in fine-silty or fine-loamy sediments derived from calcareous sedimentary rocks. Soils formed in these parent materials tend to have lower bulk densities than alluvium from monzonite or ancient river alluvium. The latter contain more sand coarser than 0.1 mm, less silt, and generally less clay than the alluvium from calcareous sedimentary rocks. The lower bulk densities are found both for B horizons (or horizons in this position) and for K horizons. Perhaps related to their lower bulk densities, linear extensibility (Method 4D, Soil Survey Staff, 1972) is lower for the same relative silicate clay contents for the Torrifluvents and Calciorthids formed in sediments derived from sedimentary rocks.

Table 77. Bulk density values related to kind of horizons

Kind of horizons	No. horizons	Bulk density 1/ mean	range
		----g/cc----	
Argillic horizons 2/	18	1.62	
B2 horizons of Calciorthids 3/	8	1.45	1.26-1.52
K2 horizons	19	1.69	
Noncalcareous parent material	12	1.73	1.56-1.87
Calcareous parent material	7	1.62	1.45-1.78

1/ Air-dry clod bulk density of fine earth (Method 4Alb)
2/ Horizon with maximum bulk density; buried B2t horizons excluded.
3/ B2 or B2ca horizon with maximum bulk density; buried horizons excluded. Pedons 61-1, 61-2 are coarse-loamy and formed in soil materials originating from ancient river alluvium. Others are fine-loamy or fine-silty and developed in parent materials with limestone influence.

98a. Atterberg Limits

Table 77a contains the liquid limit (LL) and plastic index (PI) for selected horizons. The noncarbonate clay as a percent of the carbonate-containing less than 0.5 mm is given in the table and is the principal measurement employed for data reduction. Herein, clay if not qualified refers to this clay percentage. The less than 0.5 mm composition base is used because Atterberg Limits are determined on the material passing no. 40 sieve (less than 0.4 mm).

Figure 51a shows the dependence of LL on clay and figure 51b the dependence of PI. The population is drawn from B2t horizons that contain less than 5 percent carbonate; many are noncalcareous. All of the samples are from pedons with parent materials that are largely or entirely from igneous rocks (section 34). The samples are high in sand and low in silt (fig. 51c).

LL is strongly dependent on clay but the increase with percent of clay is relatively low compared to many other soil materials the clays of which contain an appreciable portion of montmorillonite (section 88b). The B2t horizons of pedons 60-9 and 60-10 have appreciable exchange capacity in the sand and silt. The relatively high LL is a manifestation of clay-like properties of the sand and silt.

Table 77b contains LL and PI for samples of B and C horizons from pedons with parent materials originating wholly or largely from sedimentary rocks (table 77a; section 34). All but one of the samples contain over 40 percent silt (fig. 51c). The samples are all high in carbonate and most contain appreciable carbonate clay. LL and PI have been computed from the total clay using the relationships in figures 51a and 51b, respectively. Measured and computed LL are reasonably similar. The discrepancies are on a relative basis larger for PI.

Table 77c gives LL and PI for K horizons only (K1 and K2, but not K2m). The range in LL of from 24 to 36 is narrow; the PI range of 2 to 18 is wide and encompasses nearly the complete range for all samples from the project excepting the B2t of Terino 60-5. The samples have a wide range in noncarbonate clay and in carbonate clay. LL and PI have been computed for the samples from pedons formed in parent materials originating mainly from igneous rocks using the calculation relationships in figures 51a and 51b, respectively, and the sum of the noncarbonate and the carbonate clay. The calculated LL and PI are similar to the respective measured values.

Table 77a. Liquid limit (LL) and plastic index (PI) for selected horizons, and associated clay percentages[1/]

Series	Pedon	Depth	Horizon	LL	PI	2/
		cm				pct
Berino variant	59-6	0-13	A1	19	4	19.7
		30-51	B22tca	27	2	24.3
		71-91	B2tb	37	17	40.1
		168-201	B2tb2	28	11	23.4
		201-231	K21b2	25	10	15.4
Bucklebar	59-7	0-15	A	16	2	17.8
		38-58	B22tca	27	9	29.8
Bucklebar variant	59-8	28-46	B22t	32	13	37.7
		71-112	2K21b	28	11	20.6
Caralampi	59-14	5-20	A1	23	6	22.4
		46-76	B21t	34	14	40.6
		147-173	Cca	25	6	22.6
Caralampi	59-15	23-43	B22t	38	14	44.5
Whitlock	60-2	0-5	A2	15	1	20.1
		5-10	Bca	24	7	26.6
		23-36	K1	29	2	18.0
Terino variant	60-5	0-8	A1	25	8	17.9
		8-20	B1t	28	11	26.2
		23-38	B21t	63	33	67.1
Dona Ana	60-6	41-51	B22tca	33	17	33.3
		51-64	K1	33	13	24.2
		64-86	K21	27	11	13.7
		112-142	K22	32	10	15.4
Berino	60-7	33-43	B22tca	32	16	36.2
		193-229	3K2b	31	10	10.8
Pinaleno	60-9	0-10	A1	23	6	17.5
Rilloso variant	60-11	18-30	2K22	28	9	12.3

1/ Atterberg limits determined by the Lincoln Soil Mechanics Laboratory. Measurements on the < 2 mm material passing No. 40 sieve (0.4 mm).

2/ Measured non-carbonate clay computed to a carbonate-containing basis as a percentage of the < 0.5 mm. Computation assumes no carbonate in 2-0.5 mm.

Table 77a, continued.

Series	Pedon	Depth	Horizon	LL	PI	2/
		cm				pct
Santo Tomas	60-12	28-53	A13	23	3	17.3
Berino	60-13	0-8	A1	17	0	16.4
		8-28	B21t	22	6	25.3
		28-43	B22t	32	14	35.1
		43-56	B23tca	32	15	31.1
		56-71	K1	28	10	19.9
		71-86	K2	23	7	19.2
Reagan	60-14	0-5	A1	28	8	22.3
		56-76	B22	34	12	34.0
Glendale	60-15	0-5	A	19	3	12.2
		38-64	C2	26	7	20.9
		86-112	C4	27	8	20.6
Dalby taxadjunct	60-16	23-48	C1	41	19	60.6
Reagan	60-17	0-8	A	24	6	31.0
		20-43	B22	27	9	30.1
		76-112	K2	33	12	36.4
Headquar-ters	60-18	23-33	B22tca	29	10	30.3
Aladdin variant	60-19	0-20	A11ca	23	4	14.4
		48-76	A13ca	24	5	14.1
Stellar	60-21	0-8	A2	27	8	37.7
		25-51	B2t	33	15	44.0
		79-99	K1	36	18	37.8
Buckle-bar	60-22	43-66	B22t	26	11	30.1
Stellar	61-3	0-8	A2	29	6	32.4
		8-18	B21t	30	11	43.4
		36-48	B23t	35	14	45.6
Dona Ana	61-4	15-33	B22tca	39	16	33.7
Cruces	61-7	25-36	B21t	18	2	17.3
Onite	62-3	20-30	B22t	19	3	18.4
		43-61	3C2ca	19	3	12.7

Table 77a, continued.

Series	Pedon	Depth	Horizon	LL	PI	2/
		cm				pct
Reagan	65-1	5-13	A	26	6	15.1
		66-94	B23ca	30	13	28.0
		173-190	2K31b	24	8	8.9
Anthony variant	65-2	117-130	5B1b	22	3	16.5
		180-216	5B3b	23	7	18.0
Anthony	65-3	18-38	3A	20	2	13.2
Dona Ana	65-5	25-41	B22tca	23	9	21.1
		89-114	K22	23	9	12.1
Dona Ana	65-6	33-58	K21	24	6	10.9
Dona Ana phase	65-7	18-33	B22tca	21	8	17.7
Upton	66-5	1-5	A	16	3	14.4
		8-20	B22ca	27	5	14.3
Reagan	66-6	0-8	A	20	4	17.9
		15-33	B21	29	10	32.9
		48-64	B23ca	30	11	39.9
Reagan variant	66-7	0-8	A	23	6	23.8
		18-30	B21ca	29	10	34.1
Bucklebar	66-8	15-30	B21t	23	10	31.4
		51-81	B21tb	25	12	31.1
Coxwell variant	66-9	15-33	B22t	40	16	30.4
		84-122	B33	36	15	23.3
Coxwell variant	66-10	13-25	B22t	39	16	34.8
Mimbres	66-14	0-10	A	23	5	19.6
		28-43	B22ca	30	13	30.5
		69-91	B22cab	34	14	27.1
Pinaleno	67-4	18-30	B2t	22	6	26.2
Pinaleno	67-5	15-36	B2t	25	10	25.8
SND-3	67-6	0-5	A	21	4	26.7
		25-38	B22t	37	17	51.2

Table 77a, continued.

Series	Pedon	Depth	Horizon	LL	PI	2/
		cm				pct
Bucklebar	68-2	15-33	B2t	22	6	21.3
Onite	68-3	13-23	2B2t	19	3	22.2
Bucklebar	68-4	28-46	B2t	23	9	24.0
Onite variant	68-5	13-23	B22t	18	2	15.0
Reagan	68-7	0-5	A	22	6	25.4
		23-41	B22	27	10	27.3
		58-86	K2	28	11	22.6
Bucklebar	68-8	5-30	B1t	25	9	25.0
Berino	68-9	13-28	B22t	24	9	29.2
Headquarters variant	69-8	6-10	A2	27	8	27.3
		23-49	B22t	44	19	50.6
Coxwell variant	70-1	11-21	B2t	30	10	33.1
Onite	70-5	6-16	B21t	18	3	24.2
		16-32	B22t	20	6	22.2
		157-169	3C3	18	3	19.8
Onite	70-6	15-34	B21t	22	6	19.2
Berino	70-7	0-7	A2	20	5	23.1
		7-18	B2t	26	7	33.3
Terino	70-8	18-28	B22t	29	10	37.1

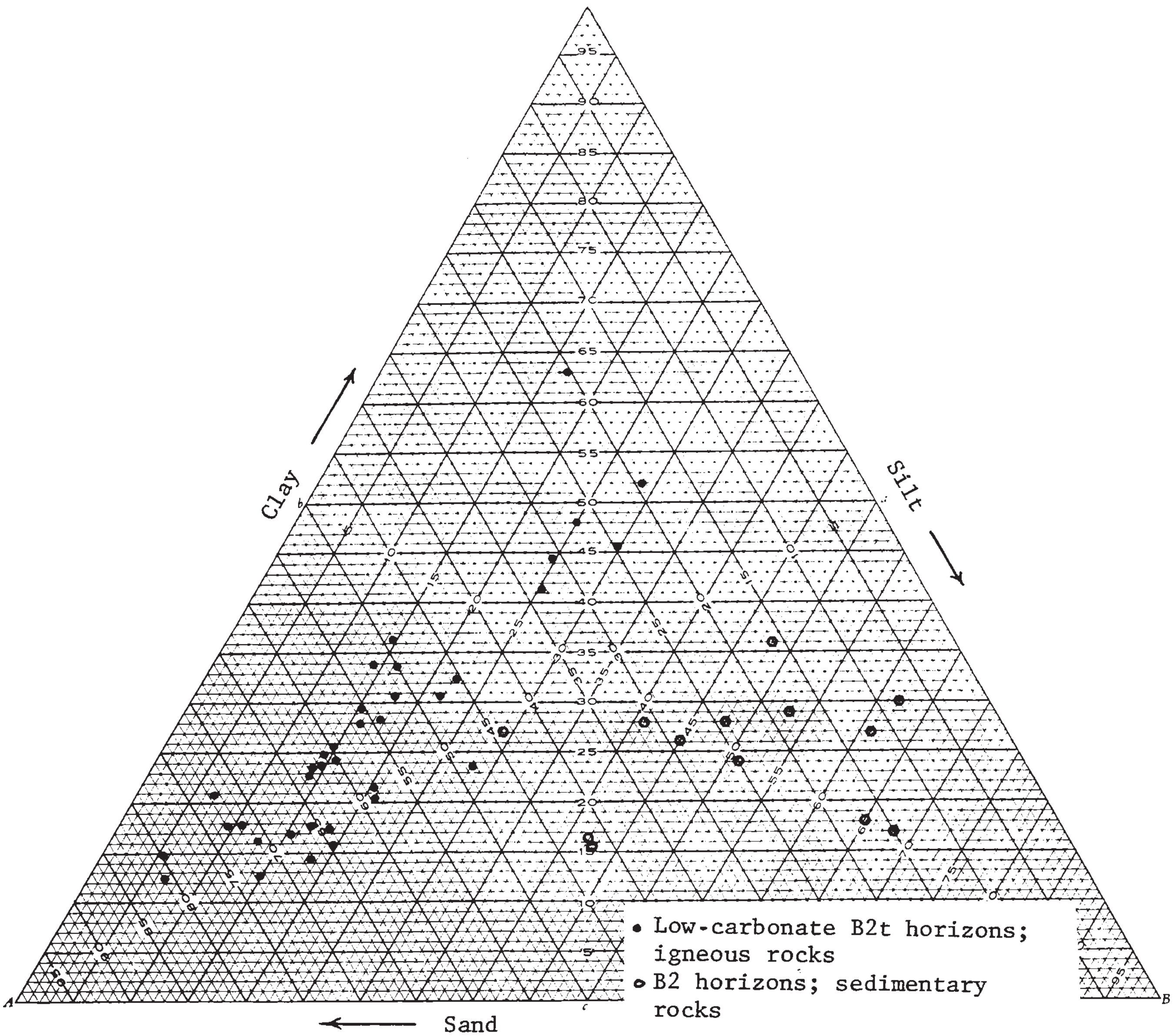


Figure 51a. Sand, silt and clay percentages for horizons of soils from igneous rock and sedimentary rock parent material sources. Former determined on carbonate-free soil material; latter on carbonate-containing with carbonate clay treated as silt.

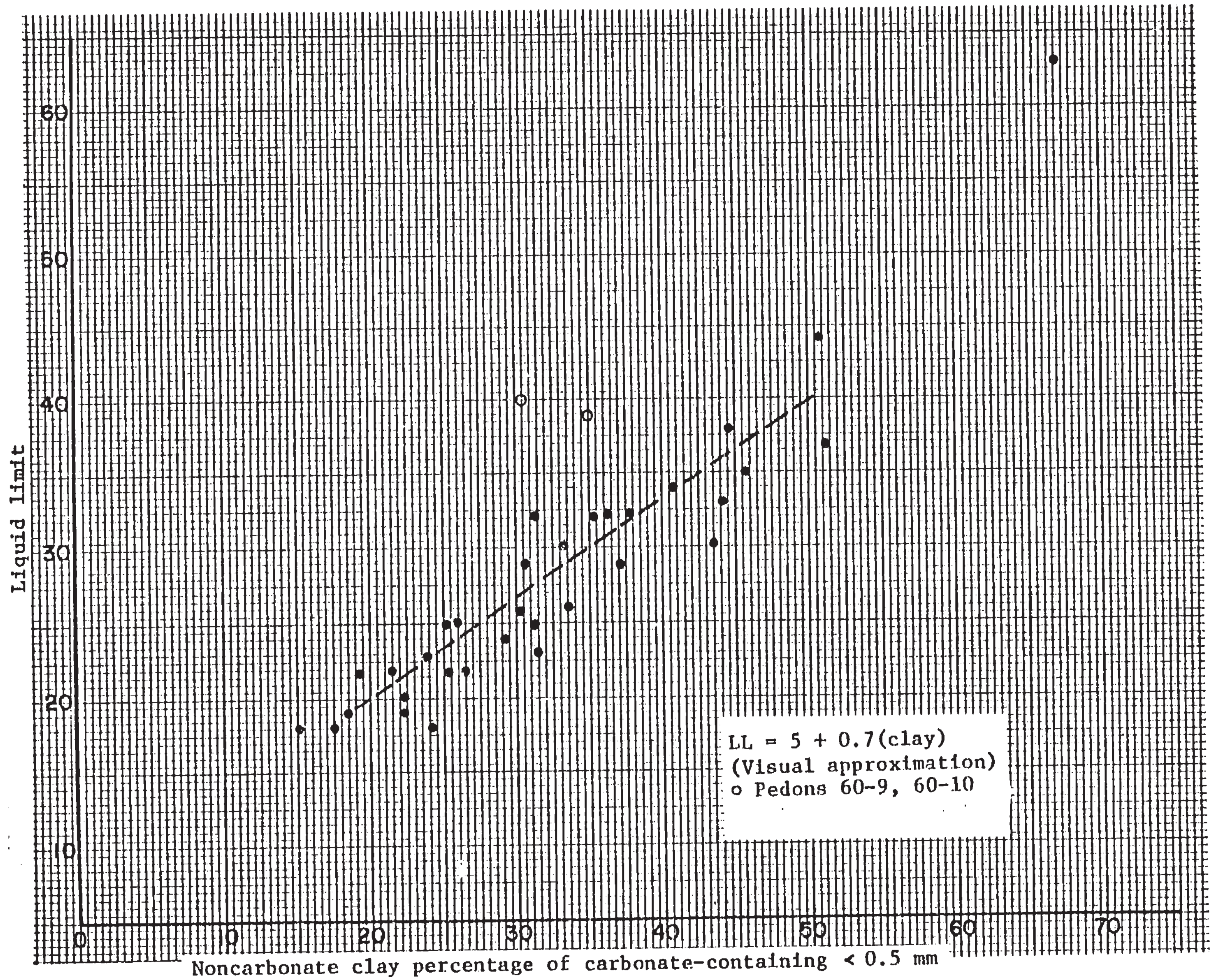


Figure 51b. Liquid limit versus the measured non-carbonate clay computed to a carbonate-containing base for the < 0.5 mm. Restricted to B2t horizons with < 5 percent carbonate in < 2mm.

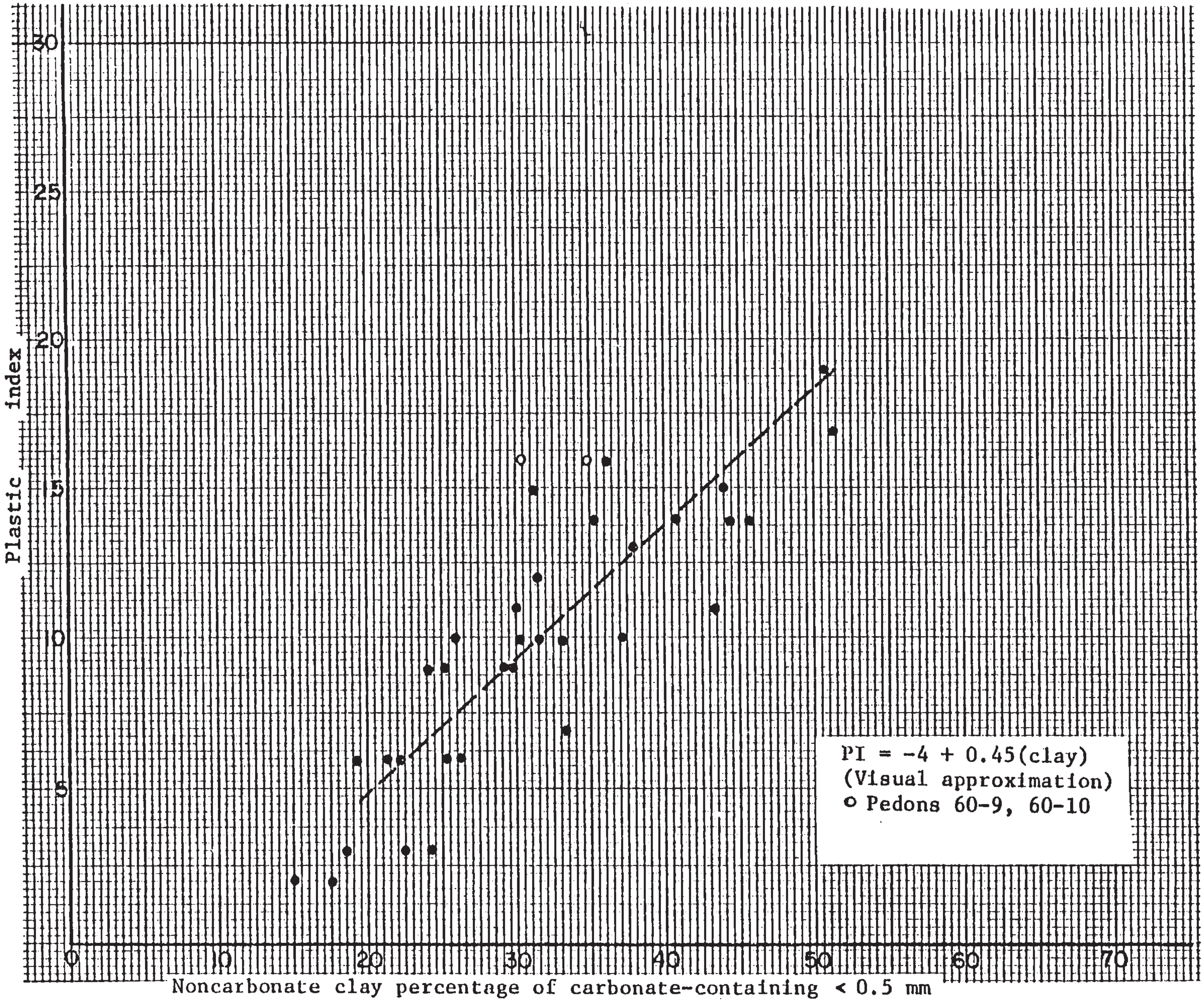


Figure 51c. Plastic index versus the measured non-carbonate clay computed to a carbonate-containing base for the < 0.5 mm. Restricted to B2t horizons with < 5 percent carbonate in < 2 mm.

Table 77b. The measured and calculated liquid limit (LL) and plastic index (PI) for B or C horizons from pedons developed in parent materials derived from sedimentary rocks.

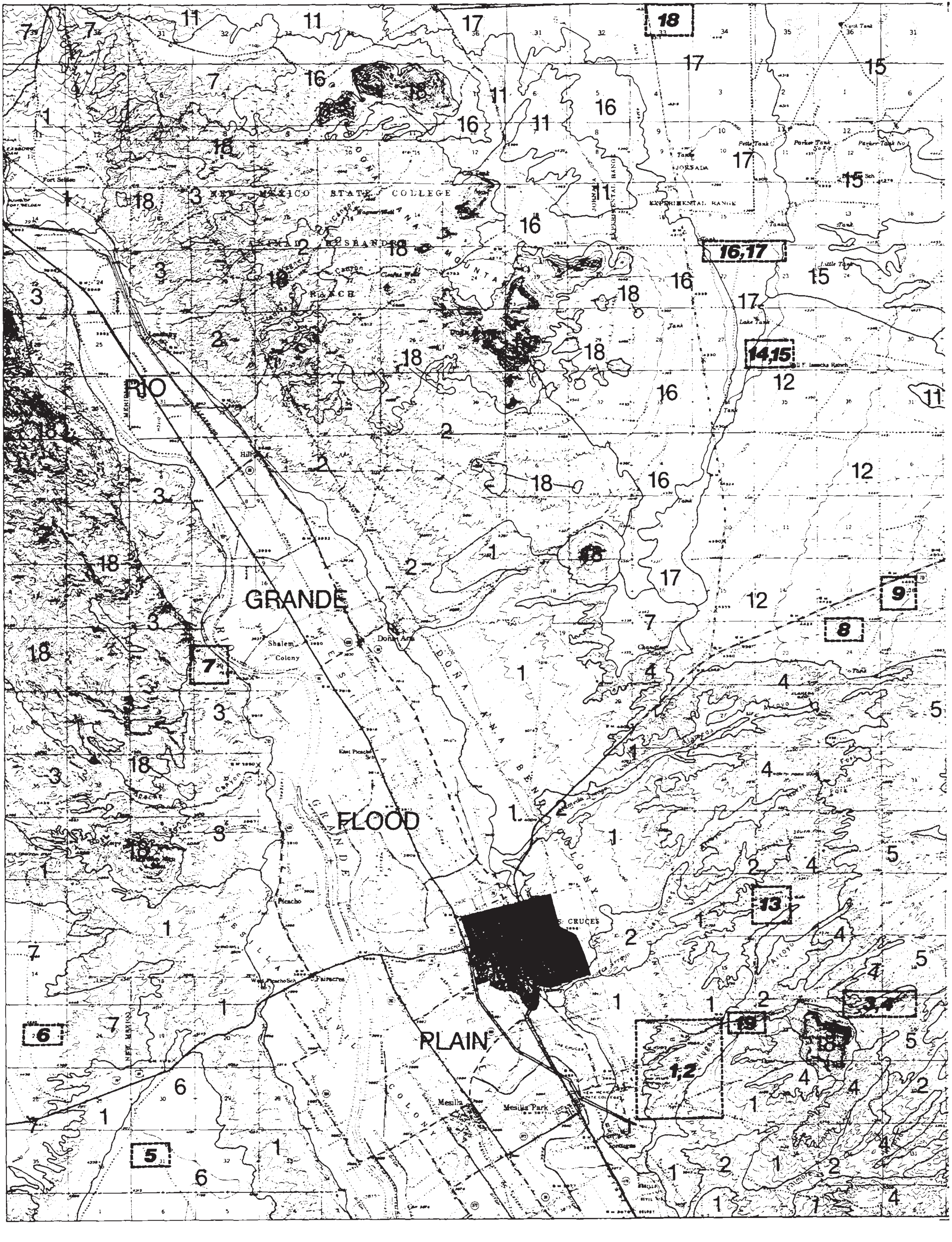
Pedon	Depth	Horizon	LL		PI		1/	2/
			M3/	C3/	M3/	C3/		
	cm							
60-14	56-76	B22	34	34	12	15	30	12
60-15	38-64	C2	26	23	7	7	16	8
	86-112	C4	27	22	8	7	17	7
60-17	20-43	B22	27	30	9	12	28	7
65-1	66-94	B23ca	30	25	13	9	24	4
65-2	117-130	5B1b	22	17	3	4	15	2
	180-216	5B3b	23	18	7	5	16	3
66-6	15-33	B21	29	29	10	11	27	7
	48-64	B23ca	30	36	11	16	36	8
66-7	18-30	B21ca	29	24	10	13	29	8
66-14	28-43	B22ca	30	30	13	12	28	8
	69-91	B22cab	34	32	14	13	27	11
68-7	23-41	B22	27	32	10	13	28	10

1/ Measured noncarbonate clay in carbonate-contain < 0.5 mm.
2/ Carbonate clay in carbonate-containing < 0.5 mm.
3/ M = measured; C = calculated based on the total clay using the dependence on clay obtained for the B2t horizons low in carbonate from pedons developed in parent material derived from igneous rocks.

Table 77c. Liquid limit (LL) and plastic index (PI) for noncemented K horizons as measured and as calculated from the total clay (noncarbonate and carbonate) in the < 0.5 mm material.

Pedon	Depth	Horizon	LL M5/	LL C5/	PI M5/	PI C5/	1/	2/	3/
	cm						------pct------		
59-6	201-231	K21b2	25	31	10	13	15	23	38
59-8	71-112	2K21b	28	31	11	13	21	15	37
60-2 4/	23-36	K1	29	23	2	8	18	8	26
60-6	51-64	K1	33	34	13	15	24	18	42
	64-86	K21	27	25	11	9	14	15	29
	112-142	K22	32	25	10	9	15	13	28
60-13	56-71	K1	28	23	10	7	20	5	25
	71-86	K2	23	23	7	7	19	6	25
60-17	76-112	K2	33		12		36	19	55
60-21	79-99	K1	36	42	18	20	38	15	53
65-1	173-190	2K31b	24		8		9	16	25
65-6	33-58	K21	24		6		11	23	34
68-7	58-86	K2	28		11		23	19	42

1/ Measured noncarbonate clay in carbonate-free < 2 mm material computed to carbonate-containing < 0.5 mm base.
2/ Carbonate clay measured in carbonate-containing < 2 mm computed to < 0.5 mm base.
3/ Sum of carbonate clay and noncarbonate clay.
4/ Shallowness and presence of cemented coatings of carbonate on pebbles suggests some cementation of carbonate in fine earth, which may be responsible for discrepancy between measured and computed Atterberg Limits.
5/ M = measured; C = calculated using the dependence on clay obtained for B2t horizons low in carbonate from pedons developed in parent material derived from igneous rocks.


RIO
GRANDE
FLOOD
PLAIN
NEW MEXICO STATE COLLEGE
JORNADA
EXPERIMENTAL RANGE
Shalem
Colony
Doña Ana
East Picacho Sch.
Picacho
Fairacres
Mesilla
Mesilla Park
Fort Selden
Hill
Lake Tank
Parker Tank
Petts Tank
Little Tank
16,17
14,15
13
3,4
1,2
19
18
9
8
7
6
5

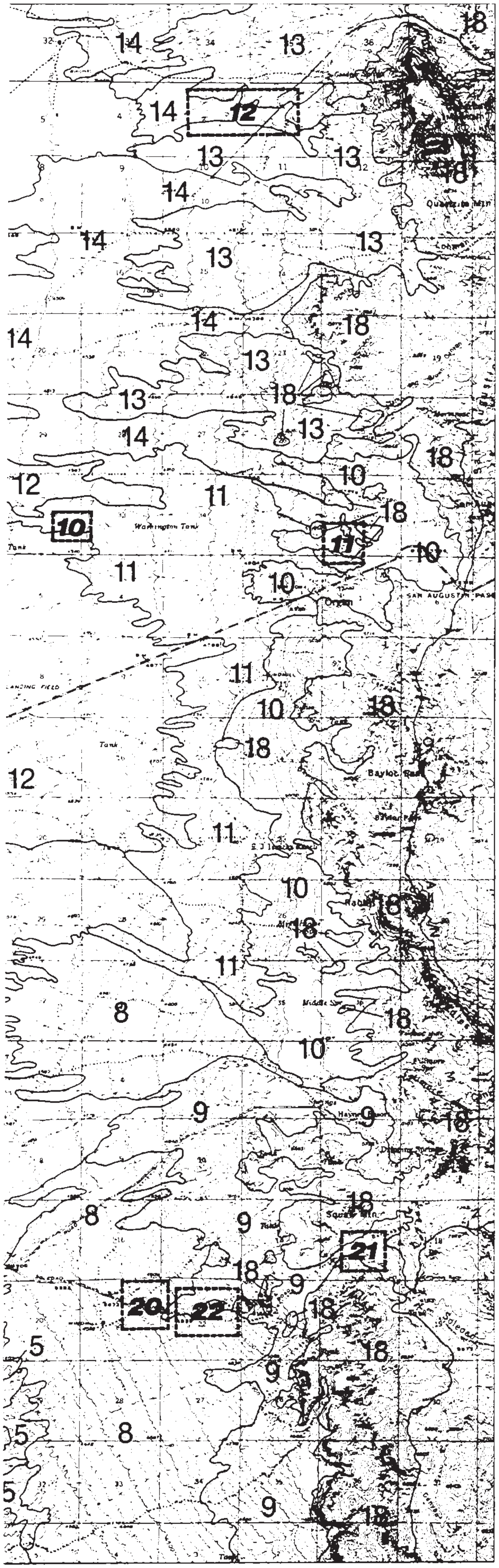


Figure 52. General soil map.

1. Bluepoint-Kokan association.
2. Nickel-Arizo-Kokan complex.
3. Tencee-Upton-Dalian complex.
4. Caliza-Haplargids complex.
5. Monterosa-Algerita complex.
6. Onite-Pintura complex.
7. Cruces association.
8. Terino-Pinaleno association.
9. Boracho-Terino-Santo Tomas association.
10. Caralampi-Nolam-Aladdin association.
11. Onite association.
12. Berino-Bucklebar association.
13. Conger-Monterosa, carbonatic variant complex.
14. Glendale-Anthony complex.
15. Algerita-Dona Ana-Reagan complex.
16. Dona Ana-Onite-Anthony association.
17. Stellar-Reagan-Algerita association.
18. Rock outcrop and soils.

Rectangles with numbers are included for cross-reference to Study Areas of a volume, in preparation, that is intended primarily for use in the field.

99. GENERAL SOIL MAP

Soils of the detailed map (section 121; Appendix) have been grouped into 18 generalized mapping units shown in figure 52. Seventeen of these are soil associations and complexes; one designates rock outcrop and soils. Mapping units designated associations in the general map have at least one component mapping unit from the detailed map that is not a complex.

The soils have been grouped according to their general physiographic position as follows: (1) the valley border of the Rio Grande; (2) the piedmont slopes; and (3) the basin floor north of Highway 70. Some of the major soils and geomorphic surfaces are shown diagrammatically (figs. 53-60). The legend is given below and is presented in numerical order, 1 through 18 (fig. 52).

100. SOILS OF THE VALLEY BORDER

101. No. 1, Bluepoint-Kokan association (Torripsamment-Torriorthent association).

These soils occur on fans and terraces (primarily of Fillmore age) that descend to, or are truncated by the flood plain; and on narrow ridge crests and colluvial slopes of ridge sides. On the west side of the valley the ridges are high and steep; a structural bench has formed on gravel-capped ridges. There are common saddles (formed by drainageways encroaching on ridge crests) in the ridges and slopes of their sides range from 15 to 35 percent. Slopes are gentler on the east side of the valley where slopes of ridge sides commonly range from about 3 to 10 percent.

Torripsamments (Bluepoint soils) are dominant. Torriorthents (Kokan and Yturbide soils) dominate high, narrow ridges bordering the scarp of lower La Mesa on the west side of the valley. Arizo soils (Torriorthents) are not as steep as Kokan soils and occur on many of the Fillmore terraces along the arroyo channels. Small areas of Calciorthids (mostly Whitlock and Rilloso soils) are preserved on some of the ridges on the east side of the valley.

102. No. 2, Nickel-Arizo-Kokan complex (Calciorthid-Torriorthent complex).

These soils occur in dissected terrain west of the Dona Ana Mountains and along major arroyos in the southeastern part of the area. Most areas have been strongly dissected by arroyos; ridge remnants of alluvial fans and terraces, usually the Picacho surface, are prominent in many places. Narrow Fillmore terraces are commonly inset against the ridge remnants. Nearest the valley, dissection has been so severe that the original depositional slope of the fans has been substantially altered and the Picacho surface has been replaced by the younger Fillmore. Saddles are common in such areas. Longitudinal slopes along ridge crests range from about 2 to 5 percent; slopes of ridge sides range from about 5 to 35 percent.

Calciorthids (Caliza and Nickel soils) dominate the ridge crests in stabler areas. The calcic horizon of these soils has been truncated on very narrow ridges and Torriorthents (commonly Kokan soils) occur on both the ridge crests and ridge sides. Torriorthents (mostly Arizo soils) are dominant on Fillmore terraces inset against the remnants. Haplargids and Paleargids are preserved on stablest parts of the Picacho surface, mainly in the southeastern part of the area.

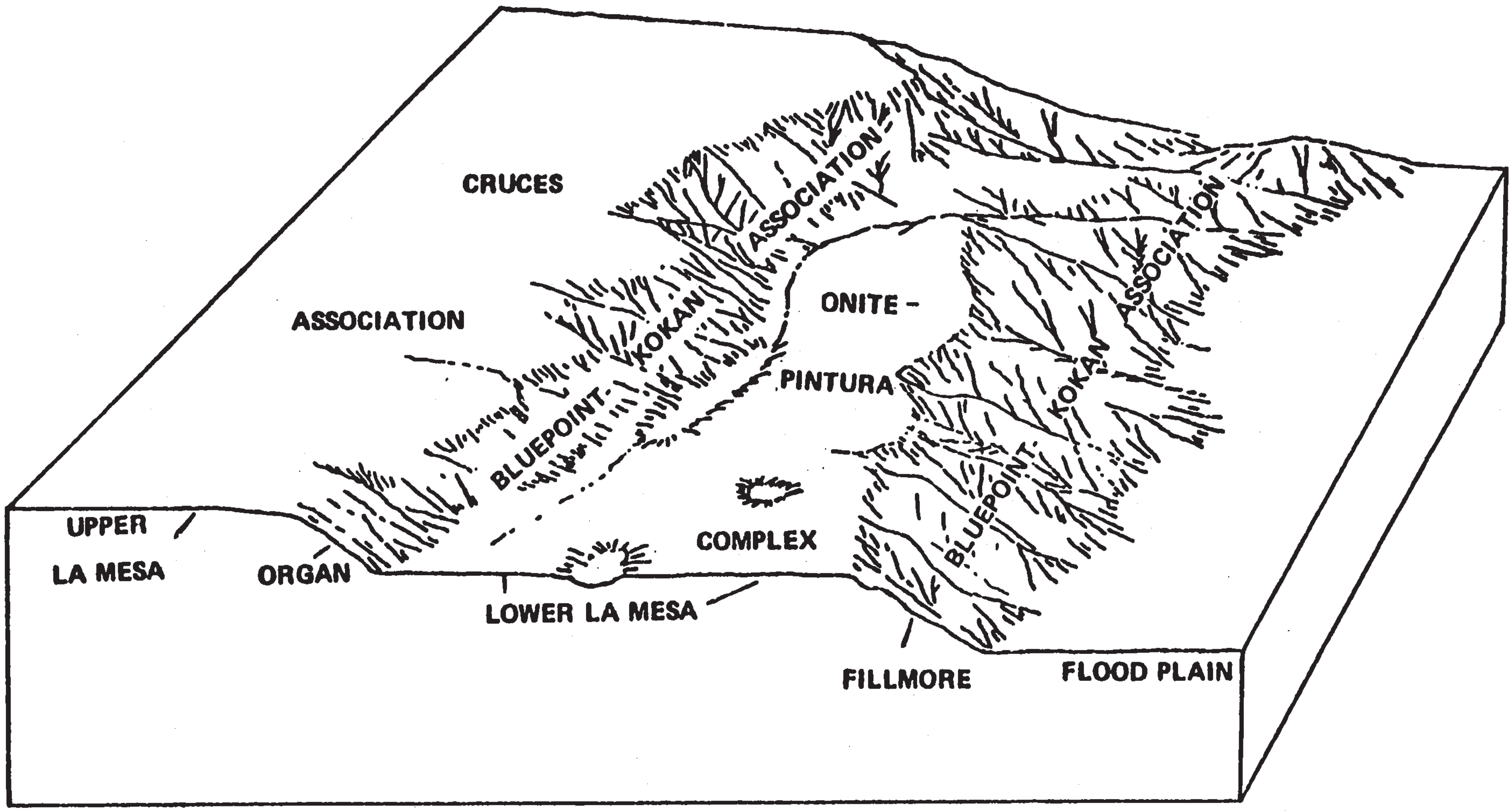


Figure 53. Soils (fig. 52) and geomorphic surfaces along the valley border south of Picacho Mountain.

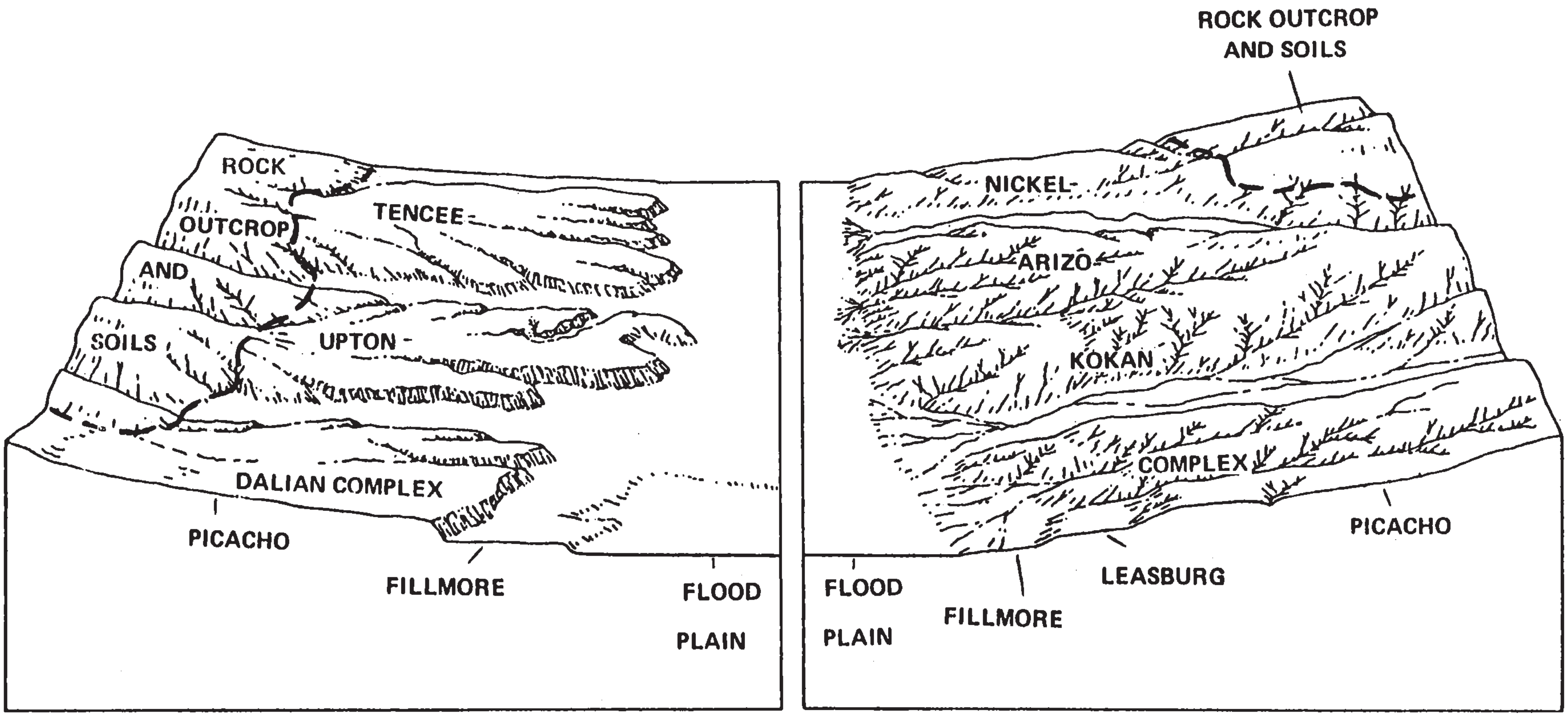


Figure 54. Soils (fig. 52) and geomorphic surfaces on the west and east side of the valley border, north of Picacho Mountain and between the Robledo and Dona Ana Mountains. The greater degree of preservation of the Pleistocene fans (Picacho surface) on the west (left) side is thought to be largely due to the essentially continuous petrocalcic horizons in Tencee and Upton soils. This is apparently caused by the high-carbonate alluvium derived from the Robledo Mountains.

103. No. 3, Tencee-Upton-Dalian complex (Paleorthid-Torriorthent complex).

This unit occurs east and south of the Robledo Mountains. In most places the area is characterized by high Picacho or Tortugas fan remnants that have been deeply dissected. Fillmore terraces are inset against the high fan remnants and are about one to several m higher than the arroyo channels. Steep colluvial wedges occur on sides of the remnants. In places, the Fillmore sediments coalesce to form small fans beyond the lower edges of the remnants. Small areas of the Leasburg surface occur in places and are intermediate in elevation between the Fillmore and Picacho. Longitudinal slopes range from 3 to 5 percent. Most side slopes along margins of the Picacho remnants range from about 25 to 50 percent; in places they are nearly vertical.

Paleorthids (Tencee and Upton soils) are dominant on the broad crests of the Picacho remnants. Calciorthids (Weiser soils) occur on the Leasburg surface, and on narrow Picacho remnants where the petrocalcic horizon has broken up because of landscape dissection and soil truncation. Torriorthents (mostly Dalian soils) dominate the Fillmore terraces and also the colluvial wedges of the sides of the Picacho remnants. Torrifluvents (mostly Glendale and Anthony soils) occur in low-gravel areas of Fillmore alluvium near the flood plain.

104. No. 4, Caliza-Haplargids complex (Calciorthid-Haplargid complex).

Most areas of this mapping unit are strongly dissected and high narrow ridges are prominent. A structural bench has formed on gravel-capped ridge crests. Saddles are common in ridge crests in the western part. The eastern part of the unit generally lacks a structural bench because gravel is less common, particularly as thick deposits at accordant elevations. Locally, slopes along ridge crests range from 2 to 5 percent; slopes of ridge sides range from 5 to 35 percent.

Calciorthids (Caliza soils) are dominant on highest, stablest ridges of the structural bench; Torriorthents (Kokan and Yturbide soils) and Torripsamments (Bluepoint soils) are dominant on ridge sides. A sinuous scarp occurs on the east side of the gravels and the structural bench. East of the scarp the gravel passes beneath dissected paleosols (Haplargids, dissected). On ridge sides the paleosols are either exposed or underlie a thin mantle of colluvium. On broadest ridge crests, Haplargids or Paleargids developed on the original depositional surface (Jornada I) have been preserved.

105. No. 5, Monterosa-Algerita complex (Paleorthid-Calciorthid complex).

High ridges are characteristic; terraces occur below them in places, particularly in the southern part of the unit. Successively higher terraces above the arroyo channels in this terrain are Fillmore; Picacho; small areas of Tortugas; and Jornada I, which is on the highest ridges. Slopes along ridge crests range from 2 to 3 percent; ridge sides slope from 5 to 35 percent.

Algerita soils are dominant in the northern part of the area, occurring mainly on the Jornada I ridges, but also on Tortugas and Picacho. Southward

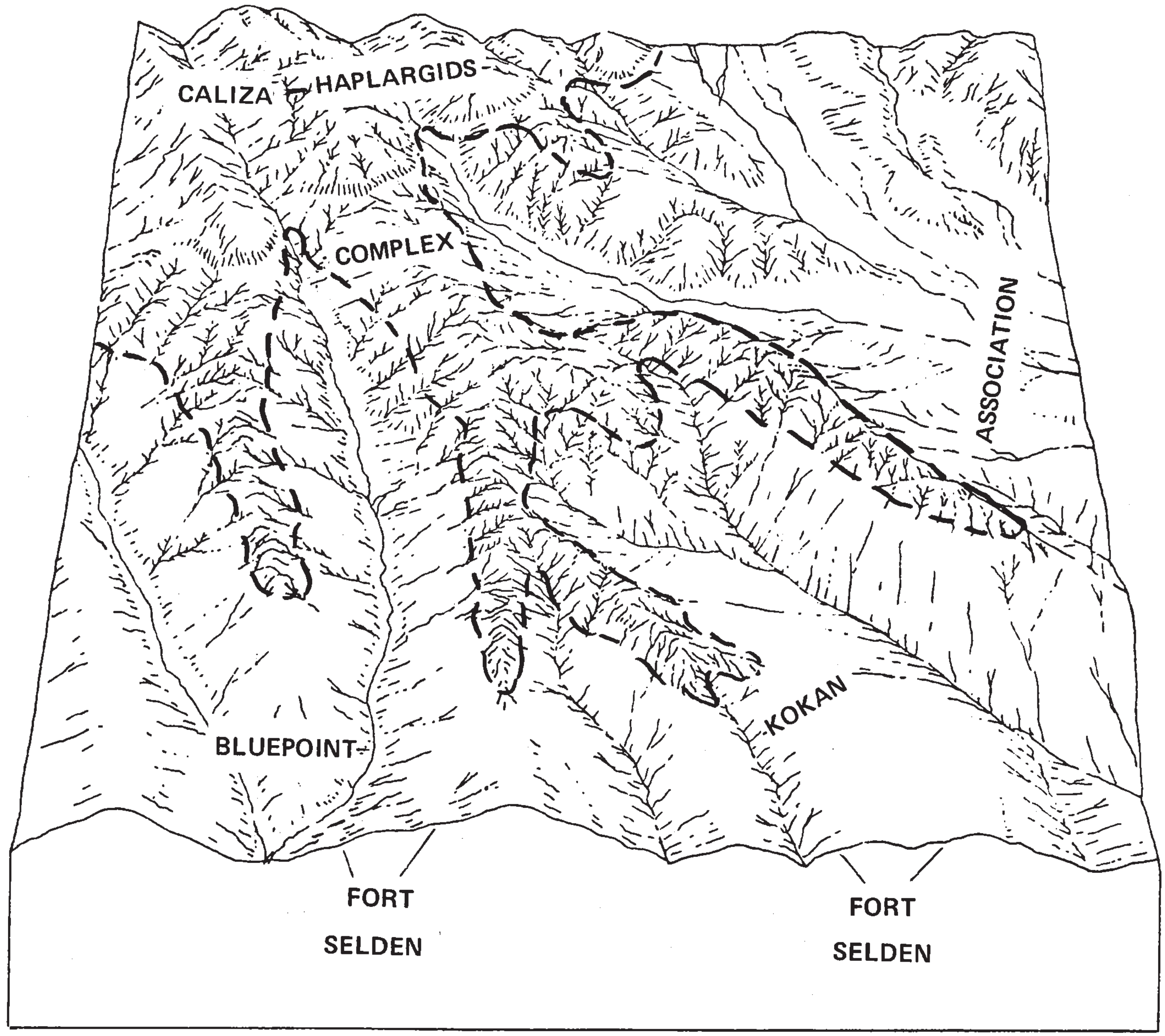


Figure 55. Soils (fig. 52) and geomorphic surfaces on the eastern side of the valley border, north of Tortugas Mountain. Narrow ridge crests in the central part of the diagram are structural benches formed by exhumation of gravelly sediments deposited by the ancestral Rio Grande. The scarp marks the boundary between the benches and dissected Haplargids to the east. Most of this dissected terrain is of Fort Selden age. The cross section cuts sandy ridges with little gravel.

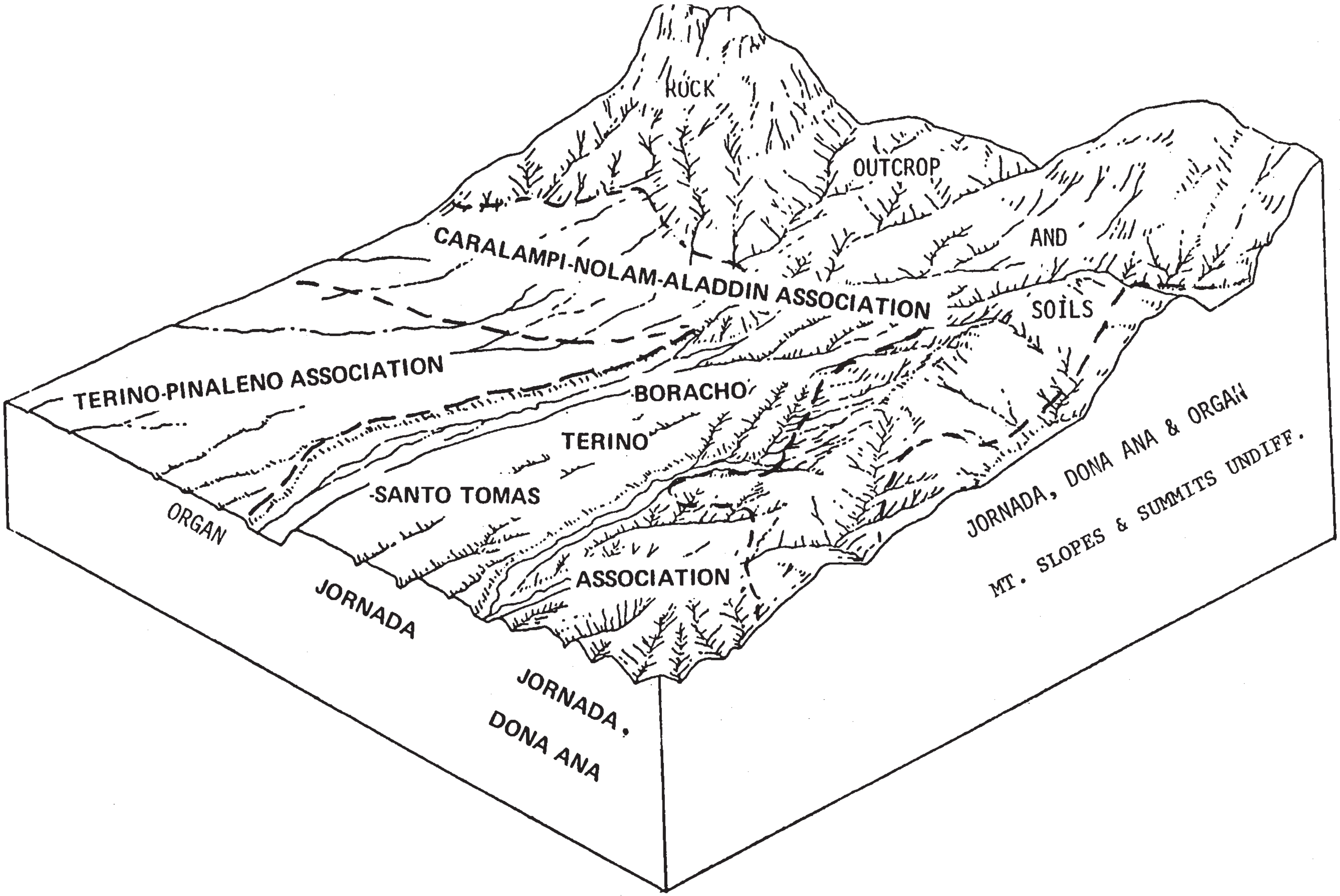


Figure 56. Soils (fig. 52) and geomorphic surfaces along the front of the central part of the Organ Mountains in the vicinity of Fillmore and Ice Canyons.

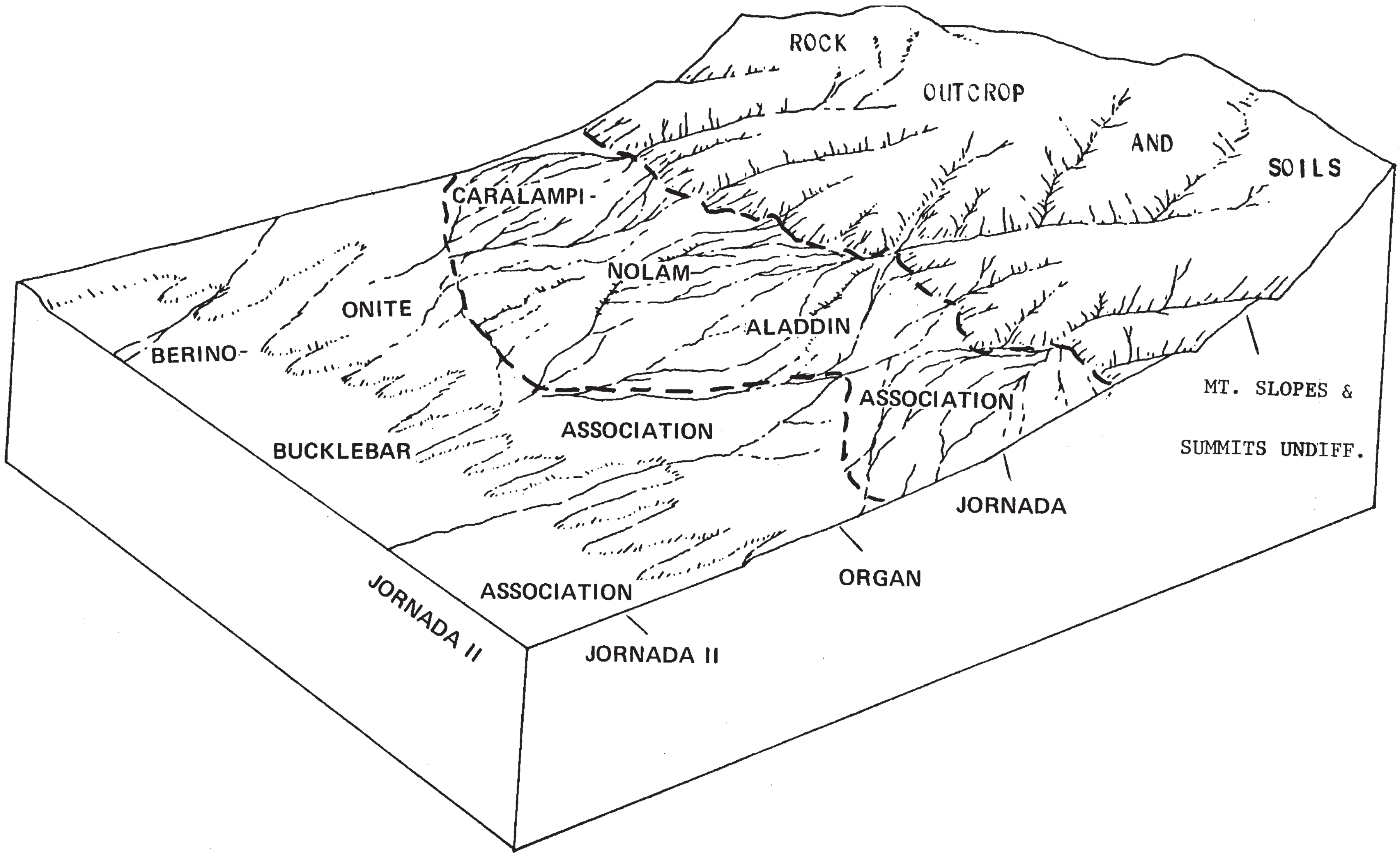


Figure 57. Soils (fig. 52) and geomorphic surfaces of the fans and fan-piedmont downslope from the northern (monzonite) part of the Organ Mountains.

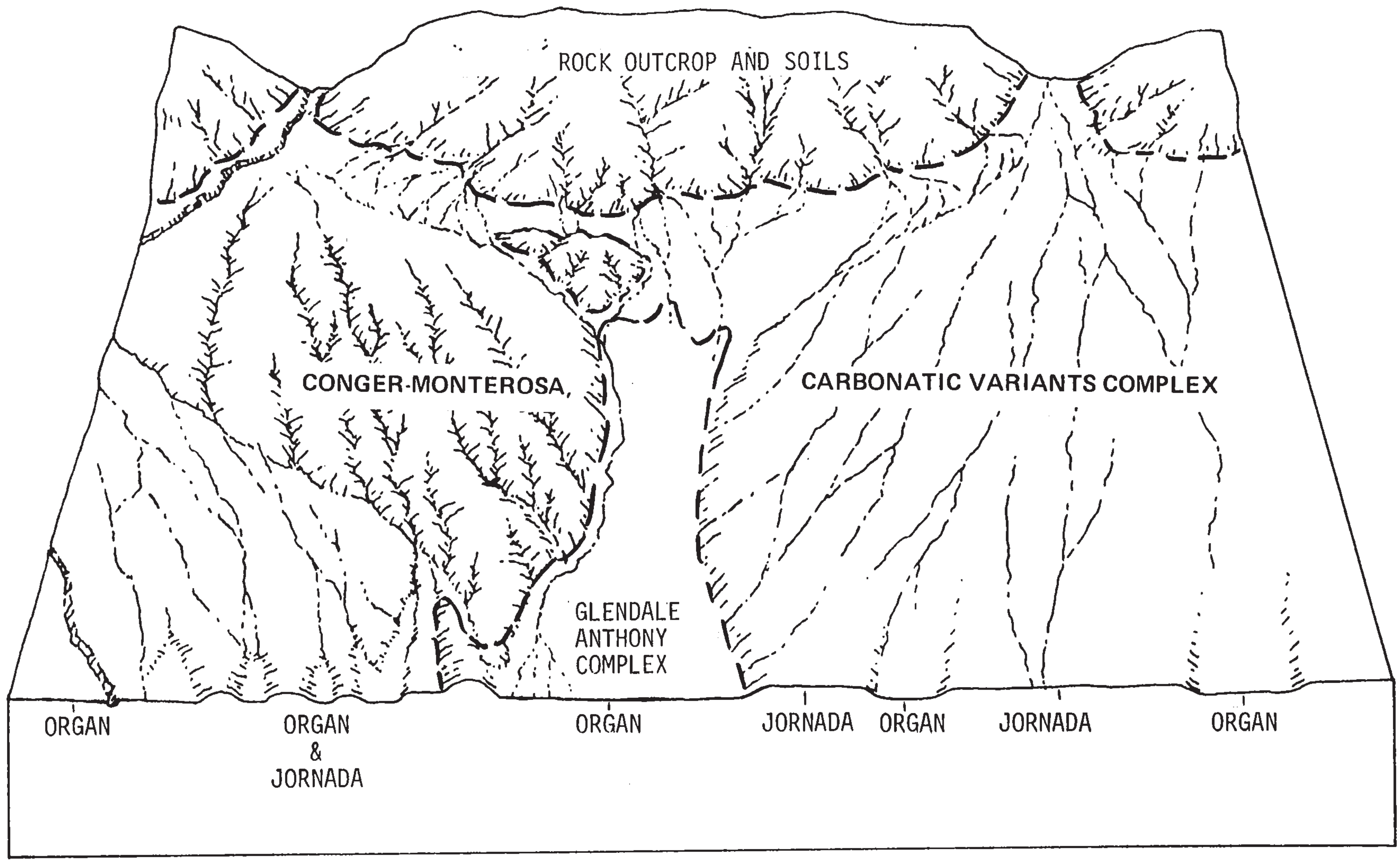


Figure 58. Soils (fig. 52) and geomorphic surfaces downslope from the San Andres Mountains. Two large Pleistocene fans (from Bear and Lohman Canyons) are separated by a Holocene valley fill.

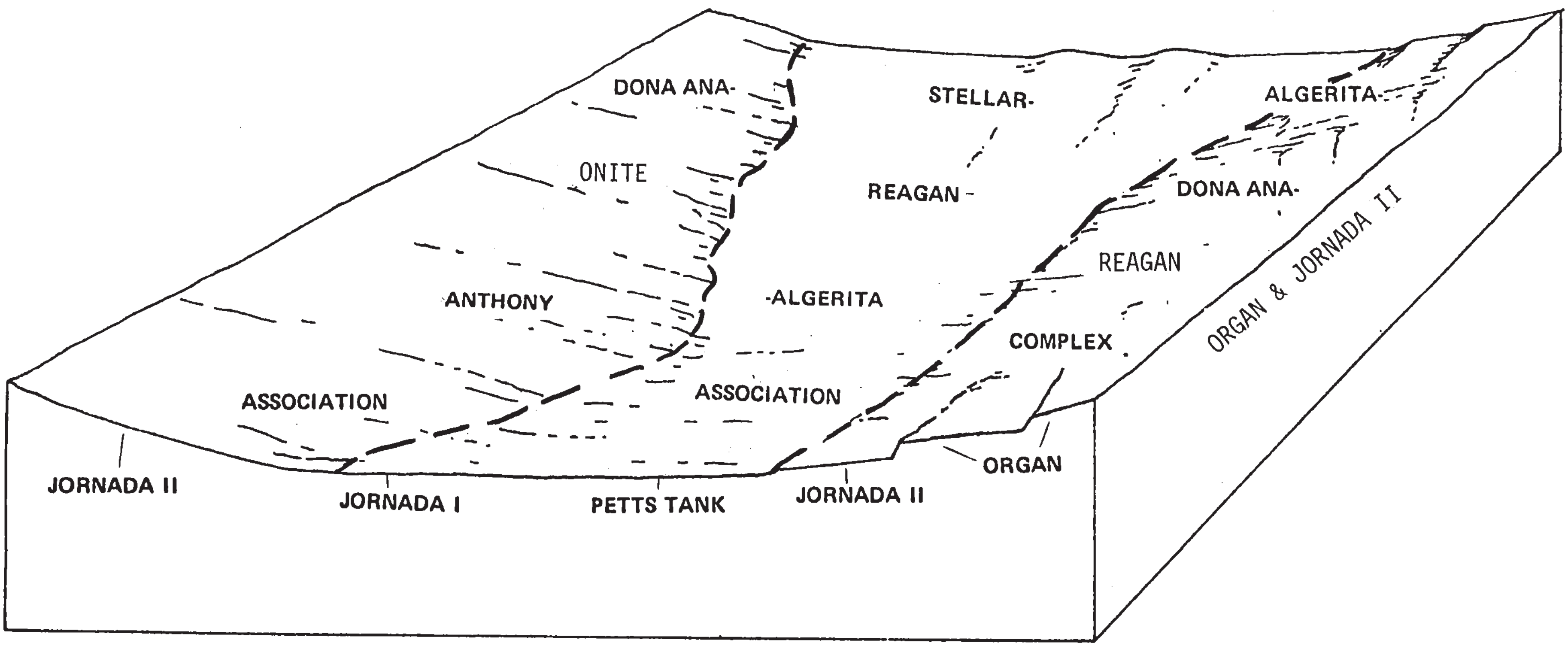


Figure 59. Soils (fig. 52) and geomorphic surfaces in the northern part of the closed-basin floor and the adjacent piedmont slopes north of Hwy. 70.

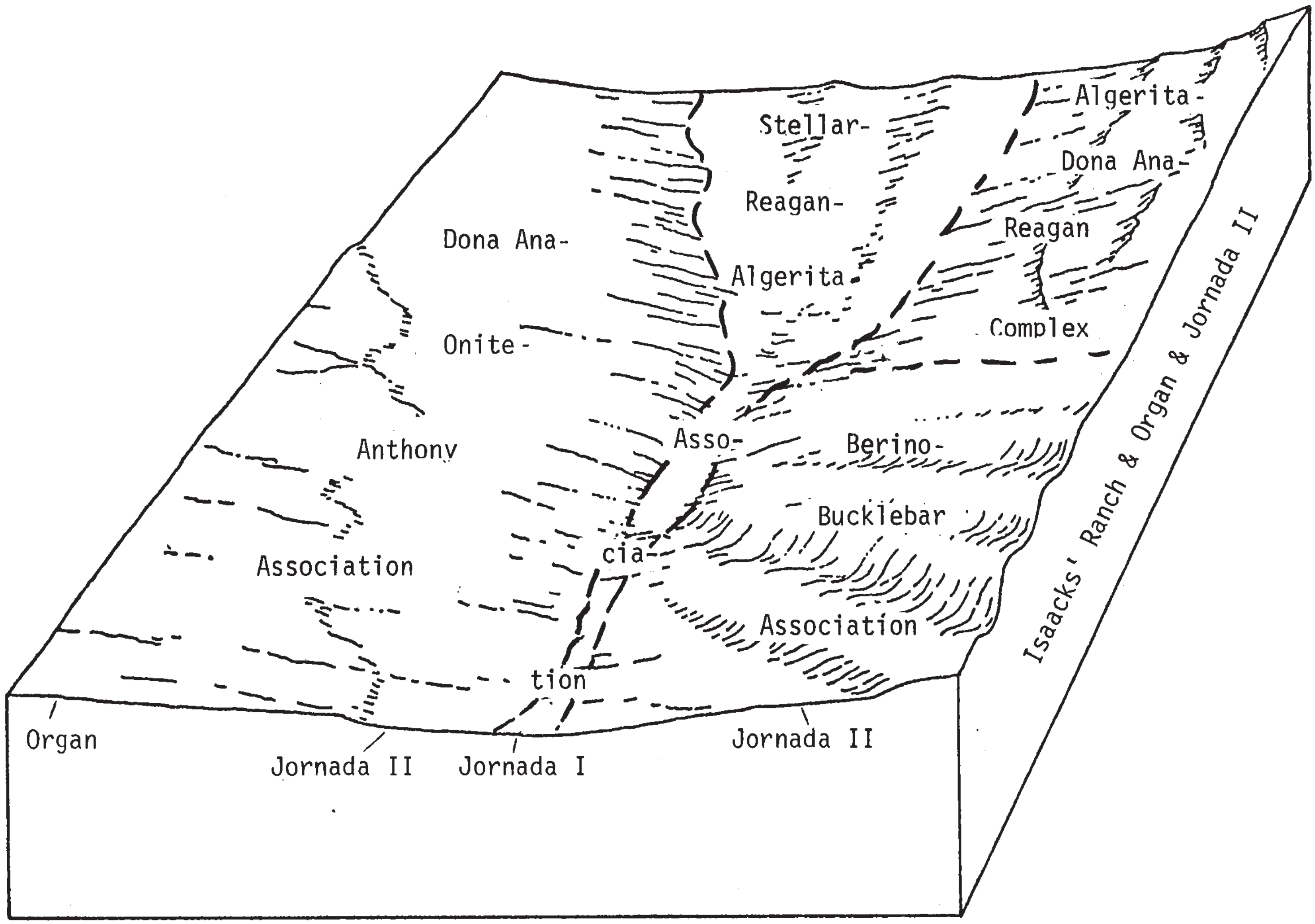


Figure 60. Soils (fig. 52) and geomorphic surfaces in the southern part of the basin floor (by Isaacks' Lake playa) and the adjacent piedmont slopes.

the parent materials are much more gravelly. This has caused the development of a petrocalcic, instead of a calcic horizon and the dominant soils are therefore Paleorthids (mostly Monterosa soils) instead of Calciorthids. Haplargids (Nolam soils) and Peargids (Cruces, loamy-skeletal variant) are generally dominant on the Picacho surface with the Calciorthids and Paleorthids occurring in less stable areas where the soils have been partially truncated. Torriorthents (mostly Arizo soils) dominate the Fillmore terraces.

106. No. 6, Onite-Pintura complex (Haplargid-Torripsamment complex)

These soils are on lower La Mesa, a relict basin floor west of the valley. Slopes are level or nearly level between coppice dunes, which are particularly prominent in the southern part of the unit.

Haplargids (Onite, deep petrocalcic phase) with deep petrocalcic horizons are dominant. Other Haplargids are the Bucklebar and Sonoita soils; they occur in pipes that penetrate the petrocalcic horizon of Onite, deep petrocalcic phase. Bucklebar soils also occur in small depressions. Paleargids occur on several slight ridges and in places around the periphery of lower La Mesa. Torripsamments (Pintura soils) occur in coppice dunes with sandy textures to at least 1 m.

107. No. 7, Cruces association (Paleargid association)

Soils of this mapping unit occur on and adjacent to upper La Mesa, a relict basin floor occurring west of the valley and in smaller areas near Goat Mountain and north of Fort Selden. Slopes are level or nearly level on the basin floor. Areas along the scarp and below it slope 3 to 5 percent towards the valley.

Paleargids (mostly Cruces soils) are dominant on the basin floor. Haplargids (Bucklebar soils) occur in pipes. Paleorthids (Tencee soils) occur along scarps cut in valleyward margins of the remnants. Calciorthids (Jal soils) occur on ridges downslope from the scarp.

108. SOILS OF THE PIEDMONT SLOPES

109. No. 8, Terino-Pinaleno association (Paleargid-Haplargid association).

These soils occur mostly on the fan-piedmont in the southeastern part of the area, extending mountainward in many places where they occur on fans. Gullies and arroyos are common in places but the areas between are fairly stable. Slopes range from 2 percent in the western part of the unit to 6 percent in the eastern part, nearest the mountains.

Paleargids (Terino soils) are dominant, with fewer Haplargids (mostly Pinaleno, some Nolam). The change from dominantly Orthids in mapping unit 5 to dominantly Arigds in this unit is caused by a decrease in landscape dissection and associated soil truncation. The argillic horizon, which has been truncated and carbonate-engulfed on the Jornada I ridges in mapping unit 5, is still preserved in mapping unit 8. The Paleargids are dominant and most continuous on Jornada I ridges, but also occur on Jornada II and Dona Ana surfaces. Pinaleno soils occur in scattered Holocene deposits, which have buried the older soils in many places.

110. No. 9, Boracho-Terino-Santo Tomas association (Calciustoll-Haplustoll-Haplargid association).

These soils occur in a belt paralleling the front of the Organ Mountains. Cobbles and pebbles are usually present on the surface and in the soil. This unit encompasses the largest area of the Dona Ana surface, the highest and oldest surface along the mountain fronts. Substantial areas of Jornada I and II surfaces are also present. They occur both as well preserved terraces and as ridge sides of the Dona Ana remnants. The Organ surface usually occurs in general topographic lows adjacent to arroyos; in some areas just below mountain canyons Organ sediments spread out as small fans that cut into or bury older soils. Most longitudinal slopes range from about 5 to 15 percent but many of the fans are dissected and ridge sides are steep, ranging up to 50 percent.

Soil patterns are complex because of variations in soil age and landscape dissection. Calciustolls (Boracho soils) are most common on the Dona Ana remnants, occurring on steep sides of many ridges and on some ridge crests. Paleargids (Terino soils) occur on broadest areas of the Dona Ana surface where argillic horizons are still preserved. Terino soils and their moderately deep variant occur on the Jornada I terraces. Haplargids (Nolam soils) occur on Jornada surfaces where the soils have a calcic horizon within 1 m of the surface; Caralampi soils are similar but lack a calcic horizon within 1 m. The latter soils are most common at highest elevations on the Jornada I and II surfaces. Haplustolls (Santo Tomas soils and their Torriorthentic variant) are on the Organ surface. Argiustolls (Earp soils) are on oldest and stablest parts of the Organ surface where an argillic horizon has formed in addition to the mollic epipedon.

111. No. 10, Caralampi-Nolam-Aladdin association (Haplargid-Haplustoll association).

This belt of soils occurs along the front of the Organ Mountains. Cobbles, stones, and in places boulders, are common on the surface and in the soils in many places south of Organ. Slopes usually range from about 5 to 15 percent, in places reaching 40 percent on the sides of ridges at highest elevations.

Because of considerable variation in soil age and landscape stability, soil patterns are extremely complex in most areas. Organic carbon generally increases mountainward because of higher elevation, greater precipitation and more abundant vegetation. Haplargids (Nolam and Caralampi soils) are the most extensive soils, being dominant on stablest surfaces of Jornada age. There are smaller areas of soils on the Organ surface. Haplustolls (the loamy-skeletal Santo Tomas soils and their Torriorthentic variant) are most common in and just below the larger canyons. Other Haplustolls (the coarse-loamy Aladdin soils) are dominant in less gravelly areas, particularly in the vicinity of Organ. Argiustolls (mostly Earp soils) occur in scattered stabler, oldest areas of the Organ surface.

112. No. 11, Onite association (Haplargid association).

Most of these soils are on the Organ surface (a few are on Isaacks' Ranch surface) below soils of mapping unit 10. There are few coarse fragments. Slopes range from 2 to 5 percent.

Haplargids (Onite soils) are dominant, with smaller areas of Camborthids (mostly Pajarito soils) which occur primarily at lower elevations and in slightly younger alluvium. There are also small areas of other Haplargids (Sonoita soils) which occur at highest elevations west of the Organ Mountains, and north of the La Mesa rim in the northwest part of the project. Soils of this unit are commonly underlain by buried soils that emerge at the land surface downslope.

113. No. 12, Berino-Bucklebar association (Haplargid association).

These soils occur on a broad, coalescent fan-piedmont. Slopes range from 1 percent near the basin floor to 3 percent at highest elevations.

Haplargids (Berino and Bucklebar soils) are dominant. Bucklebar soils occur on Organ and Isaacks' Ranch surfaces, and are most common in drainageways. Berino soils are older (Jornada II surface) and their buried analogues underlie the soils of Organ and Isaacks' Ranch age. Torripsamments (Pintura soils) occur in dunes where sediments with sandy textures are at least 1 m thick. Torrifluvents (Pintura, thin variant) occur where the dune sediments are from 50 to 100 cm thick and overlie buried soils of finer texture.

114. No. 13, Conger-Monterosa, carbonatic variant complex (Paleorthid complex).

These soils occur on large fans of Jornada age, west of the San Andres Mountains. Longitudinal slopes along the ridge crests range from 2 to 5 percent. Ridge remnants are common and have side slopes from 5 to 20 percent.

Paleorthids (mostly Conger soils and Monterosa, carbonatic variant) are dominant. Smaller areas of Calciorthids (mainly Jal soils) also occur. Most of the Calciorthids are on lower slopes, where gravel is less common and calcic, instead of petrocalcic, horizons have formed. Calciustolls (mostly Boracho, carbonatic variant) occur on stablest sites at highest elevations.

115. No. 14, Glendale-Anthony complex (Torrifluvent complex).

Soils of this mapping unit occur on Organ terraces between large Jornada fans of mapping unit 12, and on a coalescent fan-piedmont downslope. Slopes range from 1 percent near the basin to 4 percent near the mountains. Scarplets occur in places and range in height from a few cm to 1 m or more.

Torrifluvents (Glendale soils) are dominant on gentler slopes in the western part of the unit. Anthony soils, also Torrifluvents, are dominant on steeper slopes in the eastern part of the unit. The soils are usually underlain by buried soils that emerge at the land surface downslope (mapping unit 15).

116. No. 15, Algerita-Dona Ana-Reagan complex (Calciorthid-Haplargid complex).

Most soils occur in broad drainageways, with some occurring on very slight ridges between drainageways. Scarplets, a few cm to about 1 m high, occur in drainageways. Slopes range from 1 percent near the basin floor to 2 percent at higher elevations.

Calciorthids (Reagan, light subsoil variant) of Holocene age occur above scarps and overlie Calciorthids of Pleistocene age. Calciorthids (Algerita soils) are most common below scarps. Haplargids (Dona Ana soils) occur mainly on slight ridges (between broad drainageways) where carbonate content of the parent materials is low enough that an argillic horizon developed. Other haplargids (Headquarters soils) occur in stabler areas, mostly in drainageways where textures are finer and organic carbon is higher.

117. No. 16, Dona Ana-Onite-Anthony association (Haplargid-Torrifluvent association).

These soils occur downslope from the Dona Ana Mountains, primarily on a coalescent fan-piedmont of Jornada age. Most slopes range from 1 percent near the basin floor to about 7 percent next to the mountains. Near the mountains, sides of the scattered ridge remnants slope from 10 to 35 percent.

Haplargids (mostly Dona Ana soils with some Tres Hermanos) occur on stablest, low-gravel areas of the Jornada surface. Paleargids (Terino and Casito soils) occur in very gravelly, stable areas. Calciorthids (Nickel soils) and Paleorthids (Delnorte soils) occur on Jornada ridges nearest the mountains. Haplargids (Onite; Onite, gravelly variant, and Pinaleno soils) occur on stablest areas of Organ age. Torrifluvents (Anthony soils) occur on less stable areas of the Organ surface. Small areas of Haplustolls (Aladdin soils) border the northern part of the Dona Ana Mountains.

118. SOILS OF THE BASIN FLOOR NORTH OF HIGHWAY 70

119. No. 17, Stellar-Reagan-Algerita association (Haplargid-Calciorthid association).

This area is level or nearly level, and much of it receives runoff from adjacent slopes of the fan-piedmont. Slight ridges occur in the northern and southern part of the basin floor.

Haplargids (Stellar soils) of Jornada I age have formed in low-carbonate sediments derived mainly from the Dona Ana Mountains. Calciorthids (Algerita soils) of Jornada I and La Mesa age have formed in low-carbonate sediments of the ancestral Rio Grande and occur mainly in the center of the basin floor where it widens to the north. Other Calciorthids (Reagan soils) occur on the eastern side of the basin floor (Petts Tank surface) and have formed in high-carbonate sediments from the San Andres Mountains. Torrerts (Dalby soils) occur in Isaacks' Lake Playa and in a small playa east of the New Mexico State University Ranch.

120. NO. 18, ROCK OUTCROP AND SOILS

This mapping unit consists primarily of bedrock outcrops in and adjacent to the mountains. Discontinuous areas of soils occur between the outcrops. In areas of noncalcareous bedrock the soils are dominantly Argids. Where the bedrock is high in carbonate the soils are primarily Entisols.

121. THE DETAILED MAP

The detailed map of the study area (see Appendix) was made on aerial photographs at a scale of 1:15,840. In addition, selected areas were mapped on a scale of 1:7,920 (section 125). Twenty-two new series were proposed during the course of the study. These are listed below.

Aladdin	Casito	Kokan	Rilloso	Terino
Algerita	Cruces	Monterosa	Santo Tomas	Tonuco
Bucklebar	Dalian	Nolam	Stellar	Vado
Cacique	Hawkeye	Onite	Tencee	Yturbide
Caliza	Headquarters			

All but three of these (Yturbide, Tonuco, and Kokan) have type locations in the study area, and all but two (Rilloso and Tonuco) are established series. Descriptions and photographs of many of these soils are located in Index 1.

122. MAPPING CONVENTIONS

The soil mapping units consist of (1) soils belonging to one or more dominant series, variants, or phases (termed "dominant soils"), which are capitalized in the tables of composition at the beginning of each mapping unit description, and (2) lesser proportions of other soils (termed "inclusions"), each of which occupy 10 percent or less of the mapping unit. Soils estimated to occupy less than 5 percent of a unit are grouped together and designated "other inclusions". Percentages of dominant soils are estimated to be within ± 10 percent of the figures given.

Except for broadly defined mapping units (section 198), the mapping units are named as phases of series, variants of series, or as complexes or associations of series. Soil phases have been used in several ways. One pertains to the average texture of the surface layer (as used here, the upper 15 cm). This is indicated by a series name followed by a textural designation (e.g., Stellar clay loam). Another phase designation refers to the horizon of carbonate accumulation (e.g., Onite, deep petrocalcic phase). Variants indicate soils that differ sufficiently from established series to warrant series recognition, but are too small in known extent to justify a new series. In soil complexes, the dominant soils occur in such intricate patterns that they cannot be mapped separately at a scale of 1:15,840. Some units designated variants would also be soil complexes (section 124) and other complexes are not so designated because of name conflicts. Soils are not considered complexes if the dominant soil occupies at least 50 percent of a mapping unit and no other component occupies more than 10 percent of the unit. In soil associations, the dominant soils could be mapped separately at a scale of 1:15,840.

Conventional slope classes (Soil Survey Staff, 1951) were not used because a system was desired whereby both longitudinal (that is, down an alluvial fan or similarly sloping surface) and transverse (in dissected terrains) slopes could be indicated. Also in many places one slope (e.g., 2 percent) extends for long distances and it was desired to indicate this. Slope readings were therefore made directly according to the following system.

In undissected areas that are level or nearly level transversely, slope was shown as:

$$\frac{15M}{2} = \frac{\text{mapping unit}}{\text{slope}}$$

In dissected areas having a fairly consistent longitudinal slope with a distinct transverse slope, two slope components were noted: the longitudinal slope along the ridge crest, and the dominant transverse slope (the slope of ridge sides) thus:

$$\frac{10RR}{2\text{-}20} = \frac{\text{mapping unit}}{\text{longitudinal slope-transverse slope}}$$

Dissected areas having a fairly consistent longitudinal slope and dominantly steep, but highly variable transverse slope were designated as:

$$\frac{11Y}{1\text{-}d} = \frac{\text{mapping unit}}{\text{longitudinal slope-transverse slope (most slopes range from about 15 to 40 percent)}}$$

Some strongly dissected areas have no consistent longitudinal slope and a transverse slope that is dominantly steep but highly variable. Saddles are common in ridge crests of such areas. These slopes were designated as:

$$\frac{11X}{d} = \frac{\text{mapping unit}}{\text{longitudinal slopes along ridge crests commonly range from about 1 to 10 percent; transverse slopes generally range from about 15 to 40 percent}}$$

The 0 designation includes slopes ranging from 0 to 1/2 percent. A mapping unit designation alone (e.g., 15M) indicates that a slope reading was not taken in the area of the symbol.

123. AREAS OF SOIL MAPPING UNITS

Areas of the mapping units are given in table 78. Both the size of the mapping delineations and the number of constituent soils range widely. Some small delineations reflect the desirability of recognizing soils of special significance to an understanding of soil and landscape evolution. For example, in

Table 78. Mapping units and areas, alphabetically

Mapping unit names and field symbols	Acres	Percent of total	Section	Page
Adelino clay loam (13P)	96.	0.05	150	394
Aladdin gravelly sandy loam (13MO)	2,721.	1.2	160	477
Aladdin gravelly sandy loam, calcareous variant (13LGO)	138.	0.1	164	524
Algerita sandy loam (57)	929.	0.4	196	682
Algerita sandy loam, eroded (56)	1,551.	0.7	197	695
Algerita sandy clay loam (16L)	6,953	3.1	172	575
Algerita complex (16MA)	3,489.	1.5	146	366
Andesite rock outcrop and Argids (40V)	4,910.	2.2	204	704
Anthony complex (13V, 13ML, 13LG)	7,021.	3.1	162	499
Arizo complex (13F)	6,781.	3.0	128	257
Berino sandy loam (15MA)	858.	0.4	168	557
Berino-Bucklebar association (15M)	16,332.	7.2	166	529
Bluepoint sand (13Y)	30,038.	13.3	129	262
Bluepoint complex (13X)	1,606.	0.7	130	270
Boracho complex (10RO)	1,779.	0.8	186	637
Boracho very gravelly fine sandy loam, carbonatic variant (10LO)	528.	0.2	183	622
Bucklebar complex (14P)	750.	0.3	133	285
Canutio gravelly sandy loam, loamy subsoil variant (103ML)	965.	0.4	159	471
Caralampi very gravelly sandy loam (14RO)	165.	0.1	176	597
Caralampi-Nolam complex (12MO,123R)	4,430.	2.0	180	613
Casito-Terino complex (12V)	2,912.	1.3	179	609
Conger complex (10LL)	6,501.	2.9	178	604
Cruces fine sandy loam (12P)	4,366.	1.9	152	406
Dalby clay (53)	262.	0.1	189	645
Dalian complex (13G)	2,858.	1.3	131	278
Delnorte complex (10R)	1,345.	0.6	139	317
Dona Ana fine sandy loam (16LS)	762.	0.3	170	563
Dona Ana sandy clay loam (16VG)	3,299.	1.5	171	568
Dona Ana-Algerita complex (16M)	1,388.	0.6	169	558
Entisols, eroded (40B)	1,124.	0.5	200	700
Glendale-Reagan complex (13L)	3,476.	1.5	163	516
Hap gravelly sandy loam (15MG)	519.	0.2	167	551
Haplargids, dissected (11Y)	5,957.	2.6	199	699
Jal sandy loam (11L)	1,316.	0.6	173	586
Kokan-Bluepoint complex (11X)	4,314.	1.9	143	347
Kokan-Nickel complex (10W)	4,092.	1.8	135	294
Monterosa very gravelly sandy loam (10MLO, 100R)	541.	0.2	181	616
Monterosa complex (10RR)	7,098.	3.1	145	358
Monterosa very gravelly sandy loam, carbonatic variant (100L)	890.	0.4	182	618
Monzonite rock outcrop and Argids (40M)	6,621.	2.9	202	703
Nickel complex (11R)	3,250.	1.4	140	327
Nickel-Delnorte complex (10V)	2,014.	0.9	177	600
Nolam complex (12RR)	871.	0.4	138	303
Onite sandy loam (13MM)	3,539.	1.6	158	464
Onite-Pajarito complex (13M)	3,529.	1.6	157	445
Onite-Pintura complex (15P)	2,880.	1.3	149	379
Pinaleno very gravelly sandy loam (13R)	3,983.	1.8	155	425
Reagan clay loam (51)	2,442.	1.1	191	659
Rhyolite rock outcrop and Argids (40R)	12,118.	5.4	203	703
Santo Tomas-Earp complex (13RO)	1,068.	0.4	156	436
Sedimentary rock outcrop and Entisols (40L)	16,741.	7.4	201	701
Sonoita loamy sand (15S)	506.	0.2	147	369
Stellar clay loam (16V)	2,407.	1.1	193	673
Stellar clay loam, overflow (55)	592.	0.2	194	677
Tencee complex, eroded (10C)	3,030.	1.4	151	399
Tencee-Upton complex (10L)	5,616.	2.5	141	339
Terino very gravelly sandy loam (12R)	8,060.	3.6	175	590
Terino very gravelly loam, thick solum variant (12RO)	68.	0.05	185	628
Tres Hermanos-Onite complex (14V)	825.	0.4	161	493
Weiser-Dalian complex (11LG)	750.	0.3	136	300
TOTAL:	225,970	100%		

Ice Canyon of the Organ Mountains there is a remnant of the Dona Ana surface, one of the oldest geomorphic surfaces in the area. The remnant is a ridge which occupies only 68 acres. The soil of the ridge crest may have started its development early in mid-Pleistocene time; and the ridge crest appears quite stable, which should favor the preservation of soil horizons. This distinctive soil has been grouped with soils on ridge sides into a mapping unit for which there is only one delineation. Such separation emphasizes, for the purpose of genetic studies, very small areas of soils which are of little areal importance but of great significance to soil and landscape history. Similarly, the mapping is more detailed in the more complicated areas. Large-scale (1:7920) maps were also made in a number of cases.

Delineations are larger in other instances. For example, all areas of soils in coppice dunes were not specifically separated. Since some dunes occur in small, isolated areas, the separation of all areas of the dune soils and their associated soils would have required a number of additional mapping units. Instead, separations were made largely on the basis of older soils that are more regular in occurrence, and the soils of dunes were handled as inclusions or as dominant soils depending on their extent. Delineations are also larger in areas where the soil patterns are simple and the soils extensive. Two examples are the Berino-Bucklebar association (15M) and Bluepoint sand (13Y).

124. THE CHARACTER OF SOIL PATTERNS IN THE STUDY AREA.

Table 79 gives the percentages of dominant soils in the mapping units, and factors affecting the degree of complexity of the soil patterns. These factors are important because they also apply to extensive areas elsewhere in the Southwest.

The percentages of mapping unit composition may be divided into four general classes of homogeneity (table 80). In 9 mapping units the most extensive soil occupies from 70 to 90 percent of the unit; in 16 units it occupies from 50 to 65 percent; in 13 units it occupies from 35 to 45 percent; and in 16 units the most extensive soil occupies from 20 to 30 percent of the unit.

Table 80 summarizes factors affecting complexity of the soil patterns. Major soils of mapping units having a high proportion of single series occur on landscapes that are undissected or only slightly dissected and that lack substantial deposition by wind; particle size does not differ greatly; and discontinuous argillic, calcic or petrocalcic horizons are not present. These areas occur mostly in the basin floors and on the middle and lower piedmont slopes.

The most complex patterns of soil distribution and the largest number of soils in mapping units are found in landscapes that have class 3 to 5 dissection. The soil patterns are complex because various diagnostic horizons (argillic, calcic, petrocalcic) have been truncated in some places but not in others, and because these horizons have been truncated in an intricate pattern. Landscape dissection is a major factor determining the location of the Mollisol-Aridisol boundary because it can result in chromas or values too high for a mollic epipedon. Landscape dissection has also resulted in abrupt changes in particle-size families. It is the single most important factor affecting the complexity of soil patterns in the study area.

Table 79. Mapping units, percentages of dominant soils

FACTORS AFFECTING THE

Pedogenic

Mapping unit	Percentage(s) of dominant soil(s)[1/]	Landscape factors: Dominant class of landscape dissection[2/]	Landscape factors: Wind erosion and deposition[3/]	Landscape factors: Anastomosing arroyo	Uniform lack of argillic horizon	Uniform lack of calcic horizon	Uniform lack of petrocalcic horizon
Adelino cl (13P)	90	1			X	X	X
Stellar cl, overflow (55)	85	1					X
Caralampi vgsl (14RO)	80	2				X	X
Berino sl (15MA)	75	1					X
Jal sl (11L)	75	1			X		X
Onite complex (13MM)	75	1				X	X
Pinaleno vgsl (13R)	70	1				X	X
Dona Ana fsl (16LS)	70	1					X
Reagan cl (51)	70	1			X		X
Stellar cl (16V)	65	1					X
Aladdin gsl (13MO)	65	2			X	X	X
Algerita sl, eroded (56)	65	1			X		X
Bluepoint s (13Y)	65	3			X	X	X
Dalby c (53)	65	1			X	X	X
Dona Ana scl (16VG)	65	2					X
Glendale-Reagan complex (13L)	65,15	2			X		X
Aladdin gsl, calcareous variant (13LGO)	65,35	2			X	X	X
Monterosa vgsl (10MLO, 100R)[4/]	60	3			X	X	
Hap gsl (15MG)	60	3					X
Sonoita ls (15S)	60	2				X	X

1/ "Dominant soils" occupy more than 10 percent of a mapping unit. The pedogenic and landscape factors listed
2/ Refers to 5 classes of landscape dissection (see section 17).
3/ Sufficient to place soil in another category.
4/ Typic and Ustollic Paleorthids are major components.
5/ One soil has carbonatic mineralogy and the other has mixed mineralogy.

and factors affecting the complexity of soil patterns.

COMPLEXITY OF SOIL PATTERNS Factors							
Uniform presence of argillic horizon	Uniform presence of calcic horizon	Uniform presence of petro-calcic horizon	Argillic horizon not present in all soils	Calcic horizon not present in all soils	Petrocalcic horizon not present in all soils	Difference in texture[3/]	Difference in coarse fragments[3/]
X	X						
X							
X	X						
	X						
X							
X							
X	X						
	X						
X	X						
	X						
X	X						
				X			
							X
		X					
X	X						
X							

apply to dominant soils only.

Table 79 , continued.

Mapping unit	Percentage(s) of dominant soil(s)[1/]	Landscape factors: Dominant class of landscape dissection	Landscape factors: Wind erosion and deposition	Landscape factors: Anastomosing arroyo	Uniform lack of argillic horizon	Uniform lack of calcic horizon	Uniform lack of petrocalcic horizon
Terino vgsl (12R)	60	2				X	
Algerita sl (57)	60,20	1			X		X
Cruces fsl (12P)	50	1				X	
Monterosa vgsl, carbonatic variant (100L)	50,20	4			X	X	
Boracho vgfsl, carbonatic variant (10LO)	50,35	3			X	X	
Algerita complex (16MA)	45	3			X		
Canutio gsl, loamy subsoil variant (103ML)	45,15	2			X	X	X
Onite-Pintura complex (15P)	45,20	1	X				
Berino-Bucklebar association (15M)	45,25	1					X
Terino vgl, thick solum variant (12RO)	45,30	2				X	
Tencee complex, eroded (10C)	45,35	4			X		
Anthony complex, (13ML, 13V, 13LG)	40	2			X	X	X
Monterosa complex (10RR)	40,15	3			X	X	
Delnorte complex (10R)	40,20,20	3			X		
Nickel-Delnorte complex (10V)	40,30	3					
Onite-Pajarito association (13M)	40,40	1					
Nolam complex (12RR)	35,25	2					
Dona Ana-Algerita complex (16M)	35,25,15	1	X				
Boracho complex (10RO)	30	4					
Tres Hermanos-Onite complex (14V)	30,20,15	2					X
Conger complex (10LL)	30,25[5/]	3					

Uniform presence of argillic horizon	Uniform presence of calcic horizon	Uniform presence of petro-calcic horizon	Argillic horizon not present in all soils	Calcic horizon not present in all soils	Petrocalcic horizon not present in all soils	Difference in texture	Difference in coarse fragments
X		X			X		
	X					X	
X		X					
		X					
		X					X
	X						
							X
			X	X			X
X				X			
X		X				X	
				X			X
		X					
					X		X
			X				
			X	X		X	
				X			
							X

Table 79, continued.

Mapping unit	Percentage(s) of dominant soil(s)[1/]	Landscape factors: Dominant class of landscape dissection	Landscape factors: wind erosion and deposition	Landscape factors: Anastomosing arroyo	Uniform lack of argillic horizon	Uniform lack of calcic horizon	Uniform lack of petrocalcic horizon
Tencee-Upton complex (10L)	30,25	2			X	X	
Weiser-Dalian complex (11LG)	30,25,15	4			X		
Bucklebar complex (14P)	30,25,20	1					
Bluepoint gsl (13X)	30,25,25,20	5		X	X	X	X
Santo Tomas-Earp complex (13RO)	30,30,25	2				X	X
Nickel complex (11R)	25,15	3			X		
Kokan-Nickel complex (10W)	25,15,15	4			X		X
Caralampi-Nolam complex (123R, 12MO)	25,20	2					X
Algerita scl (16L)	25,20,20	2					X
Arizo complex (13F)	25,25	2		X	X	X	X
Dalian complex (13G)	25,25	2		X	X	X	X
Casito-Terino complex (12V)	25,25,20	2					
Kokan-Bluepoint complex (11X)	20,20,15,15	5			X		X

Uniform presence of argillic horizon	Uniform presence of calcic horizon	Uniform presence of petro-calcic horizon	Argillic horizon not present in all soils	Calcic horizon not present in all soils	Petrocalcic horizon not present in all soils	Difference in texture	Difference in coarse fragments
		X					X
				X			
			X			X	
						X	X
			X				
				X			
				X		X	
X				X			
			X			X	
X		X					
				X		X	X

Table 80. Relation of mapping unit homogeneity to factors causing complex patterns of soils.

Factors causing complex patterns	Class of homogeneity and frequency of occurrence of factors causing complex patterns 70-90% (9 units)	50-65% (16 units)	35-45% (13 units)	20-30% (16 units)
Class of landscape dissection[1]				
3	0	25	31	13
4	0	6	8	13
5	0	0	0	13
Anastomosing arroyo	0	0	0	19
Wind erosion and deposition	0	0	8	0
Argillic horizon not present in all soils	0	0	23	19
Calcic horizon not present in all soils	0	6	31	38
Petrocalcic horizon not present in all soils	0	6	15	0
Difference in texture	0	6	15	31
Difference in coarse fragments	0	6	31	25

1/ See section 17.

Other factors affect the soil patterns to a lesser degree. Organic carbon values and sand/clay ratios determine the distribution of Typic and Ustollic subgroups. Also, the factors listed in table 79 apply to major components only. Thickness of young deposits (without diagnostic horizons) on buried soils cause complex patterns in small areas (see also sections 24, 161, 172). Pipes are locally important where they are large enough for a polypedon (e.g., some pipes of upper La Mesa).

Reasons for homogeneity of specific mapping units are presented in a number of places to give an idea of the factors involved for specific soils (see sections 155, 158, 175, 176, and 194).

125. ORGANIZATION OF MAPPING UNIT DESCRIPTIONS

Items in the mapping unit descriptions are arranged as indicated below.

Mapping unit composition. The list of soils in some units is fairly long since an attempt was made to keep track of the most common soils even though they might not be extensive in some of the mapping units. This was done in order to determine their character and degree of occurrence in various parent materials and parts of the landscape. Presence of less common soils has also been noted in many places, to give some idea of the morphological variety encountered in the study area.

Location, landscape, vegetation.

Typical pedon(s), properties and ranges. This section presents information on typical pedons, properties and ranges of characteristics of dominant soils. Most of the ranges of characteristics are in a table in which typical properties are underlined; entries not underlined indicate the range. Abbreviations follow the Soil Survey Manual (Soil Survey Staff, 1951). Descriptions of typical pedon(s) are given here or their location elsewhere in the text is indicated. The Bt horizons of many soils of Pleistocene age have hues of both 2.5YR and 5YR, with the 5YR part commonly thickest and in the upper part of the Bt. Thus the approximate range in hue of the Bt horizon is often encountered in one pedon.

Soil occurrence. The character of the soil patterns, and occurrence of specific soils is described here.

Soil boundaries. This section presents information about boundaries to major adjacent units. Some sections have a block diagram showing the soil-landscape relations, and the boundaries and stratigraphy of some of the units.

Other studies. Additional studies were conducted in some mapping units. Some of the studies are along transects and involve soils of more than one mapping unit. Large-scale soil maps and tables of laboratory data are presented. The tables give some of the laboratory data (which is presented in full in the Appendix) selected to illustrate various features of the soils. The data in these tables are for the carbonate-containing less than 2 mm material unless otherwise indicated. Laboratory methods are discussed in section 33.

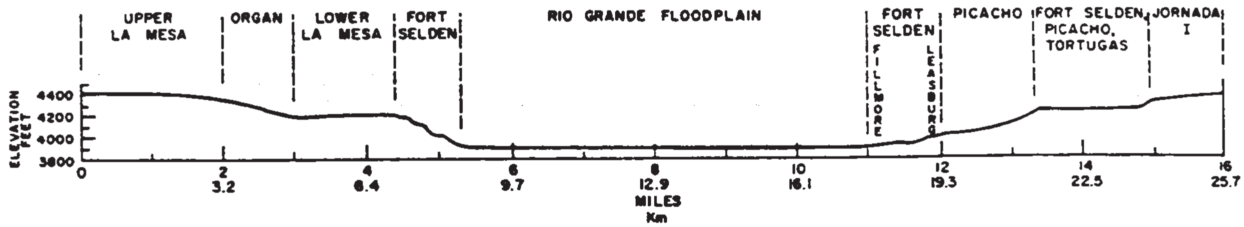


Figure 61. Cross section near University Park, showing geomorphic surfaces and approximate elevations.

126. SOILS OF THE VALLEY BORDER

Soils of the valley border are significant from the standpoint of pedogenesis because of the stepped sequence of geomorphic surfaces, presence of high- and low-carbonate parent materials, and the highly variable degree of soil truncation. By means of the stepped sequence and the associated chronologic markers, the soils may be chronologically related to each other to study the effects of age on soil morphology. Similarly, the effects of shifts in parent materials on soil development can be studied while the soil-forming factors of age, climate and topography are kept constant. Morphology of soils that have been truncated in varying degree can also be assessed and compared to the soils of stable sites. The valley border also illustrates morphological effects of polygenesis in soils that started their development at various times since mid-Pleistocene.

Geomorphic surfaces of the stepped sequence (fig. 61) present a broad array of soils that increase in development with increasing age. The relative ages of the soils are demonstrated by their position in the stepped sequence: the soils are progressively older on the progressively higher surfaces.

Because of strong landscape dissection in many places, soils illustrating this developmental array occur only where the surfaces are relatively stable and well preserved. On La Mesa, such areas are characterized by level or nearly level slopes that are continuous for long distances. On alluvial-fan and terrace surfaces, stable areas are characterized by interfluves that are level or nearly level transverse to longitudinal slopes of the alluvial-fan and terrace surfaces. Soils are partly preserved on crests of some ridges characteristic of strongly dissected landscapes. In areas of extreme dissection, divides have been lowered, ridges are very narrow, and genetic horizons of whole soils have been truncated. In the latter case, young soils of the Fillmore surface occur high in the dissected landscape. Table 81 shows major soils of the valley border and their relation to geomorphic surfaces and soil age, development and classification.

The stages of carbonate accumulation are valuable chronological and stratigraphic markers for the soils (section 68). Table 81a summarizes the stages of carbonate accumulation for soils of the valley border.

* * *

Table 81a. Stages of carbonate accumulation for soils of the valley border.

Stage: Nongravelly soils	Stage: Gravelly soils	Youngest geomorphic surface on which stage of horizon occurs, and age	
I	I	Fillmore	Holocene
II	II, III	Leasburg	Latest Pleistocene
III	III, IV	Picacho	Late-Pleistocene
III	IV (multiple laminar zones)	Jornada I	Late-mid-Pleistocene
IV		La Mesa	Mid-Pleistocene

Table 81. Relation of soil development, horizonation and classification to major soils, soil age and geomorphic surfaces of the valley border.

Geomorphic Surface	Soil Age, Years B.P. or epoch	Soil Development → Torriorthents[1/] Pedologically unmodified materials	Torripsamments Partial disruption of strata	Entisols ABC or AC	CAMBORTHIDS ABC	HAPLARGIDS ABtK	CALCIORTHIDS AK or ABK	PALEARGIDS ABtKm	PALEORTHIDS AKm	Solum[2/] Thickness (Meters)
Arroyo channel	--	SND #6								
(Coppice Dunes)[3/]	<100 (?)		Pintura							
Fillmore	1000 to 4000			Bluepoint Arizo Kokan Yturbide Dalian[4/] Canutio	Vado[3/] Pajarito					0.5 - 1
Leasburg	>7500 Latest Pleistocene			Canutio	Mimbres Pajarito	Bucklebar	Weiser[4/]			
Picacho	Late Pleistocene					Nolam Dona Ana	Caliza Nickel Algerita	Cruces 1-sk var. Casito	Monterosa Delnorte Upton[4/] Tencee[4/]	1 - 1.5
Tortugas	Late to mid-Pleistocene								Monterosa Upton[4/] Tencee[4/] Delnorte	1.5 - 2
Jornada I[6/]	Late mid-Pleistocene						Nickel Algerita	5/	Monterosa Delnorte	
La Mesa 6/	Early mid-Pleistocene							Cruces Cacique	Tonuco Tencee	2 - 3

1/ Most arroyo channel deposits are too gravelly for Torripsamments.

2/ Solum includes the genetic horizons--A, B, K and Cca horizons. Solum thickness may be considered another facet of soil development since there is a general increase in solum thickness with age. Thicknesses given represent soils of stablest sites.

3/ Coppice dunes are not designated by a geomorphic surface name.

4/ Formed in high-carbonate parent materials (mostly east of the Robledo Mountains) and have carbonatic mineralogy. All other soils have formed in low-carbonate parent materials and have mixed mineralogy except for the ancient soils of La Mesa in which broken-up fragments of the petrocalcic horizon (instead of limestone pebbles) are responsible for the carbonatic mineralogy.

5/ Argids occur on stable Jornada I, east of the high Jornada I ridges considered here (see "soils of the piedmont slopes").

6/ Strictly speaking, soils of Jornada I and La Mesa are not part of the valley border. Parts of these surfaces next to the valley border are included here, however, because they are important members of the stepped sequence of surfaces. A small area of Organ alluvium between upper and lower La Mesa is also included here; it is the same age as the Fillmore.

127. Soils of the Fillmore surface.

The Fillmore is the first major terrace above the arroyo channels. In places the Fillmore surface and associated colluvium extend from the terraces up the sides of adjacent ridges. In addition to soils of the Fillmore there are minor areas of soils of the Leasburg, Organ, and Picacho surfaces. All soils have formed in low-carbonate materials except soils of the Dalian complex.

Potsherds of the El Paso Brown pottery dating from about 800 to 900 A.D.[5/] have been found on the older and more extensive part of the Fillmore geomorphic surface. Soils of this part of the Fillmore surface must therefore be at least 1000 years old. Radiocarbon ages of buried charcoal indicate maximum ages for soils of the Fillmore (section 15).

The C-14 ages at depths of about 1 m, and beneath the genetic horizons, range from about 2600 to 4000 years old. Most soils of the Fillmore surface must be less than about 4000 years old. Soils of the Fillmore must have formed under a climate very similar to the present one, and their morphology cannot be attributed to a Pleistocene pluvial. Soils of the Fillmore illustrate the beginnings of soil horizons. All soils except those less than several hundred years old show a stage I horizon of carbonate accumulation. In soils that have formed in low-carbonate materials and that occur on the oldest and stablest parts of the Fillmore, soil morphology indicates that silicate clay is accumulating at the present time by illuviation (section 128). Because of the limited time available for pedogenesis, however, the amount of illuvial clay (as indicated by particle size distribution analyses and by thin section studies) is usually too small for an argillic horizon. Soils of the Fillmore surface also show the effect of carbonate content of parent materials on young soils. Upper horizons of some soils formed in low-carbonate parent materials are noncalcareous. Infiltration of moisture has been sufficient to remove most of the carbonate in the dustfall and also small amounts that may have been in the surficial part of the alluvium. In contrast, all soils formed in high-carbonate parent materials are strongly calcareous throughout. There is so much allogenic carbonate in the soils that the soil moisture associated with the present climate has been unable to remove it all from upper horizons.

Carbonate content of the parent materials is not the only factor involved in soils that are calcareous throughout. Many soils formed in parent materials low in carbonate are strongly calcareous throughout. Such soils are (1) very young, so that small amounts of carbonate that may have been in the parent materials have not yet been leached out of the soil; (2) the soils have been mixed intensively by soil fauna, thus overcoming the effects of leaching; or (3) the soils have been truncated, and horizons of carbonate accumulation that were once beneath the surface have been brought to the surface by erosion. Soil truncation is common along the valley border because of strong landscape dissection; erosion cycles of various ages and locations have been caused by shifts of the Rio Grande. Some soils have been completely truncated by the Rio Grande and by local tributaries.

5/ Personal communication, Stewart Peckham, Museum of New Mexico, Santa Fe, N. M.

Four mapping units occur on the Fillmore surface:

128. ARIZO COMPLEX (13F)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
ARIZO	TYPIC TORRIORTHENTS	SANDY-SKELETAL	25
SND-6	ENTISOLS		25
Anthony	Typic Torrifluvents	Coarse-loamy (calcareous)	5
Bluepoint	Typic Torripsamments		5
Canutio	Typic Torriorthents	Loamy-skeletal (calcareous)	5
Canutio, loamy subsoil variant	Typic Torriorthents	Coarse-loamy (calcareous)	5
Pinaleno	Typic Haplargids	Loamy-skeletal	5
Vado	Typic Camborthids	Loamy-skeletal	5
Vado, sandy-skeletal variant	Typic Camborthids	Sandy-skeletal	5
Yturbide	Typic Torriorthents	Sandy	5
Other inclusions	(Calciorthids, Camborthids, Torrifluvents)		10

LOCATION, LANDSCAPE, VEGETATION

These soils occur on the eastern side of the valley border and extend eastward along major arroyos towards the Dona Ana and Organ Mountains. The parent materials were derived from source areas upslope, including the mountains. In higher areas near the mountains, the parent materials consist largely of sediments from rhyolite; in places there are additions from andesite and monzonite. Towards the flood plain, sediments from the sand and rounded gravel of ancient river alluvium are an important component of the parent materials. Elevations range from about 3900 to 4700 feet.

The landscape consists of arroyo channels and narrow (commonly less than several hundred m) terraces inset against sediments of adjacent higher surfaces. The terraces extend headward along large arroyos, and commonly range from about 1/2 to 2 m higher than the channels. Slope ranges from about 2 percent adjacent to the valley, to 3 percent near the mountains.

Vegetation on the terraces is mostly creosotebush. There is usually little or no vegetation in the main channels of the arroyos, but large shrubs are common along channel margins. These shrubs are mainly desert willow, Mormon tea, creosotebush, brickellbush, sumac, Apache plume, and burro brush.

TYPICAL PEDONS, PROPERTIES AND RANGES

Soils of this mapping unit are commonly calcareous throughout along the border of the Rio Grande Valley. On stable sites towards the mountains, however, upper horizons are noncalcareous in many places.

Arizo

A typical pedon of Arizo is described below. The location is in the Dona Ana Bend Colony, about 1 1/2 miles north of Dona Ana and about 0.1 mile east of Interstate Highway 10, south bank of arroyo. Figure 62 is a photograph of the pedon and its landscape. A table of properties and ranges follows the description.

Soil surface. Desert pavement of rhyolite pebbles; a discontinuous layer of reddish sand occurs between and beneath pebbles and rests on the A horizon.

A 0-3 cm. Pinkish gray (7.5YR 6/2, dry) or dark brown (7.5YR 4/2, moist) fine sandy loam; weak medium platy; soft; upper 1/4 inch vesicular; no roots; effervesces weakly; abrupt smooth boundary.

Bca 3-18 cm. Brown (8YR 5.5/3, dry) and dark brown (8YR 3.5/3, moist), gravelly light fine sandy loam; massive; soft; few roots; few thin carbonate coatings, primarily on pebble bottoms; effervesces strongly; clear wavy boundary.

2C1ca 18-31 cm. Light brown (7.5YR 6/4, dry) and brown (7.5YR 5/4, moist) very gravelly loamy fine sand-fine sandy loam; massive and single grain; loose and soft; roots common; thin, continuous carbonate coatings and filaments on pebbles; effervesces violently; abrupt wavy boundary.

2C2ca 31-58 cm. Light brown (7.5YR 6/3, dry) or brown (7.5YR 4.5/3, moist) very gravelly loamy sand; loose; single grain; very few roots; few thin, discontinuous carbonate coatings on pebbles; very little interstitial material; effervesces strongly; abrupt wavy boundary.

2C3ca 58-89 cm. Lenses <1/2 inch thick, poorly defined, of sand and fine gravel; markedly firmer in place than above; scattered thin carbonate coatings on pebble bottoms; effervesces weakly.

Table 82. Typical (underlined) and range in selected properties for major horizons of Arizo.

Horizon	Depth cm	Particle Size <2mm	Particle Size >2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-3	sl ls, s	0-75	5YR- 7.5YR	4-6	3-5 4	2-4
B	3-18	sl ls	0-75	5YR- 10YR 8YR	4-6 5.5	3-5 3.5	3,4
Cca	18-31	ls, s	35-75	7.5YR- 10YR	5,6	4,5 5	3,4
Control section		ls, s	35-75				

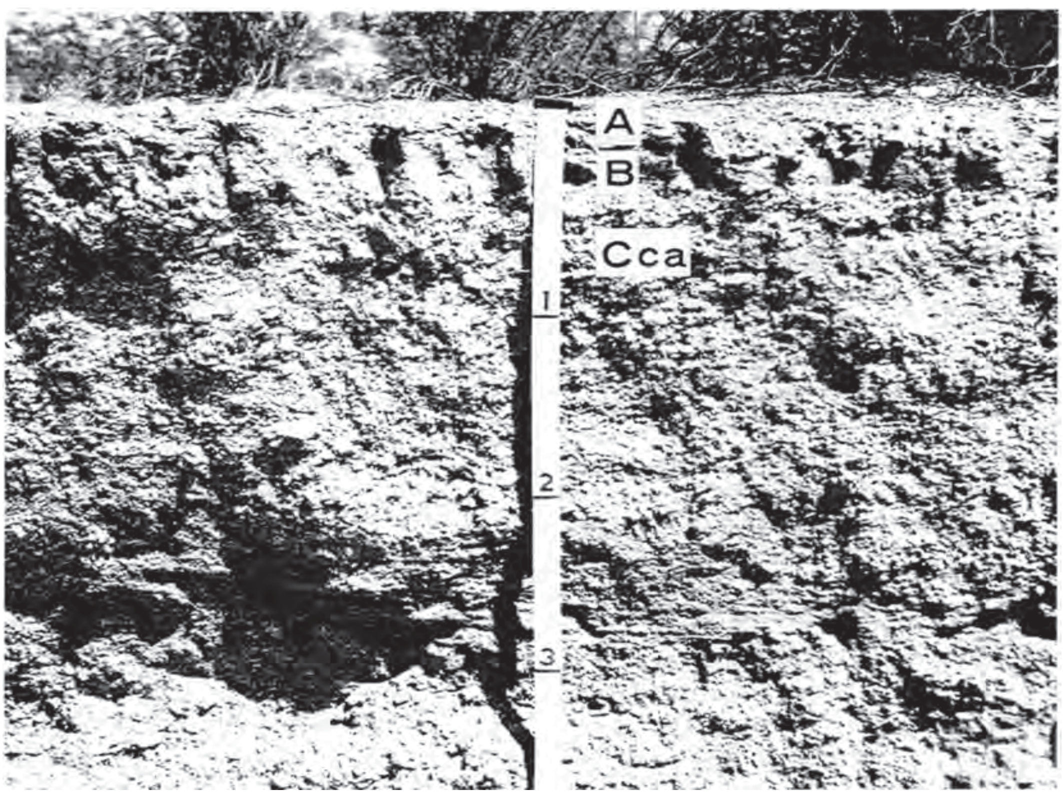


Figure 62. Upper. Landscape of a Typic Torriorthent, Arizo gravelly sandy loam, on the Fillmore surface. Vegetation is creosotebush. Slope is 3 percent. On the skyline is a Picacho remnant (left) and the Leasburg surface (right); the latter is a structural bench cut in ancient river alluvium.

Lower. Arizo gravelly sandy loam. Scale is in feet.

SND-6

Materials in active arroyo channels have been observed in only a few places in the study area. Depending upon content of coarse fragments (Orthent-Psamment separation, section 18) the materials would be classified as either Torriorthents or Torripsamments.

SOIL OCCURRENCE

The soils occur in complex patterns caused by numerous arroyo channels, by abrupt changes in texture of parent materials, and by differences in age and stability of the Fillmore surface. Soils of this mapping unit show the beginnings of soil horizons, and also illustrate several of the few Camborthids in the region. In this terraced terrain, Camborthids occur only in a few very small parts of some of the lowest terraces (Fillmore), which are common in this mapping unit. Older soils of higher surfaces and other mapping units are too strongly developed for the Camborthids.

Torriorthents. The sandy-skeletal ARIZO; loamy-skeletal Canutio; Canutio, loamy subsoil variant; and Yturbide, occur on youngest and least stable parts of the Fillmore surface. Commonly these are next to or near the main arroyo channels and smaller drainageways. Such areas tend to be very slightly lower than stabler parts away from the channels. Some of the stablest of these soils have color B horizons, but carbonate maxima extend above 25 cm, and this is not allowed in the cambic horizon.

Entisols. SND-6 occurs in arroyo channels.

Camborthids. These Camborthids have reddish brown B horizons thick enough to qualify as cambic horizons, and occur only in highest, stablest positions of the Fillmore surface. The soils are the coarse-loamy Pajarito; the loamy-skeletal Vado; and Vado, sandy-skeletal variant. These cambic horizons are usually noncalcareous and they are redder than adjacent horizons.

Haplargids. Soils of this mapping unit also show incipient development of the argillic horizon. These soils (Pinaleno) have formed in very gravelly materials, and are similar to the Camborthids discussed above except that silicate clay increases enough for an argillic horizon.

Torripsamments. Bluepoint soils occur in low-gravel, coarse-textured alluvium, mostly on gentler slopes near the flood plain.

Calciorthids. Occur on a very few small, isolated ridge remnants of the Picacho surface.

Torrifluvents. The coarse-loamy Anthony soils and Vinton, sandy-skeletal variant, occur where organic carbon decreases irregularly with depth or remains above 0.2 percent to a depth of 1.25 m.

SOIL BOUNDARIES

Soils of this mapping unit extend headward along major arroyos and are bordered by many different soils. The boundaries are usually caused by a younger alluvium and geomorphic surface in unit 13F. Topographically the boundaries are usually easy to see because in most places the margins of the mapping unit are marked by the edges of terraces abruptly inset against higher alluvium. Vegetation is usually more abundant and taller along the arroyos because of the larger amount of moisture received by arroyos.

129. BLUEPOINT SAND (13Y)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
BLUEPOINT	TYPIC TORRIPSAMMENTS		65
Pintura	Typic Torripsamments		10
Yturbide	Typic Torriorthents	Sandy	10
Other inclusions (Torrifluvents, Torriorthents, Torripsamments, Haplargids, Calciorthids, Entisols)			15

LOCATION, LANDSCAPE, VEGETATION

These soils occur extensively on both sides of the valley border, mainly in the southern part of the study area. Parent materials are largely reworked and in-place sandy sediments of ancient river alluvium. Elevations range from about 3900 to 4400 feet.

The soils occur on terraces, fans and ridges. Arroyos descend to the flood plain of the Rio Grande. In places, side drainageways extend from arroyos towards the ridges. Rills and small gullies occur on many of the ridge sides. Coppice dunes are common on some of the ridge crests and fans. Longitudinal slopes of ridge crests range from about 2 to 5 percent; ridge sides slope mainly from 3 to 10 percent, with a few sloping 25 to 35 percent. Areas adjacent to the flood plain are commonly gently undulating and slope 2 to 3 percent.

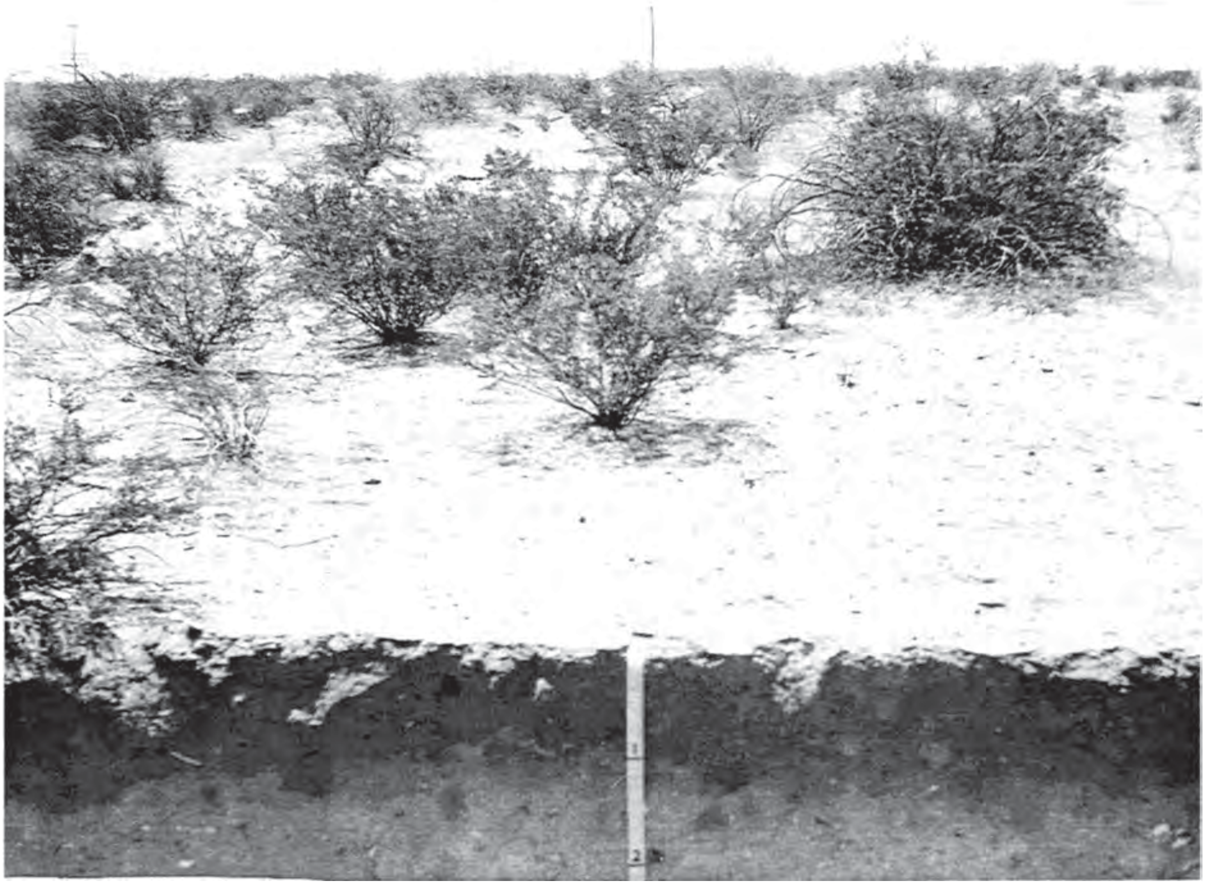
Vegetation consists mainly of creosotebush, with scattered mesquite, sand dropseed, mesa dropseed, bush muhly, Mormon tea, ratany, and prickly pear. Vegetation on dunes is mainly mesquite, in places with four-wing saltbush or creosotebush.

TYPICAL PEDON, PROPERTIES AND RANGES

At stablest sites, such as centers of broadest ridges, the soils are noncalcareous to depths of 50 to 75 cm. The reddest B horizon observed has hues of 7.5YR as compared to the C horizon hue of 10YR. Thick sand occurs beneath these soils; no bedrock or petrocalcic horizons occur within a depth of many m.

Bluepoint

A typical pedon of Bluepoint is described in the Appendix (pedon 59-10). Figure 63 is a photograph of the pedon and its landscape. A table of properties and ranges is given below.



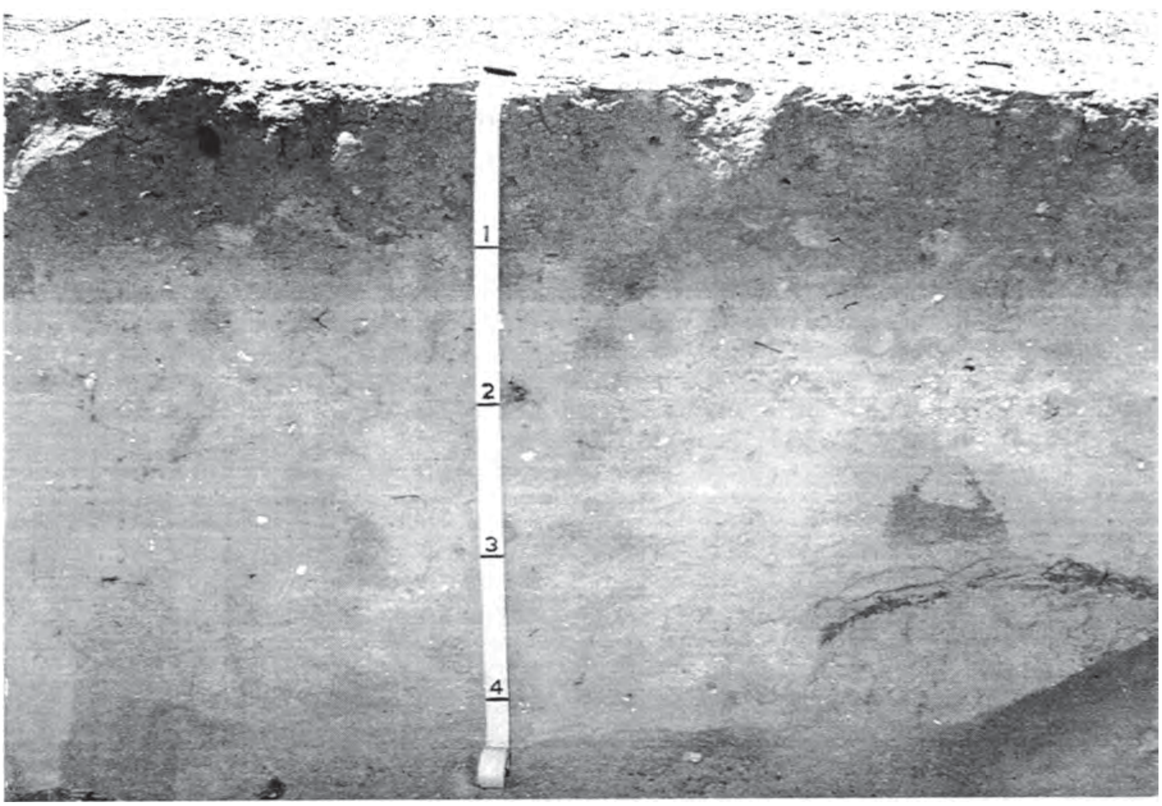


Figure 63. Upper. Landscape of the Typic Torripsamment, Bluepoint 59-10, o the Fort Selden (probably Fillmore) surface. Vegetation consists of creosot bush, mesquite, and a few *Yucca elata*. Slope is 6 percent.
Lower. Bluepoint 59-10. Scale is in feet.

Table 83. Typical (underlined) and range in selected properties for major horizons of Bluepoint.

Horizon	Depth	Particle Size		Hue	Value		Chroma
	cm	< 2mm	> 2mm, % Vol.		Dry	Moist	
A	0-13	s ls,sl	0-5	5YR- 10YR	5,6	4,5	2-4 2
B	13-43	s ls	0-15	5YR- 10YR	4-6 5	3-5 4	2-4
C1ca	43-64	s ls	0-15	5YR- 10YR	6,7 6.5	4,5	2,3 2
Control section		s, ls	0-15				

Other. Youngest Bluepoint pedons have no B horizon and no horizon of carbonate accumulation. Such soils are generally calcareous throughout. Only small areas of Bluepoint soils have 5YR hue and it is inherited from the parent materials. These soils occur just below the scarp of upper La Mesa, on portions of the Organ or Fillmore surface and occur in sandy sediments eroded from upper horizons (with 5YR hue) of soils on La Mesa surface.

SOIL OCCURRENCE

Torripsamments. BLUEPOINT soils are dominant over the whole area and occur on terraces, fans and ridges. Pintura soils occur in coppice dunes. Bluepoint soils occur on the sides of some of the steeper ridges.

Torriorthents. The sandy-skeletal Arizo soils and Yturbide (15 to 35 % gravel) occur with increases in gravel content and are most common in or near former arroyo channels. The Torriorthent Canutio, loamy subsoil variant, is found in places near the flood plain.

Calciorthids. The coarse-loamy Whitlock soils occur on crests of some ridges that probably date in part from Picacho time.

Torrifluvents. Anthony, Gila and Vinton soils and Vinton, sandy-skeletal variant occur in places near the flood plain.

Haplargids. The coarse-loamy Onite and fine-loamy Berino soils occur on a few ridges north of Fort Selden.

Camborthids. The coarse-loamy Pajarito soils occur in a few places near the flood plain.

Entisols. SND-6 occurs in arroyo channels.

SOIL BOUNDARIES

Table 84 gives information about boundaries to major adjacent units.

Table 84. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Tencee complex, eroded (10C)	The boundary has been caused by landscape dissection. Sand beneath soils of unit 10C has been exhumed and is at the surface on the 13Y side of the boundary.
Kokan-Nickel complex (10W) and Nickel complex (11R)	The boundaries have been caused by a younger alluvium and geomorphic surface (Fort Selden) in unit 13Y. The boundaries to soils of both the 10W and 11R units are similar and distinct (soils on both of these units occur on large terraces along major arroyos). Sandy sediments of unit 13Y have buried analogues of soils of 10W and 11R units in many places along the margins. In other places, parts of unit 13Y are inset against soils of the 10W and 11R units.
Bluepoint complex (13X) and Kokan-Bluepoint complex (11X)	The boundaries have been caused by the erosion of gravel and concomitant exhumation of sandy sediments beneath the gravel. The boundary is near the contact of the lowermost gravelly beds on the underlying sand. The topographic boundary is winding and distinct. The gravelly sediments are more resistant to erosion than the underlying sandy sediments and steep gravelly ridges have formed. The boundary occurs at the base of the steep ridges. Ridges in the sandy sediments (unit 13Y) are less steep and slopes are smoother. Vegetatively the transition is commonly marked by increase in size of the creosotebush in unit 13Y.
Arizo complex (13F)	The boundary is due to increase in gravel content and arroyos in unit 13F. Topographically the boundary is distinct because the soils of unit 13F occupy the topographic lows in which large arroyos occur.

OTHER STUDIES

Other studies in this unit concern Bluepoint 59-10 and the Fillmore Arroyo radiocarbon site.

A Torripsamment in reworked river alluvium

The location of Bluepoint 59-10 (fig. 63; table 85) is shown in figure 64

* * *

Table 85. Laboratory data for two Torripsamments, Bluepoint 59-10 and 59-17.

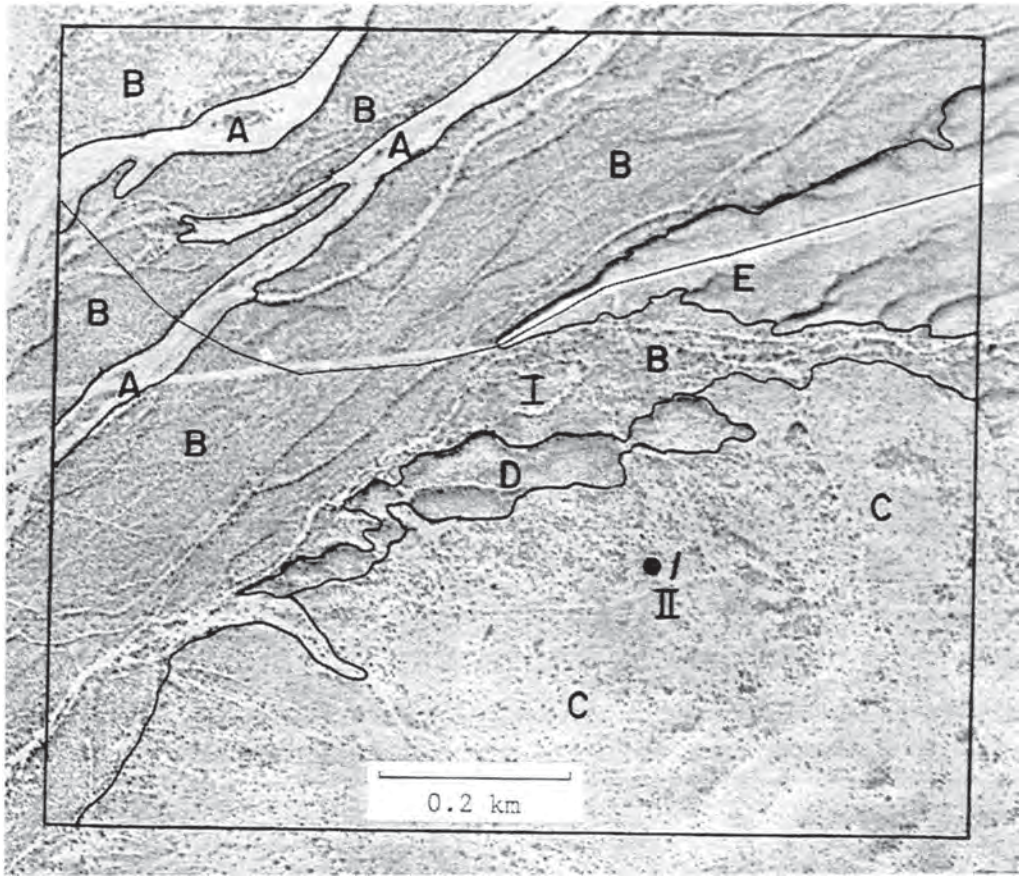
Horizon	Depth	Sand 1/	Silt 1/	Clay 1/	Vol. > 2 mm	Extractable Fe	Carbonate	Organic carbon
	cm	pct	pct	pct	pct	pct	pct	pct
Bluepoint 59-10								
A	0-13	90	5	5	tr	0.4	0.1	0.14
B	13-43	90	5	5	tr	0.4	0.5	0.11
C1ca	43-64	92	3	5	tr	0.4	2.7	0.11
C2ca	64-114	94	3	3	tr	0.3	2.4	0.05
C3	114-140				tr		tr	
Bluepoint 59-17								
C	0-13	85	10	5	1		0.4	0.16
B	13-25	84	11	5	5		0.1	0.14
C1ca	25-48	85	10	5	5		0.6	0.11
C1ca	48-71	85	10	5	5		1.0	0.09
C2ca	71-117	83	10	7	5		1.8	0.15
2C3ca	117-127	83	11	6	35		4	0.16
3C4ca	127-140	93	3	4	65		2	0.05

1/ Carbonate-free basis.

* * *

(upper), a soil map of an area in which Bluepoint occurs extensively on ridge sides. The cross section (fig. 64, lower) shows a situation in which the chrono-topographic relation of the valley border stepped sequence is reversed: the soils of a high surface are younger than those below. Mid-Pleistocene river alluvium (which occurs in high ridges) has moved downslope and in places has buried soils of the Picacho surface along its margin.

Bluepoint 59-10 has a thin A horizon, a noncalcareous B horizon and a C horizon that is lighter colored and contains almost no clay (table 85). The B horizon is slightly browner and darker than the C horizon. Thin sections show very thin coatings of oriented clay on sand grains in the B horizon; these coatings are lacking in the C horizon. Lack of reddening in the B horizon may be due to the parent materials, which are very low in ferromagnesian minerals that may be susceptible to weathering in an arid environment. The low extractable iron (table 85) reflects the scarcity of these minerals. Other soils with more iron also have redder B horizons (sections 83, 94).



NNW ⟷ SSE

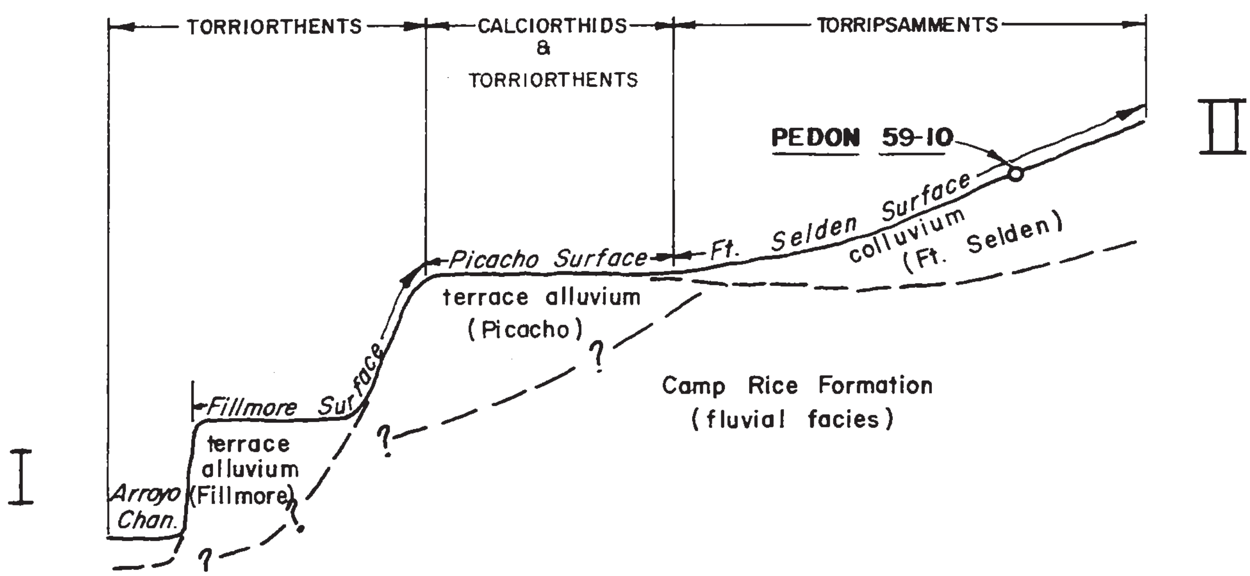


Figure 64. Upper. Soil map in the vicinity of Bluepoint 59-10. A = Torriorthents (arroyo channels). B = Arizo-Torriorthent complex (Fillmore and arroyo channel surface). C = Bluepoint sand (Fort Selden surface). D = Nickel gravelly sandy loam (Picacho surface). E = Delnorte complex (Picacho surface). I to II locates cross section, below.

Lower. Cross section from I to II, soil map.

The above factors suggest an atmospheric origin for some of the clay in the B horizon as well as for carbonate in the Cca horizon. The carbonate accumulation (table 85) is typical of soils of Fillmore age and the carbonate horizon is Stage I.

The Fillmore Arroyo radiocarbon site

Bluepoint 59-17 (fig. 65; table 85) occurs in a Fillmore terrace. A hearthsite (see pedon description, Appendix) is present a few m east at a depth corresponding to the lower Cca horizon. Charcoal from this hearthsite dates the horizons above as less than 2600 years old.

The uppermost horizon is a youthful deposit with thin, distinct strata. Beneath, stratification is absent and there is evidence of soil development. The B horizon is noncalcareous while underlying horizons are calcareous and are higher in carbonate (table 85). Clay values are essentially straight line with depth and organic carbon is low (table 85). There are scattered faint carbonate coatings on sand grains in the Cca horizon, which is in stage I of carbonate accumulation. In places, authigenic carbonate occurs more prominently as very thin coatings on pebbles. A small amount of allogenic carbonate was present in the parent materials (see Appendix).

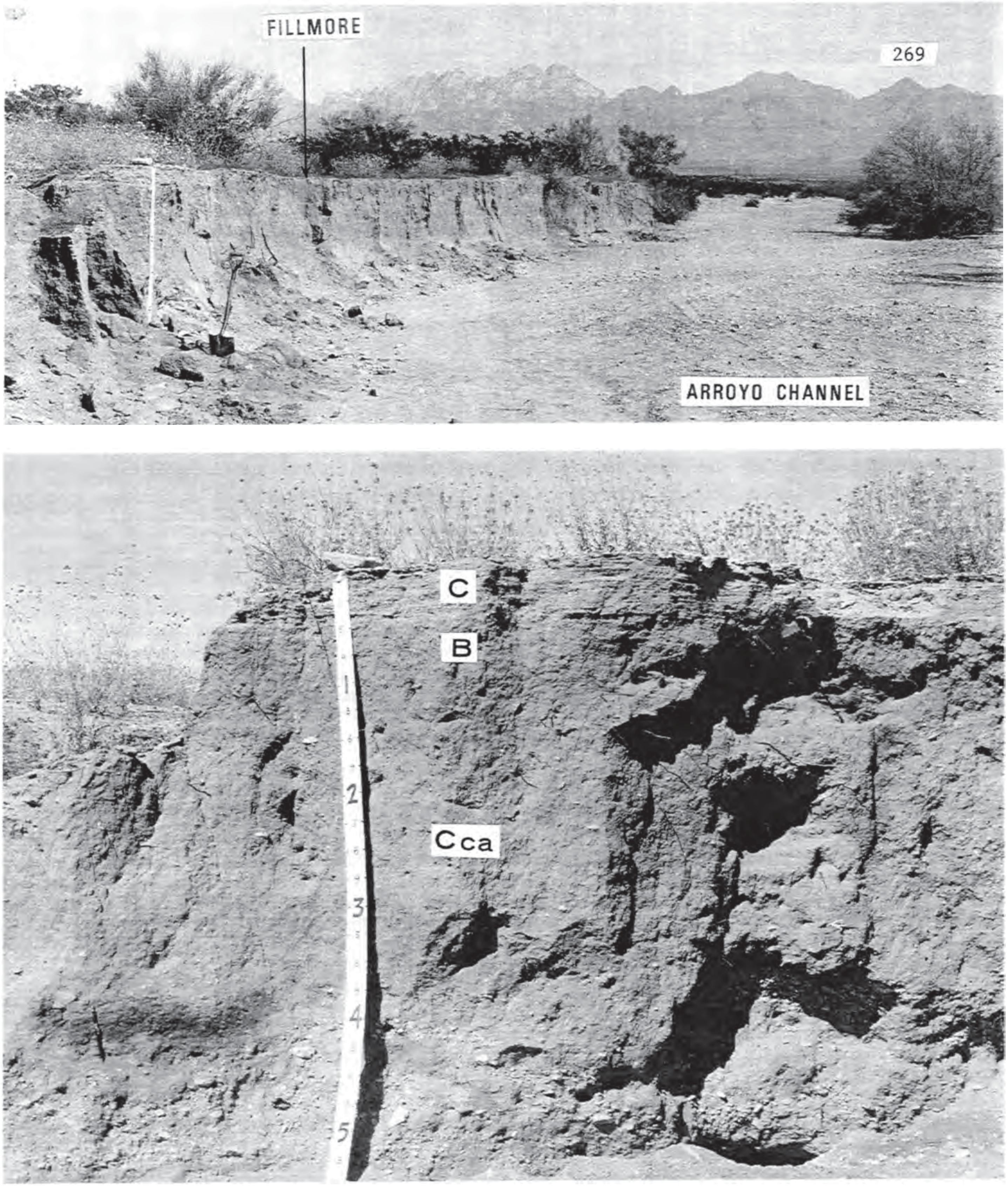


Figure 65. Upper. Landscape just east of the Typic Torripsamment, Bluepoint 59-17, at the Fillmore Arroyo radiocarbon site. Fillmore surface at left; Organ Mountains in background.

Lower. A Typic Torripsamment about 5 m east of Bluepoint 59-17. Scale is in feet. Charcoal dated at 2620 ± 200 yr was recovered from hearthsite at left.

130. BLUEPOINT COMPLEX (13X)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
BLUEPOINT	TYPIC TORRIPSAMMENTS		25
KOKAN	TYPIC TORRIORTHENTS	SANDY-SKELETAL	25
YTURBIDE	TYPIC TORRIORTHENTS	SANDY	30
SND-6	ENTISOLS		20

Other inclusions (Calciorthids, Torriorthents).......................... < 1/2

LOCATION, LANDSCAPE, VEGETATION

These soils occur discontinuously along both sides of the valley border. On the west side of the valley they are mostly south of Picacho Mountain, just below the La Mesa scarp; there is also a small delineation in the northern part of the area. On the east side of the valley there is one small delineation in the southern part of the area and a discontinous belt near the flood plain north of Dona Ana. The soils have formed in ancient river alluvium and in surficial colluvium of Holocene age. The old alluvium has been exhumed from beneath La Mesa surface south of Picacho Mountain, and commonly from beneath the Picacho surface north of Dona Ana. Elevations range from about 3900 to 4200 feet.

These soils occur on ridges that range from slight to steep. On the west side of the valley, below the La Mesa scarp, the ridges are high and steep. There are common saddles in the ridges; slopes along ridge crests range from about 1 to 5 percent. Ridge sides slope from about 15 to 35 percent, and gullies are numerous. In many places these sediments form a structural bench. Ridges are lower and less prominent on the east side of the valley.

Vegetation consists mainly of creosotebush; in places there are a few mesquite, snakeweed, fluffgrass, Mormon tea, and dropseed.

TYPICAL PEDONS, PROPERTIES AND RANGES

Many of these soils are noncalcareous to depths ranging from about 2 to 25 cm. Others are calcareous throughout. In most places these soils have formed in thick sandy sediments with no bedrock, calcic or petrocalcic horizon within a depth of many m.

Bluepoint

A typical pedon of Bluepoint is described below. The location is the SW 1/4 Sec. 33, T23S, R1E, north side of ridge, about 25 m downslope from ridge crest, about 100 m west of the Yturbide pedon described later. Figure 66 is a photograph of the pedon and its landscape. The description is followed by a table of properties and ranges.

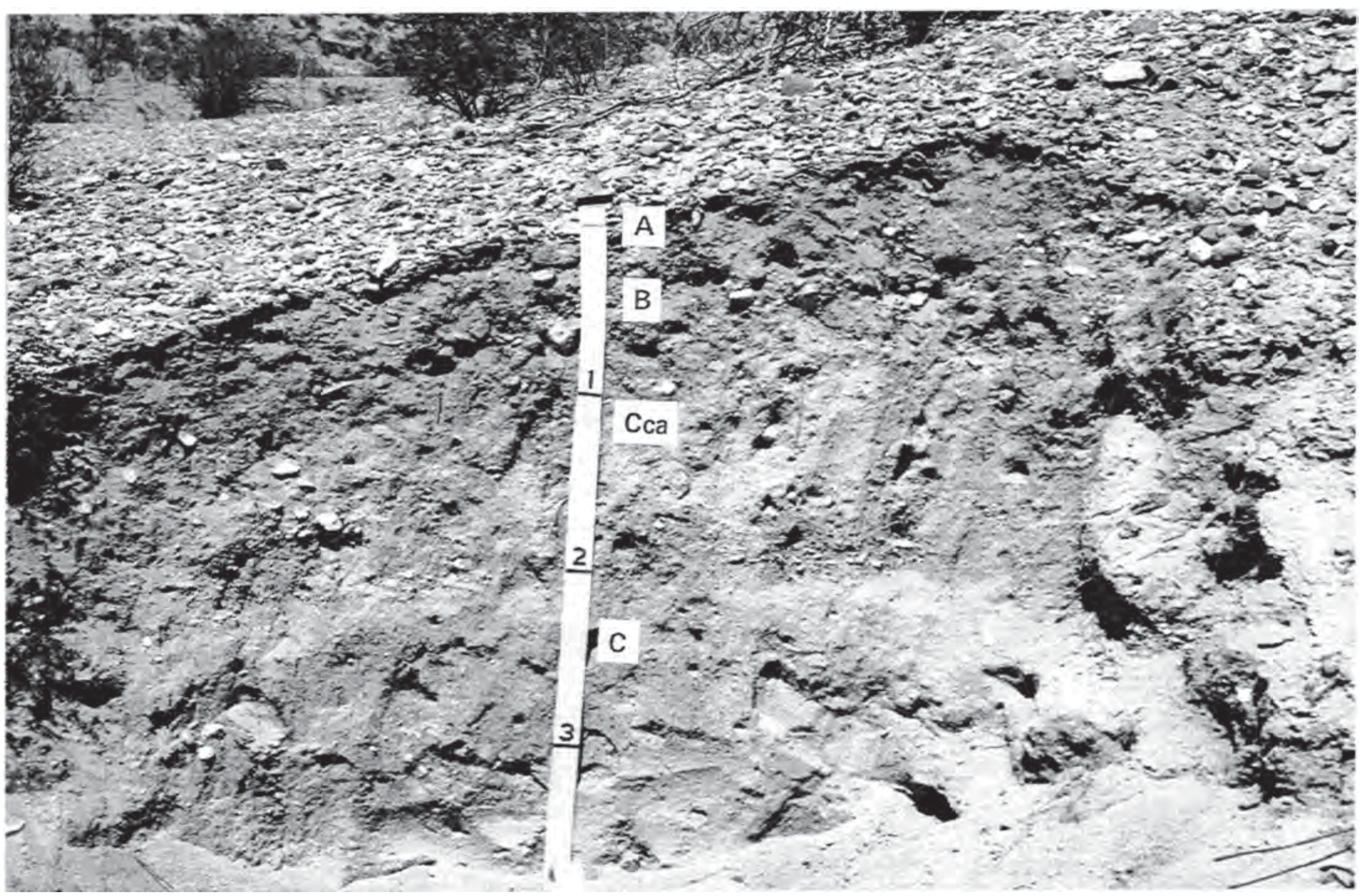


Figure 66. Upper. Landscape of a Typic Torripsamment, Bluepoint gravelly sandy loam, Fillmore surface. Vegetation consists of a few creosotebush, mesquite, one Mormon tea, and a very few dead clumps of fluffgrass. Slope is 35 percent.

Lower. Bluepoint gravelly sandy loam. Scale is in feet.

Soil surface: About 95 percent covered with desert pavement of coarse fragments up to 10 cm diameter, mostly between 1/4 and 3 cm diameter. The gravels consist of quartz, chert, and mixed igneous rocks, including pink granite, rhyolite and andesite.

A2 0-4 cm. Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) very gravelly light sandy loam; weak very fine crumb, except for the upper 1/2 cm, which is weak medium platy; soft; very few roots; noncalcareous; abrupt smooth boundary.

B2ca 4-23 cm. Brown (7.5YR 5/4, dry) or dark brown (7.5YR 4/4, moist) gravelly light sandy loam; massive; soft; few roots; thin stainings of clay on sand grains and pebbles; thin, patchy and filamentary carbonate coatings on a few pebbles; most parts effervesce weakly, few parts noncalcareous; clear smooth boundary.

B3ca 23-30 cm. Brown (7.5YR 5.5/4, dry 7.5YR 4.5/4, moist) gravelly sand; massive, soft; few roots; carbonate coatings on pebbles, mainly on pebble bottoms; effervesces strongly; clear wavy boundary.

C1ca 30-56 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) sand; massive; soft; very few roots; few rodent burrows, 3 to 10 cm diameter, filled with loose sand; thin carbonate coatings on sand grains and pebbles; effervesces strongly; clear wavy boundary.

C2 56-102 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) sand; generally massive and soft, with some parts loose and single grain; few roots; noncalcareous and effervesces weakly.

Table 86. Typical (underlined) and range in selected properties for major horizons of Bluepoint.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-4	sl ls,s	0-75	7.5YR- 10YR	5,6	4,5	2-4
B2	4-23	sl ls	0-25	7.5YR- 10YR	4-6 5	3-5 4	3,4
C	30-102	s, ls	0-15	10YR	6,7	4,5	2,3
Control section		s,ls	0-15				

Kokan

See section 143 for a description of Kokan.

Yturbide

A typical pedon of Yturbide is described below. The location is the SW 1/4 Sec. 33, T23S, R1E, north side of ridge, 10 m downslope from crest. Figure 67 is a photograph of the pedon and its landscape. The description is followed by a table of properties and ranges.

Soil surface: About 90 percent covered with desert pavement consisting of rounded quartz, rhyolite, andesite, pink granite, and miscellaneous other igneous rocks. Gravels in about half the desert pavement range from about 1/2 to 3 cm in size, with rest mostly 5 to 10 cm size, and some from 2 to 5 mm size.

A2 0-4 cm. Pinkish gray (7.5YR 6/2, dry) or dark brown (7.5YR 4/2, moist) very gravelly loamy sand; generally massive between pebbles, with some parts breaking out as weak medium platy; soft; few roots; noncalcareous; abrupt smooth boundary.

B21 4-10 cm. Brown (7.5YR 5/3, dry) or dark brown (7.5YR 3.5/3, moist) very gravelly heavy loamy sand; massive; soft; roots common; thin brown coatings of clay on sand grains and pebbles; noncalcareous; abrupt smooth boundary.

B22ca 10-19 cm. Light brown (7.5YR 6/4, dry) or dark brown (7.5YR 4/4, moist) very gravelly heavy loamy sand; massive; soft; roots common; pebbles and sand grains discontinuously coated with carbonate; most of the carbonate is on the undersides of pebbles; some of gravel fragments are carbonate-cemented fragments, 5 to 10 cm in diameter, derived from carbonate horizon once present on the ridge crest upslope; effervesces strongly; clear wavy boundary.

C1ca 19-47 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) gravelly loamy sand; there is definitely slight cementation caused by carbonate accumulation; massive; slightly hard; few roots; thin, mostly continuous carbonate coatings on pebbles and sand grains; effervesces strongly; clear wavy boundary.

C2ca 47-79 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) gravelly sand; massive; soft; thin, discontinuous carbonate coatings on pebbles and sand grains; few shrub roots, mainly 1 mm to 5 mm in diameter, with some roots finer; effervesces strongly; clear wavy boundary.

C3ca 79-105 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) gravelly sand; soft and loose; massive and single grain; very few roots; thin, discontinuous carbonate coatings on pebbles and sand grains; some parts effervesce strongly, other parts effervesce weakly or are noncalcareous.

Remarks. The C1ca horizon, 19-47 cm, is the carbonate maximum. The increased hardening in this horizon, as compared to the C3ca horizon, is caused by carbonate accumulation.

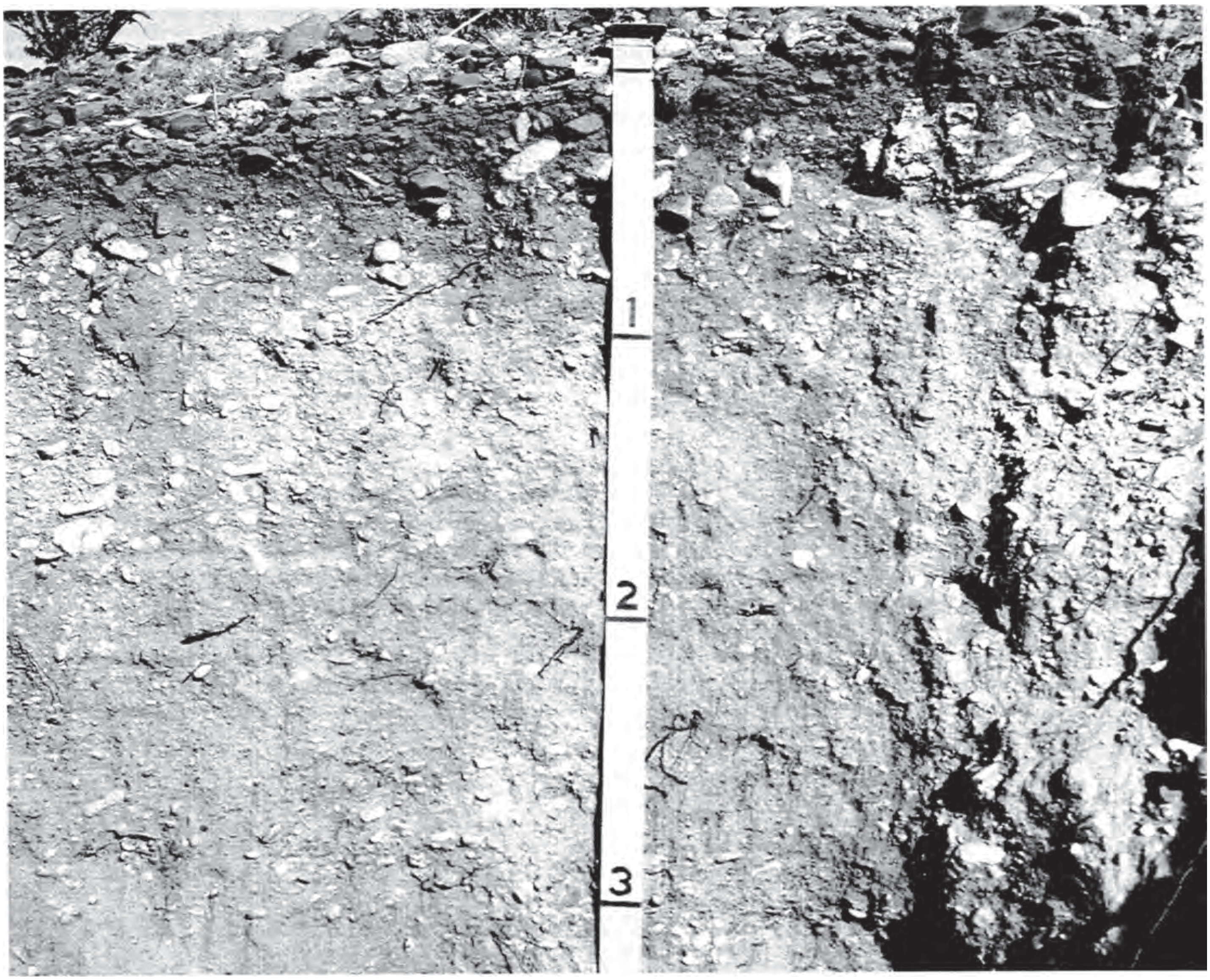


Figure 67. Upper. Landscape of Yturbide very gravelly loamy sand, a Typic Torriorthent, on the Fillmore surface. Vegetation is creosotebush, mesquite, and scattered fluffgrass. Slope is 20 percent.
Lower. Yturbide very gravelly loamy sand. Scale is in feet.

Table 87. Typical (underlined) and range in selected properties for major horizons of Yturbide.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-4	<u>ls</u> sl	0-75	<u>7.5YR-</u> 10YR	5,<u>6</u>	3,<u>4</u>	<u>2</u>-4
B2	4-19	<u>ls</u> sl	10-75	<u>7.5YR-</u> 10YR	4-6 <u>5</u>	3-5 <u>4</u>	3,<u>4</u>
Clca	19-47	<u>ls</u> s	15-35	<u>10YR</u>	6,<u>7</u>	4,<u>5</u>	2,<u>3</u>
Control section		ls,s	15-35				

SND-6

Materials in active arroyo channels have been observed in only a few places in the study area. Depending upon content of coarse fragments (Orthent-Psamment separation, section 18) the materials would be classified as either Torriorthents or Torripsamments.

SOIL OCCURRENCE

Texture is the principal difference among the major soils. Changes from the gravelly Orthents to the low-gravel Psamments are determined by shifts of gravel content in the control section. These textural changes are often abrupt, and are primarily responsible for the intricate pattern of the soils.

Torriorthents. The Kokan soils, sandy-skeletal, are usually most common on crests of highest ridges, with smaller areas occurring on low terraces adjacent to arroyo channels. YTURBIDE has less gravel (averaging 15 to 35 % gravel in the control section); these soils are found mainly on shoulders of ridges and adjacent to arroyo channels. Fine-loamy Torriorthents (SND-8) occur in beveled, finer-textured strata that crop out on ridge sides. These strata show little or no evidence of pedogenesis.

Torripsamments. BLUEPOINT soils occur mainly on middle and lower parts of ridge sides and in places are dominant on entire ridges at lower elevations.

Calciorthids. Narrow strips of Caliza soils occur on some of the stablest ridge crests.

Entisols. SND-6 occurs in arroyo channels.

SOIL BOUNDARIES

Table 88 gives information about boundaries to major adjacent units. Some of the boundaries are illustrated in figure 68.

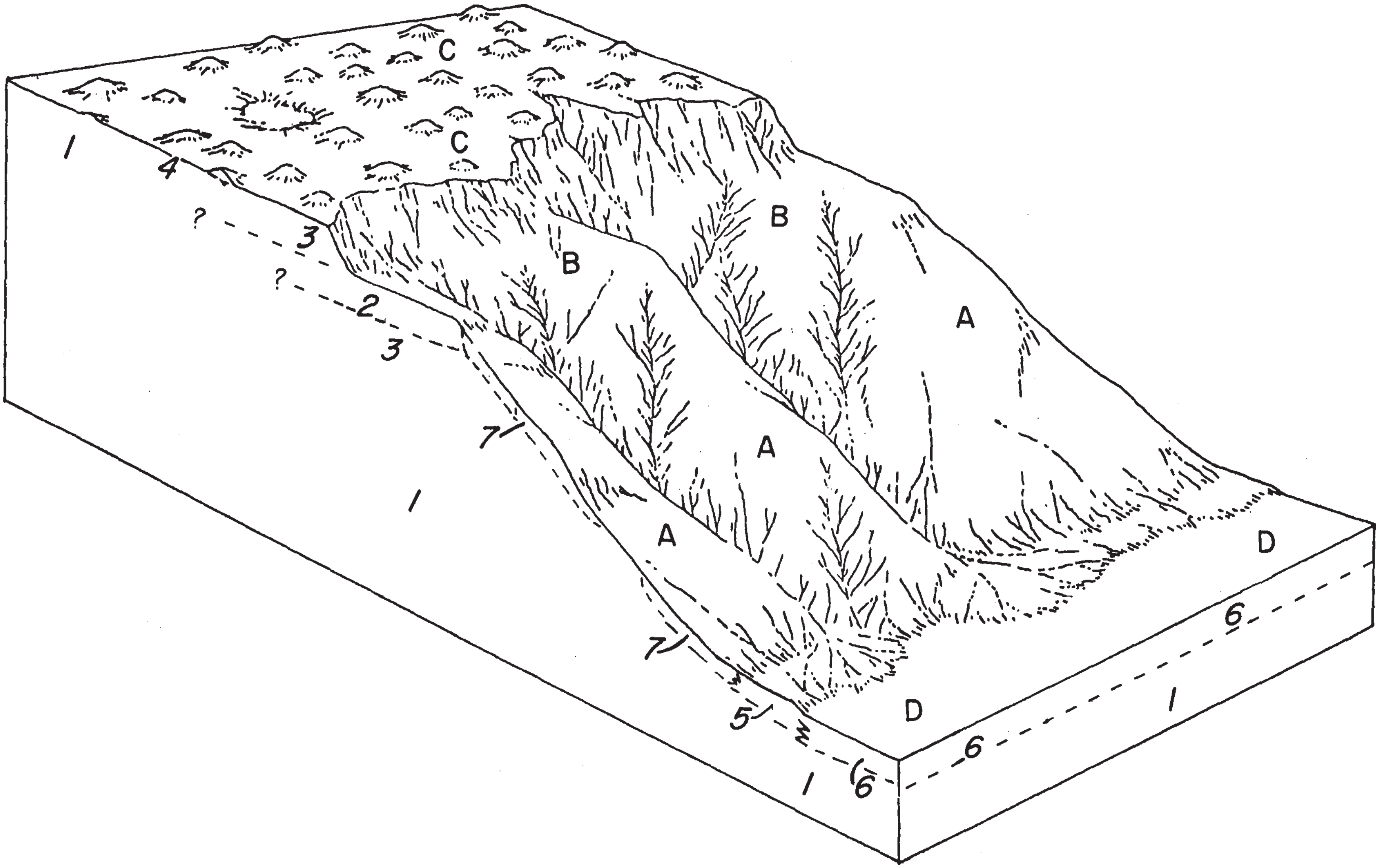


Figure 68. Block diagram of soil-landscape relations and soil stratigraphy in an area of Bluepoint complex, Bluepoint sand, and Onite-Pintura complex. A = Bluepoint sand (Fillmore surface). B = Bluepoint complex (Fort Selden surface) on structural bench. C = Onite-Pintura complex (lower La Mesa surface). D = Soils of the Rio Grande flood plain (not included in this study).

1 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium) and soils. 2 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium), gravelly. 3 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium), nongravelly. 4 = Dune sediments. 5 = Fillmore alluvium. 6 = Rio Grande deposits (late Quaternary river alluvium). 7 = Fillmore colluvium.

Table 88. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Tencee complex, eroded (10C)	Landscape dissection has caused the boundary. Gravelly river sediments beneath soils of unit 10C have been exhumed by erosion and are at the surface on the 13X (downslope) side of the boundary. The topographic boundary is distinct, occurring along the scarp between the nearly level basin floor (unit 10C) and steep ridges of the exhumed gravel (unit 13X).
Kokan-Nickel complex (10W) Weiser-Dalian complex (11LG) Nickel gravelly sandy loam (11R)	Landscape dissection has caused the boundary. Gravelly river sediments, buried beneath soils of units 10W, 11LG and 11R, emerge at the surface on the 13X (downslope) side of the boundary. The topographic boundary is not prominent (since ridge terrain also occurs upslope) but is usually marked by a digitating scarp and steeper slopes.
Bluepoint sand (13Y)	Landscape dissection has caused the boundary. Sandy sediments buried beneath gravel of unit 13X have been exhumed and are at the surface in unit 13Y. The topographic boundary is apparent, occurring between steep ridges of unit 13X and the gentler slopes of unit 13Y.
Onite-Pintura complex (15P)	Landscape dissection has caused the boundary by exhumation of gravel beneath soils of unit 15P. The topographic boundary is distinct, occurring between the nearly level, relict basin floor (unit 15P) and steep ridges of the exhumed gravel (unit 13X). Also, vegetation is much less dense on steep ridges of unit 13X.

131. DALIAN COMPLEX (13G)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
DALIAN	TYPIC TORRIORTHENTS	LOAMY-SKELETAL, CARBONATIC	25
SND-6	ENTISOLS		25
Anthony	Typic Torrifluvents	Coarse-loamy (calcareous)	10
Canutio	Typic Torriorthents	Loamy-skeletal (calcareous)	5
Dalian, sandy-skeletal variant	Typic Torriorthents	Sandy-skeletal, carbonatic	10
Gila	Typic Torrifluvents	Coarse-loamy (calcareous)	5
Glendale	Typic Torrifluvents	Fine-silty (calcareous)	10
Other inclusions (Torriorthents, Paleorthids, Calciorthids)			10

LOCATION, LANDSCAPE, VEGETATION

Soils of this mapping unit occur primarily east and south of the Robledo Mountains. There are also smaller areas west of the northern part of the Dona Ana Mountains. These soils have formed in alluvial-fan sediments derived primarily from limestone and calcareous sandstone, in places with some rhyolite. Elevations range from about 3950 to 4400 feet.

The soils occur mostly on Fillmore terraces and fans with a few small included areas of older surfaces. The Fillmore terraces are inset against older sediments underlying higher surfaces, commonly the Picacho. These older sediments have been very deeply incised, especially along the eastern front of the Robledo Mountains. The Fillmore sediments, in turn, have been trenched by arroyos to depths ranging from about 1/2 to 2 meters, with greatest entrenchment next to the flood plain. Slopes range from 2 to 8 percent.

The soils have been disturbed by cultivation in many places near the flood plain. Native vegetation consists of creosotebush, mesquite, prickly pear, Mormon tea, tarbush, and four-wing saltbush.

TYPICAL PEDONS, PROPERTIES AND RANGES

Most soils are strongly calcareous throughout. Where the sediments contain little or no limestone the soils may be noncalcareous in the upper few cm.

Dalian

A typical pedon of Dalian is described in the Appendix (pedon 66-4). Figure 69 is a photograph of the pedon and its landscape. A table of properties and ranges is given below.

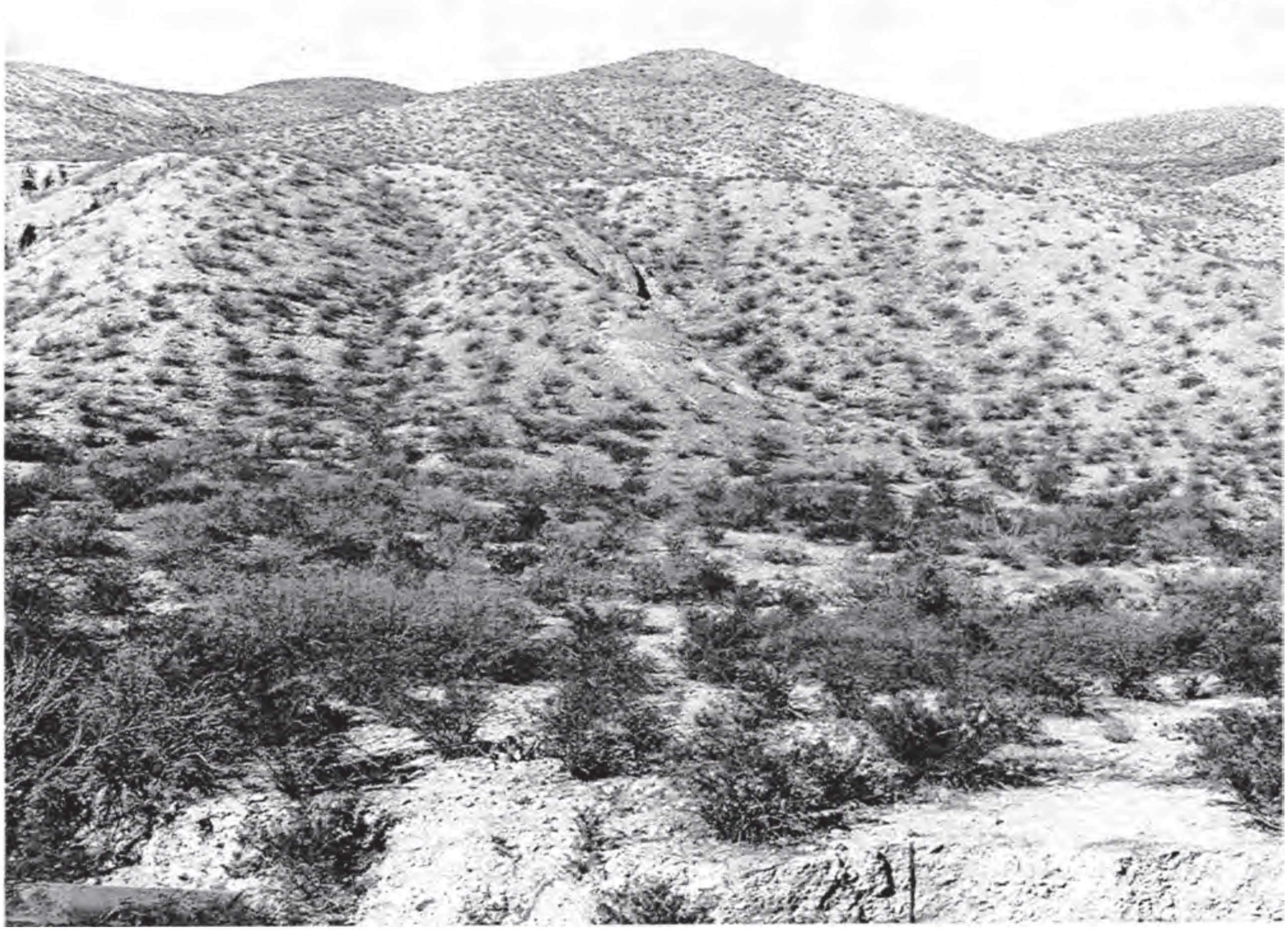


Figure 69. Upper. Landscape of a Typic Torriorthent, Dalian 66-4, on the Fillmore surface. Vegetation is creosotebush, mesquite, and a few prickly pear. Slope is 5 percent.

Lower. Dalian 66-4. Scale is in feet.

Table 89. Typical (underlined) and range in selected properties for major horizons of Dalian

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-4	sl l	0-75	7.5YR- 10YR	6,7	4,5	2-4 3
B	4-13	sl l	0-75	7.5YR- 10YR	6,7 6.5	4,5	3,4
Clca	13-30	sl l	35-75	7.5YR- 10YR	5-7 6.5	4-6	3-5
Control section		sl,l	35-75				

Other. The B horizon is only a few cm thick, is above the carbonate maximum and would be a cambic horizon except that it is too thin. Youngest Dalian soils have no B horizons and no macroscopic horizons of carbonate accumulation.

SND - 6

Materials in active arroyo channels have been observed in only a few places in the study area. Depending upon content of coarse fragments (Orthent-Psamment separation, section 18) the materials would be classified as either Torriorthents or Torripsamments. In this unit most would probably be Torriorthents because of the high content of coarse fragments.

SOIL OCCURRENCE

The anastomosing channels of arroyos cause complex patterns of arroyo channels and the soils adjacent to the channels. Most of the few undisturbed pedons observed have evidence of carbonate accumulation in the form of scattered filaments or grain coatings but the accumulations are too shallow to permit recognition of a cambic horizon.

Torriorthents. The loamy-skeletal DALIAN soils and their sandy-skeletal variant have carbonatic mineralogy, a reflection of the high carbonate content of their very gravelly parent materials. The loamy-skeletal Canutio soils occur where the sediments contain substantial amounts of rhyolite, so that mineralogy is mixed instead of carbonatic.

Entisols. SND-6 occurs in arroyo channels.

Torrifluvents. Anthony, Glendale and Gila soils occur on gentler slopes near the flood plain. In these soils organic carbon either decreases irregularly with depth or remains above 0.2 percent to a depth of 1.25 m. Glendale soils are fine-silty. Anthony and Gila soils are coarse-loamy. Anthony soils average fine sandy loam or sandy loam in the control section; Gila soils average textures of loam, light silt loam, or very fine sandy loam.

Calciorthids and Paleorthids. Calciorthids occur in a few small included remnants of the Leasburg surface and in dissected areas of the Picacho. Paleorthids occur on a few small, stabler areas of the Picacho surface.

SOIL BOUNDARIES

Table 90 gives information about boundaries to major adjacent units. Some of the boundaries are illustrated in figure 70.

Table 90. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Tencee-Upton complex (10L)	The boundary is due to a marked difference in slope between the steep ridge sides (unit 10L) and the more gently sloping terraces (unit 13G) between the ridges. The Fillmore ridge-side slopes are on the 10L side of the boundary whereas the more gently sloping Fillmore terraces are on the 13G side of the boundary. The boundary is topographically prominent since slope of the ridge sides commonly ranges from 25 to 50 percent and the terraces slope from 2 to 8 percent.
Weiser-Dalian complex (11LG)	The boundary is due to a prominent difference in slope between the steep ridge sides (unit 11LG) and the more gently sloping terraces (unit 13G) between the ridges. The topographic boundary is prominent.

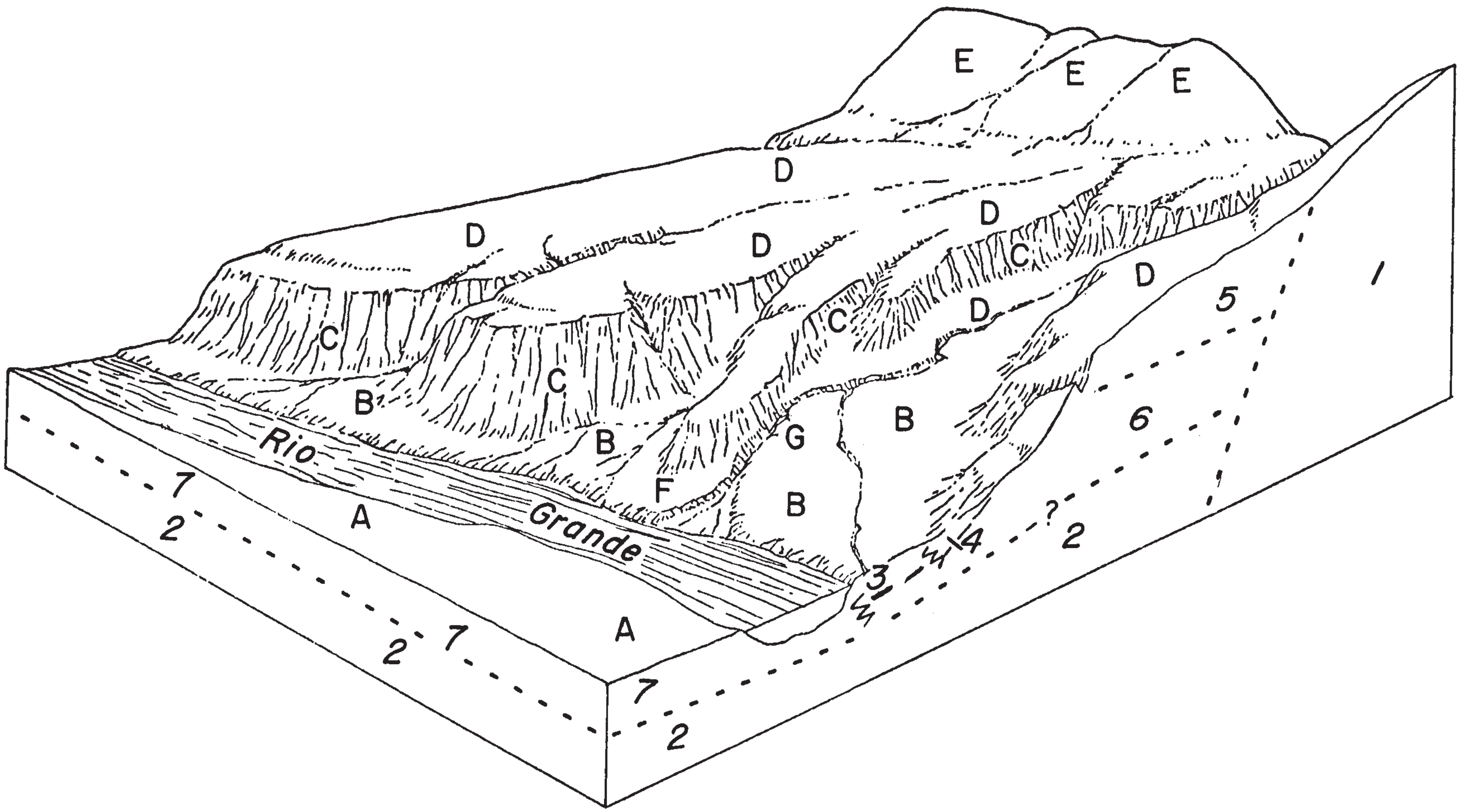


Figure 70. Block diagram of soil-landscape relations and soil stratigraphy in an area of Tencee-Upton complex and Dalian complex, in the vicinity of the Shalam Colony radiocarbon site. Soils of the Rio Grande flood plain not included in this study. A = Soils of the Rio Grande flood plain. B = Dalian complex (Fillmore and arroyo channel surfaces). 3 = Dalian complex (Fillmore ridge side, colluvium). D = Tencee-Upton complex (Picacho surface). E = Torriorthents and sedimentary rock outcrop (mountain slopes and summits). F = Location of charcoal horizons. G = Dalian 66-4.
1 = Bedrock (sedimentary). 2 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium). 3 = Fillmore alluvium. 4 = Fillmore colluvium. 5 = Picacho alluvium. 6 = Picacho river alluvium (ancient river alluvium). 7 = Rio Grande deposits (late Quaternary river alluvium) and soils.

OTHER STUDIES: THE SHALAM COLONY RADIOCARBON SITE

Two charcoal horizons were dated at this site (Ruhe, 1967; section 15). The uppermost was dated at 2850 ± 120 yr B.P. and was beneath a soil developed in very gravelly alluvium. This soil must therefore be less than about 2800 yr old. At the time of sampling the soil surface above the charcoal was disturbed. The upper deposits were traced upstream and a soil was sampled at an undisturbed site (Dalian 66-4).

The location of Dalian 66-4 (fig. 69; table 91) is shown in figure 71, a

* * *

Table 91. Laboratory data for a Typic Torriorthent, Dalian 66-4.

Horizon	Depth	Sand	Silt	Clay	$CaCO_3$ equiv (mm) < 2	$CaCO_3$ equiv (mm) < 0.002	Organic carbon
	cm	pct	pct	pct	pct	pct	pct
A	0-4	64	25	11	19	tr	0.62
Bca	4-13	69	19	12	25	2	0.94
C1ca	13-30	69	18	13	30	2	0.73
C2ca	30-53	75	14	11	30	1	0.47
C3ca	53-79	78	12	10	33	1	0.35
C4	79-109	74	13	13	34	2	0.23
C5	109-140	75	12	13	36	1	0.14
	0-79 1/						

1/ 45 percent coarse fragments by volume; $CaCO_3$ equivalent of 61 percent.

* * *

soil map showing soil distribution in the vicinity. The main evidence of pedogenesis consists of thin carbonate coatings on pebbles in the Cca horizon. This stage I horizon of carbonate accumulation is characteristic of soils of the Fillmore surface. It is also found in soils of the same age at the Gardner Spring radiocarbon site (section 162). The soil is strongly calcareous and contains abundant limestone fragments throughout. Reddish brown B horizons (characteristic of stable soils of this age formed in low-carbonate parent materials) do not occur in these soils. Organic carbon for the fine earth is relatively high, nearly 1 percent in the B horizon. This is perhaps due to the relatively abundant and large vegetation (fig. 69). The plants may have obtained water from anastomosing streams in adjacent arroyo channels.

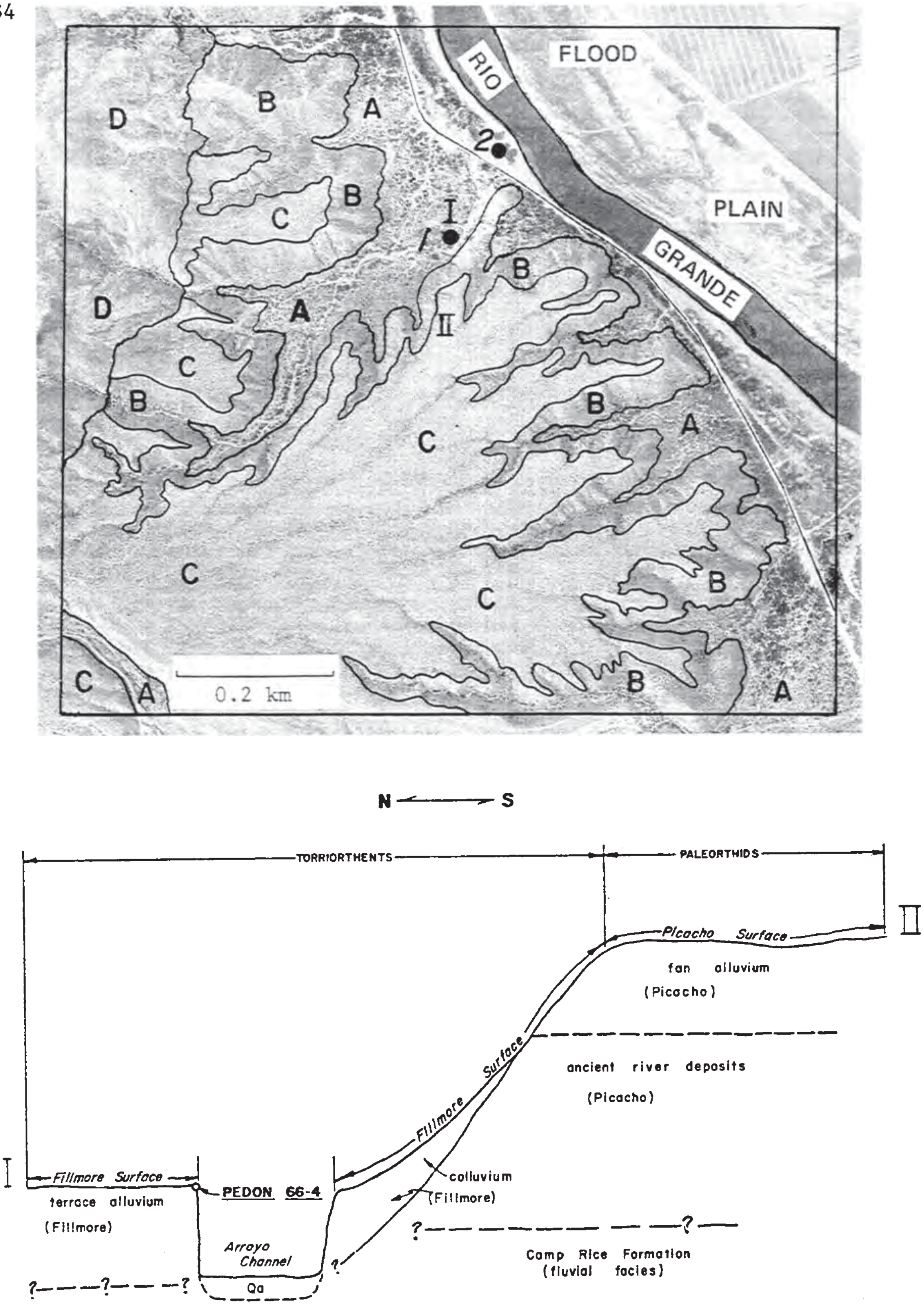


Figure 71. Upper. Map of soils in the vicinity of the Shalam Colony radiocarbon site. A = Dalian-Torriorthent complex (Fillmore and arroyo channel surfaces). B = Dalian very gravelly sandy loam (Fillmore ridge sides). C = Tencee-Upton complex (Picacho surface). D = Torriorthent-rock outcrop (Mountain slopes and summits, undifferentiated). 1 = Dalian 66-4; 2 = dated charcoal horizons. I to II locates cross section.

Lower. Cross section from I to II on the soil map.

132. Soils of the Leasburg surface

Soils of the Leasburg surface have morphology intermediate between weakly developed soils of the Fillmore and strongly developed soils of the Picacho surface. Evidence of illuvial clay is more distinct in certain soils of the Leasburg surface than in soils of the Fillmore. Nongravelly soils of the Leasburg are in stage II of carbonate accumulation whereas soils of the Fillmore are in stage I of accumulation and soils of the Picacho are in stage III. Soils of the Leasburg surface also are a chronological connection to soils of the Pleistocene, being the youngest soils that have formed in part in the Pleistocene. Only scattered small areas of the Leasburg surface are well preserved and have soils that indicate the magnitude of pedogenesis associated with the span of Leasburg time. The largest of these is in the vicinity of Fort Selden.

133. BUCKLEBAR COMPLEX (14P)

MAPPING UNIT COMPOSITION

Series	Subgroup	Family Criteria	Percentage of Mapping Unit
BUCKLEBAR	TYPIC HAPLARGIDS	FINE-LOAMY	30
MIMBRES	TYPIC CAMBORTHIDS	FINE-SILTY	25
PAJARITO	TYPIC CAMBORTHIDS	COARSE-LOAMY	20
Onite	Typic Haplargids	Coarse-loamy	10
Other inclusions (Torriorthents, Calciorthids, Paleorthids)			15

LOCATION, LANDSCAPE, VEGETATION

The soils occur in the vicinity of Fort Selden. They have formed in parent materials of mixed lithology but with only minor amounts of allogenic carbonate. Origin of the parent materials has not been precisely determined. It appears likely that the soils may have formed in sediments that were derived from higher slopes to the east, but the sediments may represent a flood plain deposit. Elevations range from about 4000 to 4100 feet.

The Leasburg surface occurs primarily as two level or nearly level "flats" that differ only a few feet in elevation. Bordering the flats are gentle to moderate slopes leading to the flood plain of the Rio Grande. Occasional gullies have cut the sediments of these slopes. Much of the area in the flats has been leveled to some degree for irrigation.

Most of the area is under cultivation. In a few undisturbed places, the native vegetation is preserved and commonly consists of creosotebush, snakeweed, and mesquite. Scattered clumps of tobosa occur on the Mimbres soils where they are not under cultivation. Vegetation on the gravelly soils around the edges of the mapping unit consists of creosotebush and mesquite.

TYPICAL PEDONS, PROPERTIES AND RANGES

These soils are commonly underlain by buried soils at depths of from one to several m. The buried soils usually rest on gravel or sand.

Bucklebar

See Appendix (pedon 59-7) for description of Bucklebar.

Mimbres

A typical pedon of Mimbres is described in the Appendix (pedon 66-14). Figure 72 is a photograph of the pedon and its landscape. Table 92 gives some of the properties and ranges.

Table 92. Typical (underlined) and range in selected properties for major horizons of Mimbres.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-10	l,_cl_ scl	0-1	_7.5YR_	5,_6_	3.5-5 _4_	2-4 _3_
B2	10-43	_cl_ scl	0-1	_7.5YR-_ 10YR	5,_6_	3.5-5 _4.5_	_3_,4
Control section		cl	0-1				

Other. These soils are calcareous throughout. Most of them have been plowed and moved to some degree for irrigation. The pedon described occurred in a preserved area along the railroad right-of-way. Soils in the plowed area have Ap horizons of varying thickness, with most common textures being sandy clay loam and clay loam.

Pajarito

A typical pedon of Pajarito is described in the Appendix (pedon 61-9). Figure 73 is a photograph of the pedon and its landscape. Table 93 gives some of the properties and ranges.

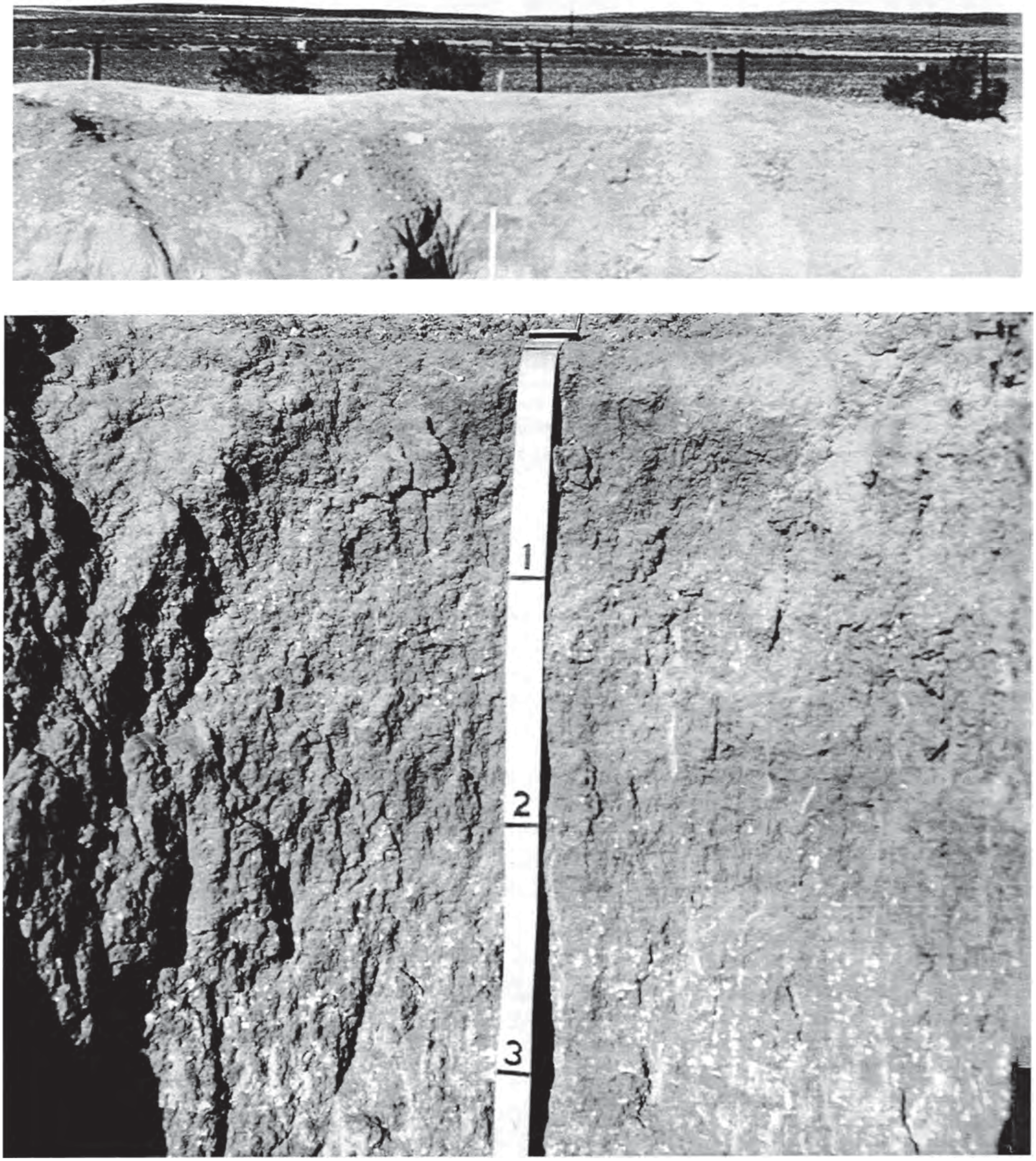


Figure 72. <u>Upper</u>. Landscape of a Typic Camborthid, Mimbres phase 66-14, on the Leasburg surface. In nearby uncultivated areas of the railroad right-of-way, the vegetation is tobosa, creosotebush, and mesquite. The area is level. The sampled pedon was covered and preserved by the spoil bank.

<u>Lower</u>. Mimbres phase 66-14. Stage II carbonate nodules are distinct. Scale is in feet.

Figure 73. Upper. Landscape of a Typic Camborthid, Pajarito 61-9, on the Leasburg surface. Vegetation is mainly creosotebush, with a few snakeweed. The area is very nearly level, but is on the edge of a shoulder that slopes slightly to the west.

Lower. Pajarito 61-9. Scale is in feet.

Table 93. Typical (underlined) and range in selected properties for major horizons of Pajarito.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-15	sl	0-5	7.5YR-	5,6	4,5	2-4
B	15-84	sl	0-5	5YR- 7.5YR 6.5YR	5-7 6.5	4-6 5	3,4
C	84-104	ls sl	0-5	7.5YR- 8YR	6,7 6.5	5,6	2-4
Control section		sl	0-5				

Other. These soils are usually calcareous throughout but are noncalcareous in the upper several cm in a few spots. The soils have been plowed over much of the area but the described soil had not been plowed.

SOIL OCCURRENCE

Since most soils of this mapping unit are under cultivation, upper horizons have been mixed in many places. However, some soils are quite well-preserved along the railroad right-of-way (fig. 72). Mimbres soils are exposed along the northern part of the railroad cut and grade to the Bucklebar soils, which are exposed in the southern part of the cut.

Camborthids. PAJARITO soils occur mainly in the western part of the unit, whereas MIMBRES soils are located mainly in the central and north central parts.

Haplargids. The fine-loamy BUCKLEBAR soils and coarse-loamy Onite soils occur mainly in the southern and eastern part of the mapping unit.

Calciorthids and Paleorthids. The loamy-skeletal Nickel and sandy-skeletal Caliza soils (Calciorthids) occur around the edges of the mapping unit near the flood plain. Simona soils (Paleorthids), also occur in these areas.

Torriorthents. The sandy-skeletal Arizo soils and Canutio, loamy subsoil variant, occur along margins of the unit next to the flood plain.

SOIL BOUNDARIES

Table 94 gives information on boundaries to major adjacent soils. Figure 74 illustrates some of the boundaries.

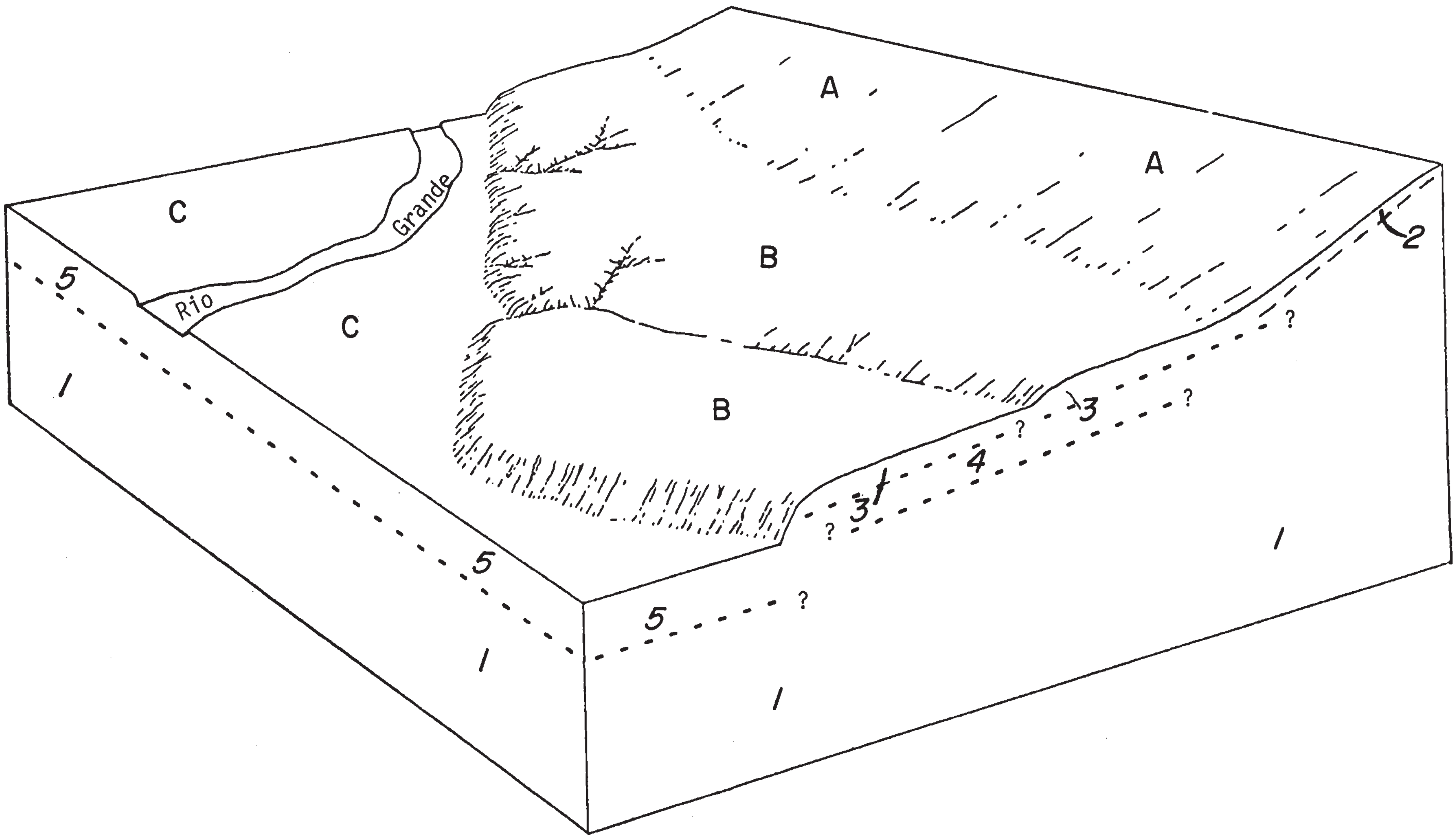


Figure 74. Block diagram of soil-landscape relations and soil stratigraphy in an area of Bucklebar complex (in the vicinity of Fort Selden). A = Bluepoint sand. B = Bucklebar complex. C = Soils of the Rio Grande flood plain (not mapped).
1 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium). 2 = Fillmore and Fort Selden colluvium and alluvium and soils. 3 = Leasburg alluvium and soils. 4 = Picacho river alluvium (ancient river alluvium). 5 = Rio Grande deposits (late Quaternary river alluvium).

Table 94. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Bluepoint complex (13X)	Landscape dissection has caused the boundary. Low-gravel sediments above very gravelly materials have been eroded away, so that gravel in soils of unit 13X is at or near the surface.
Bluepoint sand (13Y)	The boundary has been caused by a younger alluvium and geomorphic surface (Fillmore) in unit 13Y. Topographically the boundary is distinct, occurring along the margins between the level or nearly level 14P unit, and the 2 percent slopes of the 13Y unit.

OTHER STUDIES: TWO CAMBORTHIDS ON THE LEASBURG SURFACE

Additional studies in this unit concern Pajarito 61-9 and Mimbres 66-14. Figure 73 shows Pajarito 61-9 and landscape. The pedon has a cambic horizon since the carbonate maximum is below 25 cm. Data are in table 95.

* * *

Table 95. Laboratory data for two Typic Camborthids.

Horizon	Depth	Sand 1/	Silt 1/	Clay 1/	Carbonate	Moist bulk density	Organic carbon
	cm	pct	pct	pct	pct	g/cc	pct
Pajarito 61-9							
A	0-5	81	10	9	3.2		0.17
A3ca	5-15	79	11	10	4		0.19
B1ca	15-28	78	12	10	5		0.21
B21ca	28-43	80	9	11	6		0.14
B22ca	43-64	87	9	4	5		0.18
B3ca	64-84	86	7	7	2.8		0.10
C	84-104	88	7	5	0.8		0.07
2K1b	104-127	87	8	5	7		0.07
2K2b	127-152	64	26	10	20		0.08
Mimbres 66-14							
A	0-10	61	19	20	4	1.31	0.59
B21ca	10-28	40	23	37	12	1.46	0.40
B22ca	28-43	49	19	32	8		0.27
B21cab	43-69	45	22	33	5	1.43	0.20
B22cab	69-91	32	38	30	11	1.33	0.20
B31cab	91-114	39	38	23	11	1.40	0.19
B32cab	114-142	49	28	23	11		0.16
Bcab2	142-173	64	18	18	5	1.62	0.11

1/ Carbonate-free basis.

* * *

The sampling site of Pajarito 61-9 has been obliterated by machinery. The pedon occurred about 0.4 mi (0.6 km) east of the Fort Selden ruins, on the western margin of the easternmost of two "flats" that constitute the Leasburg remnant. Pajarito 61-9 formed in low-gravel sandy sediments. It is similar in this respect to Bluepoint soils of the Fillmore surface, but is more strongly developed. The B horizon of Pajarito 61-9 has subangular blocky structure and is also a stage II carbonate horizon with carbonate nodules. The carbonate maximum by laboratory analysis occurs in the B horizon and coincides with the maximum morphological expression of carbonate (nodules) in the profile. The B horizon also contains a slight silicate clay maximum (table 95) and has scattered reddish brown peds suggesting slight silicate clay accumulation. Pajarito 61-9 is strongly calcareous throughout; illuviation of silicate clay may not be a present feature of pedogenesis (section 78).

The buried K horizon (table 95) has been observed in a number of places, including the northern end of the railroad cut in which Mimbres 66-14 (following section) was sampled. In places an argillic horizon is also present above the K horizon. The buried soil may be associated with a late phase of the Picacho surface.

The sampling site for Mimbres 66-14 (fig. 73) occurs along the railroad right-of-way. Carbonate morphology and a few pebbles at the base of the B22ca horizon along the cut suggest that the material from 0 to 43 cm is a younger deposit that buried the horizons beneath. The A horizon is well preserved beneath the spoil. There is a silicate clay increase, but the required amount of oriented clay for an argillic horizon is thought not to be present because of the carbonate content (table 95). The moderately low bulk density of the silty material (table 95) is typical (section 98). The decrease in bulk density from the upper to the lower B, and the greater bulk density of the buried B are also typical.

Morphology of the carbonate accumulation (stage II, nodular) is similar to that of Pajarito 61-9, although more carbonate is present in Mimbres 66-14. The carbonate C-14 age was obtained for carbonate in the B22cab horizon. The age (6150 years B.P.) does not conflict with the proposed age of 8-15 kyrs for soils of the Leasburg surface, since the carbonate would have been emplaced after soil development started.

134. Soils of the Fillmore and Picacho surfaces

These areas have been so strongly dissected that only discontinuous remnants of the Picacho surface have been preserved on crests of narrow ridges. Ridge sides are of Fillmore age and grade to Fillmore terraces between the remnants. Minor remnants of the Leasburg surface border the Picacho remnants in a few places. See section 137 for a general discussion of the genetic significance of soils of the Picacho surface. Soils of two mapping units occur on this complex of surfaces--the Kokan-Nickel complex and the Weiser-Dalian complex.

135. KOKAN-NICKEL COMPLEX (10W)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
CALIZA	TYPIC CALCIORTHIDS	SANDY-SKELETAL	20
KOKAN	TYPIC TORRIORTHENTS	SANDY-SKELETAL	20
NICKEL	TYPIC CALCIORTHIDS	LOAMY-SKELETAL	15
Canutio	Typic Torriorthents	Loamy-skeletal (calcareous)	10
Canutio, loamy subsoil variant	Typic Torriorthents	Coarse-loamy (calcareous)	5
Delnorte	Typic Paleorthids	Loamy-skeletal, shallow	5
Rilloso	Typic Calciorthids	Sandy	5
SND-6	Entisols		10
Yturbide	Typic Torriorthents	Sandy	5
Other inclusions (Haplargids, Calciorthids, Torriorthents)			5

LOCATION, LANDSCAPE, VEGETATION

These soils occur primarily on the eastern side of the valley border, west of the Dona Ana Mountains, with smaller areas in the southern part of the study area. The soils have formed in alluvial-fan sediments derived mainly from rhyolite, in places with andesite, monzonite, and rounded gravel of mixed lithology. Elevations range from about 4000 to 4400 feet.

Most areas have been strongly dissected by arroyos; long, narrow ridges are prominent. Narrow terraces are inset against some of the ridge remnants. Waterways and gullies extend laterally from the arroyos and have incised the ridges in places. In some areas arroyo dissection has been so severe that the original depositional slope has been substantially altered even on ridge crests. Saddles are common in such areas. Longitudinal slopes along ridge crests range from 2 to 5 percent; transverse slopes of ridge sides range from 5 to 35 percent.

Vegetation is primarily creosotebush; there are a few prickly pear and mesquite.

TYPICAL PEDONS, PROPERTIES AND RANGES

Most soils are calcareous throughout. In places the B horizon has a very thin (2 to 5 cm) horizon of 5YR hue in the upper part. Some of the pebble tops are stained reddish brown and in places are noncalcareous.

Caliza

A typical pedon of Caliza is described below. The location is the NE 1/4 Sec. 2, T21S, R1E, north side of arroyo. Figure 75 is a photograph of the pedon and its landscape. A table of properties and ranges follows the description.

Figure 75. Upper. Landscape of a Typic Calciorthid, Caliza very gravelly sandy loam, on a dissected Picacho remnant. Vegetation is creosotebush. Slope is 3 percent.

Lower. Caliza very gravelly sandy loam. Scale is in feet.

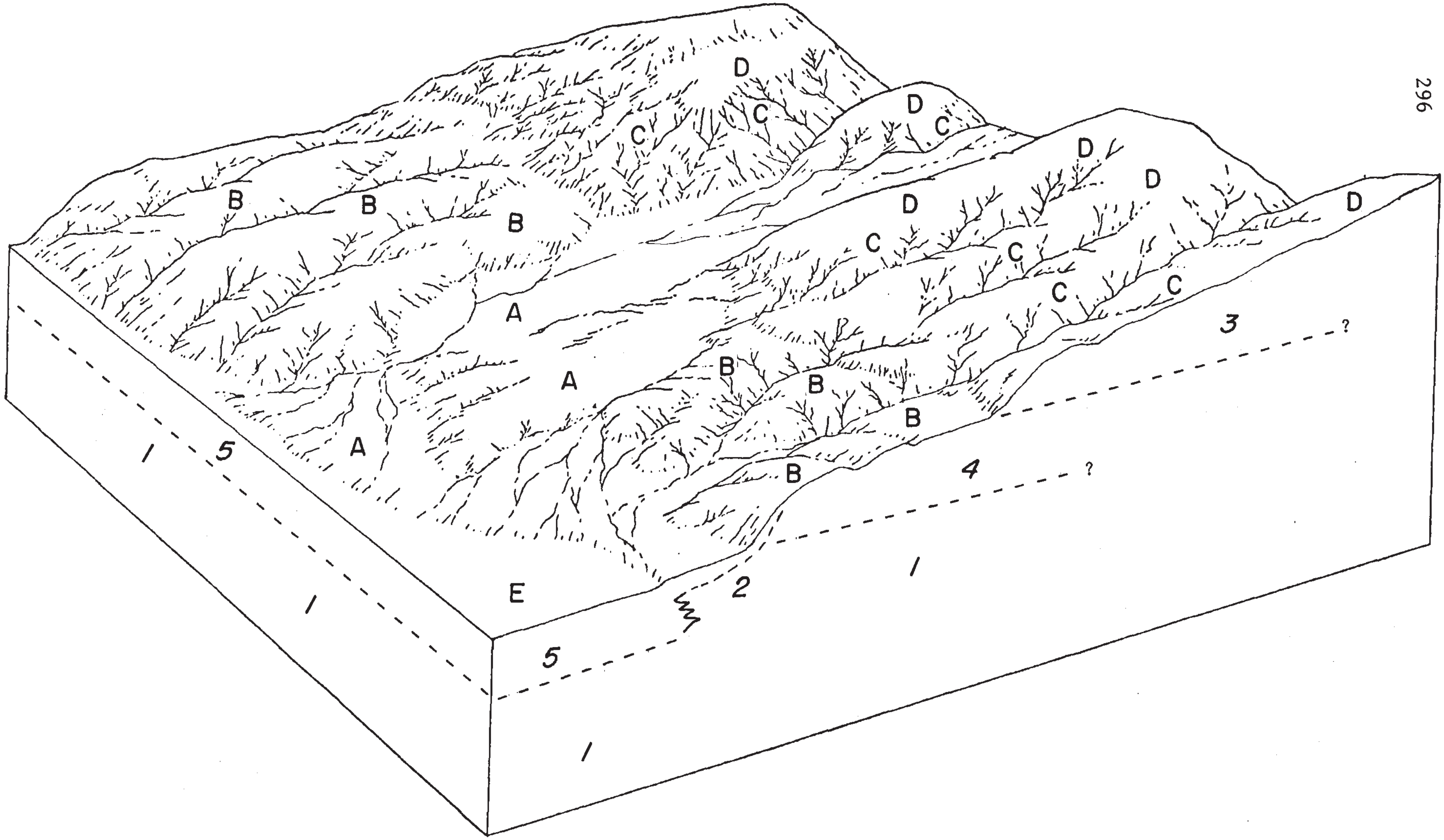


Figure 76. Block diagram of soil-landscape relations and soil stratigraphy in an area of Arizo complex, Bluepoint complex, Kokan-Nickel complex, and Nickel complex. A = Arizo complex (Fillmore and arroyo channel surfaces). B = Bluepoint complex (Leasburg surface on ridge crests; Fillmore surface on ridge sides) on structural bench. C = Kokan-Nickel complex (Fillmore and Picacho surfaces). D = Nickel complex (Picacho surface). E = Soils of the Rio Grande flood plain (not included in this study).
1 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium). 2 = Fillmore alluvium and soils. 3 = Picacho alluvium and soils. 4 = Picacho river alluvium (ancient river alluvium). 5 = Rio Grande deposits (late Quaternary river alluvium).

Soil surface. Desert pavement of rhyolite pebbles; some pebbles partly coated with carbonate; discontinuous layer of loose reddish sand occurs between and beneath pebbles, and rests on the A horizon.

A 0-3 cm. Pinkish gray (7.5YR 6/2, dry) dark brown (7.5YR 4/2, moist) very gravelly sandy loam; moderate medium platy; soft; upper 1/8 inch vesicular; effervesces strongly; abrupt smooth boundary.

Bca 3-18 cm. Pinkish gray (7.5YR 6.5, dry) and brown (7.5YR 4.5/2, moist) very gravelly sandy loam; massive to single grain; soft to loose; roots common; thin carbonate coatings on pebbles, mainly on undersides; some pebble tops carbonate-free; effervesces strongly; clear smooth boundary.

K2 18-56 cm. Pinkish white (7.5YR 8/2, dry), pinkish gray (7.5YR 7/2, moist), and pinkish gray (7.5YR 7/2, dry), brown (7.5YR 5/4, moist) very gravelly sandy loam; massive; hard when removed; very hard in place; few roots; thick carbonate coatings on pebbles and sand grains; effervesces strongly; clear wavy boundary.

K3 56-86 cm. Pinkish white (7.5YR 8/2, dry), pinkish gray (7.5YR 7/2, moist), and pinkish gray (7.5YR 7/2, dry), brown (7.5YR 5/4, moist) very gravelly loamy sand; massive and single grain; soft and loose; few roots; discontinuous carbonate coatings on pebbles; few carbonate filaments on material in pebble interstices; effervesces strongly; clear wavy boundary.

Cca 86-127 cm. Light brown (7.5YR 6/4, dry) or brown (7.5YR 4/4, moist) very gravelly sand; massive; soft, very friable; no roots; a few discontinuous lenses, 1 to 5 cm thick, of very gravelly loamy sand to light sandy loam; effervesces strongly.

Table 96. Typical (underlined) and range in selected properties for major horizons of Caliza.

Horizon	Depth cm	Particle Size <2mm	Particle Size >2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-3	sl ls	0-70	7.5YR- 10YR	5-7 6	3.5-5 4	2-4
B	3-18	sl	25-75	5YR- 10YR 7.5YR	5-7 6.5	4,5 4.5	2-4
K2	18-56	sl,ls	35-75	5YR- 10YR 7.5YR	7-9 8	5-7	2-4
C	86-127	s ls	35-75	7.5YR- 10YR	5-7 6	4-6	3,4
Control section		s,ls	35-75				

Other. Depth to the calcic horizon (the K2 horizon in the description) is usually 10 to 25 cm, ranging from 2 to 50 cm. Principle variation in the

K horizon is in its degree of cementation, which in places is cemented, but not enough for a petrocalcic horizon. Commonly, the material softens sufficiently when moistened that it can be field-textured (very gravelly sandy loam). In places there are a few zones of 5YR hue in its upper part. The K horizon thins markedly towards the ridge sides, where the Caliza soils grade to Torriorthents.

SOIL OCCURRENCE

Calciorthids. The Calciorthids occur only on stablest ridge crests, where part of the Picacho surface and its soils have been preserved. The sandy-skeletal CALIZA and loamy-skeletal NICKEL soils are dominant and their occurrence is dependent on the texture of the control section. The sandy Rilloso soils average from 15 to 35 percent gravel in their control section. The coarse-loamy Whitlock soils average sandy loam textures.

Torriorthents. These soils occur on ridge sides; in saddles of ridge crests where divides have been lowered; on narrow Fillmore terraces and on the small Leasburg remnants. The sandy-skeletal Kokan occurs on sides of ridges. The sandy-skeletal Arizo; the sandy Yturbide; and Canutio, coarse-loamy variant differ only in particle size of their control sections.

Entisols. SND-6 occurs in arroyo channels.

Haplargids and Paleorthids. Paleorthids occur on stablest Picacho remnants where sediments are very gravelly. A few Haplargids occur on stabler areas near the Dona Ana Mountains.

Haplargids, dissected. Occur on some ridge sides where buried soils have been beveled and covered by a few inches of colluvium.

SOIL BOUNDARIES

Table 97 gives information on boundaries to major adjacent units.

Table 97. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Nickel complex (11R)	Landscape dissection in unit 10W has caused the boundary; calcic horizons formerly present in the 10W unit have been truncated in many places and in these areas the soils are mainly Torriorthents. Topographically the boundary is distinct, changing quite abruptly from interfluves that are nearly level transversely (unit 11R) to narrow ridges (unit 10W).
Arizo complex (13F)	Usually the boundary has been caused by a marked increase in slope; the soil boundary was drawn along the contact between the steep ridge sides (unit 10W) and gently sloping terraces (unit 13F). The boundary is topographically prominent because soils of 13F unit occur on low terraces inset against the much higher ridges of unit 10W.
Bluepoint sand (13Y)	The boundary has been caused by a younger alluvium and geomorphic surface (usually Fillmore, in places Ft. Selden) in unit 13Y. The topographic boundary is usually distinct because the 13Y soils are either inset below ridges of 10W unit or overlap them along upslope margins.

136. WEISER-DALIAN COMPLEX (11LG)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
DALIAN	TYPIC TORRIORTHENTS	LOAMY-SKELETAL, CARBONATIC	25
JAL	TYPIC CALCIORTHIDS	COARSE-LOAMY, CARBONATIC	15
WEISER	TYPIC CALCIORTHIDS	LOAMY-SKELETAL, CARBONATIC	30
Canutio, loamy subsoil variant	Typic Torriorthents	Coarse-loamy (calcareous)	10
Dalian, sandy skeletal variant	Typic Torriorthents	Sandy-skeletal, carbonatic	10
SND-6	Entisols		5
Other inclusions (Paleorthids)			5

LOCATION, LANDSCAPE, VEGETATION

The soils occur in scattered small areas west of the Dona Ana Mountains and east and south of the Robledo Mountains. The soils have formed in alluvial-fan and terrace sediments derived primarily from limestone and calcareous sandstone, in places with smaller amounts of shale and igneous rocks such as rhyolite. Elevations range from about 4000 to 4400 feet.

Ridges are prominent; the sediments have been strongly dissected by arroyos. Side waterways and gullies extend laterally from arroyos and have incised the ridges. Slopes along ridge crests range from about 2 to 5 percent; slopes of ridge sides range from 5 to 50 percent.

Vegetation consists mostly of creosotebush, in places with mesquite, prickly pear, and whitethorn.

TYPICAL PEDONS, PROPERTIES AND RANGES

These soils are strongly calcareous throughout. They are in thick deposits with no bedrock within many meters, although some carbonate cementation occurs in places.

Dalian

See section 131 for a description and table of ranges of properties.

Jal

See section 173 for a description and table of ranges of properties.

Weiser

A typical pedon of Weiser is described below. The location is the SW 1/4 Sec. 36, T22S, R1W, north bank of arroyo. A table of properties and ranges follows the description.

Soil surface: Between vegetation the soil surface is nearly 100 percent covered with coarse fragments, mostly limestone, with a few reddish sandstone. Most of the fragments are 1 to 2 cm in diameter, ranging up to 15 cm in diameter. A few fragments are partly coated with carbonate.

Aca 0-4 cm. Pinkish gray (7.5YR 7/2, dry) or brown (7.5YR 5/3, moist) very gravelly heavy sandy loam; weak medium and coarse platy; soft; no roots except below plants; thin, mostly continuous carbonate coatings on pebbles, with some of the larger pebbles having carbonate-free tops; effervesces strongly; abrupt smooth boundary.

Bca 4-16 cm. Pinkish gray (7.5YR 7/3, dry) or brown (7.5YR 5/3, moist) very gravelly heavy sandy loam; massive and weak fine and very fine crumb; soft; thin carbonate coatings on pebbles; few roots; effervesces strongly; clear wavy boundary.

K21 16-37 cm. Fine earth is pinkish gray (7.5YR 7/2, dry) or brown (7.5YR 5/3, moist), with grain coatings of pinkish white (7.5YR 8/2, dry) or pinkish gray (7.5YR 7/3, moist); very gravelly sandy loam; massive; generally soft but some parts are weakly carbonate-cemented and slightly hard; very few roots; pebbles continuously coated with carbonate and there are some weakly cemented clusters of pebbles; effervesces strongly; clear wavy boundary.

K22 37-64 cm. Fine earth is pinkish gray (7.5YR 7/3, dry) or brown (7.5YR 5/3, moist) very gravelly sandy loam; massive; soft; very few roots; carbonate coatings on pebbles; the coatings are thinner than above and there is less cementation; effervesces strongly; clear wavy boundary.

C1ca 64-80 cm. Light brown (7.5YR 6/4, dry) or dark brown (7.5YR 4/4, moist) very gravelly light sandy loam; massive; slightly hard; thin, discontinuous carbonate coatings on pebbles; very few roots; effervesces strongly; clear wavy boundary.

C2 80-106 cm. Light brown (7.5YR 6/4, dry) or dark brown (7.5YR 4/4, moist) very gravelly sand; massive; soft; very few roots; some pebbles have thin, discontinuous carbonate coatings; effervesces strongly; clear wavy boundary.

C3 106-146 cm. Light reddish brown (5YR 6/3, dry) or reddish brown (5YR 4/4, moist) very gravelly sandy loam; massive; soft and slightly hard; no roots; effervesces strongly; abrupt wavy boundary.

2C4 146-170 cm. Light reddish brown (6YR 6.5/3, dry) or reddish brown (6YR 5/3, moist) sandy clay loam; moderate medium and coarse subangular blocky; hard; no roots; a few fine carbonate filaments, 1 to 5 mm long; effervesces strongly.

Table 98. Typical (underlined) and range in selected properties for major horizons of Weiser.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-4	sl	10-75	7.5YR- 10YR	5-7 7	4,5	2-4 3
B	4-16	sl	10-75	7.5YR- 10YR	5-7 7	4,5	3.4
K2	16-64	sl	35-75	7.5YR- 10YR	6-9 8	5-8 7	3,4
C	64-146	ls,s	35-75	5YR- 10YR 7.5YR	5-7 6	3.5-5 4	3,4
Control section		sl	35-75				

Other. Depth to the calcic horizon (K2 horizon in the description) ranges from 10 to 40 cm. The K2 horizons in some pedons are discontinuously cemented but not enough for petrocalcic horizons.

SOIL OCCURRENCE

Soil occurrence is determined by landscape position and texture. Calciorthids, and in places Paleorthids, occur on stablest ridge crests, while Torriorthents occur on very narrow, truncated ridge crests and on ridge sides.

Calciorthids. WEISER soils, loamy-skeletal, are dominant on ridge crests. JAL soils, coarse-loamy, occur in occasional low-gravel spots on the ridge crests.

Torriorthents. DALIAN soils, loamy-skeletal, occur on ridge sides, on some of the very narrow ridge crests, and along margins of arroyos. Canutio, loamy subsoil variant, occurs on ridges and along channel margins where the 25 to 100 cm control section averages less than 35 percent by volume of coarse fragments.

Entisols. SND-6 occurs in arroyo channels.

Paleorthids. Paleorthids occur only on few spots on stablest ridges of the Picacho surface, and where the sediments are very gravelly.

SOIL BOUNDARIES

Table 99 gives information on boundaries to major adjacent soils.

Table 99. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Tencee-Upton complex (10L)	Commonly, the boundary has been caused by a younger alluvium and geomorphic surface (Leasburg) in unit 11LG. In places the boundary is caused by landscape dissection. Usually the boundary is distinct because the 11LG soils occur on a lower surface than do the 10L soils, or occur in strongly dissected areas adjacent to less dissected areas of unit 10L.
Dalian complex (13G)	Usually the boundary has been caused by a prominent increase in slope; the soil boundary was drawn along the contact of the lower margin of the steep ridge sides (unit 11LG) and the gently sloping terraces (unit 13G). Topographically the boundary is prominent because low terraces of unit 13G are inset against higher ridges of unit 11LG.
Bluepoint complex (13X)	The boundary has been caused by landscape dissection. Rounded gravel, buried beneath sediments of unit 11LG, emerges at the surface on the 13X side of the boundary. The topographic boundary is fairly distinct, with unit 13X occurring on gentler slopes of structural benches below steeper slopes of unit 11LG.

137. Soils of the Picacho surface.

Large remnants of the Picacho surface occur in places along the valley border. Whereas Entisols are most common on the Fillmore surface and weak Aridisols dominate the Leasburg surface, only prominent Aridisols (Haplargids, Paleargids, Calciorthids, Paleorthids) occur on the Picacho surface.

Soils of the Picacho started their development in late-Pleistocene time and must have formed in part during the major pluvial from 17,000 to 23,000 yr B. P. The Picacho surface is a significant pedogenic marker for several reasons. It marks the first appearance of a prominent argillic horizon in soils of the valley border. Soils of the Picacho surface are morphologically more complex: whereas soils of the Fillmore and Leasburg surfaces have relatively minor horizons of carbonate and clay accumulation, soils of the Picacho surface have much greater maxima of clay or carbonate, or both; and in the Argids, there is often considerable interpenetration of carbonate and silicate clay. The transition from stage III to IV of carbonate accumulation and initial development of the petrocalcic horizon in very gravelly materials is shown in soils of the Picacho surface. The transition from the Argids to the Calciorthids and Paleorthids by soil truncation--illustrating one mode of genesis for these two great groups-- is demonstrated by soils of the Picacho surface. The development of Calciorthids and Paleorthids without truncation--and without formation of an argillic horizon--is also shown (in high-carbonate parent materials) by soils of the Picacho surface.

Four mapping units occur on the Picacho surface:

138. NOLAM COMPLEX (12RR)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
CRUCES, LOAMY-SKELETAL VARIANT	PETROCALCIC PALEARGIDS	LOAMY-SKELETAL, SHALLOW	35
NOLAM	USTOLLIC HAPLARGIDS	LOAMY-SKELETAL	25
Casito	Petrocalcic Ustollic Paleargids	Loamy-skeletal, shallow	5
Delnorte	Typic Paleorthids	Loamy-skeletal, shallow	5
Monterosa	Ustollic Paleorthids	Loamy-skeletal, shallow	5
Nickel	Typic Calciorthids	Loamy-skeletal	5
Terino	Petrocalcic Ustollic Paleargids	Loamy-skeletal, shallow	10
Other inclusions (Torriorthents, Haplargids, Entisols)			10

LOCATION, LANDSCAPE, VEGETATION

These soils occur east, northeast and southeast of Tortugas Mountain. Parent materials are sediments derived mainly from rhyolite; in the northern part of the area there are small amounts of andesite in the alluvium. Elevations range from about 4300 to 4600 feet.

Large Picacho terraces are the most prominent landscape features in most places. The terraces usually range from about 0.1 to 0.2 mi across and from one-half to one mile long. The terraces are inset against alluvium underlying the Jornada I or Tortugas surfaces. While the soils have been cut by small arroyos and gullies along the terrace margins, central portions of the terraces are relatively stable and level transversely. Longitudinal slopes are about 2 percent.

Vegetation consists mainly of creosotebush, ratany, mesquite, and prickly pear. Whitethorn and snakeweed also occur in places.

TYPICAL PEDONS, PROPERTIES AND RANGES

Cruces, loamy-skeletal variant.

A pedon of Cruces, loamy-skeletal variant is described in the Appendix (pedon 59-16). The pedon is typical except that the laminar horizon is more prominently developed than usual. A table of properties and ranges is given below.

Table 100. Typical (underlined) and range in selected properties for major horizons of Cruces variant.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-4	sl l	0-75	5YR- 7.5YR	4-6	3-5 4.5	2-4
B2t	4-33	sl, scl	35-75	2.5YR- 5YR	4-6	3-5 4	4-6
K2m	33-47	--	--	7.5YR- 10YR	6-9	5-8 7	2-4 3
Cca	111-120	ls, s	35-75	7.5YR- 10YR	5-7 6	4-6 5	3,4
Control section		scl, sl	35-75				

Other. Laminar horizons are usually single and in places are absent. Where the carbonate maximum does not qualify as a petrocalcic horizon these soils grade to the Nolam soils. These soils are usually noncalcareous in the upper one to several dm but some pedons are calcareous throughout.

Nolam

A typical pedon of Nolam is described in section 175. A table of properties and ranges is given below.

Table 101. Typical (underlined) and range in selected properties for major horizons of Nolam.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-5	sl	15-75	5YR- 7.5YR	5,6	4,5	2-4
B2t	5-43	scl cl	35-75	2.5YR- 5YR	4-6 5	3,4	4-6
K2	43-61	sl	10-75	7.5YR- 10YR	6-9 8	5-8 7	3,4
C	132-180	ls s sl	10-75	7.5YR-	5,6	4,5	3,4
Control section		scl,cl	35-75				

Other. Depth to the calcic horizon (the K2 horizon in the description) ranges from 25 to 75 cm. These soils are noncalcareous to depths ranging from about 10 to 75 cm. Carbonate cementation occurs in the K horizons of some pedons, but not enough for a petrocalcic horizon.

SOIL OCCURRENCE

Soil occurrence in this mapping unit is dependent largely on gravel content and landscape stability.

Paleargids. The Petrocalcic Paleargids, CRUCES, LOAMY-SKELETAL VARIANT, are dominant in stablest areas. Their Ustollic analogues, Terino soils, occur mostly in the eastern part of the unit where content of coarse fragments is particularly high. Casito soils, also Petrocalcic Ustollic Paleargids, are found in slightly truncated positions near drainageways and interfluve shoulders. Casito soils are similar to Terino soils except that all subhorizons of the argillic horizon contain some authigenic carbonate in the form of thin pebble coatings or filaments. Not enough carbonate has accumulated to completely mask the argillic horizon, however. Remnantal parts are preserved as red or reddish-brown fine earth between the pebbles.

Haplargids. NOLAM soils occur in places where the petrocalcic horizon has not yet developed. Nolam soils have calcic horizons that are commonly cemented in part, but not enough for petrocalcic horizons. There is enough gravel in the control section to meet the greater than 35 percent by volume requirement. Commonly the gravel content in the horizon of carbonate accumulation is somewhat lower than in that of adjacent Paleargids. The coarse-loamy Onite and fine-loamy Berino soils occur almost wholly in one large area northeast of Tortugas Mountain.

Paleorthids. The loamy-skeletal, Typic Paleorthids, Delnorte soils, are most common in places on the Picacho remnants where truncation has been strongest, in slight drainageways and along the terrace shoulders. These soils are usually calcareous throughout. All or nearly all evidence of any Bt horizon has been masked by carbonate, removed by truncation, or mixed by soil biota. Monterosa soils, Ustollic Paleorthids, occur in similar places but have more organic carbon. These places are usually at higher elevations, or are highly gravelly and have more roots.

Torriorthents. The loamy-skeletal Canutio and sandy-skeletal Arizo soils have formed primarily in Fillmore colluvium of ridge sides. Where the colluvium is thin, the soils have formed partly in the underlying Picacho alluvium.

Entisols. SND-6 occurs in arroyo channels.

Calciorthids. The loamy-skeletal Nickel soils occur on shoulders of the terraces. Calcic horizons of these soils usually have some cementation, but not enough for petrocalcic horizons.

SOIL BOUNDARIES

Table 102 presents information on boundaries to major adjacent units. Figure 77 shows boundaries and stratigraphy of some of the units.

Table 102. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Delnorte complex (10R)	Landscape dissection has caused the boundary. Both soils, in most places, occur on the same geomorphic surface (Picacho). The topographic boundary is not distinct but occurs near drainageways where dissection and soil truncation has been sufficient to remove the argillic horizon or mask it by carbonate engulfment.
Monterosa complex (10RR)	There are two main causes for the boundary. One is a younger alluvium and geomorphic surface in unit 12RR, which is inset against the higher ridges of unit 10RR. The other concerns the degree of landscape dissection, which has been very slight in unit 12RR, where Argids are well preserved. This contrasts with the narrow ridges of unit 10RR, where argillic horizons have been truncated or carbonate-engulfed, or both. The topographic boundary is prominent because the 12RR soils occur on terraces that are inset against the higher ridges of unit 10RR.
Haplargids, dissected (11Y)	Cause of the boundary is similar to that between 12RR and 10RR, but there has been much greater dissection in unit 11Y. The topographic boundary is prominent, since soils of unit 11Y occur on high, dissected ridges and soils of unit 12RR occur on lower terraces inset against the ridges.
Arizo complex (13F)	The boundary has been caused by a younger alluvium and geomorphic surface in unit 13F. The topographic boundary is distinct since the 13F soils occur on low terraces inset against higher terraces of unit 12RR.

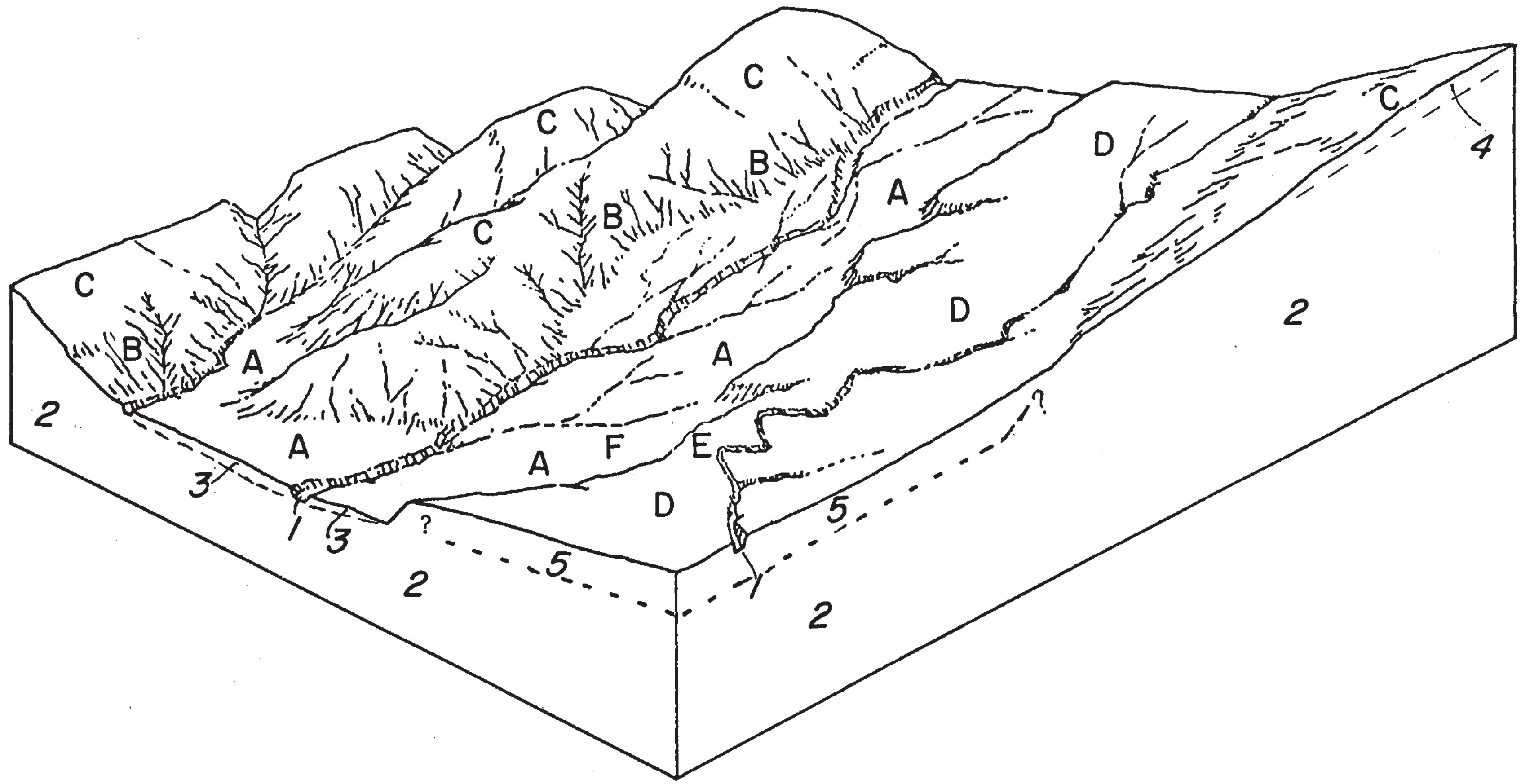


Figure 77. Block diagram of soil-landscape relations and stratigraphy in an area of Arizo complex; Haplargids, dissected; Monterosa complex; and Nolam complex, east of Tortugas Mountain. A = Arizo complex (Fillmore and arroyo channel surfaces). B = Haplargids, dissected (complex of surfaces younger than Jornada I). C = Monterosa complex (Jornada I on ridge crests; post-Jornada I on ridge sides). D = Nolam complex (Picacho surface). E = Casito 60-1. F = Vado variant.
1 = Arroyo channel alluvium (not outlined). 2 = Upper Camp Rice Formation (piedmont facies) and buried soils. 3 = Fillmore alluvium and soils. 4 = Jornada I alluvium (youngest unit of the Upper Camp Rice piedmont facies) and soils. 5 = Picacho alluvium and soils.

Figure 77 a. Location of soil map (fig. 78) sampled pedons, Tortugas Mountain, and Dripping Springs Road. 1 = Vado, sandy-skeletal variant; 2 = Casito 60-2; 3 = Simona 60-10 and Monterosa 61-10; 4 = Terino pedon, 5 = Delnorte pedon and Monterosa 66-2; 6 = Cruces variant.

OTHER STUDIES

Additional studies concern soils of terraced terrain; polygenesis on the terraced terrain; and the initial development of Ustollic subgroups. Figure 77a locates the areas involved.

The soils of a terraced terrain

A study area east of Tortugas Mountain (figs. 77a, 78, 79) has terraced terrain with five geomorphic surfaces. The terrain presents soils that are very close on the landscape and that have formed in the same kind of parent materials, but that differ greatly in age and pedogenic history. From lowest and youngest to oldest and highest the surfaces are arroyo channels, Fillmore, Picacho, Tortugas, and Jornada I. Soils of the Tortugas surface are very minor in extent. The Jornada I surface occurs on crests of long ridges that are the topographic highs. The younger surfaces occur as narrow, discontinuous terraces below. Slope along the ridge crests and terraces is about 2 percent.

Typical soils occur on each surface (fig. 78). The pattern of soils is determined by differences in soil age, volume of gravel, and degree of soil truncation. Entisols (mostly Torriorthents) occur in arroyo channels. Torriorthents and Camborthids occur on the Fillmore surface. The Picacho surface is dominated by Argids. Only Orthids occur on the Tortugas and Jornada I surfaces, where ridge crests are rounded (sections 85, 145). Both Tortugas and Jornada I are dominated by Paleorthids and Calciorthids. Where the Jornada I ridges have been lowered by dissection, buried soils are at or very near the surface, particularly on the sides of ridges.

Polygenesis on the terraced terrain

Soils of the terraced terrain east of Tortugas Mountain illustrate polygenesis. Soils discussed in the following sections started their development in late-Holocene, late-Pleistocene and late mid-Pleistocene time; soils of the latter two ages illustrate morphological features attributed to polygenesis. Morphological effects of both soil truncation and changes in climate are considered. The simplest evidence of polygenesis may be illustrated by morphological comparison of soils of late-Holocene and late-Pleistocene age.

A soil of late-Holocene age. Vado, sandy-skeletal variant (fig. 80) occurs on a Fillmore terrace that is about 1 m higher than the nearby arroyo channel and that is inset against the Picacho surface (fig. 79). A description is given below.

Soil surface. About 90 percent of the surface is covered with angular rhyolite fragments, most of which range from 0.5 to 5 cm in diameter, with a very few larger or smaller than this. A discontinuous layer of loose, reddish brown sand occurs between the pebbles.

A2 0-5 cm. Pinkish gray (7.5YR 6/3, dry) or dark brown (7.5YR 4/3, moist) very gravelly sandy loam; weak medium platy and massive; soft; very few roots; a few parts of 5YR hue; noncalcareous; abrupt smooth boundary.

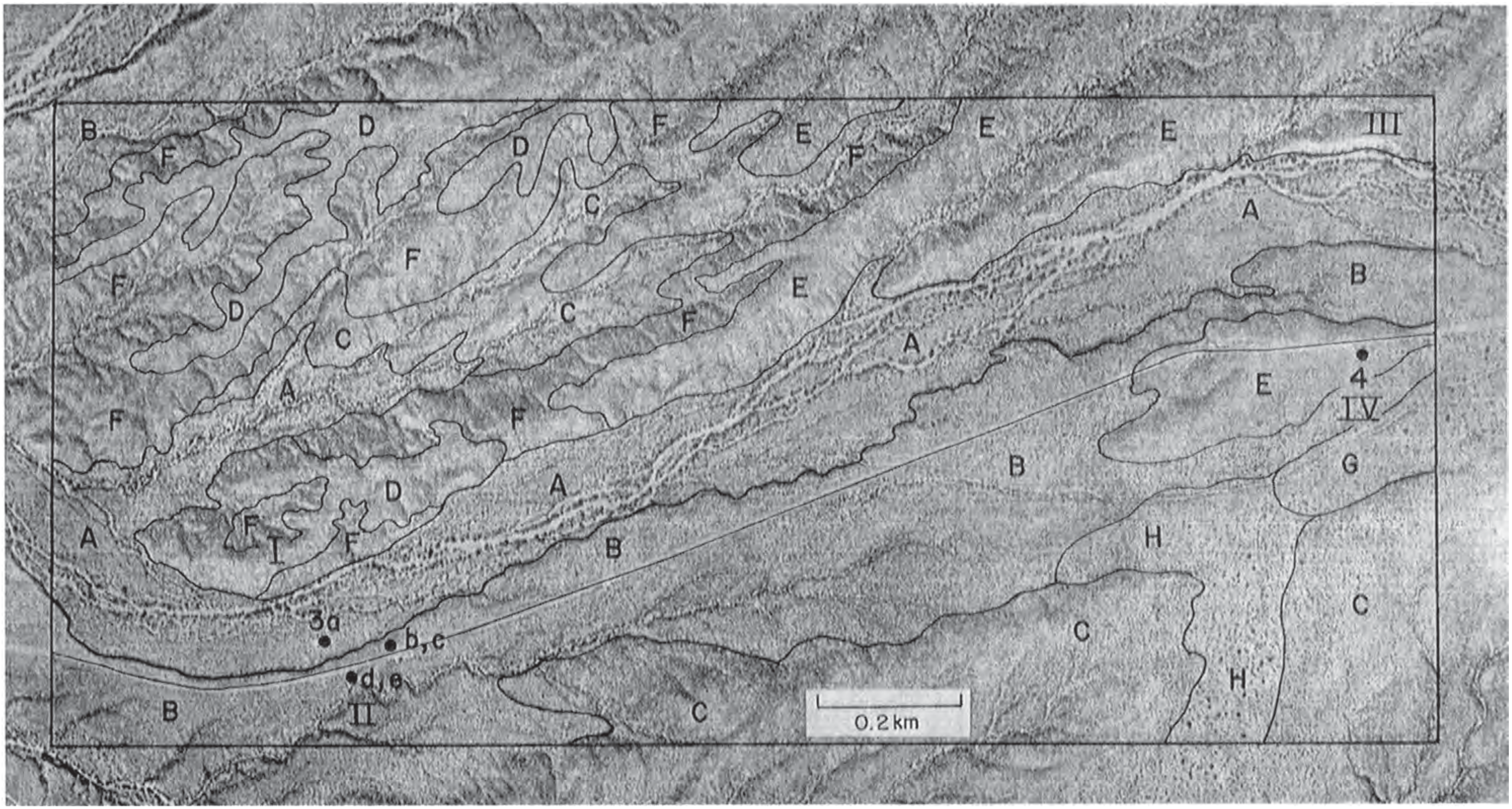


Figure 78. Map of soils in the terraced terrain east of Tortugas Mountain. A = Arizo-Torriorthent complex (Fillmore and arroyo channel surfaces). B = Nolam complex (Picacho, Fillmore and arroyo channel surfaces). C = Sonoita complex (eolian accumulation on Jornada surface). D = Monterosa complex (complex of surfaces, mainly erosional and younger than Jornada I). E = Dissected Haplargids (complex of surfaces, erosional and younger than Jornada I). 1 = Vado variant; 2 = Casito 60-1; 3 = Simona 60-10 and Montrosa 61-10; 4 = Terino pedon (table 102). See figure 79 for cross sections I to II and III to IV.

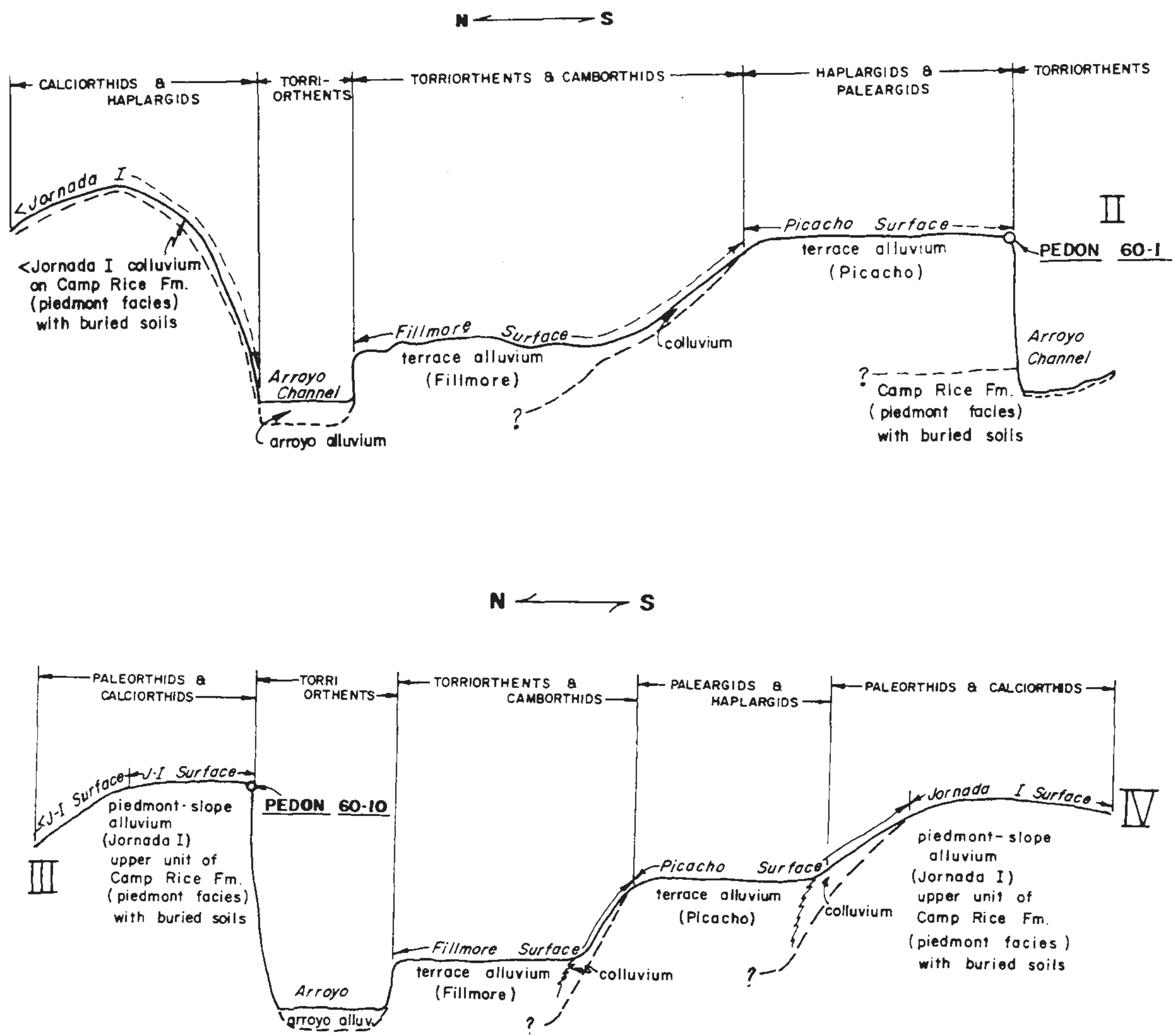


Figure 79. Cross section from I to II and III to IV, soil map.

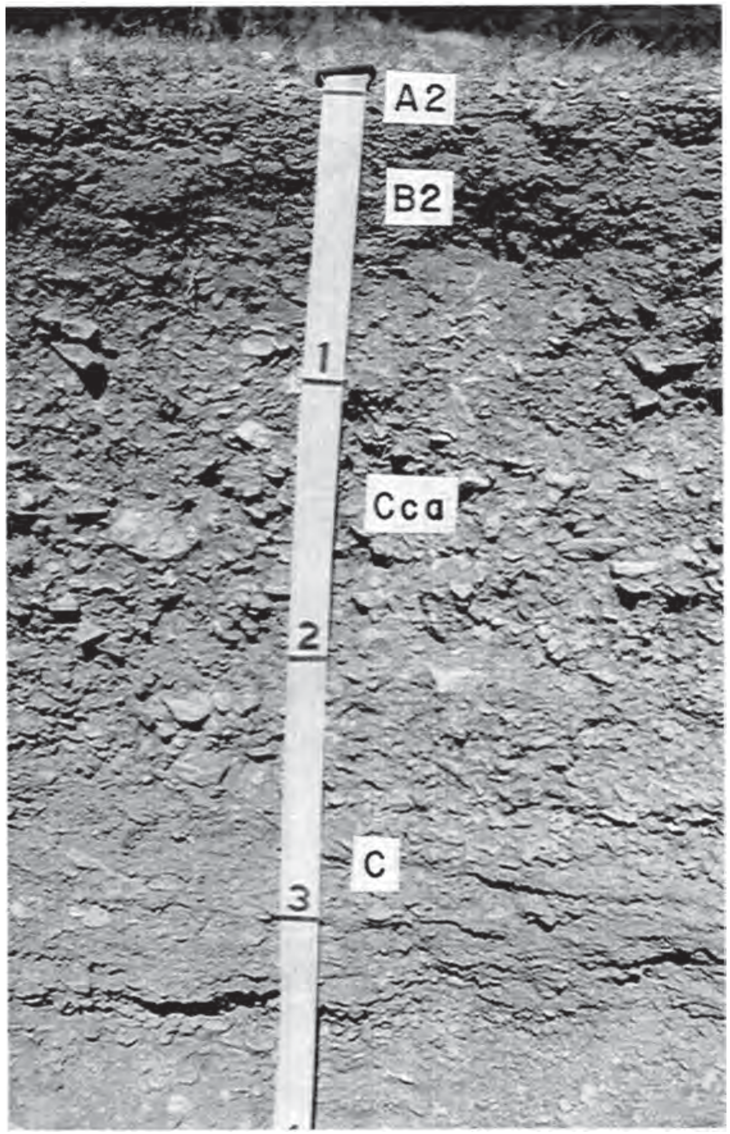


Figure 80. Profile of Vado, sandy skeletal variant. The soil occurs on a Fillmore terrace. Alluvial parent materials were deposited and soil development started in late Holocene time. The A2, B2t and Cca horizons are within reach of present moisture and are forming at the present time. Scale is in feet.

B2t 5-19 cm. Reddish brown (5YR 5/4, dry; 5YR 3.5/4, moist) very gravelly sandy loam; weak very fine crumb between pebbles; soft; few roots; sand grains and pebbles are faintly stained with clay; noncalcareous; clear wavy boundary.

B3ca 19-28 cm. Reddish brown (5YR 5.5/4, dry; 5YR 4/4, moist) very gravelly sandy loam; weak very fine crumb between pebbles; soft; few roots; sand grains are discontinuously carbonate-coated; most pebbles have carbonate-coated bottoms but tops of many pebbles are carbonate-free; fine earth effervesces strongly, some pebble tops are noncalcareous; clear wavy boundary.

C1ca 28-47 cm. Light brown (7.5YR 6/4, dry) or dark brown (7.5YR 4/4, moist) very gravelly light sandy loam; massive; soft; few roots; pebbles thinly and partially carbonate-coated, both on bottoms and tops; this horizon contains the maximum of pedogenic carbonate; effervesces strongly; clear wavy boundary.

C2ca 47-76 cm. Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) very gravelly sand; massive; soft; very few roots; thin discontinuous coatings of carbonate on pebbles, less than above and mainly on undersides; effervesces strongly; abrupt wavy boundary.

C3 76-110 cm. Light brown (7.5YR 6/4, dry) or brown (7.5YR 5/4, moist) very gravelly sand; massive; soft; no roots; in places there are distinct strata of sand, 1 to 2 cm thick and fine gravel up to 10 cm thick; other parts are very gravelly throughout, with little stratification apparent; some pebbles are carbonate-free and others have thin, patchy coatings; a few places noncalcareous, most effervesce weakly or strongly.

Development of this soil started in late-Holocene time after the very gravelly parent materials were deposited by waters of the adjacent arroyo. Judging from the coarse texture of the C horizon and of similar gravelly deposits in the present arroyo, the clay and carbonate in this soil must have been derived largely from dustfall and precipitation. These pervious, very gravelly materials should allow ready infiltration of moisture and of fine materials from atmospheric additions. The grayish color (most readily observed when dry) of the A2 horizon, together with the reddish brown color of the underlying B2 horizon, suggests loss of clay and iron from the A2 and their accumulation in the B2 horizon. However, insufficient clay has accumulated for an argillic horizon; clay content of the A2 and Bt horizons is 7.2 and 8.7 percent respectively (Lincoln Soil Survey Laboratory). Both the B and Cca horizons are within reach of wetting at the present time. The morphology of this soil and its late-Holocene age indicate that silicate clay and carbonate are slowly accumulating as a present feature of pedogenesis. This soil is monogenetic since all of its horizons must have formed in a climate much like the present, and were not formed partly during a pluvial.

A soil of late-Pleistocene age. Soils of the next highest terrace, the Picacho, illustrate soils that have formed largely in the late-Pleistocene, but that have some morphological features attributable to the Holocene. The illustrative pedon is a Haplargid of the Nolam series and occurs near, but not on the interfluve shoulder. Nolam soils have thin, grayish A2 horizons (where undisturbed), reddish brown or red argillic horizons, and calcic horizons. For present features of pedogenesis in these soils of late-Pleistocene age, their comparison with soils of the Fillmore surface is suggestive. Although the two soils differ greatly in development, there are certain similarities in overall horizonation. Both soils (1) have thin, grayish A2 horizons that range from about 2 to 5 cm thick; (2) have B horizons that are reddish brown in part and with oriented clay coatings on sand grains and pebbles; and (3) have noncalcareous A horizons and upper B horizons.

This morphological similarity indicates that silicate clay is very slowly accumulating in the upper part of the Bt horizon of Nolam soils at the present time. Similarly, the weak carbonate accumulation in the form of filaments and thin pebble coatings in the lower part of the Bt horizon is a feature of pedogenesis at the present time. This is indicated by morphological similarity to the weak carbonate accumulation in the Vado variant and by similar depths and horizon arrangement.

For an assessment of late-Pleistocene pedogenesis in these soils, the pedologic evidence cited above, together with the geomorphic evidence, clearly indicate that the argillic horizon of Nolam formed primarily during the Pleistocene. The argillic horizon once extended even deeper, but the lower part has been engulfed by subsequent carbonate accumulations, forming a K horizon that must also have formed primarily during the Pleistocene. The relationships indicate that major pedogenic processes (the illuviation of silicate clay and carbonate) occurred both during the Pleistocene pluvial periods and during the present interpluvial period. However, rates and depths of illuviation are less now, and this should be expected in view of lesser moisture available for leaching (section 9). Since the argillic horizon and the horizon of carbonate accumulation of Nolam must have formed almost wholly during a time with more effective moisture than now, this soil is considered to be polygenetic.

Some soils have polygenetic horizons caused by another process--soil truncation. The soils of interfluve shoulders illustrate progressive obliteration of the argillic horizon; with increasing distance down the shoulder, the Paleargids grade to the Paleorthids as a direct result of soil truncation. Casito 60-1 illustrates a Paleargid in this transition zone (see section 71). Below interfluve shoulders the effect of truncation is even more marked; in a narrow band around the ridge remnant the petrocalcic horizon has broken up and a calcic horizon is present instead. These soils are Calciorthids instead of Paleorthids.

<u>Soils of late mid-Pleistocene time</u>. Soils of the oldest surface--Jornada I --illustrate a different morphological effect of truncation on polygenetic expression. Steep side slopes of long, narrow ridges reflect gradual, long-continued erosion that has also affected ridge crests. In many places the upper part of the petrocalcic horizon on ridge crests is slowly breaking up. Scattered parts of a fractured, formerly continuous laminar horizon may be observed above a continuous laminar horizon in many places. The uppermost laminar horizon, being closest to the soil surface, is most susceptible to changes in soil moisture and to the activity of soil fauna and flora.

<u>Initial development of Ustollic subgroups in gravelly materials.</u>

Soils with little or no gravel are generally placed readily into Typic or

Ustollic subgroups because of a close relation of clay content to organic carbon content (section 63). Thus soils of fine-silty or fine families low in gravel usually are in Ustollic subgroups. Only a few soils in fine-loamy families are Ustollic, and these are all in the heavy end of the family. Very gravelly soils, however, are less readily classified as discussed below.

Ustollic subgroup placement requires an average minimum organic carbon percentage over a depth dependent on whether a root-limiting feature is present and its depth (section 63). Ustollic subgroups are not recognized if the petrocalcic horizon is shallower than 18 cm. If it occurs between 18 and 40 cm, sand/clay ratios and organic carbon of the uppermost 18 cm determines the placement. If it occurs at 40 cm or deeper, sand/clay ratios and organic carbon to 40 cm are the determinants. Most soils along the valley border do not meet the Ustollic requirements; organic carbon gradually increases mountainward until along the mountain fronts all soils in very gravelly materials are either in the Ustollic subgroups or are Mollisols.

Composite samples for analyses of organic carbon and particle size distribution were taken in several places in the area shown in figure 77a to study the character and distribution of the Ustollic subgroups (table 103). These

Table 103. Organic carbon and particle size distribution for three Paleargids and one Paleorthid.

Depth	Sand 1/	Silt 1/	Clay 1/	Organic carbon	> 2 mm Vol.
cm	pct	pct	pct	pct	pct
Cruces variant, shallow, Petrocalcic Paleargid, No. 6 2/					
0-18	57	23	20	0.42	60
Delnorte, Typic Paleorthid, No. 5 2/					
0-18	57	28	15	0.51	30
Casito 60-1, Petrocalcic Ustollic Paleargid, No. 2 2/					
0-18	62	22	15	0.64	55
Terino, shallow, Petrocalcic Ustollic Paleargid, No. 4 2/					
0-38	56	19	25	0.69	60

1/ Carbonate-free basis.
2/ Location in figure 77a.

samples, together with nearby pedons sampled for standard analyses (table 103) indicate the character of the Typic-Ustollic transition in the valley border area.

The data indicate that the initial occurrence of the Ustollic subgroups is in very gravelly materials because fine earth, which is the basis for reporting, is concentrated by the pebbles (section 63).

Cruces variant and Terino are on stable interfluves of the Picacho surface. Cruces variant has its petrocalcic horizon between 18 and 40 cm; that of Terino is below 40 cm. Cruces variant is not Ustollic (table 103) because of the low organic carbon content of the upper 18 cm, the common situation in soils of stable interfluves in the desertic part of the study area. When the 40 cm thickness is used for classification, the organic carbon content of deeper horizons is high enough to change the classification to Ustollic. This is shown by Terino (table 103).

Organic carbon values for the composited samples from both sides of Casito 60-1 (table 103) indicate that Casito soils contain enough organic carbon for the Ustollic subgroups. Pedon 66-2 (figs. 77a, 78) is next to a creosotebush (section 145) and has enough organic carbon for the Ustollic subgroups (table 103). However, composited samples from between creosotebushes, on the north side of the sample trench, contained too little organic carbon and the pedon is Typic (Delnorte, table 103). Thus complex Typic-Ustollic occurrence may be caused by vegetation patterns in the initial development of Ustollic subgroups.

Complex patterns of Ustollic and Typic Paleorthids also result from differences in content of coarse fragments. Two Paleorthids, one Typic (Simona 60-10) and the other Ustollic (Monterosa 61-10) were sampled on the crest of a long ridge (figs. 78, 79). Monterosa 66-2 is on a ridge to the south (fig. 77a). Laboratory data are in table 103a. Pedons 60-10 and 61-10 are only a few m apart and illustrate complex occurrence of the Typic and Ustollic Paleorthids. The Ustollic Paleorthids generally contain more gravel than adjacent Typic Paleorthids since organic carbon increases as gravel increases (section 63).

The Typic-Ustollic transition is also caused by variable depth to the Km horizon. Where the Km horizon is shallower than 18 cm the Paleorthids are Typic regardless of organic carbon content and sand-clay ratios. This seldom happens on stable ridge crests because the Km horizon is usually below 18 cm. Such Typic Paleorthids are more common on Jornada ridge sides.

The Argid-Orthid transition along the valley border

The transition from Argids to Orthids was discussed on a local basis in the previous section on polygenesis, in which Paleargids on stablest ridge crests changed to Paleorthids on ridge sides. The Argid-Orthid transition also occurs extensively along the valley border (soil maps, Appendix). West of the boundary, most soils are Orthids because of soil truncation associated with landscape dissection (Gile, 1975b). East of the boundary there is a change to primarily Argids because most soils have not been affected by dissection.

The transition from Argids to Orthids (fig. 80a) occurs where the soil parent materials were derived largely or wholly from noncalcareous rocks, so that an argillic horizon had formed and is still preserved on stablest sites. In these soils (which range in age from late to mid-Pleistocene) the argillic horizon is usually underlain by a calcic or petrocalcic horizon. If a calcic horizon is present, obliteration of the Bt horizon causes a change from a Haplargid to a Calciorthid. If a petrocalcic horizon is present, the change is from a Paleargid to a Paleorthid. The Argids occur on remnantal ridge crests that are level or nearly level transversely and have been little affected by the dissection. Orthids occur on rounded ridge crests in and near drainageways, where the argillic horizon has been truncated or engulfed by strong carbonate accumulation. Thus the boundary between Argids and Orthids can be predicted from landscape position and form.

Table 103a. Laboratory data for two Ustollic Paleorthids (Monterosa 61-10, Monterosa 66-2) and a Typic Paleorthid (Simona 60-10).

Horizon	Depth	Volume > 2 mm	Clay	Carbonate	Organic Carbon
	cm	Pct	Pct	Pct	Pct
Monterosa 61-10					
Aca	0-5	20	15	8	0.49
Bca	5-23	40	17	33	0.74
K2m	23-36	25	11	52	0.41
K31	36-56	30	7	26	0.32
K32	56-81	35	6	24	
Organic carbon, 1.4 kg/m^2 to 23 cm.					
Monterosa 66-2					
A2	0-4	20	10	tr	0.35
B21ca	4-13	40	18	5	0.71
B22ca	13-23	30	21	29	0.81
K1	23-36	10	21	43	0.64
K21m	36-43	55	17	53	0.79
K22m	43-64	40	17	35	0.29
K31	64-84	55	13	28	0.13
K32	84-107	65	12	17	0.33
C1ca	107-135	50	11	14	0.15
C2ca	135-165	60	6	6	0.09
Simona 60-10					
Aca	0-5	20	15	8	0.50
Bca	5-20	20	9	13	0.43
K21m	20-23	35	14	67	0.16
K22m	23-43	30	11	62	0.24
K23m	43-74	50	5	35	0.14
K3	74-104	50	5	21	0.09
Cca	104-127	40	7	7	
Organic carbon, 0.9 kg/m^2 to 20 cm.					

The boundary between Argids and Orthids in the terraced terrain is very sinuous because location of the boundary differs in different parts of the terrain. Where the argillic horizon has been obliterated on the highest (Jornada I) ridges, it is still extensively preserved on younger, less dissected terraces of the Picacho surface below. With increasing dissection valleyward, the argillic horizon is finally obliterated on these younger terraces also.

The morphological transition from Argids to Orthids on a given ridge usually occurs over a distance of only a few m. Downslope from the Argids of ridge crests that are level transversely, the argillic horizon first becomes calcareous, with little or no visible carbonate. With increasing distance downslope, macroscopic carbonate appears and gradually rises in the soil as truncation of thin upper horizons brings partially carbonate-impregnated horizons closer to the surface. (Truncation, by increasing slopes and runoff, also causes carbonate to accumulate at depths shallower than in adjacent areas that are level transversely.) Finally, less than 10 percent of the reddish brown, argillic horizon material remains and the soils are classified as Orthids.

Obliteration of the argillic horizon, discussed above, shows that landscape dissection (and faunal activity, section 85) can confound the relation of age to development of horizons in the B position. But the prominent K horizon remains and thus is a much more reliable indicator of soil age than the horizon in B position.

The B horizons of many of these soils may be considered as cambic horizons (if thick enough) because of the high degree of alteration since deposition of the parent materials and the start of soil formation. Also, there is evidence of abundant carbonate redistribution in the form of underlying K horizons. These cambic horizons are not diagnostic for the Camborthids because the underlying calcic or petrocalcic horizons take precedence in classification, but are very important to soil history because of their polygenetic character.

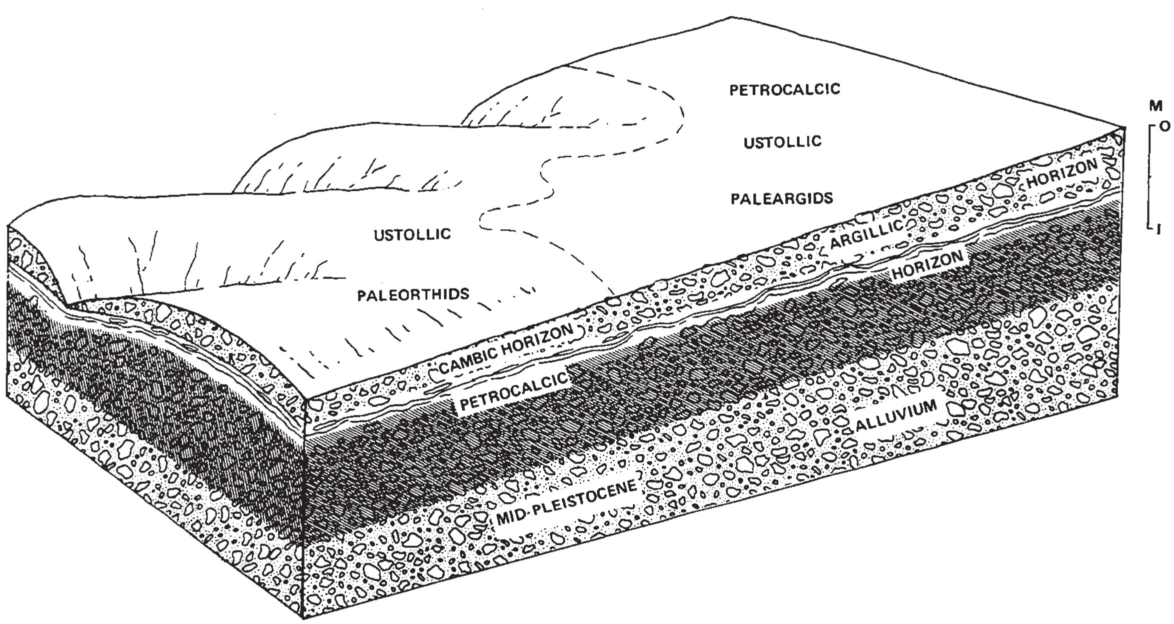


Figure 80a. Boundary between Argids and Orthids, and its relation to the dissection pattern. Paleargids occur in areas little affected by the dissection (ridge crests that are level transversely). Paleorthids occur on rounded ridge crests, and in and adjacent to drainageways.

139. DELNORTE COMPLEX (10R)

MAPPING UNIT COMPOSITION

Series	Subgroup	Family Criteria	Percentage of Mapping Unit
DELNORTE	TYPIC PALEORTHIDS	LOAMY-SKELETAL, SHALLOW	40
NICKEL	TYPIC CALCIORTHIDS	LOAMY-SKELETAL	20
SIMONA	TYPIC PALEORTHIDS	LOAMY, SHALLOW	20
Canutio	Typic Torriorthents	Loamy-skeletal (calcareous)	10
Whitlock	Typic Calciorthids	Coarse-loamy	5
Other inclusions (Torriorthents, Haplargids, Paleargids)			5

LOCATION, LANDSCAPE, VEGETATION

These soils occur in scattered small areas along the valley border. They have formed in sediments derived primarily from rhyolite. In places there are a few andesite fragments and rounded pebbles of quartz and chert. Elevations range from about 4200 to 4400 feet.

These soils are mostly located on terraces and isolated ridge remnants of the Picacho surface north and south of Tortugas Mountain. Longitudinal slope along ridge crests is about 2 percent; ridge sides slope from 10 to 35 percent. Commonly, small drainageways occur on the ridge remnants and fans.

Vegetation is mostly creosotebush and ratany; in places there are scattered mesquite and prickly pear.

TYPICAL PEDONS, PROPERTIES AND RANGES

These soils are usually calcareous throughout but range to noncalcareous in the upper 5 cm. In most places these soils have formed in thick alluvium, without buried soils or bedrock to depths of many meters. Where these soils flank Goat and Picacho Mountains, however, buried soils or bedrock may occur within a depth of a few m.

Delnorte

A typical pedon of Delnorte is described below. Location is the NE 1/4 SW 1/4 Sec. 14, T23S, R2E, crest of ridge remnant. Figure 81 is a photograph of the pedon and its landscape. A table of properties and ranges follows the description.

Soil surface: 90 percent covered with fine pebbles, mostly of rhyolite and andesite but a few rounded quartz and chert. Most of the fragments range from about 4 mm to 3 cm in diameter, with a few up to 5 cm in diameter. Most of the fragments rest loosely on the surface and are easily moved laterally with the fingers; a few are embedded in the soil.

A 0-5 cm. Pinkish gray (7.5YR 7/2, dry) or brown (7.5YR 5/4, moist) gravelly fine sandy loam; moderate thin and medium platy; soft, very few roots; thin carbonate coatings on pebbles; effervesces strongly; abrupt smooth boundary.

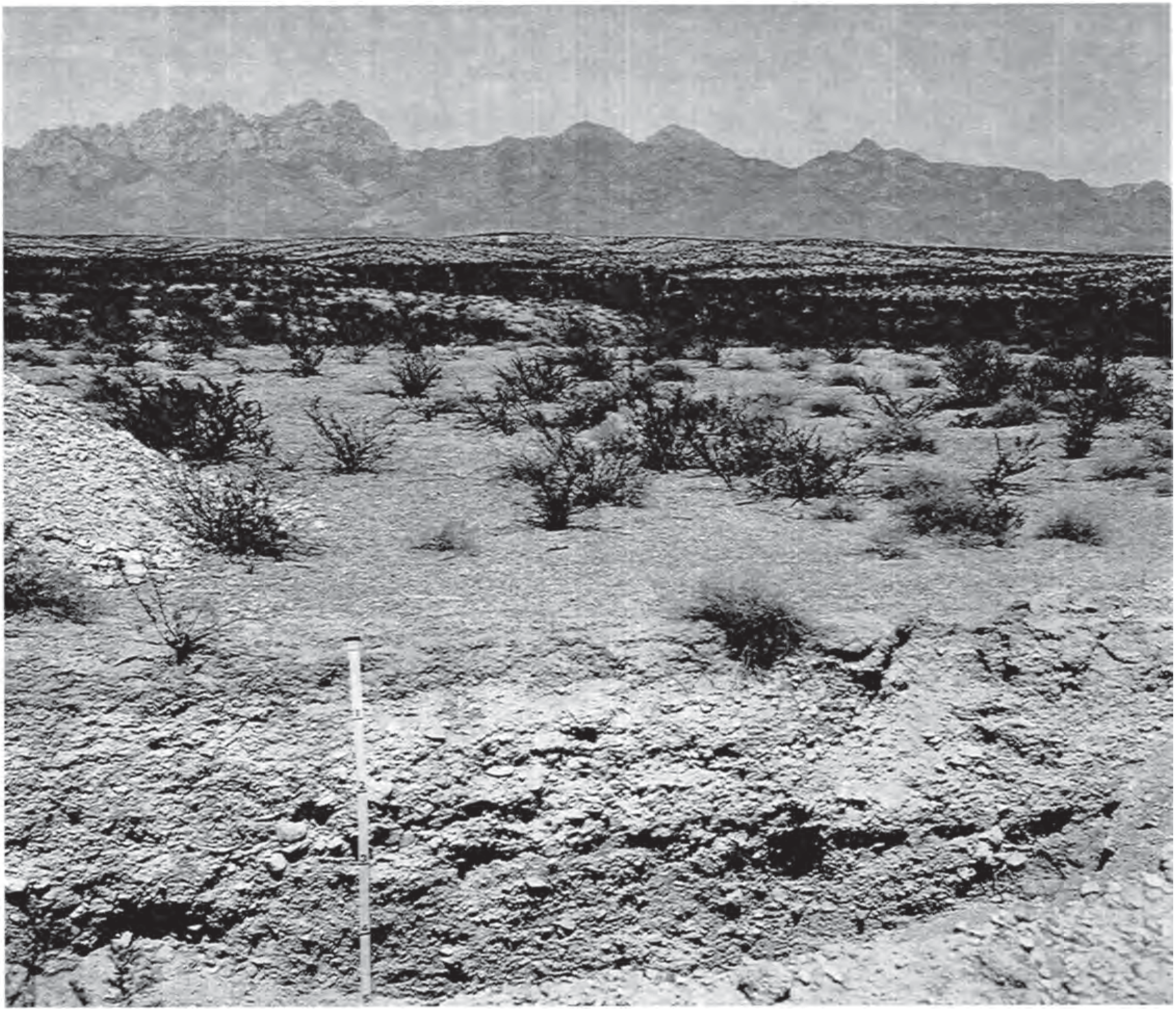


Figure 81. Landscape, Nickel and Delnorte soils. Vegetation is creosotebush and ratany. Slope is 2 percent. Organ Mountains in background. Scale is in feet.

B21ca 5-11 cm. Pinkish gray (7.5YR 6.5/3, dry) or brown (7.5YR 4.5/4, moist) gravelly heavy sandy loam; weak medium subangular blocky; slightly hard; few roots; thin carbonate coatings on pebbles, with most of carbonate on undersides; effervesces strongly; clear wavy boundary.

2B22ca 11-16 cm. Pink (7.5YR 7/4, dry) or brown (7.5YR 5/4, moist) very gravelly light sandy clay loam; massive and weak very fine crumb; soft; roots common in places, but only a few in others; pebbles thickly coated with carbonate and a few are cemented together; pockets, 5 to 15 cm wide and up to 20 cm deep, extend into the Km; effervesces strongly; clear irregular boundary.

2K2m 16-46 cm. White (7.5YR 9/2, dry) or pinkish gray (7.5YR 7/3, moist) carbonate-cemented material, with included parts of light brown (7.5YR 6.5/4, dry) or brown (7.5YR 5/4, moist); massive; very hard, very firm; no roots except for a few pockets, 1 to 5 cm diameter, of material colored light brown (7.5YR 6.5/4, dry); pebbles and sand grains separated by carbonate; effervesces strongly; clear wavy boundary.

2K31 46-72 cm. Pink (7.5YR 9/3, dry, 7.5YR 7/3, moist) very gravelly heavy sandy loam; massive; slightly hard and hard; very few fine roots; sand grains and pebbles coated and commonly separated by carbonate, but distinctly less carbonate and cementation than above; some cementation into clusters of pebbles; effervesces strongly; clear smooth boundary.

2K32 72-98 cm. Very pale brown (10YR 9/3, dry, 10YR 7/3, moist) very gravelly sandy loam; massive; slightly hard, very friable; pebbles continuously coated with carbonate, and is K-fabric, but less than above; very few roots; effervesces strongly; clear wavy boundary.

2C1ca 98-110 cm. Very pale brown (7.5YR 7/3, dry) or brown (7.5YR 5.5/3, moist) very gravelly loamy sand; massive; soft, very friable; no roots; thin, mostly discontinuous carbonate coatings on pebbles; effervesces strongly; clear wavy boundary.

2C2 110-136 cm. Pinkish gray (7.5YR 7/3, dry) or brown (7.5YR 5.5/3, moist) very gravelly sand; massive; soft; no roots; thin, discontinuous carbonate coatings on pebbles, mostly on undersides; effervesces strongly; clear wavy boundary.

2C3 136-168 cm. Alternating layers, ranging from 3 to 8 cm thick, of darker-colored layers that have little carbonate, and of lighter-colored layers with thin, mostly continuous, carbonate coatings:

1. Brown (7.5YR 5/4, dry) or dark brown (7.5YR 4/4, moist) very gravelly sand; slightly hard, friable; massive; no roots; sand grains and pebbles are weakly held together in clusters, 1 to 5 mm diameter; only very patchy, thin carbonate coatings, and some grains and pebbles are carbonate-free; effervesces weakly; abrupt wavy boundary to lighter-colored layers.

2. Pinkish gray (7.5YR 7/3, dry) or brown (7.5YR 5/3, moist) very gravelly sandy loam; massive; soft; no roots; pebbles have thin carbonate coatings, some of which are continuous; effervesces strongly; abrupt wavy boundary to darker layers.

Remarks: This Delnorte pedon and an adjacent Nickel pedon (see description in following section) well illustrate the effect of volume of gravel on development of the petrocalcic horizon. In this Delnorte pedon, which has a marginal petrocalcic horizon, coarse fragments ranging from 5 to 10 cm diameter are common in the horizon of carbonate accumulation. In the Nickel pedon, most of the pebbles are less than 4 cm diameter, with very few being as large as 10 cm. Thus the total volume occupied by coarse fragments in Nickel is less, and its carbonate horizon is not indurated.

Table 104. Typical (underlined) and range in selected properties for major horizons of Delnorte.

Horizon	Depth	Particle Size		Hue	Value		Chroma
	cm	< 2mm	> 2mm,% Vol.		Dry	Moist	
A	0-5	sl	10-70	7.5YR-10YR	5-7	3.5-5	2-4
B2	5-16	sl scl	35-75	7.5YR-10YR	5-7	3.5-5	3,4
K2m	16-46	--	--	7.5YR-10YR	6-9	5-8 7	3,4
C1ca	98-110	s,ls sl	10-75	5YR-10YR 7.5YR	5-7	3-5 5.5	3,4
Control section		sl,ls scl	35-75				

Other. Depth to the petrocalcic horizon is usally about 15 to 30 cm, ranging from 5 to 50 cm.

Nickel

A typical pedon of Nickel is described below. The location is the NE 1/4 SW 1/4 Sec. 14, T23S, R2E, crest of ridge remnant. Figure 82 is a photograph of the pedon and its landscape. A table of properties and ranges follows the description.

Soil surface: About 75 percent covered with fine pebbles, mostly rhyolite and andesite, and a few rounded quartz and chert.

A 0-5 cm. Pinkish gray (7.5YR 7/2, dry) or brown (7.5YR 5/4, moist) fine sandy loam; moderate thin and medium platy; soft; very few roots; thin carbonate coatings on pebbles; effervesces strongly; abrupt smooth boundary.

B21ca 5-10cm. Pinkish gray (7.5YR 6/3, dry) or dark brown (7.5YR 4/4, moist) sandy loam; very weak medium subangular blocky; slightly hard, very friable; very few roots; thin, discontinuous carbonate coatings on pebbles; effervesces strongly; clear wavy boundary.

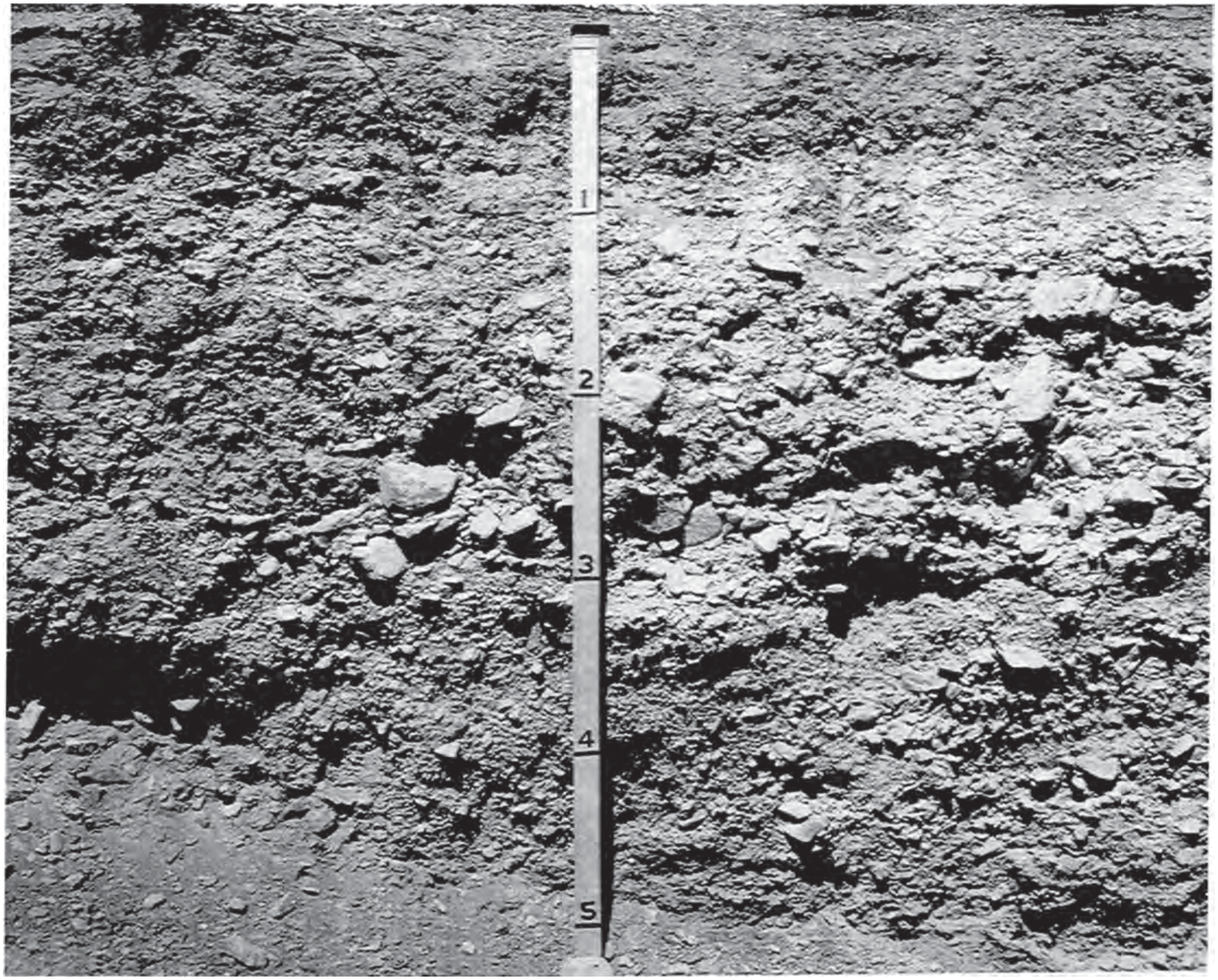


Figure 82. Delnorte, a Typic Paleorthid, to the right of the tape, where pebbles are larger and more numerous and an incipient petrocalcic horizon has formed. Nickel, a Typic Calciorthid, is left of the tape. Scale is in feet.

B22ca 10-18 cm. Light brown (7.5YR 6.5/4, dry) or brown (7.5YR 4.5/4, moist) gravelly heavy sandy loam; very weak medium subangular blocky; slightly hard, very friable; few roots, more than above; thin, mostly continuous carbonate coatings on pebbles; few carbonate filaments; effervesces strongly; clear wavy boundary.

2K1 18-36 cm. Dominantly pink (7.5YR 8/3, dry, 7.5YR 7/4, moist) with smaller amount light brown (7.5YR 6.5/4, dry) or brown (7.5YR 5/4, moist) very gravelly heavy sandy loam; weak fine and medium subangular blocky; the lighter-colored material is slightly hard and hard, friable; darker material is soft and very friable; pebbles are discontinuously cemented into clusters; all easily removed from horizon because the high-carbonate parts are separated by low-carbonate parts; roots common in the low-carbonate parts; effervesces strongly; clear wavy boundary.

2K2 36-70 cm. Pink (7.5YR 8/3, dry, 7.5YR 7/4, moist) with about 10 percent pink (7.5YR 7/3, dry) or light brown (7.5YR 6/3, moist) very gravelly light sandy clay loam; massive; mostly hard, with a few parts very hard; friable; very few roots; pebbles and sand grains separated by carbonate; effervesces strongly; clear wavy boundary.

2K3 70-105 cm. Pink (7.5YR 8/3, dry, 7.5YR 7/4, moist) very gravelly sandy loam; massive; slightly hard and hard, friable; no roots; pebbles and sand grains continuously coated with carbonate; effervesces strongly; clear wavy boundary.

2Cca 105-125 cm. Pink (7.5YR 7/3, dry) or brown (7.5YR 5/4, moist) very gravelly loamy sand; massive; soft; no roots; thin carbonate coatings on pebbles, some continuous and some discontinuous; effervesces strongly; clear wavy boundary.

2C2 125-136 cm. Pink (7.5YR 7/3, dry) or brown (7.5YR 5/4, moist) very gravelly sandy loam, massive; soft; thin, discontinuous carbonate coatings on a few pebbles; effervesces strongly; no roots.

Table 105 . Typical (underlined) and range in selected properties for major horizons of Nickel.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-5	sl	10-75	7.5YR-10YR	5-7	3.5-5	2-4
B2	5-18	sl	10-75	7.5YR-10YR	5-7 6	3.5-5 4	3,4
K2	36-70	sl scl	35-75	7.5YR-10YR	6-9 8	5-8 7	3,4
C1ca	105-125	s,ls sl	35-75	7.5YR-10YR	5-7	4,5	3,4
Control section		sl	35-75				

Other. Depth to the calcic horizon (the 2K1, 2K2, and 2K3 horizons in the description) ranges from 10 to 50 cm.

Simona

See Appendix for description of Simona (pedon 60-10). The range of characteristics is similar to that given for Delnorte except for gravel content.

SOIL OCCURRENCE

These soils illustrate the common occurrence of Typic Paleorthids in the most arid part of the study area (the border of the Rio Grande Valley). The Ustollic Paleorthids occur mostly in more moist areas mountainward. The Paleorthids and Calciorthids occur on the terrace surfaces and on the crests of the ridge remnants. The Torriorthents occur as a more or less continuous band on the sides of the ridges, tending to be quite continuous and, in the case of isolated remnants, generally encircling the ridge-crest soils.

Paleorthids. The loamy-skeletal DELNORTE soils are most common on the stabler, main parts of the ridges, fans and terraces where the textures are very gravelly. The loamy SIMONA soils occur where horizons above the Km horizon average less than 35 percent by volume of coarse fragments.

Calciorthids. The loamy-skeletal NICKEL soils are most common in strongly truncated areas and in places where gravel content is too low for development of the petrocalcic horizon, but still high enough for the skeletal family. Whitlock soils occur in a few low-gravel areas.

Haplargids. The fine-loamy Dona Ana soils occur in a few of the stablest areas of broadest ridge crests.

Paleargids. Occur only in stablest positions in centers of some of the interfluves.

Torriorthents. The loamy-skeletal Canutio soils and the sandy-skeletal Arizo soils have formed in the colluvium of ridge sides and in underlying alluvium. Their occurrence is complex and determined largely by the texture of the beveled alluvium. This alluvium is commonly of Picacho age but also includes alluvium of the Camp Rice Formation, which generally contains less clay and less gravel. Small areas of the sandy Yturbide occur; content of coarse fragments in the control section averages between 15 and 35 percent by volume.

SOIL BOUNDARIES

Table 106 gives information about boundaries to adjacent major units.

Table 106 . Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Haplargids, dissected (11Y)	The boundary has been caused by greater dissection in unit 11Y. The topographic boundary is prominent since most of the 10R soils occur on terraces inset against the much higher ridges of unit 11Y.
Arizo complex (13F)	The boundary has been caused by a younger alluvium and geomorphic surface (Fillmore) in unit 13F. Topographically the boundary is distinct; terraces of the Fillmore surface (unit 13F) are lower than and inset against higher ridges of unit 10R.

OTHER STUDIES: AN UNUSUALLY DEEP ACCUMULATION OF CLAY

Nickel 59-13, a Typic Calciorthid, has an unusually deep accumulation of clay (table 106a). See soil maps, Appendix, for location of Nickel 59-13.

Table 106a. Selected laboratory data for a Typic Calciorthid, Nickel 59-13.

Horizon	Depth	Clay[1/]	Vol. > 2 mm	Carbonate	Organic carbon
	cm	pct	pct	pct	pct
A2	0-5	10	30	6	0.25
B	5-13	12	20	15	0.34
K2	13-18	18	45	65	0.17
K31	18-48	11	60	35	0.26
K32	48-69	7	60	21	0.13
K33	69-94	7	60	10	0.10
Clca	94-132	10	70	7	
C2	132-157	19	50	3	
C3	157-168	17	2	2	
C3	168-178	13	2	3	
C4	178-203	9	1	5	
C4	203-229	10	1	9	

1/ Carbonate-free basis.

The pedon has a thin, reddish brown, carbonate-impregnated B horizon and a K2 horizon that is not quite cemented enough for a petrocalcic horizon. There is abundant gravel to depth of 157 cm (table 106a), particularly from 94 to 157 cm. Clay increases substantially at about 130 cm, in very gravelly alluvium that rests abruptly on undulating low-gravel sediments at about 160 cm. This silicate clay increase is widely separated from the maximum in the carbonate-engulfed, former argillic horizon above, with no morphological connection. The clay is too deep to have accumulated by illuviation from the surface. It is not considered to be part of a buried soil for several reasons. (1) There is essentially no evidence of mixing of sedimentary strata, which is one of the first events in soil development. (2) The clay increase coincides with undulations in the contact of high-gravel material on low-gravel material and not with the land surface. (3) Position of the clay does not correspond to the usual position of buried B horizons with respect to geologic evidence of a younger deposit. If a younger deposit is present in the area concerned then a low-clay, high-gravel base usually rests on a buried soil with more clay, instead of the clay being in the gravel.

The evidence suggests that the clay accumulated by deposition from waters of an ancient stream. First, the gravelly deposits along the cut appear to have been in a topographic low, consistent with the existence of a stream. Second, horizons of clay accumulation have been observed at depth in present arroyos, where such horizons appear to be presently forming. Third, thin horizons of clay accumulation have been observed at substantial depths beneath soils of Holocene age (e.g., Canutio 66-3 and Onite variant 68-3). In these Holocene soils, moisture through their history has been insufficient for pedogenic clay accumulation at these depths, and emplacement from the stream that deposited the sediment is strongly suggested.

140. NICKEL COMPLEX (11R)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
NICKEL	TYPIC CALCIORTHIDS	LOAMY-SKELETAL	25
WHITLOCK	TYPIC CALCIORTHIDS	COARSE-LOAMY	15
Caliza	Typic Calciorthids	Sandy-skeletal	10
Canutio	Typic Torriorthents	Loamy-skeletal (calcareous)	5
Canutio, loamy subsoil variant	Typic Torriorthents	Coarse-loamy (calcareous)	5
Delnorte	Typic Paleorthids	Loamy-skeletal, shallow	10
Kokan	Typic Torriorthents	Sandy-skeletal	10
Rilloso	Typic Calciorthids	Sandy	10
SND-6	Entisols		5
Other inclusions (Haplargids, Calciorthids)			5

LOCATION, LANDSCAPE, VEGETATION

The soils occur on the eastern side of the valley border, primarily west of the Dona Ana Mountains. There are also several delineations in the southern part of the area. The soils have formed in alluvium derived primarily from rhyolite but in places the sediments contain andesite and rounded chert and quartz. Elevations range from about 4100 to 4500 feet.

These soils occur on ridge remnants of alluvial fans. Ridge crests are of Picacho age; ridge sides are Fillmore. Most ridges show distinct evidence of truncation in the form of small waterways leading to ridge crests. However, some ridges have not been prominently rounded by erosion. These represent the stablest parts of the Picacho surface bordering the flood plain. Slopes along ridge crests range from 2 to 3 percent. Slopes of ridge sides range from about 10 to 50 percent.

Vegetation consists primarily of creosotebush; there are a few mesquite, ratany, and prickly pear.

TYPICAL PEDONS, PROPERTIES AND RANGES

These soils are calcareous throughout. They have formed in thick alluvium and no bedrock or petrocalcic horizons occur within many m.

Nickel

See section 139 for a description and ranges in characteristics for these soils.

Whitlock

These soils are similar to Nickel soils but have less gravel. See Appendix (pedon 60-2) for a description of a Whitlock pedon. The pedon is more clayey than is typical for Whitlock.

SOIL OCCURRENCE

Soil occurrence is dependent upon texture, landscape position, and amount of soil truncation. Aridisols occur on ridge crests--the oldest, stablest parts of the landscape--and Entisols are located on ridge sides.

Torriorthents. The sandy-skeletal Kokan soils, the loamy-skeletal Canutio soils and Canutio, loamy subsoil variant occur on ridge sides on very narrow ridge crests, and along margins of small arroyos.

Calciorthids. The loamy-skeletal NICKEL soils are dominant on the ridge crests. The sandy-skeletal Caliza soils and the sandy Rilloso soils occur with control-section changes in texture of the Picacho alluvium. Rilloso, Ustollic variant, occurs in a few places where requirements of organic carbon and sand/clay ratio are met.

Paleorthids, Paleorthids occur in a few areas west of the Dona Ana Mountains where the sediments are extremely gravelly and a petrocalcic horizon is preserved.

Haplargids. Occur only in two delineations in the southern part of the area. A few pedons of the fine-loamy Dona Ana soils are preserved in the centers of stablest interfluves (see "other studies" section).

Entisols. SND-6 occurs in arroyo channels.

SOIL BOUNDARIES

Table 107 presents information on boundaries to major adjacent units.

Table 107. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Kokan-Nickel complex (10W)	The boundary has been caused by greater landscape dissection in unit 10W. Because of this, calcic horizons formerly present in unit 10W have been truncated in many places and in these areas the soils are mainly Torriorthents. Topographically the boundary is quite distinct, changing abruptly from interfluves that are nearly level transversely (unit 11R) to narrow ridges (unit 10W).
Arizo complex (13F)	The boundary has usually been caused by a prominent increase in slope; the soil boundary was drawn along the contact of the lower margin of steep ridge sides (unit 11R) and the gently sloping terraces (unit 13F). Topographically the boundary is prominent since soils of unit 13F occur on low terraces inset against the much higher ridges of unit 11R.
Bluepoint sand (13Y)	The boundary has been caused by a younger alluvium and geomorphic surface (usually Fillmore, in places Fort Selden) in unit 13Y. The boundary is usually distinct since the 13Y soils are either inset below ridges on which the 11R soils occur or overlap them along upslope margins.

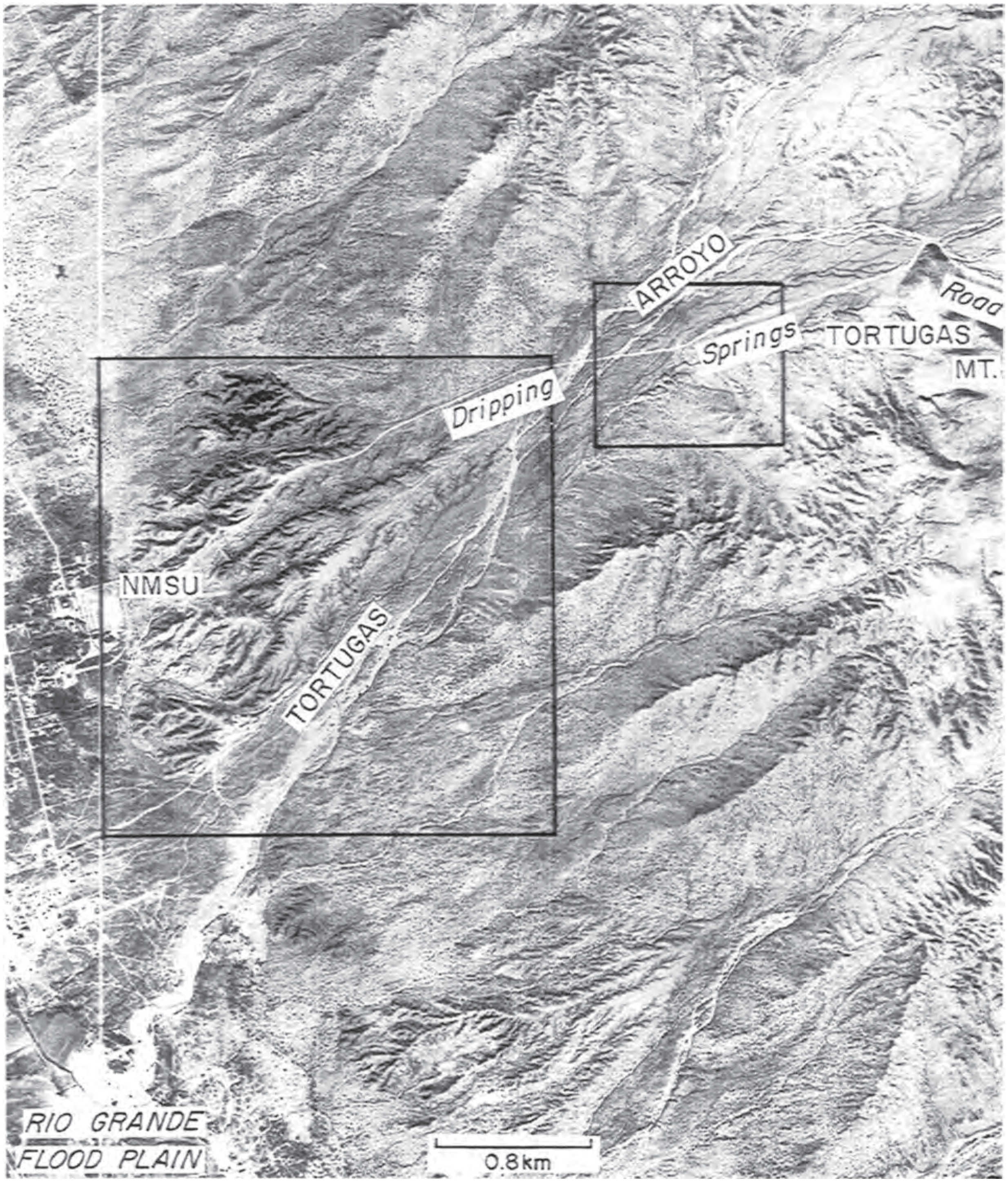


Figure 83. Location of soil map (fig. 85, large rectangle at left), Dripping Springs Road and Tortugas Mountain (right). Small rectangle at right locates soil map for section 129.

OTHER STUDIES

Additional studies concern a truncated soil with high organic carbon and soils of two ages in the late-Pleistocene. Figure 83 locates the study area.

A truncated soil with high organic carbon

Rilloso, Ustollic variant 60-11 (fig. 84) occurs on a narrow ridge and illustrates a soil in which the K horizon is very near the surface because of soil truncation. This pedon also has enough organic carbon for the Ustollic subgroups (table 107a). Other soils in this, the most arid part of the study area, generally have very low organic carbon and are Typic (see pedons 60-2 and 66-5 for examples). It is thought that only a few Ustollic subgroups occur in these most arid areas. See section 136 for a mountainward study of the Typic-Ustollic transition.

Soils of two ages in the late-Pleistocene

In places along the valley border there are small terraces adjacent to and slightly lower than the main Picacho (late-Pleistocene) fans. These small terraces may be of latest Picacho (or earliest Leasburg) age. The soils have commonly been truncated by erosion associated with valley downcutting. Only a very few places are stable enough to have soils suggesting the character of pedogenesis associated with the full span of time since soil development started on these small areas. One of the best preserved of these areas, now obliterated by construction, occurred on a ridge crest just north of Tortugas Arroyo, near University Park (fig. 87). A soil on this ridge crest was studied and compared with a soil in similar position on the main Picacho remnant just north. Parent materials of the two soils are similar, consisting of noncalcareous sand and variable amounts of gravel--mainly rhyolite, with small amounts of andesite and rounded gravel of mixed lithology.

Figure 87, lower, shows the landscape of the lower terrace; figure 88, upper, shows Onite variant. The soils have been affected by erosion as shown by encroachment of small arroyos. Waterways extend headward from arroyos into the ridge crests and have truncated the soils in varying degree. Over most of the ridge crest, erosion has been sufficiently strong that the upper few cm or more of the soils have been removed, and no argillic horizon is apparent. However, a small part of the ridge crest is relatively little-dissected (fig. 87). In this small area there is preserved a Haplargid that is intermediate in age and development between soils of the Leasburg and Picacho surfaces. Onite variant 66-1 (fig. 88) occurs in the center of the stablest part of the remnant; it has thin A and Bt horizons, and a distinct, continuous K horizon. Since the lower boundary of the argillic horizon is shallower than 25 cm, the control section extends from the top of the argillic horizon to 1 m, and the pedon is coarse-loamy.

Several features suggest that some soil truncation may have occurred, even at this relatively stable site: the gravelly desert pavement, as compared to the low-gravel underlying horizons; the nearness of slight waterways leading to arroyos that deeply cut the sediments; the abrupt upper boundary of the argillic horizon, and its closeness to the surface; and the lack of all but a very thin B1 horizon. However, since the Bt horizon is still preserved and none of the pebbles on the surface are coated with carbonate, this soil may not have been truncated more than several cm.

Table 107a. Laboratory data for an Ustollic Calciorthid, Rilloso variant 60-11.

Horizon	Depth	Clay[1/]	Vol. > 2 mm	Carbonate	Organic carbon
	cm	pct	pct	pct	pct
A	0-4	8	15	10	0.45
K21	4-18	11	40	23	0.62
2K22	18-30	14	-	16	0.42
2K22	30-43	10	3	14	0.28
3C1ca	43-64	7	15	7	0.08
3C2ca	64-86	5	20	3	0.04

1/ Carbonate-free basis.

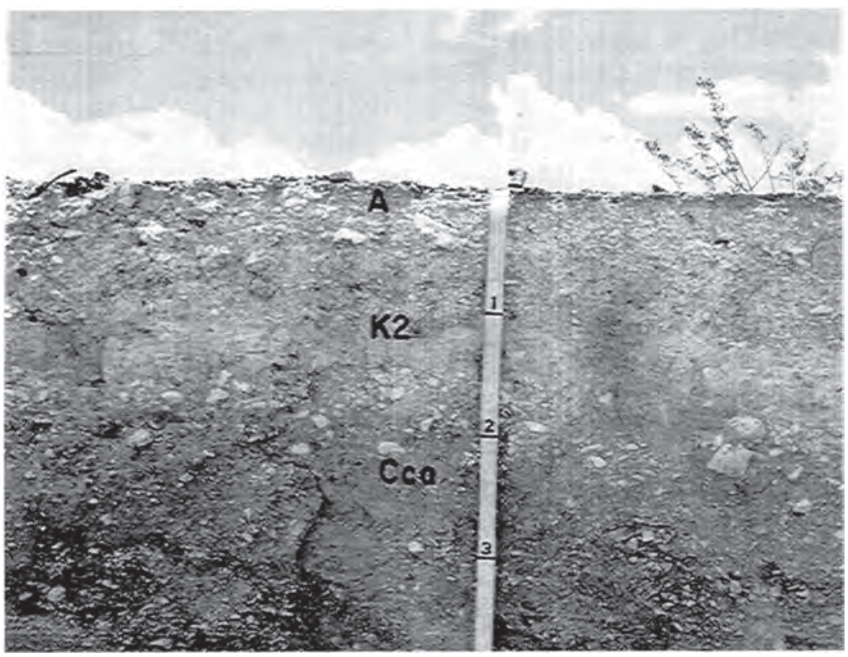


Figure 84. An Ustollic Calciorthid, Rilloso variant 60-11. Scale is in feet.

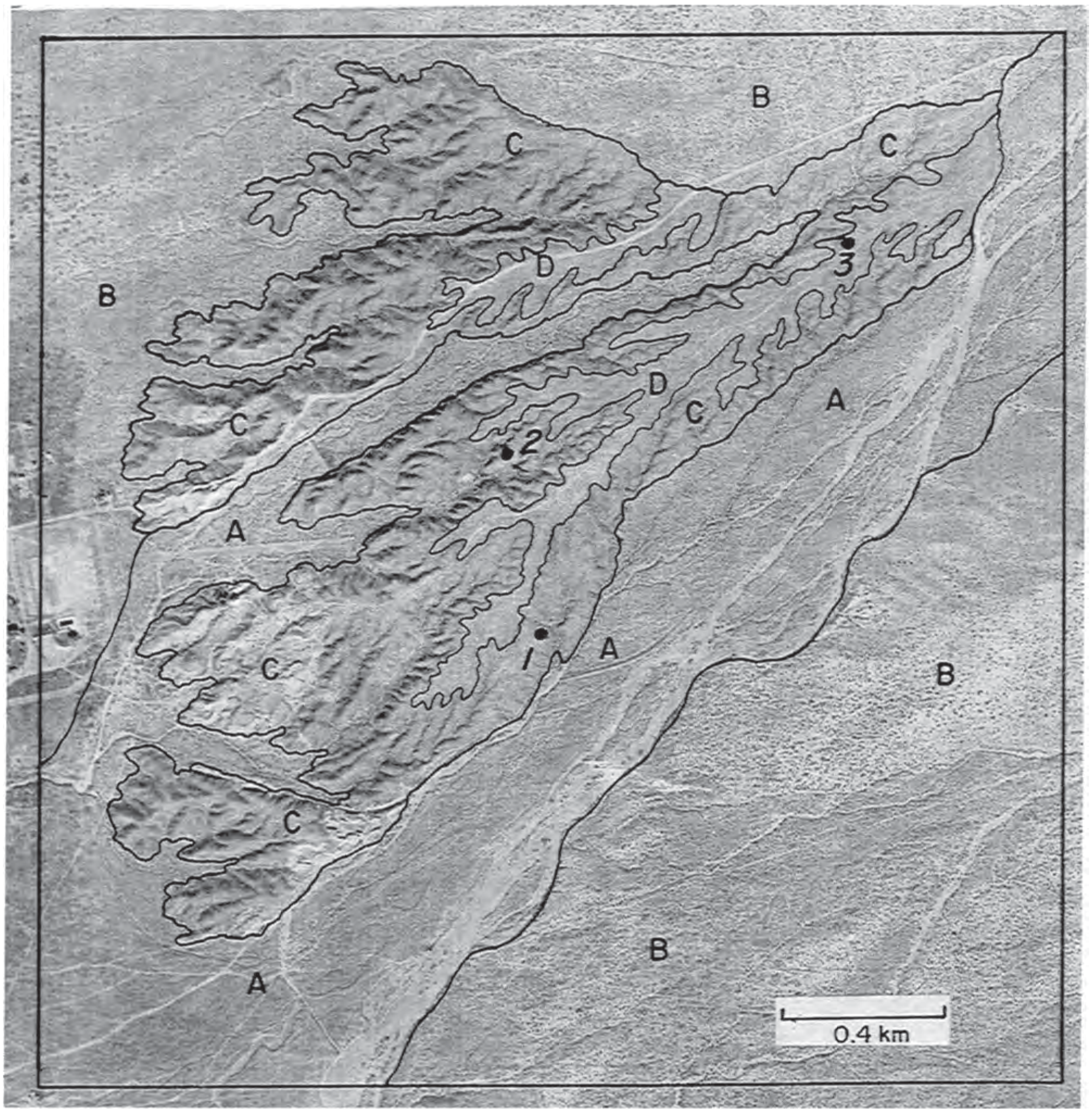


Figure 85. Map of soils in the vicinity of a late-Pleistocene fan remnant at University Park. A = Bluepoint-Arizo-Torriorthent complex (Fillmore and arroyo channel surfaces). B = Bluepoint sand (Fillmore and Fort Selden, undifferentiated, surfaces). C = Arizo-Nickel-Torriorthent complex (Fort Selden, Picacho and arroyo channel surfaces). D = Whitlock soils (Picacho surface). 1 = Onite variant 66-1; 2 = Rilloso variant 60-11; 3 = Whitlock 60-2.

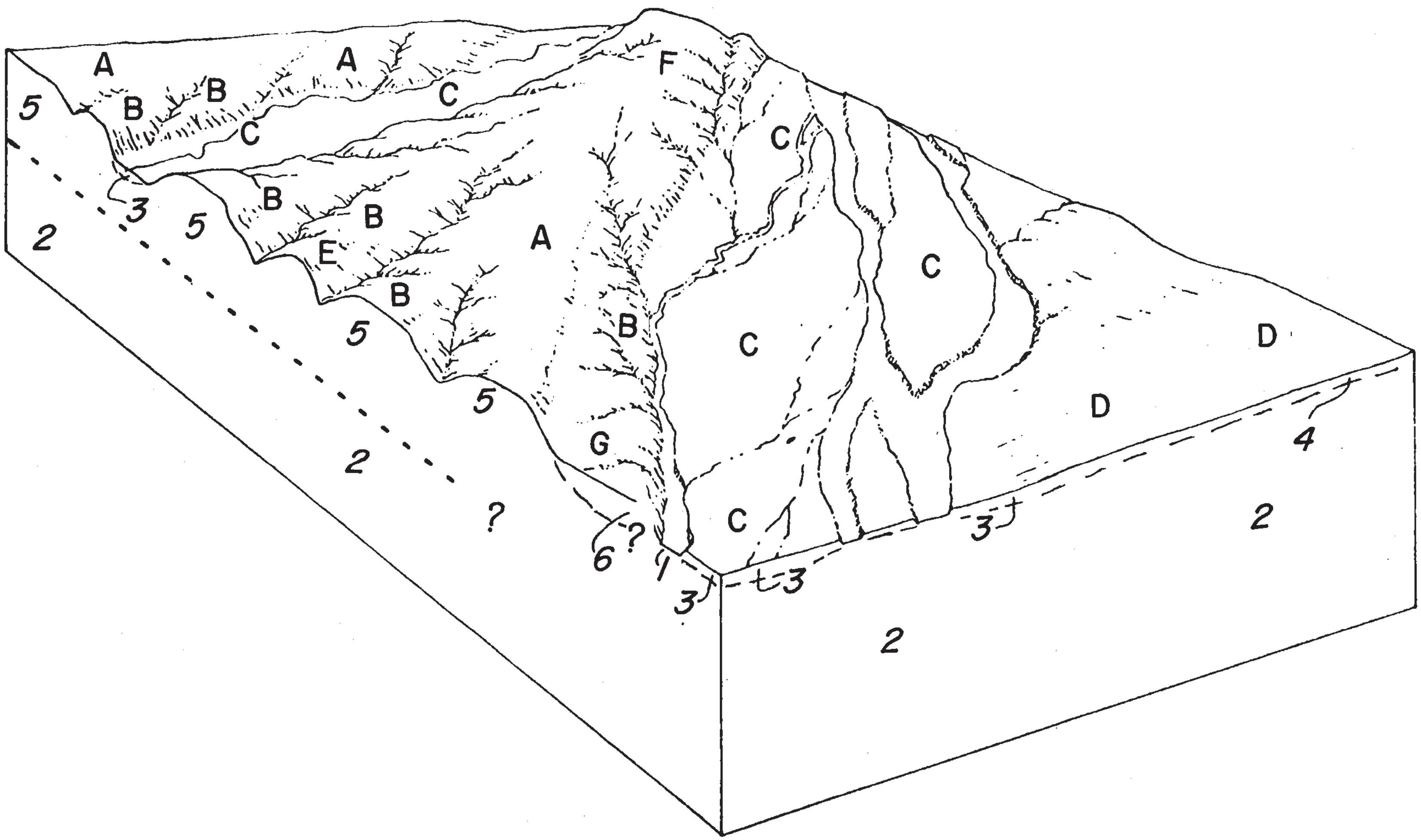


Figure 86. Block diagram of soil-landscape relations in the vicinity of University Park. A = Algerita sandy loam (Picacho surface). B = Kokan-Nickel complex (Fillmore and Picacho surfaces). C = Bluepoint-Arizo complex (Fillmore and arroyo channel surfaces). D = Bluepoint sand (Fillmore and Fort Selden surfaces). E = Rilloso 60-11. F = Whitlock 60-2. G = Onite variant 66-2.
1 = Arroyo channel alluvium (not outlined). 2 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium). 3 = Fillmore alluvium and soils. 4 = Fillmore and Fort Selden colluvium and alluvium and soils. 5 = Picacho alluvium and soils. 6 = Late Picacho alluvium and soils.

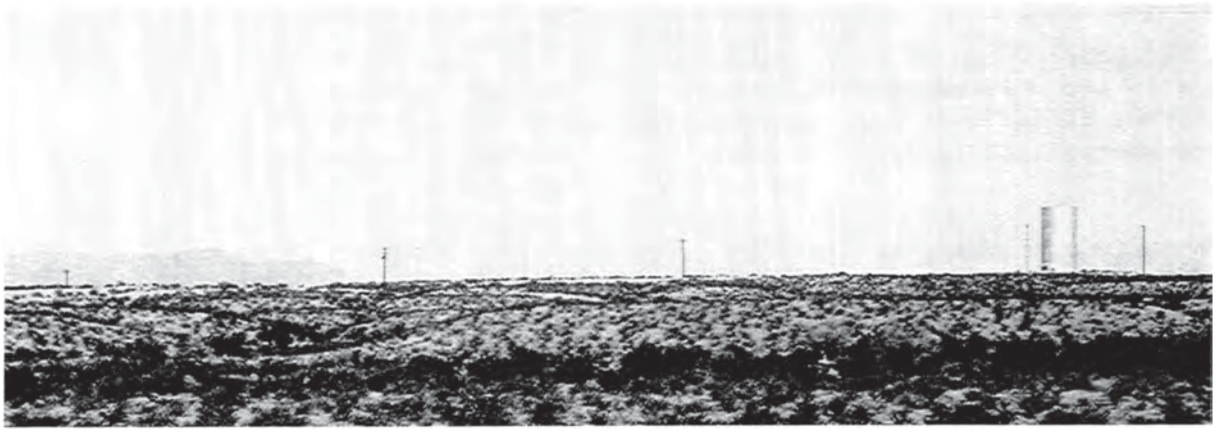


Figure 87. Upper. Landscape in the vicinity of University Park, New Mexico. Photograph taken before expansion of New Mexico State University; much of the area shown is now occupied by buildings and Interstate 25. The Fillmore surface is in the foreground. The latest Pleistocene surface occurs as a small terrace inset against the higher Picacho surface in the background. The water tower is on the Picacho surface. Longitudinal slope is 2 percent from right to left. View is north.

Lower. Site of the Typic Haplargid, Onite variant 66-1 on the latest Pleistocene surface. The site is nearly level transversely. The surface continues beyond the middle foreground as a series of ridges that accord in elevation with the surface at the pit. The Picacho surface at left; telephone poles (center), are on the Picacho. View is northeast.

A radiocarbon age of 21 kyrs was obtained for inner carbonate coatings adhering to the < 19 mm pebbles from 38 to 51 cm depth (fig. 88). This morphological type (inner coatings) and its position in the lower part of the carbonate accumulation should give a maximum or near-maximum carbonate age for this soil.

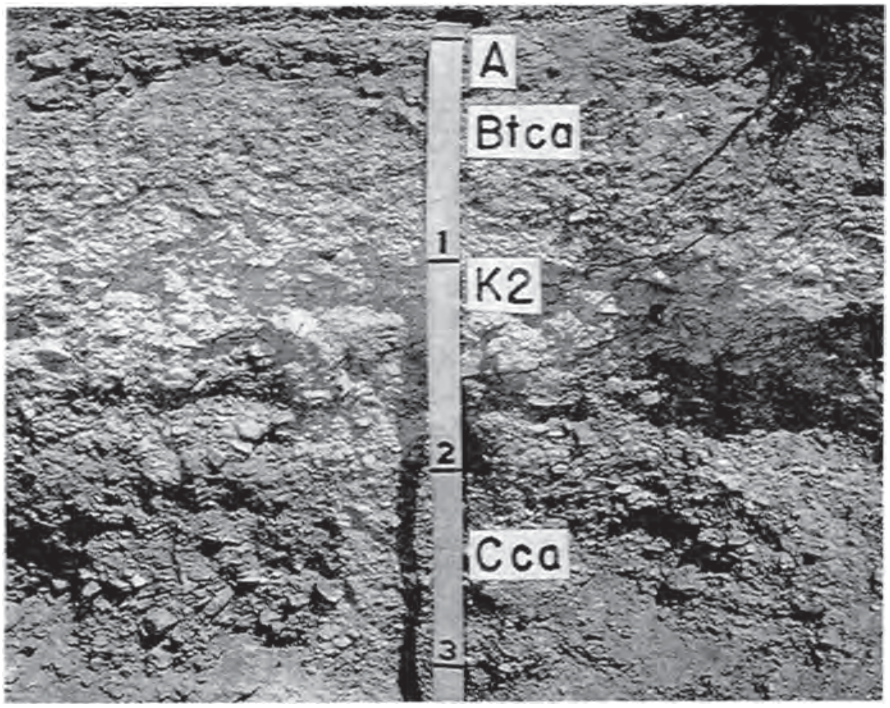
Comparison of Onite variant 66-1 with a soil on stablest Picacho shows that the genetic horizons for the latter soil are much thicker (fig. 88). Comparison of a soil on less stable Picacho also shows differences. Whitlock 60-2, a Typic Calciorthid with a carbonate-engulfed, former argillic horizon (fig. 89) occurs on the crest of a ridge on the main part of the Picacho remnant (fig. 85). Presence of nearby waterways indicates some truncation, as does the absence of an argillic horizon that is present at stablest sites. But absence of carbonate coatings on pebbles in the desert pavement, and distribution and magnitude of the carbonate accumulation (table 108) suggest that truncation has

Table 108. Laboratory data for soils of two ages in the late-Pleistocene.

Horizon	Depth	Silt 1/	Clay 1/	Vol. > 2 mm	Carbonate 2/ < 2 mm	Carbonate 2/ < 0.002 mm	Organic carbon
	cm	pct	pct	pct	pct	pct	pct
Typic Haplargid, Onite variant 66-1							
A2ca	0-5	17	23	10	8		0.15
B21ca	5-8	15	29	1	10		0.09
B22tca	8-18	16	22	3	11		0.15
K1	18-28	17	19	15	20		0.25
2K2	28-43	15	12	40	36		0.18
2C1ca	43-58	7	4	45	5		
2C2ca	58-91	5	3	55	2		
3C3ca	91-107	17	7	3	5		
Typic Calciorthid, Whitlock 60-2							
A2	0-5	19	20	30	5		0.19
Bca	5-10	19	27	2	10	2	0.23
K1	10-23	17	30	5	16	4	0.23
K1	23-36	15	22	5	23	8	0.20
K2	36-58	14	27	3	21	15	0.20
K31	58-89	15	10	10	10	6	0.24
2K32	89-122	6	7	45	16		
3Cca	122-137	10	8	30	5		

1/ Carbonate-free basis.
2/ Amounts: 66-1, 104 kg/m^2; 60-2, 220 kg/m^2.

not been great. Thickness of the carbonate accumulation in Whitlock 60-2 is substantially greater, as well as the total amount of carbonate (table 108). The silicate clay curve also extends to greater depth in Whitlock 60-2 than in



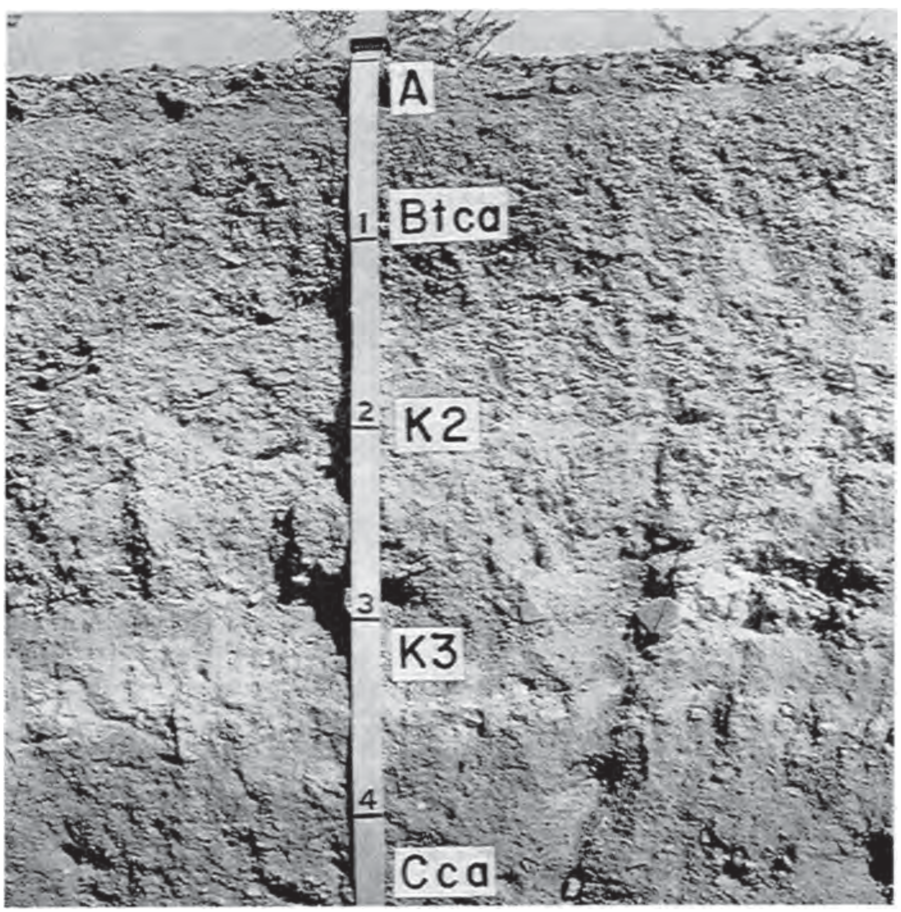


Figure 88. Upper. A Typic Haplargid, Onite variant 66-1, on latest Picacho. Scale is in feet.

Lower. A Typic Haplargid, Dona Ana, on the stablest part of the main Picacho fan. Note difference in thickness of the Bt and K horizons of the two soils. Scale is in feet.

Onite 66-1. The radiocarbon age of carbonate adhering to the less than 19 mm pebbles of the 89-122 cm horizon is 30 kyrs. This is substantially greater than the 21 kyrs for a similar horizon and kind of sample from Onite variant 66-1. Relative ages are sound since Onite variant 66-1 is known to be younger by geomorphic evidence.

Definitive statements about the age of Onite variant 66-1 are tenuous at this time. Pedogenic considerations--the relative thinness of both the silicate clay and carbonate accumulations when compared to soils that must have developed in part during the full-glacial pluvial, such as Whitlock 60-2--suggest that Onite variant 66-1 may not have developed during the pluvial, or at least during all of it. On the other hand the size of the carbonate accumulation is substantially greater than for most soils of Leasburg age.

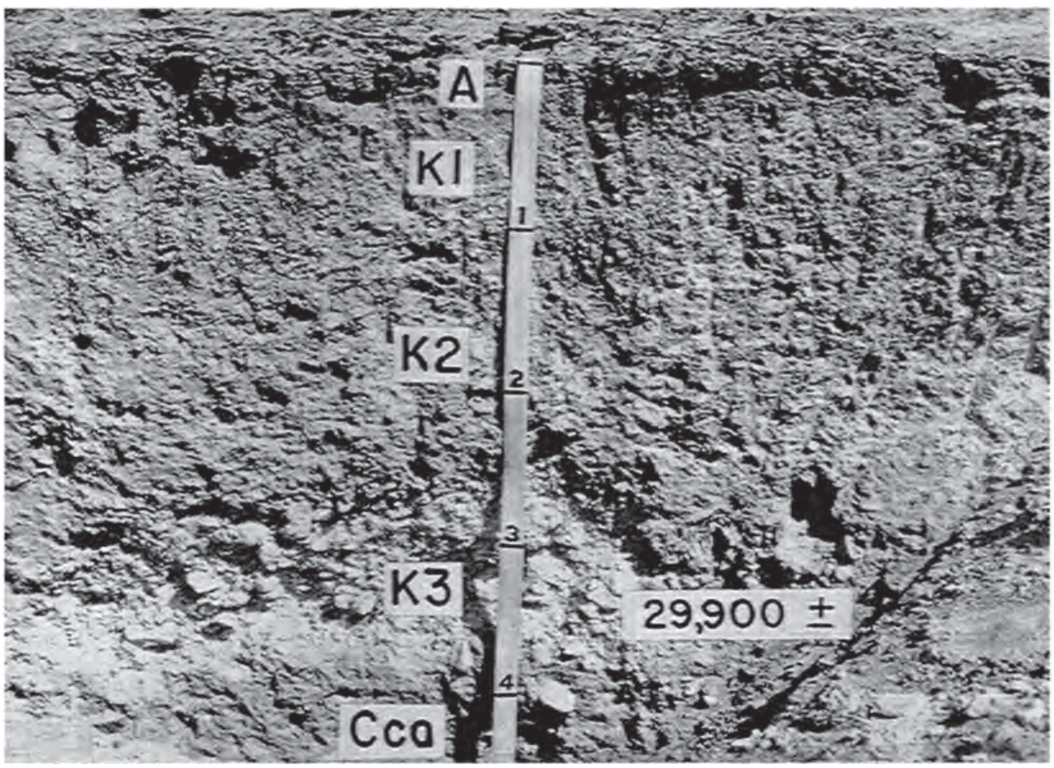


Figure 89. A Typic Calciorthid, Whitlock 60-2, on the main Picacho fan. This soil is near drainageways and has been truncated. The C14 age is greater than for the soil on latest Picacho. Scale is in feet.

141. TENCEE-UPTON COMPLEX (10L)

MAPPING UNIT COMPOSITION

Series	Subgroup	Family Criteria	Percentage of Mapping Unit
TENCEE	TYPIC PALEORTHIDS	LOAMY-SKELETAL, CARBONATIC, SHALLOW	30
UPTON	TYPIC PALEORTHIDS	LOAMY. CARBONATIC, SHALLOW	25
Dalian	Typic Torriorthents	Loamy-skeletal, carbonatic	10
Delnorte	Typic Paleorthids	Loamy-skeletal, shallow	5
Jal	Typic Calciorthids	Coarse-loamy, carbonatic	10
Simona	Typic Paleorthids	Loamy, shallow	5
Weiser	Typic Calciorthids	Loamy-skeletal, carbonatic	5
Other inclusions (Torriorthents, Calciorthids)			10

LOCATION, LANDSCAPE, VEGETATION

These soils occur east and south of the Robledo Mountains and west of the northern part of the Dona Ana Mountains. Most soils have formed in alluvial-fan sediments derived primarily from limestone and calcareous sandstone, in places with some rhyolite. Small areas of sediments near the flood plain contain rounded gravel deposited by the ancestral Rio Grande. Elevations range from about 4000 to 4400 feet.

Ridge remnants of alluvial fans are prominent adjacent to the flood plain and extend headward to the mountain margins. The fans have been deeply dissected and the remnants separated from each other by arroyos and low Fillmore terraces. There are a few high remnants of the Tortugas surface as well as the Picacho surface. The Fillmore surface occurs on most ridge sides. Small areas of the Leasburg surface occur around the margins of the remnants. Some of the remnants are well preserved and are level transversely for substantial distances. Other remnants have been strongly dissected and narrow ridges are prominent. Slopes along the ridge crests range from 3 to 5 percent. Slopes of the steep sides of the remnants range from about 25 to 50 percent and in places are nearly vertical.

Vegetation on crests of the remnants is mainly creosotebush, with some mesquite. In places there are also scattered tarbush, prickly pear, mariola and ocotillo. A few clumps of fluffgrass occur in some areas. The steep sides of ridges (which are commonly oriented east-west) show effects of aspect on vegetation. Commonly the south-facing slopes have shrubby vegetation, mainly creosotebush (in places with some whitethorn) and barren areas are common. The north-facing slopes also have shrubs, but they are usually larger, and perennial grasses are also present--tobosa, bush muhly, and three-awn.

TYPICAL PEDONS, PROPERTIES AND RANGES

These soils are calcareous throughout. They have formed in thick alluvium that in places is carbonate-cemented below the described soils.

Tencee

A typical pedon of Tencee is described in the Appendix (pedon 62-1). A table of properties and ranges is given below.

Table 109. Typical (underlined) and range in selected properties for major horizons of Tencee.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-3	sl,l	10-75	7.5YR- 10YR	5-7 6	4-6 4.5	2-4 3
B	3-28	sl,l	35-75	7.5YR- 10YR	5-7 6.5	4-6 5	3,4
K2m	28-51	--	--	7.5YR- 10YR	6-9 8	5-8 7	2-4 3
C	86-107	ls,sl s	10-75	7.5YR- 10YR	5-7 6	4-6 5	3,4
Control section		sl,l	35-75				

Upton

A typical pedon of Upton is described in the Appendix (pedon 66-5). Figure 90 is a photograph of the pedon and its landscape. A table of properties and ranges is given below.

Table 110. Typical (underlined) and range in selected properties for major horizons of Upton.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-5	l,sl	10-75	7.5YR- 10YR	5-7	4-6	2-4 3
B	5-20	sl l	0-35	7.5YR- 10YR	5-7	4-6 5	3,4
K2m	30-58	--	--	7.5YR- 10YR	6-9 8	5-8 6	3,4
C	74-102	sl ls s	10-75	7.5YR- 10YR	5-7 6	4-6 5	3,4
Control section		sl,l	0-35				

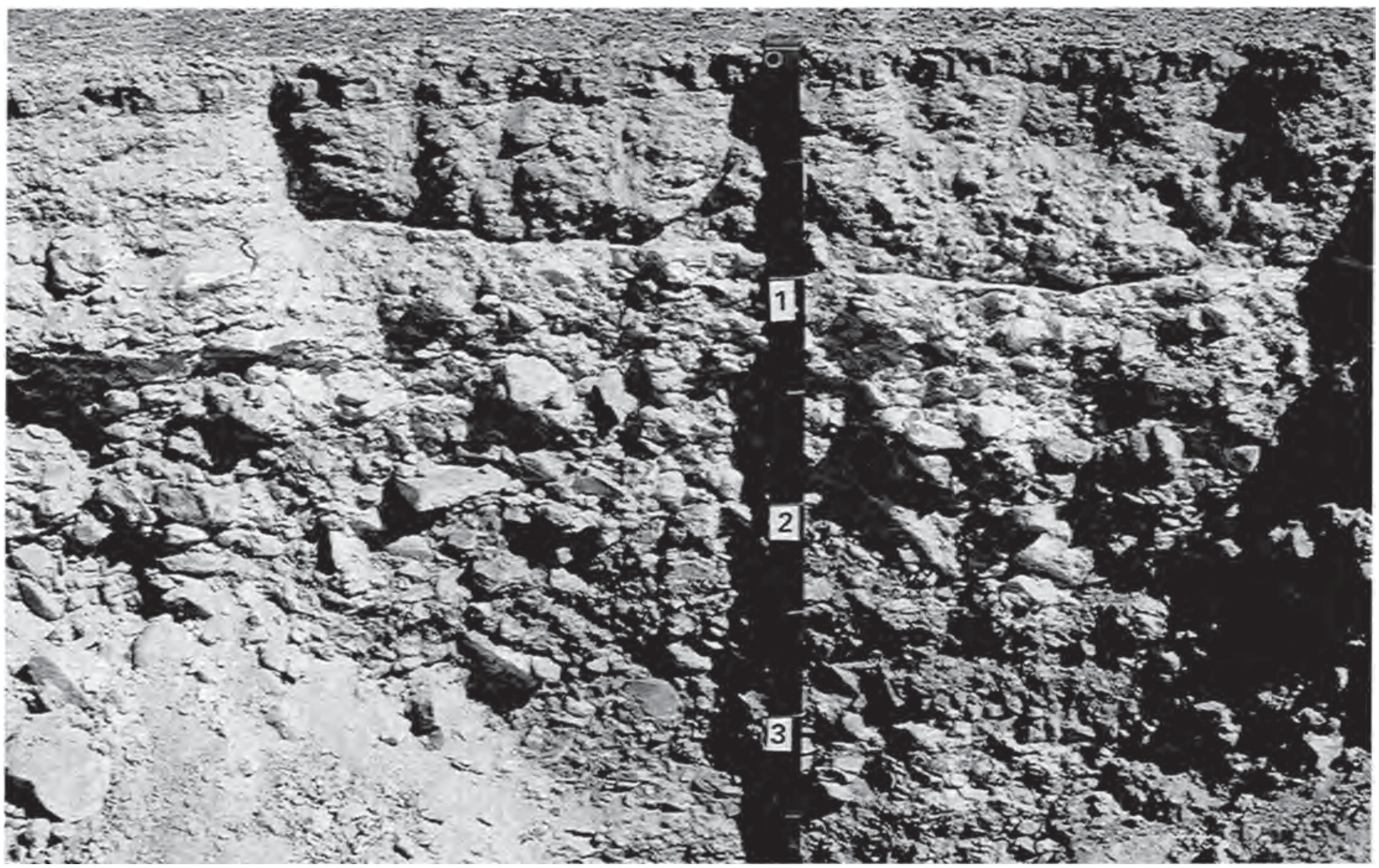


Figure 90. Upper. Landscape of a Typic Paleorthid, Upton 66-5, on the Picacho surface. Vegetation consists of a few creosotebush. Slope is 3 percent. The Robledo Mountains are in the background.

Lower. Upton 66-5. Scale is in feet.

Other. (Tencee and Upton) Depth to the K2m horizon is usually about 25 to 35 cm, ranging from 5 to 50 cm. It is shallower near the sides of the fan remnants and in drainageways.

SOIL OCCURRENCE

The Tencee - Upton complex illustrates the occurrence of Typic Paleorthids (with carbonatic mineralogy) in the driest part of the study area. Ustollic Paleorthids, with more organic carbon, occur at higher elevations west of the San Andres Mountains (section 178).

Paleorthids. The loamy-skeletal TENCEE and the loamy UPTON soils are dominant on the broad ridge crests. The loamy-skeletal Delnorte and loamy Simona soils, both having mixed mineralogy instead of carbonatic, occur where the rhyolitic sediments in the alluvium reduces the carbonate contents of the parent materials so that the soil mineralogy changes from carbonatic to mixed.

Torriorthents. The loamy-skeletal Dalian and the loamy-skeletal Canutio soils have formed in colluvium on the sides of the ridges. The sandy-skeletal Arizo soils are found on small areas of exhumed sediments of the ancestral Rio Grande, particularly around the lower ends of the Picacho remnants. The latter two soils have mixed mineralogy, and occur in areas with enough noncalcareous rock fragments to drop the carbonate content so that soil mineralogy changes from carbonate to mixed.

Calciorthids. Jal soils occur on Picacho ridge crests where content of rock fragments is low in the zone of carbonate accumulation. The loamy-skeletal Weiser soils occur mainly on rounded ridge crests where the soils of the stable Picacho have been strongly truncated. Weiser soils also occur on remnants of the Leasburg surface. Other Calciorthids occur in erosional surfaces such as the Box Canyon area (see "other studies"). These are similar to Jal and Weiser but their C horizons may be cemented too much for these soils.

SOIL BOUNDARIES

Table 111 gives information on boundaries to major adjacent units. Figure 91 shows boundaries and stratigraphy of some of the units.

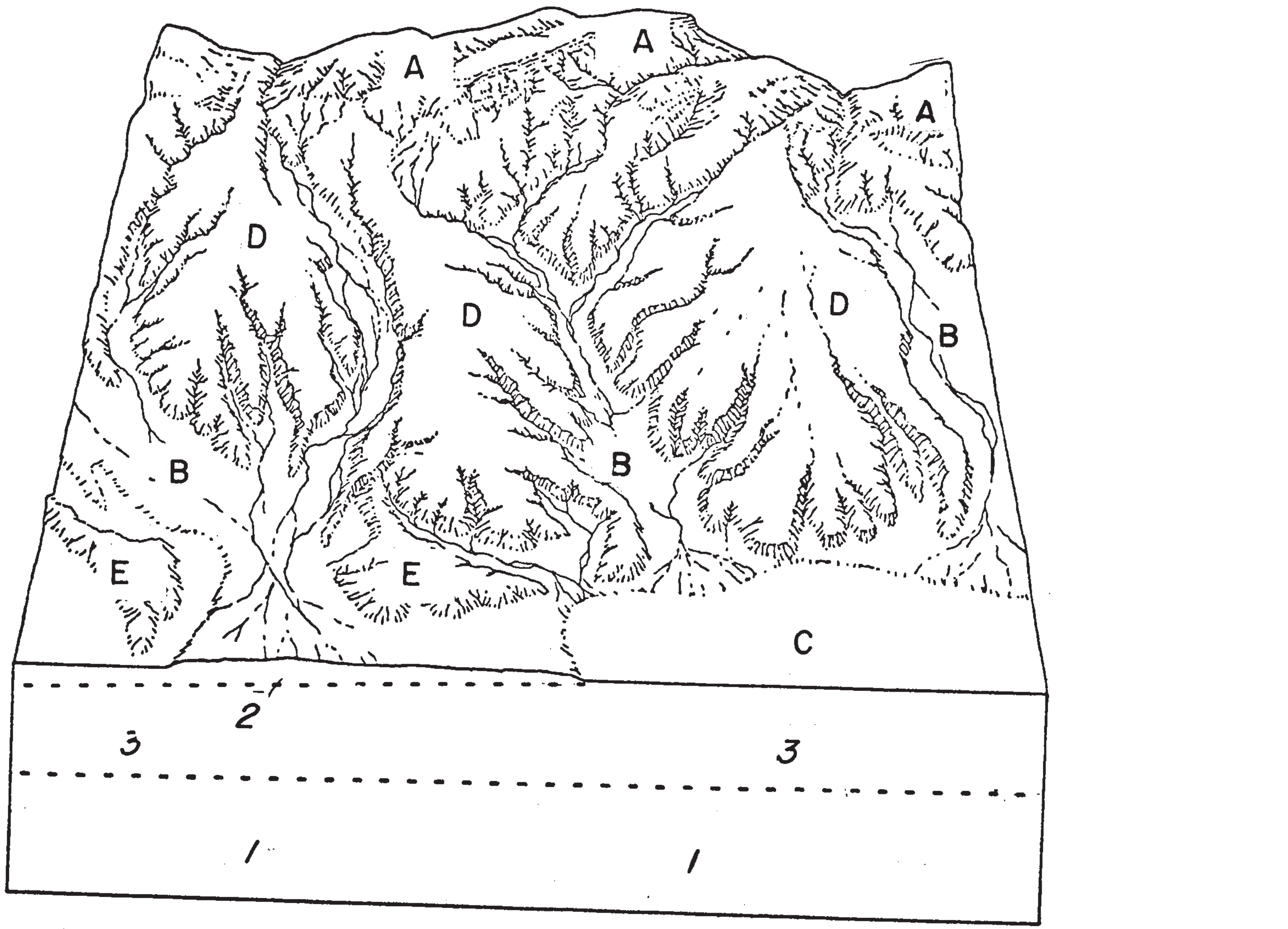


Figure 91. Block diagram of soil-landscape relations in an area of Weiser-Dalian complex, Tencee-Upton complex and Dalian complex. A = Bedrock (sedimentary). B = Dalian complex. C = Soils of the Rio Grande flood plain. D = Tencee-Upton complex. E = Weiser-Dalian complex. 1 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium). 2 = Fillmore alluvium and soils. 3 = Rio Grande deposits (late Quaternary river alluvium).

Table 111. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Weiser-Dalian complex (11LG)	The boundary has been caused by a considerable increase in landscape dissection in unit 11LG. The topographic boundary is fairly distinct, occurring between strongly dissected, narrow ridges of unit 11LG and broader ridges of unit 10L.
Nickel gravelly sandy loam (11R)	The boundary has been caused by a change in parent materials, from high-carbonate sediments of unit 10L to low-carbonate sediments of unit 11R.
Dalian complex (13G)	In places, the boundary has been caused by a younger alluvium and geomorphic surface (Fillmore) in unit 13G, inset against the older Picacho. Commonly, however, the geomorphic surface is the same (Fillmore) with the Fillmore terrace surface occurring on steep slopes leading up to the Picacho ridge remnants. The topographic boundary is prominent. Because of prominent differences in slope--the steep ridge sides commonly range from 25 to 50 percent--the boundary is drawn at the contact of the foot of the steep side slopes and the margin of the more gently sloping Fillmore terraces.
Sedimentary rock outcrop and Entisols (40L)	Cause of the boundary is a change from thick alluvium in unit 10L to bedrock which is at or near the surface in unit 40L. The topographic boundary is prominent since it is marked by the steep slopes and bedrock of the Robledo Mountains.

OTHER STUDIES

Studies in this unit have been grouped into two parts--a Paleorthid in high-carbonate parent materials, and the soils and landscape of an erosional surface in Box Canyon.

A Paleorthid in high-carbonate parent materials

Upton 66-5 occurs on a well-preserved Picacho fan west of the Robledos. Although this pedon is on one of the stablest sites, it lacks an argillic horizon (section 86). And (unlike many Calciorthids and Paleorthids formed in low-carbonate materials) no evidence has been found that it ever had an argillic horizon. This is attributed to the high-carbonate parent materials; many limestone fragments still occur throughout this soil even though it must have formed partly in a major pluvial of the Pleistocene.

The C-14 age of the laminar horizon was also obtained (section 89). The C-14 age of inorganic carbon from the laminar horizon of Upton 66-5 is about 15 kyr (section 89). This shows that pedogenic carbonate derived from carbonate rocks millions of yr old can be quite young. The date compares with an age of 14 kyr for the laminar horizon of a soil (Cruces variant 59-16) formed in rhyolitic alluvium. Both soils are on the same surface (Picacho) and are the same age (late-Pleistocene).

The K horizon of Upton (and the associated Tencee) tends to be more prominent than in soils formed on low-carbonate materials of the same age (Picacho surface, late-Pleistocene). Gross thickness of the K horizons are similar; in very gravelly materials the difference is mainly in the presence and character of the laminar horizon, which is discontinuous in soils formed on low-carbonate materials. In contrast, many Upton and Tencee soils have one continuous laminar horizon and some have two, although the uppermost one has commonly been fractured. This difference in development must have been caused by the difference in carbonate content of the parent materials. In low-carbonate materials, carbonate in the soils must have been almost entirely supplied from the atmosphere and the aggregate of calcium from this source must have been less than that supplied by the high-carbonate parent materials of the Tencee and Upton soils.

Soils and landscape of an erosional surface in Box Canyon

Most soils in this unit have formed in sediments of the constructional surfaces of alluvial fans, but some have formed in eroded terrains that cut alternating beds of high- and low-gravel alluvial fans. One such area is in the Box Canyon area, south of the Robledo Mountains and west-northwest of Picacho Mountain.

The surface has been deeply dissected. The main drainage lines are narrow canyons with nearly vertical cliffs, 5 to 25 m high. Narrow ridges occur between the canyons. Longitudinal slopes along ridge crests range from about 1 to 3 percent to the southeast; they bevel the sediments at a low angle. Slopes from edges of the cliffs to crests of the ridges generally range from about 5 to 35 percent.

The parent materials are compact high-gravel materials interbedded with low-gravel fine earth. The gravelly strata range from 1/2 to many m in thickness. Some parts are variably cemented by carbonate. The gravel is derived mainly from limestone and calcareous sandstone. Fine earth is calcareous and typically light brown or light reddish brown; texture generally ranges from sandy loam to clay loam, with few clays. These strata range in thickness from a few cm to several m. The surface is erosional and soil texture is largely inherited from the parent materials.

Main interfluves of the remnantal Tortugas surface have been extensively eroded by rills cutting back from the canyons and by general sheet erosion. This erosion has tended to follow the zones of differing gravel content, with a resultant series of low (less than 1, to several m) discontinuous scarplets and lower, relatively flat areas formed by resistant gravelly beds. Along the lower side of many of the scarplets are outcrops of beveled fine-earth strata.

Weak Calciorthids have typically formed in these small areas. Upper horizons of one of them is described below.

A 0-5 cm. Light gray (7.5YR 7/2, dry; 7.5YR 4.5/4, moist) gravelly heavy fine sandy loam; weak fine to medium platy; soft; very few roots; many fine and very fine vesicles; lower 1 cm appears brighter colored (7.5YR 5.5/4) when moist; effervesces strongly; abrupt smooth boundary.

C1ca 5-18 cm. Pink (8YR 7/3, dry; 8YR 5/4, moist) gravelly heavy fine sandy loam; weak medium subangular blocky; hard; few roots; few fine carbonate nodules; common fine carbonate filaments on and in peds; thin continuous carbonate filaments on pebbles; effervesces strongly; abrupt to clear, smooth boundary.

C2ca 18-46 cm. Light brown (8YR 6.5/3, dry; 8YR 5/4, moist) gravelly sandy loam; massive; hard; very compact in place; common white carbonate filaments; some fracture planes have thin powdery white carbonate coatings; carbonate coatings on pebbles; effervesces strongly.

Gradation to the adjacent constructional surfaces of the Picacho and Tortugas surfaces is marked by broader interfluves, decrease in dissection and rills, disappearance of scarplets and a shift to the Paleorthids (Tencee and Upton).

142. Soils of the Fort Selden, Picacho, and Tortugas (?) surfaces.

These soils occur on high structural benches (fig. 92). Exhumation of the river gravels and development of the benches started in mid-Pleistocene time and is continuing today. The gravelly benches have also been variably eroded since their development. For these reasons the age of soils on the benches varies widely.

Most of the area is the Fort Selden Group and is dominated by Fillmore ridge sides grading to Fillmore terraces. Some of the stabler ridge crests probably date from Picacho time. A few of the broadest crests may represent the Tortugas interval. In the Desert Project area the Tortugas surface is generally minor in extent; soils of these remnants have been substantially truncated. Larger remnants of the Tortugas surface do occur in one area west of the Robledo Mountains but even here the soils have been eroded. Precise statements about the pedogenic significance from the start of Tortugas time to the present are therefore difficult to make. Observations of calcic and petrocalcic horizons suggest development stronger than Picacho.

One mapping unit occurs on these surfaces, the Kokan-Bluepoint complex (11X), section 143 below.

143. KOKAN-BLUEPOINT COMPLEX (11X)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
BLUEPOINT	TYPIC TORRIPSAMMENTS		20
CALIZA	TYPIC CALCIORTHIDS	SANDY-SKELETAL	15
KOKAN	TYPIC TORRIORTHENTS	SANDY-SKELETAL	15
YTURBIDE	TYPIC TORRIORTHENTS	SANDY	20
Nickel	Typic Calciorthids	Loamy-skeletal	5
Rilloso	Typic Calciorthids	Sandy	10
SND-6	Entisols		10
Other inclusions (Paleorthids)			5

LOCATION, LANDSCAPE, VEGETATION

These soils occur mainly on the eastern side of the valley border, in the southern part of the area. The soils have formed in sand and rounded gravel of ancient river alluvium, which occurs both in-place and reworked as sideslope colluvium and as young alluvial deposits between the ridges. Elevations range from about 4200 to 4300 feet.

High ridges are a prominent landscape feature. The sediments have been cut by arroyos. Side drainageways extend from arroyos and sharply incise the ridges, forming saddles. Ridge crests are generally narrow and rounded but some are level transversely for a few feet. Highest ridges are at about the same elevation, but locally, slopes along ridge crests range from 1 to 5 percent. Ridge sides slope from 5 to 35 percent.

Vegetation on ridge crests usually consists of ratany, fluffgrass and scattered creosotebush and prickly pear. South-facing slopes tend to have less vegetation, which is mainly ratany and creosotebush. In places there are clumps of fluffgrass and three-awn, especially in or near drainageways. North-facing slopes have more vegetation and shrubs are larger, consisting of Mormon tea, ratany, few creosotebush, and common fluffgrass. Quite large clumps of three-awn and black grama occur in places, particularly on lower slopes and in drainageways.

TYPICAL PEDONS, PROPERTIES AND RANGES

The C horizon is noncalcareous in many places below the carbonate accumulation. Carbonate occurs discontinuously in some strata as coatings on pebble bottoms and in places as cylindroids. Some of the cylindroids have a branching form and resemble roots. There are scattered mudballs up to 1/2 m or more thick. Manganese coatings on pebbles and sand grains are prominent in some areas and often occur along bedding planes. Yellowish stains are prominent in some gravelly strata. These soils have formed in thick gravelly deposits, a few m thick, underlain by sandy, low-gravel deposits that are many m thick. Buried soils are generally absent and no bedrock or petrocalcic horizon occurs within a depth of many m.

A typical pedon of Caliza is described below. The location is the NE 1/4, Sec. 15, T23S, R2E, east bank of road along a pole line. Figure 92 is a photograph of the pedon and its landscape. A table of properties and ranges follows the description.

Soil surface. 95 percent covered with rounded gravel, including chert, quartz, sandstone, rhyolite, pink granite, and other igneous rocks. The fragments are mostly between 1/2 and 5 cm in diameter, with a few up to 8 cm diameter.

A 0-6 cm. Light brownish gray (10YR 6.5/2, dry) or dark brown (10YR 4/3, moist) very gravelly sandy loam; mainly weak very fine crumb between pebbles, with weak medium platy in the upper 1/2 cm; soft; very few roots; thin carbonate coatings on pebbles, mainly on pebble undersides; effervesces strongly; abrupt smooth boundary.

K2 6-33 cm. White (10YR 9/2, dry) or light gray (10YR 7/2, moist) and very pale brown (10YR 7/3, dry) or brown (10YR 5/3, moist) very gravelly sandy loam; massive; some of the lightest-colored material weakly cemented and hard, other material is soft; in cemented zones, pebbles are thickly coated and separated by carbonate; coatings on pebbles in other parts are thin; roots are common in the looser zones; effervesces strongly; clear wavy boundary.

C1ca 33-69 cm. Very pale brown (10YR 7/3, dry) or brown (10YR 5/3, moist) very gravelly loamy sand; massive; soft; very few roots; thin, discontinuous carbonate coatings on pebbles and sand grains; a few tongues of weakly cemented zones extend into this horizon from the horizon above; effervesces strongly; clear wavy boundary.

C2ca 69-101 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) very gravelly sand; massive; soft; very few roots; some pebbles and sand grains discontinuously coated with carbonate; most effervesce strongly; a few zones noncalcareous; a few light-colored, weakly carbonate-cemented zones, 5 to 10 cm

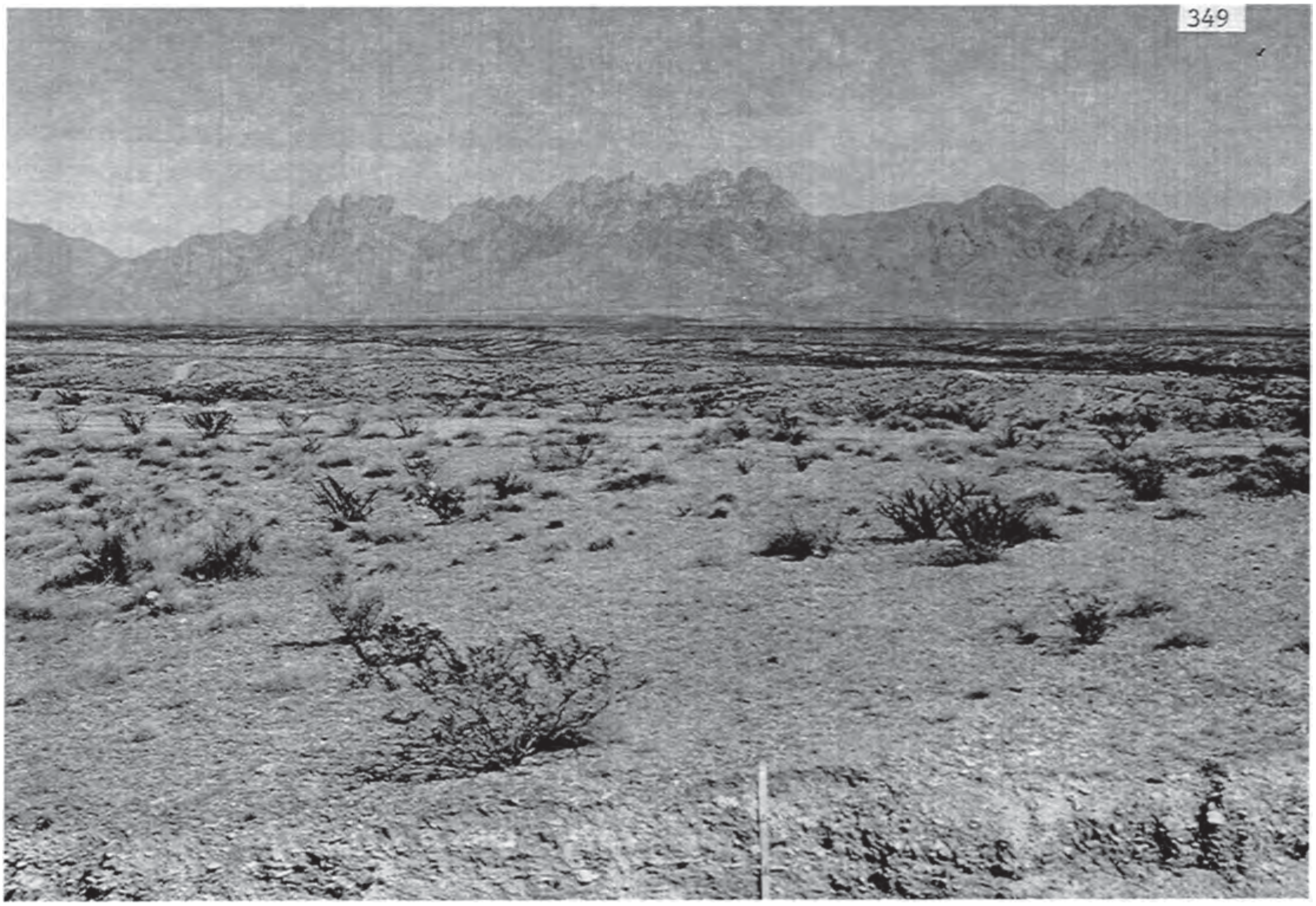


Figure 92. Upper. Landscape of a Typic Calciorthid, Caliza very gravelly sandy loam, on a structural bench formed in the Upper Camp Rice Formation (fluvial facies). Vegetation is fluffgrass, ratany, and creosotebush. The area is the nearly level crest of a ridge. The Organ Mountains are in the background. Lower. Caliza very gravelly sandy loam. Scale is in feet.

C3 101-112 cm. Light gray (10YR 7/2, dry) or brown (10YR 5/3, moist) very gravelly sand; massive and single grain; soft and loose; no roots; thin, patchy carbonate coatings on undersides of some pebbles; most parts noncalcareous or effervesce weakly, a few parts effervesce strongly.

Table 112. Typical (underlined) and range in selected properties for major horizons of Caliza.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-6	sl (underlined), ls	10-75	7.5YR-10YR (10YR underlined)	5-7, 6.5 (underlined)	3-5, 4 (underlined)	2 (underlined)-4
K2	6-33	sl (underlined), scl	35-75	7.5YR-10YR (10YR underlined)	6-9 (9 underlined)	5-8, 7 (underlined)	2 (underlined)-4
C1ca	33-69	s, ls (underlined)	35-75	7.5YR-10YR (10YR underlined)	5-7 (7 underlined)	3-5 (5 underlined)	2,3 (3 underlined)
Control section		ls,s	35-75				

Other. Depth to the calcic horizon (the K2 horizon in the description) is usually 4 to 15 cm but ranges from 2 to 50 cm. These soils are calcareous throughout. Thin B horizons are present in some pedons. The calcic horizon is partly indurated in some pedons but cementation is not continuous enough for a petrocalcic horizon.

Kokan

A typical pedon of Kokan is described below. The location is 125 feet south of Hwy. 70 at a point about two miles southwest of the Hwy. 70 - Jornada Road intersection, in a bank on the west side of a dirt road heading south.

Soil surface. Desert pavement of rounded gravel with mixed lithology--rhyolite, andesite, a few chert, pink granite--covers about 90% of the surface.

Aca 0-4 cm. Light brownish gray (10YR 6/2, dry) or dark grayish brown (10YR 4/2, moist) very gravelly loamy sand; weak fine crumb, soft; roots common; thin carbonate coatings on bottoms of some pebbles; effervesces strongly; abrupt smooth boundary.

C1ca 4-16 cm. Light brownish gray (10YR 6.5/2, dry) or brown (10YR 5/3, moist) very gravelly sandy loam; weak fine and very fine crumb; soft and loose; roots common; carbonate coatings on pebbles, many continuous but some mostly on bottoms of pebbles; effervesces strongly; clear wavy boundary.

C2ca 16-46 cm. Light gray (10YR 7/2, dry) or grayish brown (10YR 5/2, moist) very gravelly loamy sand; massive; soft; few roots; pebbles thinly and discontinuously coated with carbonate; effervesces strongly; clear wavy boundary.

C3ca 46-55 cm. Light gray (10YR 7/2, dry) or grayish brown(10YR 5/2, moist) very gravelly sand; massive and single grain; soft and loose; few roots; thin discontinuous carbonate coatings on pebbles, fewer than above; effervesces strongly; clear wavy boundary.

C4 55-84 cm. Light brownish gray (10YR 6/2, dry) or brown (10YR 5/3, moist) very gravelly sand; mostly massive and single grain, some soft and loose; very few roots; some discontinuous thin carbonate coatings on pebbles and sand grains, considered allogenic; effervesces strongly.

Ranges of these properties are similar to those of Arizo (section 128) except that these soils generally have 10YR hue.

Bluepoint, Yturbide

See section 130 for a description and ranges in properties of Bluepoint and Yturbide.

SOIL OCCURRENCE

The ridge crests have formed on erosion-resistant gravels exposed by exhumation from beneath low-gravel materials (fig. 93). As noted earlier, the sediments have been exposed to pedogenetic processes for widely ranging lengths of time. This and variations in gravel content combine to make the soil pattern very complex. Highest ridge crests that are level or nearly level transversely have the most strongly developed soils (Calciorthids and Paleorthids).

Calciorthids and Paleorthids. CALIZA (sandy-skeletal) and Nickel (loamy-skeletal) soils are dominant on stablest, highest ridge crests. There are smaller areas of the sandy Rilloso soils. In a few of the stablest areas where the sediments are highly gravelly, the soils have petrocalcic horizons and are Paleorthids.

Torriorthents. The sandy-skeletal KOKAN soils are dominant on many of the narrowest ridge crests, and also occur on some ridge sides. Progressive decrease in gravel content of the 25 to 100 cm control section causes a shift to the Torriorthent YTURBIDE (15 to 35 % gravel) and to the Torripsamment BLUEPOINT (less than 15 % gravel).

Entisols. SND-6 occurs in arroyo channels.

SOIL BOUNDARIES

Table 114 has information on boundaries to major adjacent units. Figure 93 shows boundaries and stratigraphy of some of the units.

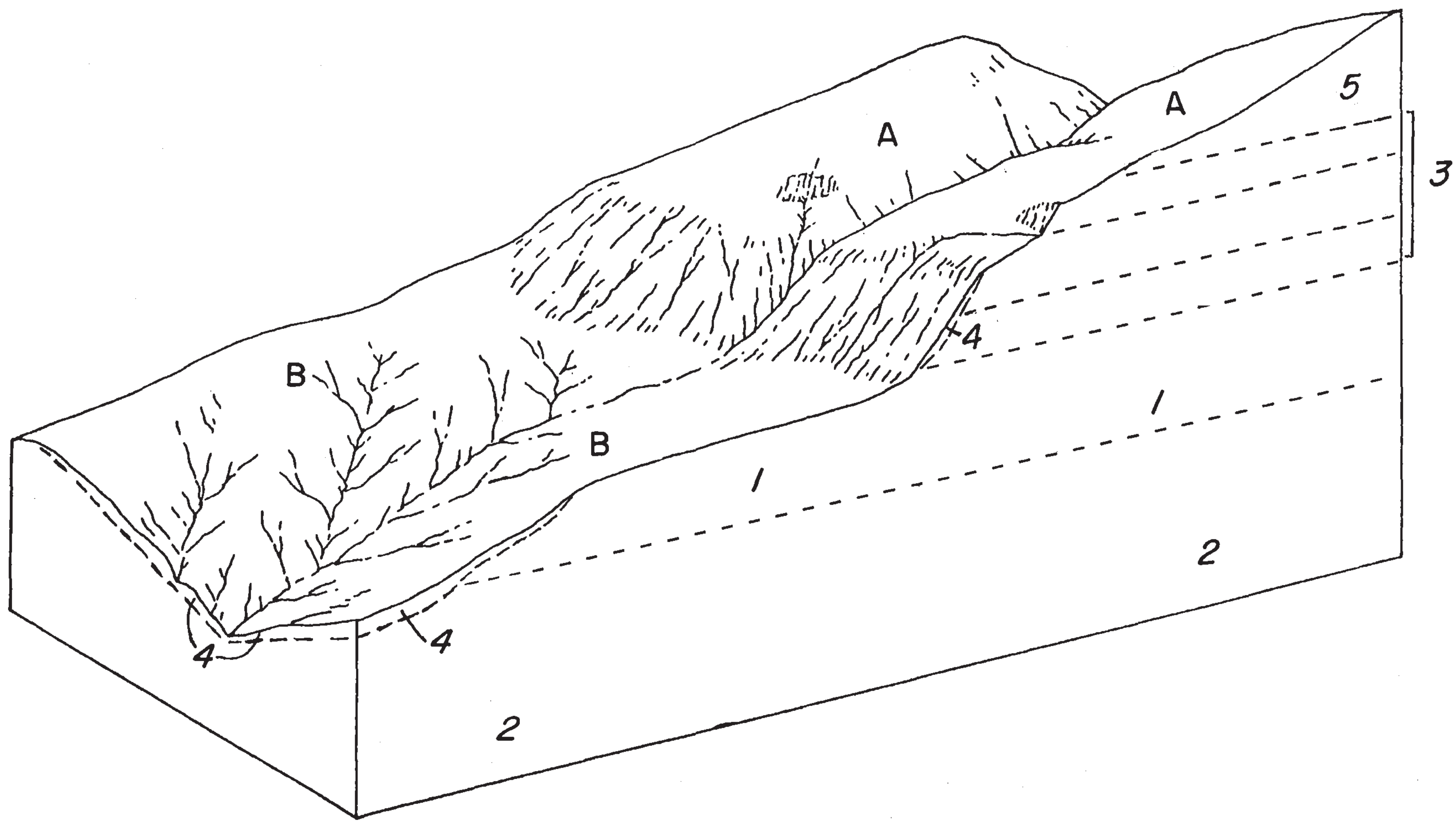


Figure 93. Block diagram of soil-landscape relations and soil stratigraphy in an area of Haplargids, dissected, and Kokan-Bluepoint complex on structural bench. Paleosols occur in the piedmont facies of the Upper Camp Rice Formation. The number of paleosols varies from one place to another; three are shown here. A = Haplargids, dissected (post-Jornada I erosion surface). B = Kokan-Bluepoint complex on structural bench (post-Tortugas).
1 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium), gravelly. 2 = Upper Camp Rice Formation, fluvial facies (ancient river alluvium), nongravelly. 3 = Upper Camp Rice Formation (piedmont facies). 4 = Fillmore colluvium. 5 = Younger than Jornada I.

Table 113. Cause and character of boundaries to adjacent major units.

To mapping unit:	
Haplargids, dissected (11Y)	The boundary has been caused by strong landscape dissection. Gravelly river sediments, buried by sediments of unit 11Y, emerge at the surface on the 11X side of the boundary. The gravel is a resistant unit and forms a structural bench consisting of high, gravelly ridges. The boundary is prominent topographically; strong dissection of the low-gravel buried soils has formed a scarp along the border between the structural bench and the dissected paleosols just upslope.
Bluepoint sand (13Y)	The boundary is due to the presence of thick sandy deposits beneath the gravelly sediments of unit 11X, and their exhumation in unit 13Y. Location of the boundary approximately corresponds to the contact of the lowermost gravelly beds on the underlying sand. The boundary can usually be observed on the ground; the gravelly sediments are relatively resistant to erosion and tend to form steep, high ridges, whereas slopes on the sandy sediments are smoother and much less steep.

OTHER STUDIES

Additional studies concern dissected paleosols and the development of structural benches. Figure 93a locates an area with these features.

The development of structural benches

Structural benches occur extensively along the river valley where low-gravel materials with paleosols have been eroded and underlying gravelly beds have been exposed. The gravelly beds are resistant to erosion and tend to form gravelly ridges with crests at about the same elevation. These ridge crests constitute the structural bench.

The paleosols are resistant to slumping and thus a scarp marks the area between the structural bench and the outcrop of paleosols. The scarp between the paleosols and the structural bench may be traced along the landscape as shown by the dashed line in figure 93a, being interrupted only by large arroyos. Distribution of soils along the scarp, and the sinuous nature of the scarp itself is shown in the soil map (fig. 93b, upper). Development of the structural bench west of the scarp is illustrated in figure 93b, lower. The structural benches are extensive along the valley border, being mostly in the southern part, and range up to about two mi in width.

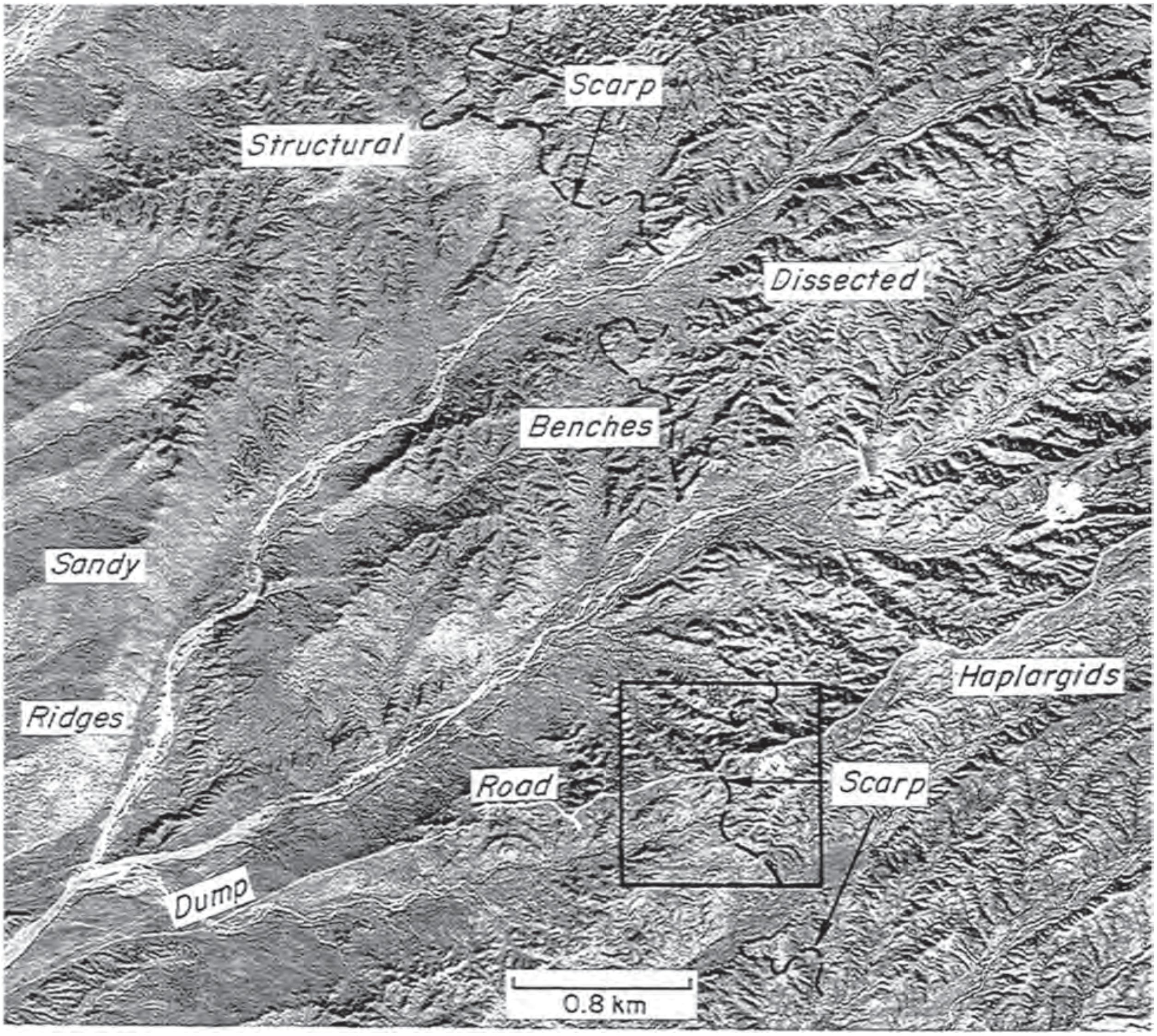
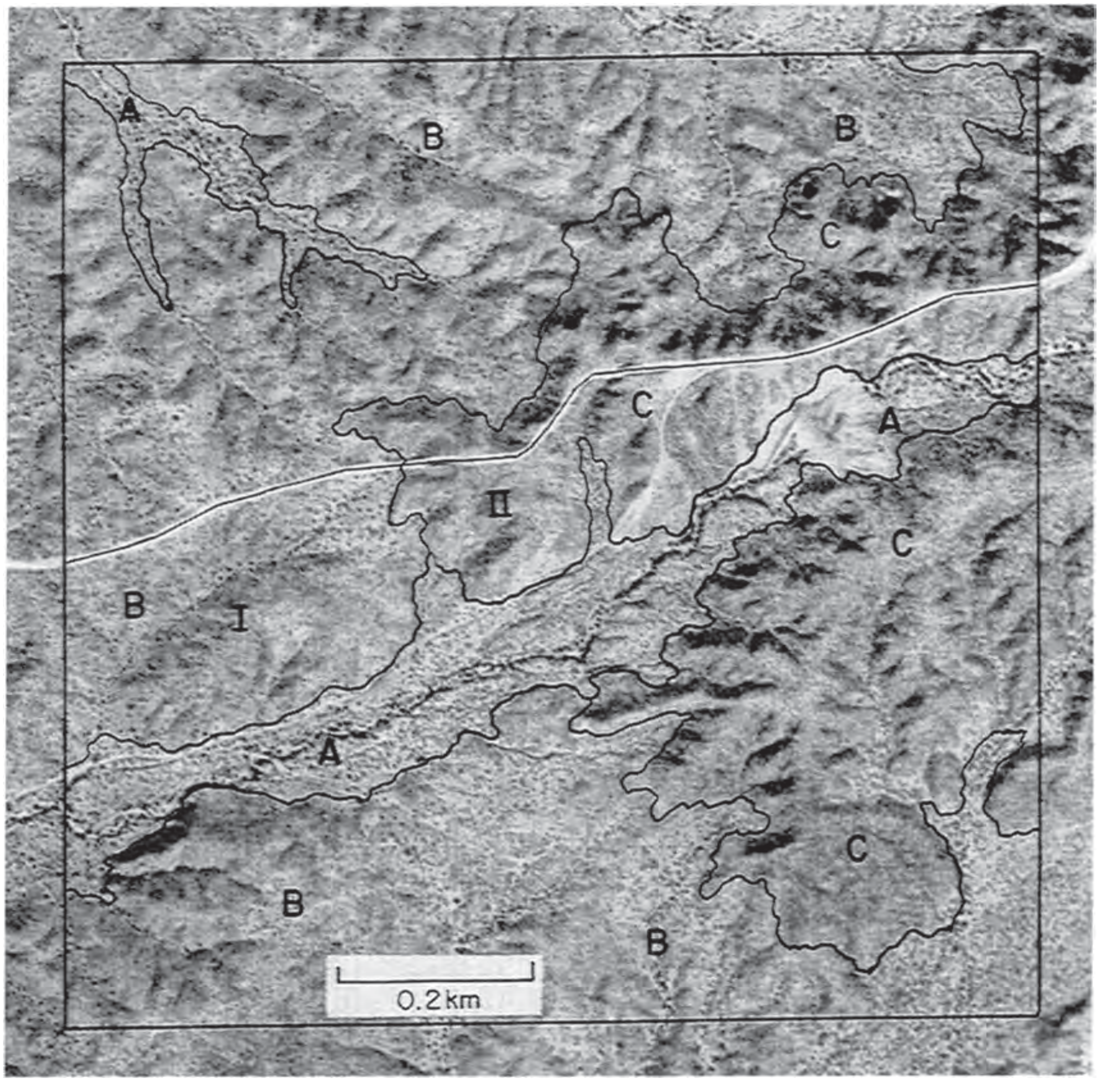


Figure 93a. Location of soil map (fig. 93b) structural benches, dissected Haplargids and the scarp between.



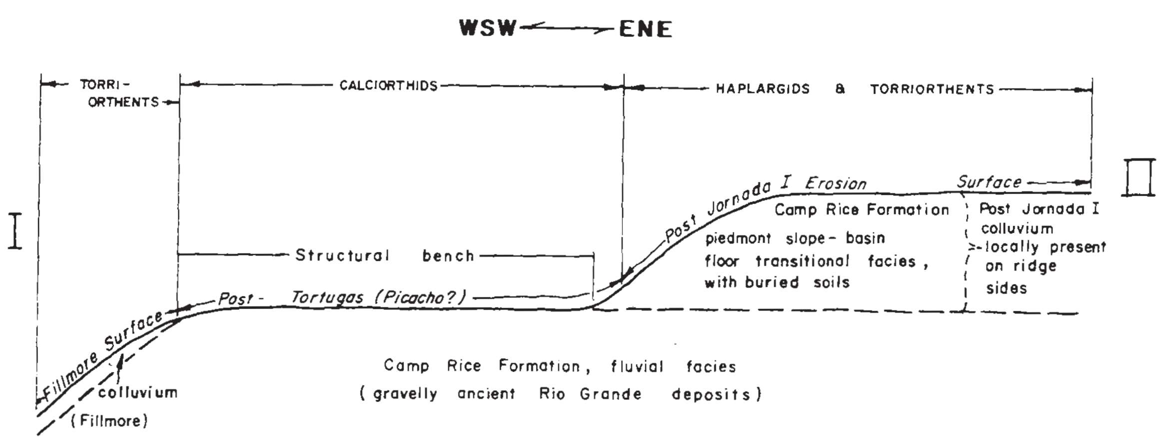


Figure 93b. Upper. Soil map across a structural bench, scarp, and dissected paleosols. A = Arizo-Torriorthent complex (Fillmore and arroyo channel surfaces). B = Rilloso-Bluepoint complex (Fort Selden, Picacho). C = Dissected Haplargids (Fort Selden, Picacho).

Lower. Cross section from points I to II, soil map.

Dissected paleosols

A broad belt of dissected paleosols occurs along the valley east of the scarp (fig. 93a). The paleosols are in the unit "Dissected Haplargids" (section 199). The paleosols are still buried in most places, but are discontinuously exposed over a very large area along the east side of the valley from the vicinity of Goat Mountain to the south boundary of the project and beyond. The paleosols mark times of general landscape stability, during which soils were formed, alternating with times of instability, during which there was erosion in some upslope areas and concurrent sedimentation downslope.

The buried soils are stratigraphically between the Upper Camp Rice Formation (fluvial facies) and sediments of the Jornada I surface. Thus they must have formed at various times early in the period of development of the soils of mid-Pleistocene La Mesa (sections 148-152). Morphology of the buried soils is very similar to soils of various ages at the present land surface and younger than Jornada I. Thus it seems likely that the climate during development of these buried soils ranged no wider than from the Holocene climates to the full-glacial maximum in the late Pleistocene (17,000-23,000 B. P.). This agrees with observations elsewhere (sections 81, 88a, 152, 160) that suggest little weathering since mid-Pleistocene time.

Two pedons in these materials have been sampled (table 114; see Appendix for descriptions). Pedon 59-9 occurs along a pipeline cut, east of the area shown in figure 93a; pedon 59-12 is south of Tortugas Mountain (see soil maps, Appendix, for location). The land-surface soils of both pedons have horizons of carbonate accumulation and are underlain at shallow depth by buried Typic Haplargids. Both buried soils have argillic horizons, horizons of carbonate accumulation, and black coatings (Mn? Fe?) on peds in the B. Occurrence of the black coatings in the B horizon, and their absence in the C horizon suggest that they were a feature of pedogenesis when the buried soils were at the land surface, and not deposited from ground water or from water associated with deposition of the overlying alluvium.

Carbonate C-14 dates for pedon 59-9 (table 114) suggest that carbonate in the B2tb horizon was emplaced from above after the buried soil had formed. This is consistent with the concentration of the carbonate in elongate bodies between structural units, and with the noncalcareous interiors of many peds. Carbonate in the C horizon has an age exceeding 30,000 yrs (table 114). This is the only dead date obtained in the project. The date may be due to deep burial of the soil with the dated carbonate, and its occurrence high in a dissected landscape. These factors should reduce the likelihood of C-14 youthening by the deeply penetrating moisture of pluvials and by water tables.

Table 114. Laboratory data for two pedons with buried Haplargids.

Horizon	Depth	Sand[1/]	Silt[1/]	Clay[1/]	Vol. > 2 mm	Carbonate	Organic carbon
	cm	pct	pct	pct	pct	pct	pct
SND-1, 59-12							
K2	0-36	77	11	12	40	10	0.52
2B1tb	36-69	72	15	13	tr	4[2/]	0.15
2B21tcab	69-91	76	11	13	tr	2	0.08
2B22tcab	91-122	79	9	12	tr	2	0.06
2B3tcab	122-152	80	9	11	tr	5	0.05
2Ccab	152-178	84	6	10	tr	6	0.05
SND-2, 59-9							
K2	0-36	79	10	11	3/	14	0.74
2B11tcab	36-51	82	8	10	tr	4	0.26
2B12tcab	51-64	86	6	8	tr	2	0.11
2B21tcab[4/]	64-71	77	8	15	tr	1	0.11
2B22tcab[4/]	71-135	69	10	22	tr	4	0.05
2B3tcab	135-165	69	14	18	tr	7	0.05
2C1cab[5/]	165-226	74	14	12	tr	14	0.04

1/ Carbonate-free basis.
2/ Peds contain 1 percent carbonate; filling among peds, 5 percent.
3/ Limestone pebbles partially dissolved in procedure to remove carbonate.
4/ Nodular carbonate (including vertical stringers) from these horizons has a C-14 age of 20,300 ± 800 yr (W-796).
5/ Carbonate nodules from this horizon are dated at > 30,000 yr (W-797).

144. Soils of the Jornada I and younger surfaces

Jornada I ridges occur extensively on the eastern side of the valley border. Surfaces younger than Jornada I occur on sides of the ridges, and in a few places younger deposits have buried the Jornada I ridges. Although there has been some soil truncation on most of these ridges, the truncated areas grade to stable areas in many places so that pedogenic comparisons may be made. The soils of Jornada I are substantially older than soils of the Picacho since they must have started their development before entrenchment of the Rio Grande Valley started. The soils of Jornada I have stronger morphologies than soils of the Picacho. The Bt horizons of soils of Jornada I have more prominent maxima of silicate clay; and carbonate horizons in very gravelly materials usually have multiple laminar horizons in contrast to the discontinuous laminar horizons most common in soils of Picacho age.

Soils of three mapping units occur on the Jornada I and younger surfaces:

145. MONTEROSA COMPLEX (10RR)

MAPPING UNIT COMPOSITION

Series	Subgroup or Order	Family Criteria	Percentage of Mapping Unit
DELNORTE	TYPIC PALEORTHIDS	LOAMY-SKELETAL, SHALLOW	15
MONTEROSA	USTOLLIC PALEORTHIDS	LOAMY-SKELETAL, SHALLOW	40
Algerita	Typic Calciorthids	Coarse-loamy	10
Nickel	Typic Calciorthids	Loamy-skeletal	10
Simona	Typic Paleorthids	Loamy, shallow	10
SND-6	Entisols		5
Other inclusions (Torrifluvents, Torriorthents, Haplargids, Paleargids			10

LOCATION, LANDSCAPE, VEGETATION

These soils occur east of the valley border in a broad, north-south belt west of the southern part of the Organ Mountains. The soils have formed in sediments derived mainly from rhyolite, with smaller amounts of andesite and monzonite in the northern part of the area. Elevations range from about 4350 to 4800 feet.

Long, east-west ridges (Jornada I remnants) are prominent in this mapping unit. Ridge crests are narrow; parts that are level transversely range from about 1 to 10 m width. Longitudinal slopes along ridge crests range from about 3 percent nearest the mountains to 2 percent in the western part of the unit. Slope of ridge sides ranges from about 5 to 35 percent. Small drainageways extend down ridge sides to arroyos or to adjacent, lower surfaces.

The Jornada I ridges, which are the topographic high in this mapping unit, are separated from each other by arroyo channels and by younger, lower surfaces. Small areas of the Tortugas surface, occurring as short (a few m) rounded remnants, abut the slightly higher Jornada I. The Picacho surface occurs primarily as narrow, discontinuous terraces that border arroyos and are inset against the higher Jornada I and Tortugas surfaces. Commonly, these terraces have not been greatly dissected and are level, or nearly level transversely. The Fillmore, the lowest surface and usually about one m or less higher than the arroyo channels, occurs as isolated remnants and as low terraces inset against sediments beneath the older surfaces. Along the eastern border of the unit, sediments of the Organ surface in places overlie or are inset against the Jornada I ridges.

Creosotebush and ratany are dominant. Whitethorn and prickly pear are common in some areas and in places--particularly at higher elevations--there are also scattered snakeweed, tarbush, ocotillo, *Yucca baccata*, Mormon tea and bush muhly.

TYPICAL PEDONS, PROPERTIES AND RANGES

Most soils are calcareous throughout because of landscape dissection and soil truncation, but range to noncalcareous in the upper several cm. A thin (few cm) "color B" horizon occurs in some soils of the broadest and stablest Jornada I ridge crests. It underlies a well developed vesicular A horizon that is a few mm thick, less red than 5YR, and of loamy texture.

Delnorte

See section 139 for a description and ranges of properties for Delnorte.

Monterosa

A typical pedon of Monterosa is described in the Appendix (pedon 66-2). Figure 94 shows the pedon and its landscape. A table of properties and ranges is given below.

Figure 94. Upper. Landscape of the Ustollic Paleorthid, Monterosa 66-2, on the Jornada I surface. Vegetation is creosotebush and ratany; there are a few whitethorn. Slope is 2 percent. The Organ Mountains are in the background. Lower. Monterosa 66-2. Scale is in feet.

Table 115. Typical (underlined) and range in selected properties for major horizons of Monterosa.

Horizon	Depth cm	Particle Size < 2mm	Particle Size > 2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-4	<u>sl</u>,l	10-75	5YR- 10YR <u>6YR</u>	5-7 <u>5.5</u>	3-5 <u>4</u>	2-<u>4</u>
B2	4-23	<u>sl</u>,l scl	35-75	5YR- 10YR <u>7.5YR</u>	5-7 <u>6</u>	3,4 <u>4.5</u>	3,<u>4</u>
K2m	36-64	--	--	7.5YR- 10YR <u>8YR</u>	6-<u>9</u>	5-8 <u>7</u>	2-4 <u>3</u>
Clca	107-135	ls <u>sl</u>,s	10-75	5YR- 10YR 6YR	5-7 <u>6.5</u>	3-5 <u>4.5</u>	3,<u>4</u>
Control section		sl,l,scl	35-75				

<u>Other</u>. Depth to the petrocalcic horizon (the K2m horizon) is usually about 25 to 40 cm, ranging from 18 to 50 cm. The K horizons tend to be thickest on ridge crests and in places of highest content of coarse fragments. In many places the uppermost laminar horizon has been fractured and mixed to some degree with fine earth. At stable sites and in very gravelly materials these soils have at most a single laminar horizon on the Picacho surface and several on Jornada I. On the Jornada I ridges, the K horizon is generally beveled on slopes steeper than about 15 percent, in places continues down the side of gentler slopes. There are occasional pipes in the K horizon; they range from about 25 cm to 2 m across. Observed pipes contain strongly calcareous material similar to that in the B horizon.

<u>SOIL OCCURRENCE</u>

Complex patterns of soil occurrence in the unit are caused by wide variations in landscape stability, landscape position and gravel content. Argids are generally absent on the Jornada I ridges because of soil truncation, carbonate engulfment and mixing by soil biota. Soils of this unit also illustrate the transition from the Typic Paleorthids to the Ustollic Paleorthids.

<u>Paleorthids</u>. The loamy-skeletal, Ustollic Paleorthids, MONTEROSA soils, are dominant on the high ridge crests. At lower elevations in the western part of the unit, they commonly occur in complex association with the loamy-skeletal Typic Paleorthids, DELNORTE soils. At higher elevations the loamy-skeletal Paleorthids are virtually all Ustollic. Other Paleorthids are the loamy Simona soils, which have less gravel and occur at lower elevations (Paleorthids at higher elevations and steeper slopes are generally skeletal). A major reason for these loamy Paleorthids being Typic at these lower ele-

vations is the low amount of gravel (section 63). The Paleorthids also extend part way down ridge sides of Jornada I age. While ridge sides of the Picacho remnants are of Fillmore age and the soils are Entisols, many ridge sides of Jornada I remnants are partly Picacho or Tortugas in age and have Paleorthids or Calciorthids. These Calciorthids and Paleorthids usually have slopes less than about 15 percent.

Calciorthids. On the ridges, decrease in gravel in the zone of maximum carbonate accumulation first causes a shift from Paleorthids to the Calciorthids, Nickel soils, which still have enough gravel for the skeletal family. Nickel soils also occur on the crests of very narrow ridges, and on the upper sides of some ridges where a formerly continuous petrocalcic horizon has been broken up as a result of soil truncation. The coarse-loamy Algerita soils occur where the alluvium contains little or no gravel. In the gentler slopes in the western part of the unit, there is often complex occurrence of Paleorthids and Calciorthids due to abrupt differences in gravel content.

Entisols. SND-6 occurs in arroyo channels.

Torriorthents. The loamy-skeletal Canutio soils; Canutio, loamy subsoil variant; and the sandy-skeletal Arizo soils commonly occur on the steepest parts of ridge sides. These soils also occur on the Fillmore terraces adjacent to arroyos.

Torrifluvents. The coarse-loamy Anthony soils occur on some of the Fillmore terraces.

Paleargids, Haplargids. In contrast to the Paleorthids on the higher surfaces, Argids are dominant on many of the small Picacho terraces; these areas have not been as strongly dissected. The loamy-skeletal Ustollic Haplargids, Nolam soils, occur where a calcic, but not a petrocalcic horizon has developed. The Paleargids Casito and Terino both have petrocalcic horizons. Casito soils have some macroscopic carbonate in all subhorizons of the Bt horizon whereas Terino soils do not.

Paleosol materials. On some ridge sides in the western part of the unit, buried soils have been beveled and are at the surface or are covered by a few inches of colluvium. These are analogues of buried soils that have been extensively exhumed in the mapping unit "Haplargids, dissected" to the west.

SOIL BOUNDARIES

Table 116 gives information about boundaries to major adjacent units. Figures 95 and 96 show boundaries and stratigraphy of some of the units.

Table 116. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Haplargids, dissected (11Y)	Landscape dissection has caused the boundary. Once-buried soils, the analogues of which are buried beneath soils of unit 10RR, emerge at or are very near the surface on the 11Y side of the boundary. Erosion associated with downcutting of the Rio Grande has stripped away nearly all sediments once overlying buried soils in unit 11Y. The topographic boundary is not prominent but is marked by the point at which considerable narrowing and downwearing of ridges commences.
Terino very gravelly sandy loam (12R)	Landscape dissection has caused the boundary. This has resulted in carbonate engulfment or truncation of the argillic horizon formerly present in the 10RR soils. The topographic boundary between these units is not prominent but is marked by a difference in width of ridges. Towards the Rio Grande Valley, ridges develop and then become narrower as degree of dissection increases. With increasing dissection and narrowing of ridges, the argillic horizon gradually disappears; the point of disappearance marks the boundary to unit 10RR.
Nolam complex (12RR)	The boundary is due to two main factors. One is a younger geomorphic surface (Picacho) and associated alluvium in unit 12RR, which is inset against the higher ridges of unit 10RR. The other concerns the degree of landscape dissection, which has been slight in unit 12RR, where Argids are well preserved.
Algerita complex (16MA)	The boundary has been caused by more coarse fragments in unit 10RR, so that most soils are skeletal and are Paleorthids. The boundary is not topographically prominent.
Pinaleno very gravelly sandy loam (13R)	The boundary has been caused by a younger geomorphic surface (Organ) and associated alluvium in unit 13R. This younger alluvium has buried or is inset against older soils of the Monterosa complex, along margins of the Jornada I ridges.

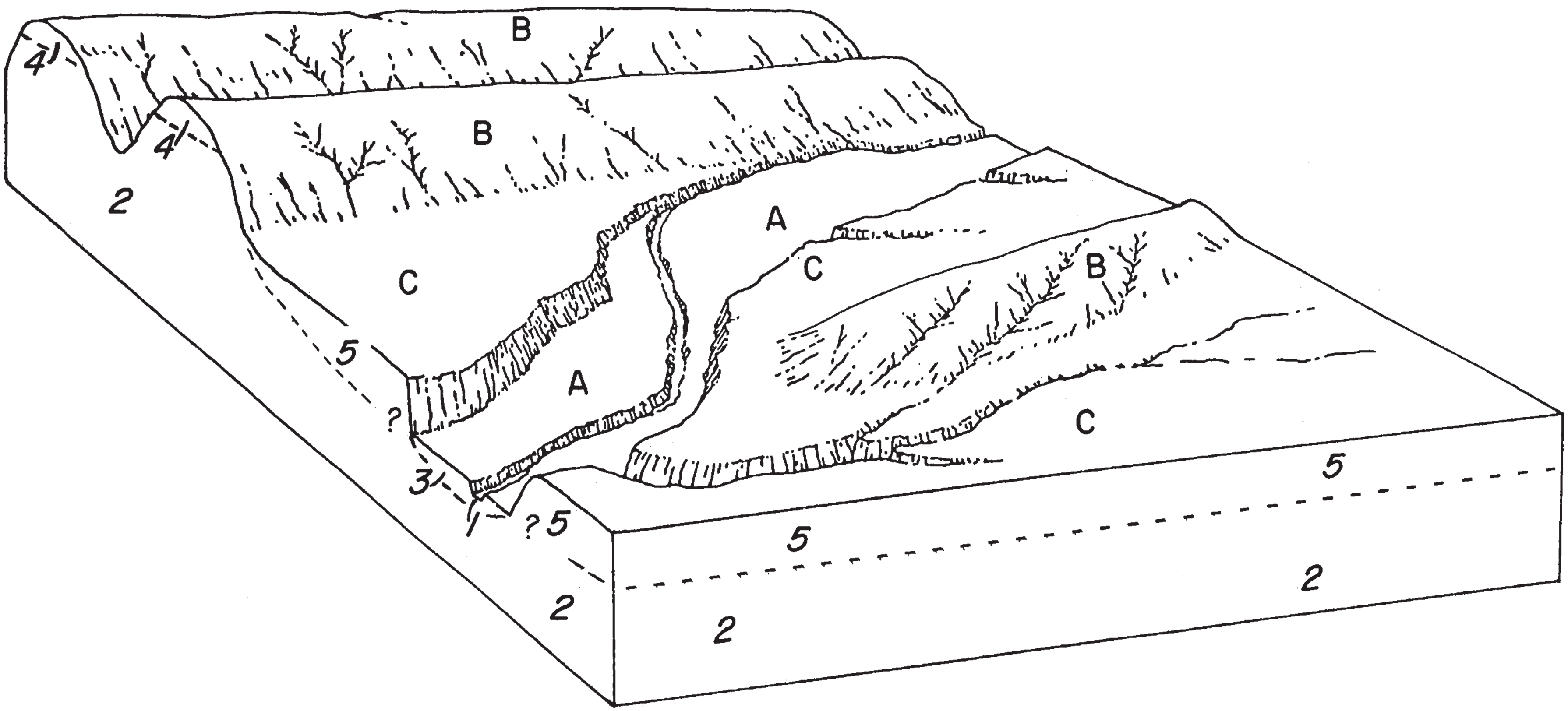


Figure 95. Block diagram of soil-landscape relations and soil stratigraphy in an area of Monterosa complex, Nolam complex, and Arizo complex, south of Tortugas Mountain. A = Arizo complex (Fillmore and arroyo channel surfaces). B = Monterosa complex (Jornada I surface on ridge crests; post-Jornada I on ridge sides). C = Nolam complex (Picacho surface).
1 = Arroyo channel alluvium (not outlined). 2 = Upper Camp Rice Formation (piedmont facies) and buried soils. 3 = Fillmore alluvium and soils. 4 = Jornada I alluvium (youngest unit of the Upper Camp Rice piedmont facies) and soils. 5 = Picacho alluvium and soils.

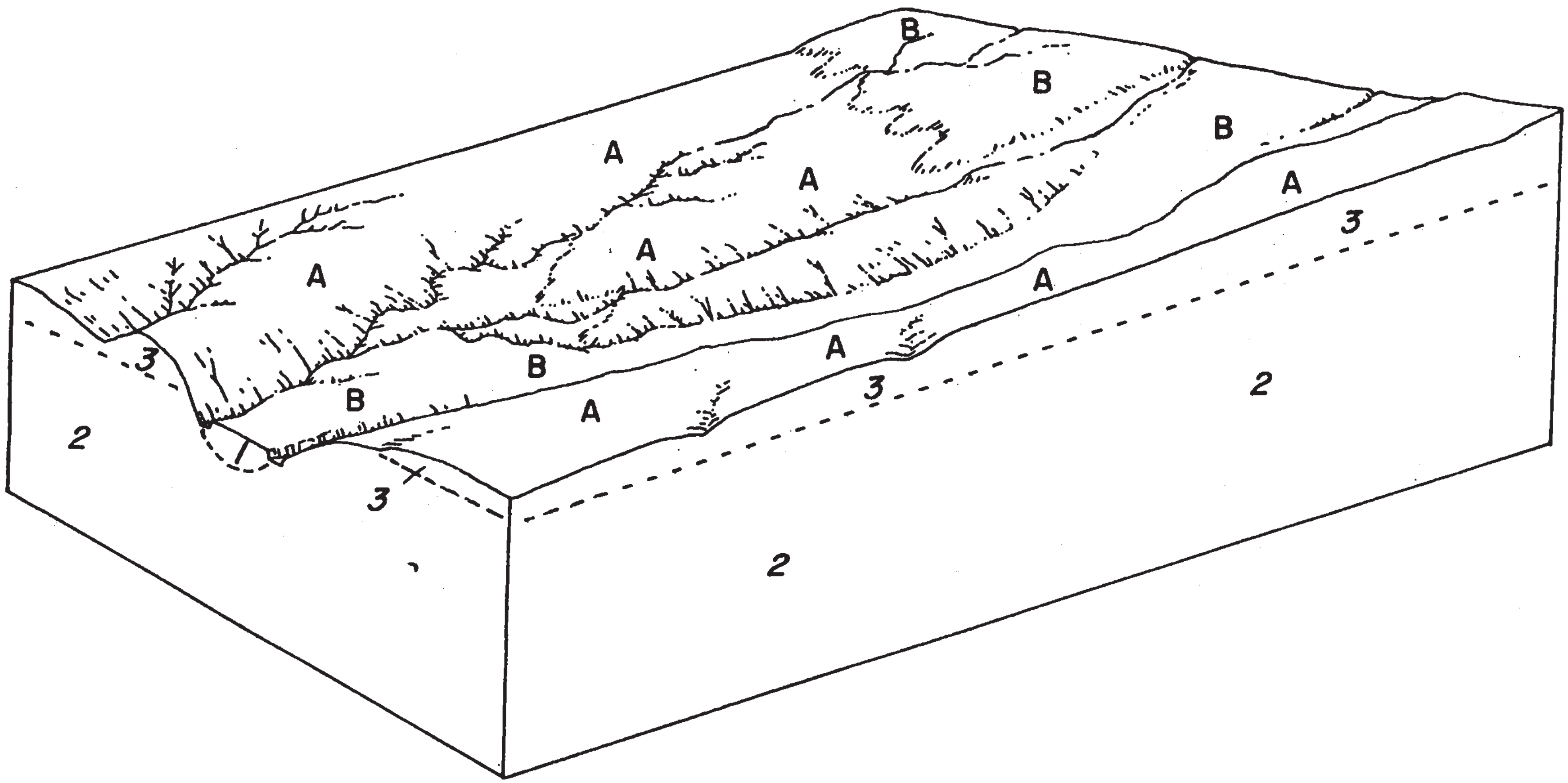


Figure 96. Block diagram of soil-landscape relations and soil stratigraphy in an area of Monterosa complex and Pinaleno very gravelly sandy loam. A = Monterosa complex (Jornada I surface on ridge crests; post-Jornada I on ridge sides). B = Pinaleno very gravelly sandy loam (Organ surface).
1 = Organ alluvium and soils. 2 = Upper Camp Rice Formation (piedmont facies) and buried soils. 3 = Jornada I alluvium (youngest unit of the Upper Camp Rice piedmont facies) and soils.

146. ALGERITA COMPLEX (16MA)

MAPPING UNIT COMPOSITION

Series	Subgroup	Family Criteria	Percentage of Mapping Unit
ALGERITA	TYPIC CALCIORTHIDS	COARSE-LOAMY	45
Anthony	Typic Torrifluvents	Coarse-loamy (calcareous)	5
Canutio	Typic Torriorthents	Loamy-skeletal (calcareous)	5
Canutio, loamy subsoil variant	Typic Torriorthents	Coarse-loamy (calcareous)	5
Delnorte	Typic Paleorthids	Loamy-skeletal, shallow	5
Monterosa	Ustollic Paleorthids	Loamy-skeletal, shallow	10
Nickel	Typic Calciorthids	Loamy-skeletal	10
Simona	Typic Paleorthids	Loamy, shallow	5
Other inclusions (Torriorthents, Haplargids, Paleargids, Entisols)			10

LOCATION, LANDSCAPE, VEGETATION

These soils occur in one large area west of the central part of the Organ Mountains, and in several smaller areas below the northern portion of the Dona Ana Mountains. The soils have formed in alluvium derived mostly from monzonite, with smaller amounts from andesite and rhyolite. Elevations range from about 4400 to 4700 feet.

Arroyos and ridges are prominent in many places. Drainageways commonly extend from the arroyos and incise the ridges. Longitudinal slopes range from 2 to 5 percent; transverse slopes of ridge sides range from about 5 to 35 percent. In the major area of occurrence west of the Organ Mountains, these soils occur on ridges and terraces of several levels and ages. The highest ridges are Jornada I. Successively lower levels of stable or relatively stable surfaces are the Tortugas, Picacho and Fillmore.

Vegetation is commonly dominated by creosotebush, in places with some mesquite, ratany, whitethorn and Mormon tea. In the main area of occurrence (west of the central part of the Organ Mountains) on highest ridges generally there are only a few creosotebush and vegetation is mainly ratany, whitethorn, Mormon tea, and a few bush muhly and fluffgrass. In these areas there is much more creosotebush, along with some *Yucca elata*, in the drainageways between the ridges.

TYPICAL PEDON, PROPERTIES AND RANGES

Algerita

A pedon description and range of characteristics of Algerita are given in section 169. Algerita soils on the highest (Jornada I) ridges differ as follows. In these areas a gravelly sandy loam commonly rests on a less gravelly calcic horizon with its upper boundary at about 25 cm. The relations suggest slow, long-continued truncation of upper horizons.

SOIL OCCURRENCE

Because of strong dissection, Bt horizons commonly have been truncated and underlying calcic horizons are very near the surface. This mapping unit is therefore dominated by Calciorthids. In the main area of occurrence the age and topographic relationships are similar to those in the Monterosa complex just south, but these soils contain less gravel and calcic horizons are therefore much more common than petrocalcic horizons.

Calciorthids. The coarse-loamy ALGERITA soils are dominant on ridge crests. The loamy-skeletal Nickel soils occur in scattered very gravelly spots where a petrocalcic horizon has not developed. These are most common on terraces lower than Jornada I but higher than Fillmore.

Paleorthids. The loamy-skeletal Ustollic Paleorthids, Monterosa soils, are dominant in most densely vegetated places where the B horizons are very gravelly. The loamy-skeletal Typic Paleorthids, Delnorte soils, are dominant in very gravelly, barren areas most common in the southwestern part of the large area west of the Organ Mountains. Simona soils, loamy, occur where horizons above the petrocalcic horizon average less than 35 percent by volume of coarse fragments.

Haplargids and Paleargids. Small areas of the fine-loamy Dona Ana and Berino soils, Haplargids, occur in scattered stable, little-eroded areas. Dona Ana soils have some macroscopic carbonate in all subhorizons while Berino soils do not. The loamy-skeletal Casito soils, Paleargids, occur in stablest, very gravelly areas of the Picacho surface.

Torriorthents. The loamy-skeletal Canutio soils; Canutio, loamy-skeletal variant; and the sandy-skeletal Arizo soils occur on some ridge sides and on narrow Fillmore terraces adjacent to arroyo channels.

Entisols. SND-6 occurs in arroyo channels.

Torrifluvents. Anthony soils occur on some of the narrow Fillmore terraces adjacent to the arroyo channels.

Haplargids, dissected. Occur on some ridge sides in the western part of the unit.

SOIL BOUNDARIES

Table 117 shows boundaries to major adjacent units.

Table 117. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Monterosa complex (10RR)	The boundary is due to an increase in particle size of dominant soils in unit 10RR. The change is from coarse-loamy 16MA to skeletal 10RR. The topographic boundary between them is not distinct.
Haplar-gids, dissected (11Y)	The boundary is due to greater dissection in unit 11Y. Once-buried soils, analogues of which are still buried in unit 11Y, emerge at or are very near the surface on the 11Y side of the boundary. Topographically the boundary is marked by a change from relatively broad ridge crests to very narrow ones.
Dona Ana-Algerita complex (16M)	The boundary is due to increased dissection in unit 16MA. Topographically unit 16M shows little evidence of landscape dissection. Distinct drainageways are absent.

147. SONOITA LOAMY SAND (15S)

MAPPING UNIT COMPOSITION

Series	Subgroup	Family Criteria	Percentage of Mapping Unit
SONOITA	TYPIC HAPLARGIDS	COARSE-LOAMY	60
Berino	Typic Haplargids	Fine-loamy	10
Onite	Typic Haplargids	Coarse-loamy	10
Onite, calcic variant	Typic Haplargids	Coarse-loamy	10
Pintura	Typic Torripsamments		10

LOCATION, LANDSCAPE, VEGETATION

The soils occur in two small areas east and southeast of Tortugas Mountain and in three areas northwest of the Dona Ana Mountains. The soils have formed in dominantly sandy sediments, with little or no gravel. Some of the sediments appear to be of eolian origin. In places, the parent materials are probably at least partly of alluvial origin, since they occur downslope from a source of alluvium. Elevations range from about 4300 to 4400 feet.

East and southeast of Tortugas Mountain, the soils occur on high, gently sloping ridge crests. Longitudinal slopes of ridge crests are 1/2 to 1 percent. Although these soils east and southeast of Tortugas Mountain occur on high, narrow ridges, they have been preserved largely because of their physiographic position, which favors landscape stability and reduction of soil truncation. The area just east of Tortugas Mountain is bedrock-defended by it; drainage from the east splits around the mountain, thus lessening the severity of dissection in this area. In the southern part of the area, the soils occur in an area defended by a remnant of La Mesa surface with its thick soils. Northwest of the Dona Ana Mountains, the soils occur downslope from the rim of La Mesa and slope from 1 to 3 percent.

East and southeast of Tortugas Mountain, these soils and their vegetation form a sharp contrast to adjacent areas. The soils have noncalcareous, sandy upper horizons with high infiltration rates. Moisture conditions are much better for vegetation than in the surrounding soils, which have been truncated, are dominantly Paleorthids, are strongly calcareous throughout, and have lower infiltration rates. Whereas vegetation of the adjacent Paleorthids consists mainly of creosotebush, these soils have a variety of vegetation—mainly snakeweed, zinnia, Mormon tea, *Yucca elata*, sumac, mesquite, and whitethorn, with scattered clumps of dropseed and bush muhly.

TYPICAL PEDON PROPERTIES AND RANGES

Between dunes the original A horizon appears to have been truncated by wind and water, and the present weak A horizon may represent the former upper part of the B1 horizon. These soils are commonly noncalcareous to 50 - 75 cm, but near borders of the mapping unit are calcareous throughout.

Sonoita

A typical pedon of Sonoita is described below. The location is the SE 1/4 Sec. 5, T24S, R3E, about 0.05 mile west of pipeline. Figures 97 and 98 shows the pedon and its landscape. A table of properties and ranges follows the description.

Soil surface. The surface is about 20 percent covered with fine, angular rhyolite pebbles mostly from 1/2 to 2 cm diameter, a few up to 3 cm diameter. The surface is weakly crusted and breaks out as plates about 1 mm thick. There are scattered dunes, about 1/2 to 3/4 m high. A discontinuous layer of loose reddish sand occurs on the surface between the dunes.

A 0-5 cm. Reddish brown (5YR 5/4, dry, 5YR 3.5/4, moist) loamy sand; weak medium platy and single grain; soft and loose; few roots; noncalcareous; surface 1/8 inch slightly crusted; abrupt wavy boundary.

B11t 5-23 cm. Yellowish red (5YR 5/6, dry, 5YR 4/6, moist) heavy loamy sand; weak very coarse prismatic, massive internally; hard, friable; few roots; sand grains coated with clay; noncalcareous, clear wavy boundary.

B12t 23-51 cm. Yellowish red (5YR 5/5, dry, 5YR 4/5, moist) light fine sandy loam; weak very coarse prismatic, massive internally; hard, friable; few roots; sand grains coated with clay; common very fine tubular pores; harder in place than above; noncalcareous; clear wavy boundary.

B21t 51-64 cm. Yellowish red (7YR 5/6, dry, 4YR 4/6, moist) light sandy clay loam, with few parts less red than above; compound weak medium prismatic and weak medium subangular blocky; hard, friable; common very fine tubular pores; sand grains coated with clay; prism faces are very slightly reflective; noncalcareous; abrupt and clear wavy boundary.

B22tca 64-84 cm. Yellowish red (5YR 5.5/6, dry, 5YR 4/6, moist and some parts 7.5YR 6/4, dry, 7.5YR 5/4, moist), with few parts redder; heavy fine sandy loam; compound weak medium prismatic and weak medium subangular blocky; hard, friable; very few fine roots; carbonate filaments common; common very fine tubular pores; most parts between filaments effervesce weakly or strongly, with a few parts noncalcareous; clear wavy boundary.

B3ca 84-140 cm. Reddish yellow (5YR 6/6, dry) and yellowish red (5YR 5/6, moist) heavy loamy fine sand; massive; slightly hard, very friable; very few fine roots; few fine tubular pores; few carbonate filaments; effervesces weakly and strongly; clear wavy boundary.

C 140-175 cm. Reddish yellow (7YR 6/5, dry) and brown (7YR 4.5/4, moist) loamy fine sand; massive; soft; no roots; in general, most parts effervesce weakly, with a few parts noncalcareous; generally noncalcareous in lower parts; abrupt smooth boundary.

Bcab 175-180 cm. Reddish yellow (5YR 6/5, dry) or yellowish red (5YR 5/5, moist) sandy loam; massive; hard, no roots; few carbonate filaments; generally noncalcareous, filamentary zones effervesce weakly or strongly; more gravel than above.

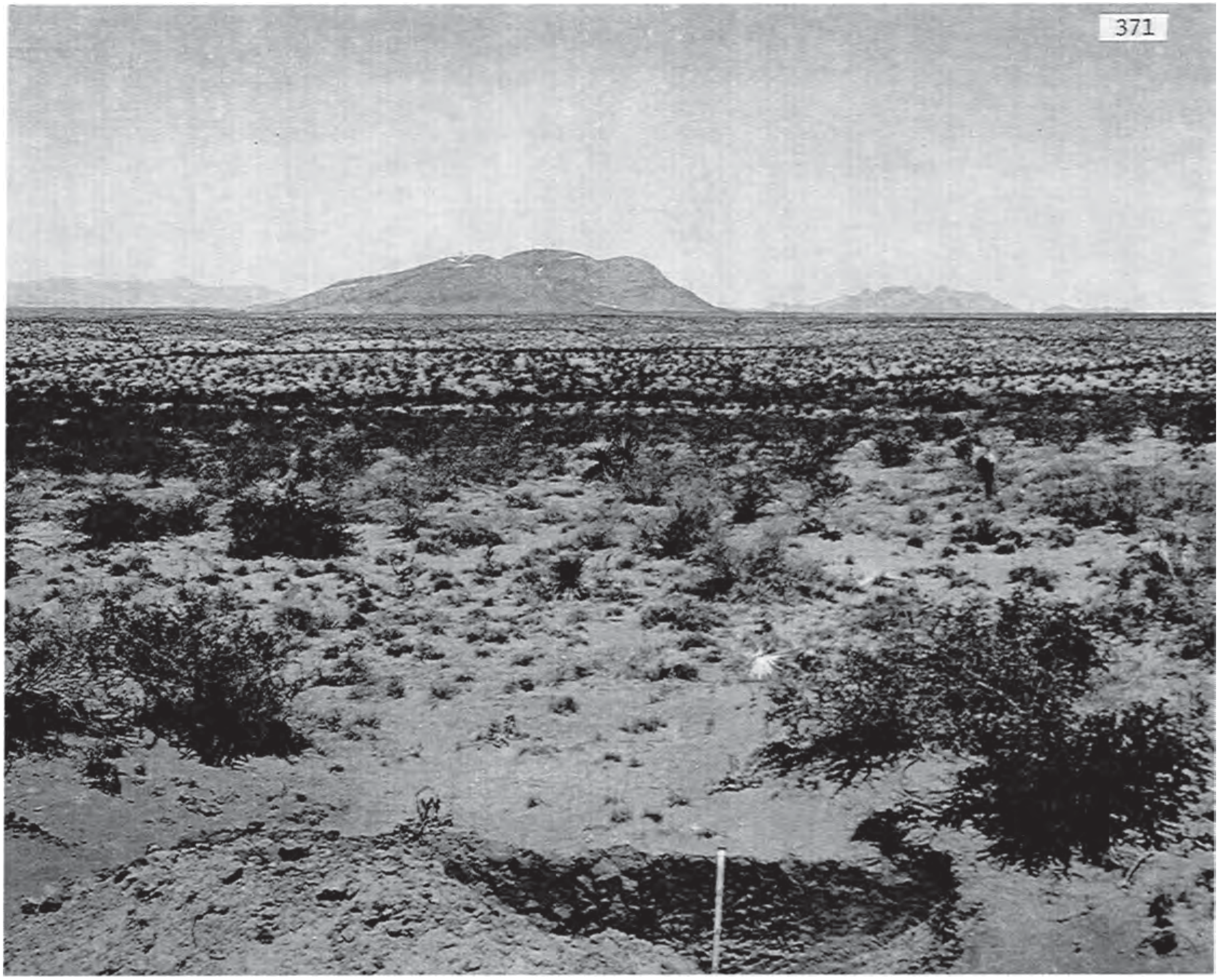


Figure 97. Landscape of the Typic Haplargid, Sonoita loamy sand (Holocene or latest Pleistocene surface). Vegetation is Mormon tea, Yucca elata, whitethorn, ratany, zinnia, sumac, scattered clumps of dropseed, and a few creosotebush. Slope is 1 percent. Robledo Mountains are on the skyline at the left; Tortugas Mountain is in the center; and the Dona Ana Mountains are to the right.

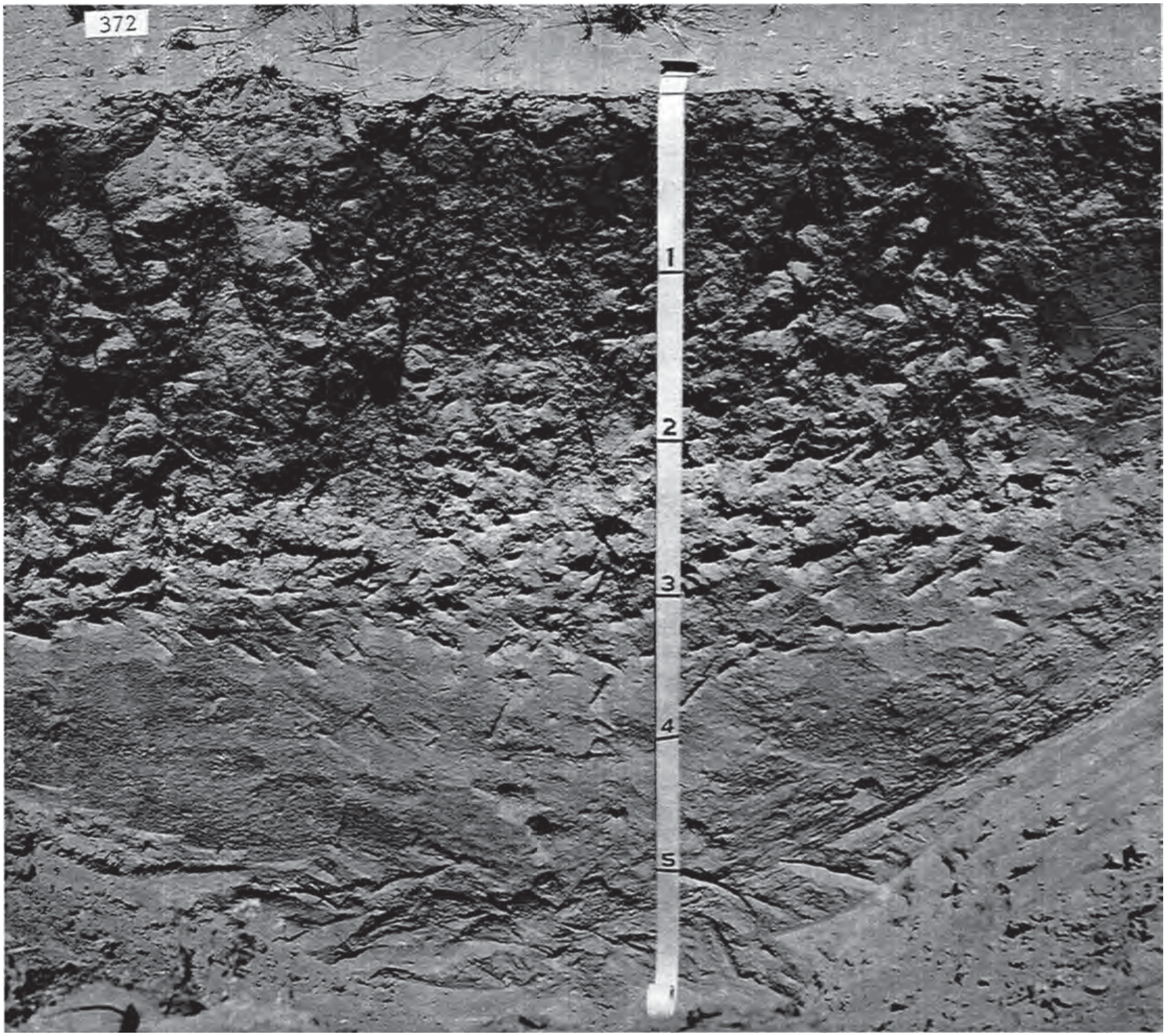


Figure 98. A Typic Haplargid, Sonoita loamy sand, in a deposit (Holocene ?) that overlies the Jornada I surface.

Table 118. Typical (underlined) and range in selected properties for major horizons of Sonoita.

Horizon	Depth cm	Particle Size < 2mm	Particle Size >2mm, % Vol.	Hue	Value Dry	Value Moist	Chroma
A	0-5	ls s	0-1	5YR- 7.5YR	4-6 5	3-5 3.5	3,4
B2t	51-84	sl lt.scl	0-1	5YR	4-6 5	3-5 4	4-6
C	140-175	ls s	0-1	7.5YR 7YR	5,6	4,5 4.5	4,5
Control section		sl	0-1				

SOIL OCCURRENCE

Sonoita soils have formed in a deposit (apparently of Holocene age) that overlies buried soils. Soil distribution is determined partly by thickness of the deposit on the buried soil. Haplargids occur where the deposit is about 1/2 to 1 m or more thick, and commonly are underlain by C horizon material that rests on the buried soil. Where the deposit is thinner, the B horizon of the Haplargid rests directly on the buried soil. Specific trends in thickness of the deposit are not known. East and southeast of Tortugas Mountain, soil occurrence depends on position on the ridge. Centers of ridges are dominated by Haplargids with thick argillic horizons and no calcic horizons. Around the edges, older soils (buried in the centers of the ridges) are at or very near the surface. These older soils have argillic horizons and calcic or petrocalcic horizons. North of the La Mesa rim, the observed deposits overlie prominent, nodular calcic horizons.

Haplargids. The coarse-loamy SONOITA soils are dominant over most of the area; they have sola more than 75 cm thick. The coarse-loamy Onite soils occur in places where the sola are less than 75 cm thick. The fine-loamy Berino soils and Onite, calcic variants are most common near margins of the mapping unit where the younger deposit is thin or absent.

Torripsamments. Pintura soils occur where sandy materials of dunes, and upper horizons of buried soils are at least 1 m thick.

SOIL BOUNDARIES

Table 119 gives information on boundaries to major adjacent units. Figure 99 shows boundaries and stratigraphy of some of the units.

Table 119. Cause and character of boundaries to adjacent major units.

To mapping unit:	Cause and Character
Tencee complex, eroded (10C)	The boundary has been caused by a younger geomorphic surface and associated sediment in unit 15S. North of Fort Selden, areas of unit 15S occur north of and downslope from the La Mesa rim (where they border the 10C and 12P units) and slope 1 to 3 percent.
Haplargids, dissected (11Y); Monterosa complex (10RR); Nolam complex (12RR)	The boundary has been caused by a younger geomorphic surface and associated sediment in unit 15S. The topographic boundaries to 11Y, 10RR, and 12RR units are distinct; soils of unit 15S are on ridges that are higher. The boundaries are vegetatively prominent as noted earlier.

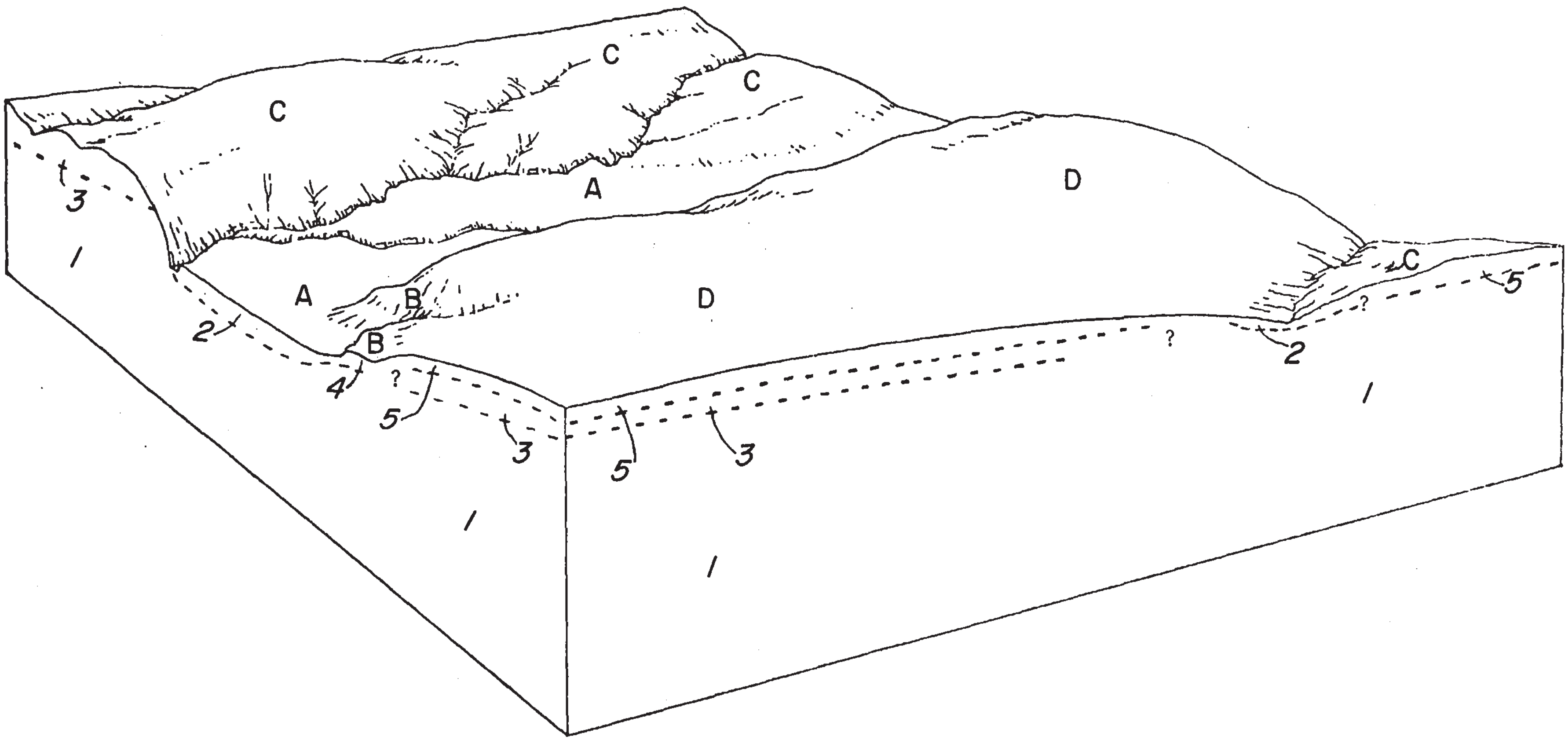


Figure 99. Block diagram of soil-landscape relations and soil stratigraphy in an area of Sonoita loamy sand, Arizo complex, Delnorte complex, and Monterosa complex. Buried soils occur in the Upper Camp Rice Formation (piedmont facies). A = Arizo complex (Fillmore and arroyo channel surfaces). B = Delnorte complex (Picacho surface). C = Monterosa complex (Jornada I surface on ridge crests; post-Jornada I on ridge sides). D = Sonoita loamy sand (unnamed Holocene or latest Pleistocene surface).
1 = Upper Camp Rice Formation (piedmont facies) and buried soils. 2 = Fillmore alluvium and soils. 3 = Jornada I alluvium (youngest unit of the Upper Camp Rice piedmont facies) and soils. 4 = Picacho alluvium and soils. 5 = Unnamed deposit (Holocene or latest Pleistocene) and soils.

148. Soils of La Mesa surface; a depression fill; and coppice dunes.

The soils of La Mesa are the oldest in the study area, with the possible exception of soils of the Dona Ana surface (section 184). La Mesa surface, which dates from mid-Pleistocene time, is a broad, relict basin floor that extends for miles along the Rio Grande Valley. Four remnants of La Mesa occur along the valley border in the study area. One of the remnants is north of Fort Selden and another is near Goat Mountain. The other two remnants are west of the Rio Grande Valley and south of Picacho Mountain.

The ancient basin floor is a relict feature along the valley border, where it has been deeply cut by the Rio Grande. These remnants have received little or no sedimentation, either from through-flowing streams or from bordering mountains, for long periods of time. For example, near Goat and Picacho Mountains the remnants are now scores of m above the present flood plain. Between the relict basin floor and the Rio Grande flood plain is a sequence of stepped geomorphic surfaces, the oldest of which (Tortugas) dates from mid to late-Pleistocene time. The basin floor south of Picacho Mountain must have been isolated both from drainage of through-flowing streams and northward from the Robledo Mountains (the closest mountain range for local contribution of sediments) since incision of the drainage system. Both the soils of La Mesa and evidence of youthful, localized sedimentation and subsequent soil formation may therefore be studied without complications of broad-scale regional deposition. Further, the erosion cycle associated with initial entrenchment of the Rio Grande must have drained any ground water tables in the sandy, pervious sediments of La Mesa adjacent to the valley rim. The effects of soil formation on these ancient sediments may thus be considered independently of any ground water table effects on soil formation subsequent to initial entrenchment of the Rio Grande.

Although La Mesa is very old, the surface as a whole appears to have been fairly stable from the standpoint of soil development. La Mesa has not been dissected by arroyos except along its scarped edges, and is nearly level. The soils themselves commonly show only minor evidence of erosion and sedimentation. The A horizons are thin and in places are absent. There has been considerable shifting of material on the surface by wind as evidenced by dunes. However, strong soil development beneath this surficial zone of movement suggest that most of La Mesa has been nearly stable for a long period of time. General horizonation (B/K2m/K3/Cca) is similar to that of many soils on younger geomorphic surfaces, but the soils are much thicker on La Mesa. The soils of La Mesa reflect the cumulative effects of pedogenic processes since mid-Pleistocene, and their complex morphologies suggest a long and variable history of soil formation.

Two distinct levels are apparent in La Mesa on the west side of the Rio Grande and are termed upper and lower La Mesa (figs. 100 and 101). Figure 100 locates "other studies" sites on upper and lower La Mesa, and shows some of the morphological features of the soils.

The elevation of lower La Mesa is about 4200 ft. Upper La Mesa has a general slope of about 1/2 percent to the south and its elevation in the area shown

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